This publication, the third in a series on drafting, is intended to strengthen students' competence in the specialized field of mechanical drafting. The text consists of instructional materials for both teachers and students, written in terms of student performance using measurable objectives. The course includes 11 units. Each instructional unit contains some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. Units are liberally illustrated and are planned for more than one lesson or class period of instruction. Information for the teacher includes an instructional/task analysis of mechanical drafting, a list of tools, materials, and equipment needed, and a reference list. Topics covered in the 11 units are the following: orientation; tools and equipment; reference materials; layouts and working drawings; dimensioning and tolerancing; fasteners and hardware; presentation drawings; materials and specifications; manufacturing processes; sheet metal developments; and power transmission. (KC)
MECHANICAL DRAFTING

by

Gerald R. McClain

Developed by the

Mid-American Vocational Curriculum Consortium, Inc.

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FOREWORD

Mechanical Drafting is the third volume of a series of drafting materials being produced by the Mid-America Vocational Curriculum Consortium. Basic Drafting: Book One and Basic Drafting: Book Two comprise the basics necessary to be employed in a drafting occupation. This book, Mechanical Drafting, is designed to be used as a supplement to them so that the student can specialize.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writer has numerous years of industry as well as teaching and writing experience. Assisting him in his efforts were committee representatives who brought with them technical expertise and experience related to the classroom and to the trade. To assure that the materials would parallel the industry environment and to be accepted as a transportable basic teaching tool, other organizations and industry representatives were involved in the developmental phases of the manual. Appreciation is extended to them for their valuable contributions to the manual.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accentuates and augments the teaching/learning process. Criterion referenced evaluation instruments are provided for uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

It is the sincere belief of the MAVCC personnel and all those members who served on the committee that this publication will allow the students to become better prepared and more effective members of the work force. If there is anything that we can do to help this publication become more useful to you, please let us know.

Merle Rudebusch, Chairman
Board of Directors
Mid-America Vocational Curriculum Consortium
PREFACE

For many years those responsible for teaching drafting have felt a need for better quality materials to use in this area. To address this need, MAVCC has previously published two texts, Basic Drafting, Book One and Basic Drafting, Book Two. During the development of these basic materials, an even greater need was established, that being supplemental materials to help the students specialize in various areas of drafting. The team of teachers, industry representatives, teacher educators, and state level supervisors who had produced the original materials accepted this challenge and have now completed the first of the supplements. Mechanical Drafting is designed to be used in addition to the the first two publications, and is developed to strengthen a student's competence in the specialized field of mechanical drafting. This field is sometimes referred to as machine drafting, but because it involves the drafting of all mechanical devices, not only machines, we decided to entitle our text Mechanical Drafting.

This publication is designed to assist teachers in improving instruction. As this publication is used, it is hoped that the student performance will improve so the students will be better able to assume a role in their chosen occupation. Every effort has been made to make this publication basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted: motivation, personalization, and localization. These areas are left to the individual instructors who should capitalize on them. Only then will this publication really become a vital part of the teaching-learning process.

In addition, we would appreciate your help. We check for content quality, spelling, and typographical errors many times in the development of a manual. It is still possible, however, for an error to show up in a publication.

We are trying to provide you with the best possible curriculum materials and will certainly appreciate your help in detecting areas where possible corrections are needed to maintain the quality you want and deserve.

Ann Benson
Executive Director
Mid-America Vocational Curriculum Consortium, Inc.
ACKNOWLEDGEMENTS

Appreciation is extended to those individuals who contributed their time and talents in the development of Mechanical Drafting.

The contents of this publication were planned and reviewed by:

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Thanks are also extended to Mary Kellum, Dan Fulkerson, and Jane Huston for their assistance with editing and proofreading.
USE OF THIS PUBLICATION

Instructional Units

Mechanical Drafting includes eleven units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the test. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated
   1. Supplies needed
   2. Equipment needed
   3. Amount of practice needed
   4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of performance terms and their synonyms which may have been used in this material:

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<th>Name</th>
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<td>Select</td>
<td>Define</td>
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<td>List in writing</td>
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<td>List orally</td>
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<td>Discuss orally</td>
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<tr>
<td>Letter</td>
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<td>Interpret</td>
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<td>Record</td>
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<td>Tell how</td>
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<td>Repeat</td>
<td>Locate</td>
<td>Tell what</td>
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<tr>
<td>Give</td>
<td>Label</td>
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</table>
Order  Distinguish  Construct
Arrange  Discriminate  Draw
Sequence  Differentiate  Make
List in order  
Classify  Build
Divide  Design
Isolate  Formulate
Sort  Reproduce

Demonstrate
Show your work  Evaluate  Prepare
Show procedure  Complete  Make
Perform an experiment  Analyze  Read
Perform the steps  Calculate  Tell
Operate  Estimate  Teach
Remove  Plan  Converse
Replace  Observe  Lead
Turn off/on  Compare  State
(Dis) assemble  Determine  Write
(Dis) connect  Perform

Additional Terms Used

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor:

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.
Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class’s attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to and in most situations should demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.
MECHANICAL DRAFTING
Instructional/Task Analysis

UNIT I: ORIENTATION

1. Terms and definitions
2. Areas of specialization
3. Industries that employ mechanical drafters
4. Job titles and descriptions
5. Steps in mechanical design and drafting work
6. Duties of mechanical drafter
7. Job classifications
8. Related occupations
9. Advantages and disadvantages of a mechanical drafting occupation
10. Minimum qualifications
11. Personality traits of drafter
12. Related skills for drafter
13. Evaluation areas
14. Abbreviations
15. Professional organizations
16. Interview a mechanical drafter
17. Observe a mechanical drafter
18. Evaluate a mechanical drawing

UNIT II: TOOLS AND EQUIPMENT

1. Terms and definitions
2. Mechanical templates
3. Precision measuring instruments
JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

9. Read micrometer settings
10. Read vernier calipers
11. Measure with scales
12. Compute mechanical drafting problems using a hand calculator
13. Use a micrometer
14. Use a vernier caliper

RELATED INFORMATION: What the Worker Should Know (Cognitive)

4. Types of welding measuring instruments
5. Types of scales
6. Primary metric unit of measurement
7. Hand calculator functions
8. Types of keyboard sequences used in hand calculators

UNIT III: REFERENCE MATERIALS

1. Terms and definitions
2. Product information literature
3. Mechanical standards references
4. Handbooks
5. Standards in ANSI drafting manual
6. ANSI standard parts
7. ANSI miscellaneous standards
8. ANSI metric standard fasteners references

9. Determine manufacturer of mechanical components from Thomas Register
JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

10. Write a letter requesting product literature for mechanical components

11. Write a technical report using reference materials

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT IV: LAYOUTS AND WORKING DRAWINGS

1. Terms and definitions
2. Title forms
3. Information or revision blocks
4. Information on a bill of material/parts list
5. Stages of design process
6. Design layouts
7. Elements of design layout sketch
8. Parts of detail drawing
9. Parts of assembly drawing
10. Information found on outline or installation assemblies
11. Information found on welding assembly drawings
12. Characteristics of forging drawings
13. Information found on a-pattern or casting drawing
14. Draw a design layout
15. Draw a set of detail drawings
16. Draw an assembly drawing
17. Complete a detailed title block and revision block
18. Complete a parts list
19. Make a drawing revision
UNIT V: DIMENSIONING AND TOLERANCING

1. Terms and definitions
2. Size and location dimensions for a geometric shape
3. Mating dimensions in an assembly drawing
4. Numerical control dimensioning
5. Fits for inch and metric units
6. Limits in inch units using basic hole system
7. Limits in metric units using basic hole system
8. Tolerance ranges for shop processes
9. Hole size limits for standard dowels
10. Limit dimensions for interchangeability of parts
11. Limit dimensions for intermediate parts
12. Symbols for tolerance and form
13. Symbols for position and form
14. Positional tolerancing
15. Angular tolerances
16. Surface quality specifications
17. Surface quality symbols
18. Surface quality notes
19. Lay symbols
JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

20. Dimension an object completely
21. Calculate and dimension clearance fit tolerances using standard fit tables
22. Calculate and dimension interference fit tolerances using standard fit tables
23. Calculate and assign tolerances to mating parts using standard fit tables
24. Calculate and dimension hole size limits for standard dowels
25. Dimension an object using position and form tolerances
26. Determine ranges of motion of limbs and spaces required for a person

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT VI: FASTENERS AND HARDWARE

1. Terms and definitions
2. Types of fasteners
3. Applications of screw threads
4. Screw threads nomenclature
5. Screw thread profiles
6. Lead of thread
7. Screw thread symbols
8. Classes of fit for unified threads
9. Classes of fit for metric threads
10. Parts of thread notes
11. Conventional representations of pipe threads
12. Types of threaded removable fasteners
13. Shapes of bolts and nuts
JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

14. Types of locknuts and locking devices

15. Types of standard cap screws

16. Types of machine screws

17. Set screw heads and points

18. Miscellaneous bolts and screws

19. Standard large and small rivets

20. Rivet symbols

21. Advantages of plastic fasteners over metal fasteners

22. Devices to lock components on a shaft

23. Types of springs

24. Types of spring clips

25. Types of keys

26. Types of machine pins

27. Washers

28. Applications of inserts

29. Types of lock washers

30. Uses for spring washer designs

31. Quick opening and locking devices

32. Miscellaneous machine elements

33. Advantages of different fasteners

34. Types of welded joints

35. Parts of a welding symbol

36. Basic arc and gas weld symbols
JOB TRAINING: What the Worker Should Be Able To Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

37. Supplementary welding symbols
38. Welding dimensions for a fillet weld
39. Resistance welding symbols
40. Using adhesives for bonding materials
41. Joint design considerations for adhesive bonding

42. Construct thread symbols
43. Construct bolts, screws, and nuts
44. Construct an assembly containing various fasteners
45. Construct a welded assembly drawing
46. Construct spring drawings to include specifications
47. Construct keys in assembled-positions
48. Write specifications for hardware from vendor catalogs

UNIT VII: PRESENTATION DRAWINGS

1. Terms and definitions
2. Types of presentation sketches
3. Steps of sketching
4. Ellipse construction
5. Shading techniques
6. Types of axonometric drawings
7. Oblique drawings
8. Parts of exploded assembly presentation drawings
9. Special requirements for patent drawings
JOBT TRAINING: What the Worker Should Be Able to Do (Psychomotor)

10. Shade pictorials
11. Construct conceptual presentation sketches
12. Construct design sketches
13. Construct a dimetric presentation drawing
14. Construct an oblique presentation drawing
15. Construct a two point presentation perspective of an object
16. Construct an exploded assembly presentation drawing

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT VIII: MATERIALS AND SPECIFICATIONS

1. Terms and definitions
2. Specifications found on mechanical drawings
3. Heat treatments for metals
4. Surface hardening treatments for metals
5. Forms of carbon steel
6. Categories of pipe
7. Specifications for tubing callouts
8. Specifications for structured steel shapes
9. Standard mill forms of materials
10. Metal properties
11. Factors to consider in selecting materials
12. Types and kinds of ferrous manufacturing metals
10. TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

12. Parts of the steel numbering system
14. Copper type metals
15. Condition of aluminium
16. Types of plastic materials
17. Refractory materials

18. Determine wire and sheet metal size from gage number
19. Select materials from a materials stockbook

UNIT IX: MANUFACTURING PROCESSES

1. Terms and definitions
2. Purposes of manufacturing processes
3. Types of drawings
4. Casting terms
5. Design procedures for casting
6. Pattern and machine dimensions
7. Design procedures for a forging
8. Design procedures for a welded assembly
9. Machine processes
10. Numerical control machinery
11. Plastics
12. Sheet metal processing
13. Sheet metal hems and joints
JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

14. Calculate bend allowance for sheet metal
15. Design a casting part
16. Design a forging part
17. Design a welded part
18. Design a thermoplastic part

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

UNIT X: SHEET METAL DEVELOPMENTS

1. Terms and definitions
2. Visualization
3. Constructing an auxiliary view
4. True length lines and true sizes of three view drawings
5. Point views of lines and edge views of planes
6. Characteristics of rotation
7. Elements of single curved surfaces
8. Finding intersections of surfaces
9. Groups of developments
10. Calculate bend allowance
11. Label points, lines, and planes in views
12. Identify true lengths and types of lines
13. Identify true sizes and types of planes
14. Construct lengths of lines and true sizes of planes using auxiliary views
15. Construct true lengths of lines by rotation
16. Construct true sizes of planes by rotation
17. Locate elements of single curved surfaces
JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

18. Construct intersections of surfaces
19. Construct intersections of surfaces using two-view method
20. Construct radial line developments
21. Construct parallel line developments
22. Construct special developments using triangulation

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT XI: POWER TRANSMISSION

1. Terms and definitions
2. Advantages of chain drives and gear drives
3. Advantages of chain drives and belt drives
4. Steps for selecting a V-belt drive
5. Types of power transmission chains
6. Types of gears
7. Parts of gear teeth
8. Parts of pinion and gear
9. Cutting data needed for spur gear drawings
10. Parts of a bevel gear
11. Cutting data needed for bevel gears
12. Cutting data needed for worm and worm wheel
13. Gear ratio
14. Gear rotation
JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

24. Construct a spur gear drawing
25. Construct a bevel gear
26. Construct a worm and worm gear
27. Calculate gear ratios
28. Determine gear rotation
29. Calculate gear speeds
30. Construct a cam drawing
31. Select a chain drive
32. Select a V-belt drive
33. Select types of bearings from handbooks

RELATED INFORMATION: What the Worker Should Know
(Cognitive)
15. Gear speed
16. Types of couplings
17. Types of bearings
18. Cam nomenclature
19. Types of cam followers
20. Types of cam motions
21. Hydraulic nomenclature
22. Pneumatic components
23. Air circuit components
Tools, Materials, and Equipment List

Triangles 45°, 30° 60°
Compass
Divider
Protractor
Irregular curve
Drafting machine with scales or
Parallel bar or T-square with adjustable triangle
Drawing media
Drawing surface or table
Drafting tape
Drawing pencils
Lead holder
Lead
Lead pointer
Paper towel or cleaning cloth
Nonabrasive hand eraser
Lettering guide for guidelines
Scale wrench
Mechanical Engineer Scale
Machinists steel rules
Metric scale
Standard fit tables
ANSI Drafting Standards Manual

(NOTE: Micrometers and vernier scale calipers need to be available for use in Unit II, "Tools and Equipment.")
REFERENCES


American National Standards Institute, 1430 Broadway, New York, NY 10018.


(NOTE: This can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)


(NOTE: This book is out of print and may be difficult to find.)


*The Kodak Compass*. Eastman Kodak Company, Rochester, NY 14650.


*Metals Stock List*, Ducommun Metals Company, P. O. Box 82356, 2101 South Villa, Oklahoma City, Ok 73018.


*Oklahoma Directory of Manufacturers and Products*. Oklahoma City: Oklahoma Industrial Development Department, 1981.

(NOTE: Each state may have one available.


*Patterson Steel Company Reference Book*. Metal Service Center, 801 North Xanthus, P.O. Box 2620, Tulsa, OK 74101.


*Shapes and Plates*. United States Steel, Pittsburgh, Pennsylvania 15230.


*Steel and Aluminum Stock List and Reference Book*, #76, Earle M. Jorgenson Co., P.O. Box 169665, Denver, Colorado 80216.

*Steel Sales Stock List*, Steel Sales Corp., 3348 S. Pulaski Rd., Chicago, IL 60623.


Additional references:


UNIT OBJECTIVE

After completion of this unit, the student should be able to list job opportunities within the mechanical drafting profession and recognize the qualifications and performance standards for positions in the profession. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to orientation with the correct definitions.
2. Define mechanical drafting.
3. List areas of specialization in mechanical drafting.
4. List industries that employ mechanical drafters.
5. Match job titles with the correct job descriptions.
6. Arrange in order the steps in mechanical design and drafting work.
7. Select duties of a mechanical drafter.
8. Match job classifications with the correct responsibilities within a manufacturing structure.
9. List related occupations for a mechanical drafter.
10. Distinguish between the advantages and disadvantages of a mechanical drafting occupation.
11. Match mechanical drafting positions with the correct minimum qualifications.
12. List important personality traits for a mechanical drafter.
13. Select important related skills for a mechanical drafter.
14. Complete a list of evaluation areas for drafters.
15. Select evaluation areas for mechanical drawings.
16. Define abbreviations of professional organizations for mechanical drafters and designers.
17. Select advantages of joining and/or participating in professional organizations.

18. Demonstrate the ability to:
   a. Interview a mechanical drafter.
   b. Observe a mechanical drafter.
   c. Evaluate a mechanical drawing.
ORIENTATION
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.
II. Provide student with information and assignment sheets.
III. Make transparencies.
IV. Discuss unit and specific objectives.
V. Discuss information and assignment sheets.
VI. Have students role play and interview each other if it is not possible for them to interview a mechanical drafter for Assignment Sheet #1.
VII. Have students set up one appointment with a mechanical drafter for use with both Assignment Sheets #1 and #2.
VIII. Provide actual mechanical drawings for use with Assignment Sheet #3.
IX. Discuss in detail the advantages and disadvantages of being a mechanical drafter.
X. Invite speakers who have experience as mechanical drafters, checkers, and designers to speak to the class about their jobs.
XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Types of Mechanical Drafting
      2. TM 2--Types of Mechanical Drafting (Continued)
      3. TM 3--Industries That Employ Mechanical Drafters
      4. TM 4--Promotional Opportunities
      5. TM 5--Check List for Evaluating a Mechanical Drafter
      6. TM 6--Check List for Mechanical Drawings
D. Assignment sheets
   1. Assignment Sheet #1--Interview a Mechanical Drafter
   2. Assignment Sheet #2--Observe a Mechanical Drafter
   3. Assignment Sheet #3--Evaluate a Mechanical Drawing

E. Test

F. Answers to test

II. References:


I. Terms and definitions

A. Technological team—Craftworkers, technicians, technologists, engineers, and scientists organized to solve a complex technical problem in a manufacturing environment

B. Technologist—Specialist in the technical details of solving an engineering problem; works as liaison between engineer and technician

(Note: A technologist sometimes works in the place of an engineer but is not a professional engineer.)

C. Designer—Engineer, technologist, or technician who has inventiveness and technical specialty

D. Product design—Design of a product or redesign of a product for consumers

E. Manufacturing design—Design of tools, fixtures, and machines for manufacturing a product

F. Mechanical designer—Technician, technologist, or engineer specialist that works in either product design and/or manufacturing design

(Note: Whether this person is a technician, technologist, or engineer depends upon the individual's experience and level of education.)

G. Level of technology—Classification of industries according to level of engineering complexity

(Note: A low level technology industry may be involved with simple mechanical parts, such as farm implements. A high level technology industry may be involved with complicated mechanical, hydraulic, or electronic parts, such as a space station.)

II. Definition of mechanical drafting—Form of drafting of mechanical parts and assemblies so that a product or manufacturing process can be produced

III. Areas of specialization in mechanical drafting (Transparencies 1 and 2)

A. Product related
   1. Machines
   2. Aerospace
   3. Structural
INFORMATION SHEET

4. Piping
5. Pressure vessel
6. Computer graphics
7. Communication
8. Sheet metal
9. Aircraft
10. Electrical power
11. Farm machinery
12. Mechanical power
13. Transportation
14. Power generation
15. Military equipment
16. Ships
17. Propulsion systems

B. Manufacturing related
   1. Machines
   2. Tool design
   3. Production design
   4. Industrial electronics
   5. Instrumentation
   6. Numerical control
   7. Plant layout
   8. Estimating
   9. Systems
  10. Power systems

IV. Industries that employ mechanical drafters (Transparency 3)
A. Transportation
B. Oil
INFORMATION SHEET

C. Manufacturing
D. Communication
E. Pipeline
F. Material fabrication
G. Electronics
H. Military
I. Aerospace
J. Farm machinery
K. Power generation
L. Ship building

V. Job titles and job descriptions (Transparency 4)

A. Trainee
   1. Traces or copies drawings made by others
   2. Revises drawings working from instructions
   3. Repairs or redraws damaged drawings
   4. Requires frequent supervision

B. Junior drafter
   1. Corrects and revises drawings
   2. May make simple detail and assembly drawings
   3. Makes sketches
   4. Requires some supervision

C. Drafter
   1. Draws details and assembly drawings
   2. Works with handbooks and reference materials
   3. Makes routine calculations
   4. Makes sketches and field notes
   5. Is completely familiar with drafting standards
INFORMATION SHEET

D. Senior drafter
   1. Handles design drafting detail assignments
   2. Exercises considerable judgment in layout
   3. Makes or reviews many calculations
   4. Has some supervisory duties

E. Checker
   1. Is an experienced drafter
   2. Checks all final drawings for errors
   3. Is directly responsible for errors
   4. Routes drawings through the department

F. Design drafter technician
   1. Works from engineering notes and specifications
   2. Does calculations
   3. Has thorough knowledge of accepted design concepts
   4. Works with statics, strength of material, machine design, kinematics, and mechanisms
   5. Has increased supervisory duties
   6. Handles complete design assignment with minimum supervision
   7. Generally has a two-year associate degree or equivalent

G. Design technologist
   1. Works with engineering staff
   2. Is a thoroughly experienced drafter
   3. Works with statics, strength of material, machine design, kinematics, and mechanisms
   4. Generally has a two or four-year college degree in mechanical design technology or design and drafting technology
   5. Has increased supervisory duties
INFORMATION SHEET

H. Senior design technologist

(NOTE: The senior design technologist may be called a product engineer or manufacturing engineer and may be the manager of the mechanical design and drafting department.)

1. Has several years experience
2. Coordinates production deadlines and cost analysis
3. Generally has a four-year college degree in mechanical design technology or engineering
4. Works with industrial designers and others responsible for social and environmental impact
5. Has increased supervisory duties

I. Chief design drafter

(NOTE: The chief design drafter may be the manager of the mechanical design and drafting department. Usually these drafters have worked their way up through the department.)

1. Responsible for all design and drafting in a company
2. Is in charge of hiring and firing
3. Sets work schedules, company drafting and design standards, and work loads
4. Generally has a four-year college degree in mechanical design technology or engineering
5. Responsible for budgeting and purchasing for department
6. Has increased supervisory duties

J. Computer-aided design drafter

1. Has all the skills of drafter
2. Has typing skills if input is by keyboard
3. Has two-year associate degree or equivalent

K. Computer-aided designer

1. Has all the skills of drafter and designer
2. Has computer programming skills
3. Has two or four-year college degree in mechanical design technology or design drafting technology
INFORMATION SHEET

VI. Steps in mechanical design and drafting work
   A. Preliminary design layout and/or rough sketches
   B. Set of working drawings
   C. Parts list and/or materials list and specifications
   D. Checking
   E. Corrections
   F. Engineer's approval
   G. Drawing release for production
   H. Revisions
   I. Prints made and sent to fabricators

VII. Duties of a mechanical drafter
   A. Read blueprints and interpret engineering sketches
   B. Prepare working drawings
   C. Compile bill of materials and/or parts list
   D. Use handbooks and reference materials to determine specifications and correct data concerning materials to be used
   E. Make necessary revisions and corrections on drawings that have been completed
   F. Maintain neat and accurate job files for jobs in progress
   G. Use all drafting equipment for mechanical drafters
   H. Maintain accurate file system for drawings
      (NOTE: In large companies this may be centralized, but in many smaller firms it is the direct responsibility of drafters to maintain the drawing files.)
   I. Establish working relationships with other personnel
   J. Dress and act in a manner acceptable to associates
INFORMATION SHEET

VIII. Job classifications and responsibilities within a manufacturing structure
A. Craftworkers—Production, skill trades
B. Technicians—Design, supervision, drafting, development, manufacturing
C. Non-registered technologists/engineers—Design, supervision, drafting, development, manufacturing
D. Registered engineers—Design, management

IX. Related occupations for a mechanical drafter
A. Estimator—Cost analyst
B. Inspector for quality control
C. Fabricator of prototypes and models
D. Manufacturing technician
E. Engineering aide
F. Sales representative for mechanical products
G. Technical illustrator
H. Numerical control programmer
I. Computer-aided drafter or designer

X. Advantages and disadvantages of a mechanical drafting occupation
A. Advantages
1. Clean indoor working conditions
2. Open job market
3. Most versatile and largest demand of all drafting areas
4. Good fringe benefit package
5. Much overtime available
6. Sense of self-satisfaction and pride
7. Good chance for advancement into higher paying occupations
8. Variety of challenging assignments
9. Opportunity to work alone on some projects
10. Individual drawing table and desk
INFORMATION SHEET

B. Disadvantages

1. Relatively confined area
2. Long hours at times of peak production
3. Responsibility to both management and production
4. Rigid accountability for accurate work
5. Knowledge of many technical fields required
6. Competition for raises and promotion
7. Very little physical exercise
8. Rigid time limits for doing work

XI. Mechanical drafting positions and minimum qualifications (Transparency 4)

A. Trainee

1. High school diploma, or be successfully working toward one
2. Course work in vocational drafting
   (NOTE: There is often a minimum grade point average that is required in this course work.)
3. One year of algebra and one year of geometry
4. Good character references
5. Good school attendance record

B. Drafter

1. High school diploma
2. Two or more years of vocational drafting
   (NOTE: There is often a minimum grade point average that is required in this course work.)
3. One or two years of algebra, one year of geometry, and one year of trigonometry
4. Good character references
5. Successful completion of an in-company training period
   (NOTE: In some companies this could be as long as one year.)
INFORMATION SHEET

C. Design drafter or computer-aided design drafter
   1. Associate degree or equivalent in mechanical design technology or
design and drafting technology
   2. Three years of drafting experience
   3. Good working credentials

D. Design technologist or computer-aided designer
   1. Associate degree or equivalent or bachelor's degree in mechanical
design technology, design and drafting technology, or mechanical
engineering
   2. Five years of drafting experience in specialty area in place of bachelor's
degree
   3. Good working credentials
   (NOTE: They may have engineer in their title, but they are not re-
quired to be licensed engineers.)

E. Licensed engineer
   1. Bachelor's or master's degree in engineering (4-5 years)
   2. Successful completion of state examination for engineering specialty
area
   3. Apprenticeship with 4-5 years of experience

XII. Important personality traits for a mechanical drafter

A. Ability to listen to and follow instructions well
B. Punctuality
C. Dependability
D. Ability to accept constructive criticism
E. Willingness to continue education
F. Ability to work quietly and patiently at detailed work for long hours
G. Flexibility to work alone at times and with others when needed
   (NOTE: In addition to personality, personal appearance is very important.)
INFORMATION SHEET

XIII. Important related skills for a mechanical drafter
   A. Speed
   B. Ability to operate drafting equipment correctly
   C. Manual dexterity
   D. Communication skills
      (NOTE: This should include language arts skills such as grammar, punctuation, and spelling.)
   E. Knowledge of materials, components, and manufacturing processes
   F. Math skills
   G. Ability to do neat, legible lettering

XIV. Evaluation areas for drafters (Transparency 5)
   A. Speed
   B. Accuracy
   C. Completeness
   D. Ability to get along with others
   E. Ability to work unsupervised
   F. Ability to conserve materials and man hours

XV. Evaluation areas for mechanical drawings (Transparency 6)
   A. Accuracy
   B. Linework
   C. Lettering
   D. Overall neatness
   E. Dimensioning
   F. Reproducibility
   G. Spelling and use of abbreviations
INFORMATION SHEET

XVI. Abbreviations of professional organizations for mechanical drafters and designers
A. AIDD--American Institute of Design and Drafting
B. SME--Society of Manufacturing Engineers
C. ASME--American Society of Mechanical Engineers
D. AIIE--American Institute of Industrial Engineers
E. AIAA--American Institute of Aeronautics and Astronautics
F. JETS--Junior Engineering Technical Society
G. ICET--Institute for Certification of Engineering Technicians
H. NCGA--National Computer Graphics Association

(NOTE: Some of these organizations have student chapters.)

XVII. Advantages of joining and/or participating in professional organizations
A. Find out about job opportunities
B. Keep up with changing technology
C. Make contacts and new friends within the industry to find job openings
D. Obtain personal library of technical reference material
E. Obtain certification credentials

(NOTE: Many of these credentials are recognized nationally. These can be extremely important if a person wants to change localities within the United States.)
Types of Mechanical Drafting

A. Product Related

1. Machines
2. Aerospace
3. Structural
4. Piping
5. Pressure Vessel
7. Communications
8. Sheet Metal
9. Aircraft
10. Electrical Power
11. Farm Machinery
12. Mechanical Power
13. Transportation
14. Power Generation
15. Military Equipment
16. Ships
17. Propulsion Systems
Types of Mechanical Drafting
(Continued)

B. Manufacturing Related

1. Machines
2. Tool Design
3. Production Design
4. Industrial Electronics
5. Instrumentation
6. Numerical Control
7. Plant Layout
8. Estimating
9. Systems
10. Power Systems
Industries That Employ Mechanical Drafters

A. Transportation
B. Oil
C. Manufacturing
D. Communication
E. Pipeline
F. Material Fabrication
G. Electronics
H. Military
I. Aerospace
J. Farm Machinery
K. Power Generation
L. Ship Building
Promotional Opportunities

Manager of Mechanical Design & Drafting Department

Chief Design Drafter

Computer-Aided Designer

Senior Design Technologist

Checker

Design Technologist

Senior Drafter

Design Drafter Technician

 Drafter

Junior Drafter

Trainee
Check List for Evaluating a Mechanical Drafter

A. Speed
B. Accuracy
C. Completeness
D. Ability to Get Along with Others
E. Ability to Work Unsupervised
F. Ability to Conserve Materials and Man Hours
Check List for Mechanical Drawings

A. Accuracy
B. Linework
C. Lettering
D. Overall Neatness
E. Dimensioning
F. Reproducibility
G. Spelling and Use of Abbreviations
ASSIGNMENT SHEET #1--INTERVIEW A MECHANICAL DRAFTER

Directions: Make an appointment with a mechanical drafter who is presently employed in that capacity. Ask the following questions and record the answers in the blanks provided.

1. What is your career title?

2. What tasks do you perform on the job?

3. What educational training and occupational experience is required for this job?

4. What personality traits are most important in your field?

5. What skills and knowledge are required in this occupation?

6. What is the approximate starting salary of workers in your occupation?

7. What is the employment outlook for the future in this career?
ASSIGNMENT SHEET #1

8. What are the possibilities for advancement in this field? __________________________

9. What is your favorite part of this job? ________________________________________

10. What is your least favorite part of the job? ____________________________________
UNIT I

ASSIGNMENT SHEET #2 - OBSERVE A MECHANICAL DRAFTER

Directions: After you finish Assignment Sheet #1, ask the mechanical drafter if you could watch quietly for about an hour in order to observe the drafter's work habits. Make comments in the blanks provided, and rate in the following areas:

<table>
<thead>
<tr>
<th></th>
<th>EXCELLENT</th>
<th>GOOD</th>
<th>FAIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Speed</td>
<td></td>
<td></td>
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<tr>
<td>2. Accuracy</td>
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<tr>
<td>3. Completeness</td>
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<tr>
<td>4. Ability to get along with others</td>
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<tr>
<td>5. Ability to work unsupervised</td>
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</tbody>
</table>

A. Ability to get along with others

B. Ability to work unsupervised
6. Ability to conserve materials and man hours

(NOTE: You may not be able to give a fair evaluation for all areas in only one hour, but rate what you see to the best of your ability.)
Directions: Evaluate a mechanical drawing of a fellow student or one provided by the instructor. Make comments in the blanks provided and evaluate in the following areas:

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<th>EXCELLENT</th>
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<tbody>
<tr>
<td>1. Accuracy</td>
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<tr>
<td>2. Linework</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3. Lettering</td>
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<tr>
<td>4. Overall neatness</td>
<td></td>
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<tr>
<td>5. Dimensioning</td>
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</tbody>
</table>
6. Reproducibility

<table>
<thead>
<tr>
<th>EXCELLENT</th>
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7. Spelling and use of abbreviations

<table>
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(NOTE: You may want to actually reproduce the drawing, or ask the instructor how well it would reproduce.)
1. Match the terms on the right with the correct definitions.

   a. Engineer, technologist, or technician who has inventiveness and technical specialty
   b. Craftworkers, technicians, technologists, engineers, and scientists organized to solve a complex technical problem in a manufacturing environment
   c. Design of a product or redesign of a product for consumers
   d. Technician, technologist, or engineer specialist that works in either product design and/or manufacturing design
   e. Specialist in the technical details of solving an engineering problem; works as liaison between engineer and technician
   f. Design of tools, fixtures, and machines for manufacturing a product
   g. Classification of industries according to level of engineering complexity

2. Define mechanical drafting.

3. List eight areas of specialization in mechanical drafting.
   a.
   b.
   c.
   d.
4. List six industries that employ mechanical drafters.

a. 

b. 

c. 

d. 

e. 

f. 

5. Match the job titles on the right with the correct job descriptions.

_____ a. Coordinates production deadlines and cost analysis 

_____ b. Handles complete design assignment with minimum supervision 

_____ c. Traces or copies drawings made by others 

_____ d. Exercises considerable judgment in layout 

_____ e. May make simple detail and assembly drawings 

_____ f. Is completely familiar with drafting standards 

_____ g. Works with statics, strength of material, machine design, kinematics, and mechanisms 

_____ h. Checks all final drawings for errors 

_____ i. Has typing skills if input is by keyboard 

_____ j. Is in charge of hiring and firing 

_____ k. Has computer programming skills 

1. Trainee 

2. Junior drafter 

3. Drafter 

4. Senior drafter 

5. Checker 

6. Design drafter technician 

7. Design technologist 

8. Senior design technologist 

9. Chief design drafter 

10. Computer-aided design drafter 

11. Computer-aided designer
6. Arrange in order the steps in mechanical design and drafting work by placing the correct sequence numbers in the appropriate blanks.

- a. Drawing release for production
- b. Revisions
- c. Engineer's approval
- d. Corrections
- e. Prints made and sent to fabricators
- f. Checking
- g. Set of working drawings
- h. Parts list and/or materials list and specifications
- i. Preliminary design layout and/or rough sketches

7. Select duties of a mechanical drafter by placing an "X" in the appropriate blanks.

- a. Visit construction site
- b. Make necessary revisions and corrections on drawings that have been completed
- c. Compile bill of materials and/or parts list
- d. Read blueprints and interpret engineering sketches
- e. Supervise construction crew
- f. Prepare working drawings
- g. Type office correspondence
- h. Use all drafting equipment for mechanical drafters

8. Match the job classifications on the right with the correct responsibilities within a manufacturing structure.

- a. Design, supervision, drafting, development, manufacturing
- b. Design, management
- c. Production, skill trades

1. Registered engineers
2. Non-registered technologists/engineers
3. Technicians
4. Craftworkers

9. List five related occupations for a mechanical drafter.

a. 

b. 

c. 

10. Distinguish between the advantages and disadvantages of a mechanical drafting occupation by placing an "X" next to the advantages.

a. Relatively confined area
b. Open job market
c. Good chance for advancement into higher paying occupations
d. Very little physical exercise
e. Responsibility to both management and production
f. Much overtime available
g. Good fringe benefit package

11. Match the mechanical drafting positions on the right with the correct minimum qualifications.

(Note: Some qualifications can be answered by more than one position.)

a. Course work in vocational drafting
b. Successful completion of state examination for engineering specialty area
c. Three years of drafting experience
d. Five years of drafting experience in specialty area in place of bachelor's degree
e. Associate degree or equivalent in mechanical design technology or design and drafting technology
f. Bachelor's or master's degree in engineering

12. List four important personality traits for a mechanical drafter.

a. 

b. 

c. 

d. 

13. Select important related skills for a mechanical drafter by placing an "X" in the appropriate blanks.

   ____ a. Slow
   ____ b. Ability to operate drafting equipment correctly
   ____ c. Manual dexterity
   ____ d. Ability to do survey work
   ____ e. Knowledge of materials, components, and manufacturing processes
   ____ f. Math skills
   ____ g. Ability to do neat, legible lettering

14. Complete the following list of evaluation areas for drafters.

   a. Speed
   b. 
   c. Completeness
   d. 
   e. Ability to work unsupervised
   f. Ability to conserve materials and man hours

15. Select evaluation areas for mechanical drawings by placing an "X" in the appropriate blanks.

   ____ a. Lettering
   ____ b. Cleverness of design
   ____ c. Linework
   ____ d. Dimensioning

16. Define the following abbreviations of professional organizations for mechanical drafters and designers.

   a. AIIE--
   b. SME--
   c. AIDD--
   d. ICET--
17. Select advantages of joining and/or participating in professional organizations by placing an "X" in the appropriate blanks.

_____ a. Make contacts and new friends within the industry to find job openings

_____ b. Obtain certification credentials

_____ c. Requires dues to be paid for membership

_____ d. Keep up with changing technology

_____ e. May take away from family time once a month

18. Demonstrate the ability to:

a. Interview a mechanical drafter.

b. Observe a mechanical drafter.

c. Evaluate a mechanical drawing.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
UNIT I

ANSWERS TO TEST

1. a. 6  e. 3
    b. 5  f. 7
    c. 1  g. 4
    d. 2

2. Mechanical drafting—Form of drafting of mechanical parts and assemblies so that a product or manufacturing process can be produced.

3. Any eight of the following:
   a. Machines  j. Electrical power  s. Production design
   b. Aerospace  k. Farm machinery  t. Industrial electronics
   c. Structural  l. Mechanical power  u. Instrumentation
   d. Piping  m. Transportation  v. Numerical control
   e. Pressure vessel  n. Power generation  w. Plant layout
   g. Communication  p. Ships  y. Systems
   h. Sheet metal  q. Propulsion systems  z. Power systems
   i. Aircraft  r. Tool design

4. Any six of the following:
   a. Transportation  g. Electronics  s. Production design
   b. Oil  h. Military  t. Industrial electronics
   c. Manufacturing  i. Aerospace  u. Instrumentation
   d. Communication  j. Farm machinery  v. Numerical control
   e. Pipeline  k. Power generation  w. Plant layout
   f. Material fabrication  l. Ship building  x. Estimating
      y. Systems  z. Power systems

5. a. 8  f. Any except 1 or 2  k. 11
    b. 6  g. 6, 7
    c. 1  h. 5
    d. 4  i. 10 or 11
    e. 2  j. 9

6. a. 7  f. 4
    b. 8  g. 2
    c. 6  h. 3
    d. 5  i. 1
    e. 9

7. b, c, d, f, h

8. a. 2, 3  c. 4
    b. 1
9. Any five of the following:
   a. Estimator-cost analyst
   b. Inspector for quality control
   c. Fabricator of prototypes and models
   d. Manufacturing technician
   e. Engineering aide
   f. Sales representative for mechanical products
   g. Technical illustrator
   h. Numerical control programmer
   i. Computer-aided drafter or designer

10. b, c, f, g

11. a. 1, 2  c. 3  e. 3, 4
     b. 5  d. 4  f. 5

12. Any four of the following:
   a. Ability to listen to and follow instructions well
   b. Punctuality
   c. Dependability
   d. Ability to accept constructive criticism
   e. Willingness to continue education
   f. Ability to work quietly and patiently at detailed work for long hours
   g. Flexibility to work alone at times and with others when needed

13. b, c, e, f, g

14. b. Accuracy
    d. Ability to get along with others

15. a, c, d

16. a. American Institute of Industrial Engineers
     b. Society of Manufacturing Engineers
     c. American Institute of Design and Drafting
     d. Institute for Certification of Engineering Technicians

17. a, b, d

18. Evaluated to the satisfaction of the instructor
TOOLS AND EQUIPMENT
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify tools and equipment and use the equipment to solve problems. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

(NOTE: Students are expected to have covered units on tools, equipment, and scales from Basic Drafting, Book One before attempting this unit.)

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to tools and equipment with the correct definitions.
2. Complete a list of mechanical templates.
3. Match machinist precision measuring instruments with the correct functions.
4. Identify types of welding measuring instruments.
5. Identify types of scales used in mechanical drafting.
6. Name the primary metric unit of measurement used in mechanical drafting.
7. Classify the scales used in mechanical drafting.
8. Complete a list of hand calculator functions.
9. Distinguish between the types of keyboard sequences used in hand calculators.
10. Demonstrate the ability to:
    a. Read micrometer settings.
    b. Read vernier calipers.
    c. Measure with scales.
    d. Compute mechanical drafting problems using a hand calculator.
    e. Use a micrometer.
    f. Use a vernier caliper.
TOOLS AND EQUIPMENT
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.
II. Provide student with information, assignment, and job sheets.
III. Make transparencies.
IV. Discuss unit and specific objectives.
V. Discuss information and assignment sheets.
VI. Demonstrate and discuss the procedures outlined in the job sheets.
VII. Invite a machinist and/or welder to class to discuss measuring devices.
VIII. Display several types of tools and related items used in various machine and welding shops.
IX. Allow students to measure with devices.
X. Discuss the importance of accuracy and precision with students.
XI. Use a computer, if available, along with the hand calculator in Assignment Sheet #6.

(NOTE: Students who normally have problems with math seem to master the calculator without much problem once they figure out sequences.)

XII. Refer to Basic Drafting, Book Two for teaching skills related to construction of tangents and ellipses.
XIII. Show template catalog.
XIV. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1-Templates-General Purpose
      2. TM 2-Template-Threaded Fasteners
      3. TM 3-Template-Ellipses
4. TM 4--Templates--Miscellaneous
5. TM 5--Types of Machinist Rules
6. TM 6--Uses of Rules--Measurement Transfer
7. TM 7--Uses of Rules
8. TM 8--Outside Micrometer Parts
9. TM 9--Reading a Micrometer
10. TM 10--Parts of the Inside Micrometer
11. TM 11--Inside Micrometer Set
12. TM 12--Uses of the Inside Micrometer
13. TM 13--Uses of the Inside Micrometer (Continued)
14. TM 14--Parts of a Depth Micrometer
15. TM 15--Uses of the Depth Micrometer
16. TM 16--Machinist Precision Instruments
17. TM 17--Machinist Precision Instruments (Continued)
18. TM 18--Dial and Vernier Calipers
19. TM 19--Vernier Scales
20. TM 20--Welding Measuring Instruments
21. TM 21--Mechanical Engineer Scale
22. TM 22--Machinist Steel Rules
23. TM 23--Algebraic Keyboard
24. TM 24--Hand Calculator Keyboard Sequences

D. Assignment Sheets
1. Assignment Sheet #1--Read Micrometer Settings
2. Assignment Sheet #2--Read Vernier Calipers
3. Assignment Sheet #3--Measure with Scales
4. Assignment Sheet #4--Compute Mechanical Drafting Problems Using A Hand Calculator
E. Answers to assignment sheets

F. Job sheets
   1. Job Sheet #1--Use a Micrometer
   2. Job Sheet #2--Use a Vernier Caliper

G. Test

H. Answers to test

II. References:


I. Terms and definitions

A. Template--A thin, flat, plastic tool with various size openings of different shapes used to expedite the drawing of standard features.

B. Precision instruments--Instruments used by machinists to measure and gage products.

(NOTE: Gage is often spelled gauge.)

C. Transfer artwork--Preprinted letters, symbols, and shading that can be rubbed on or cut out for drawings to save drafting time.

D. Scale--Instrument used as a standard of reference when drawing an object to a proportional size.

E. Hand calculator--Calculating device to solve mathematical problems.

F. Logic--Arrangement of a sequence of operations.

G. Datums--Points, lines, or other geometric shapes assumed to be exact from which the location or geometric form of features of a part may be estimated.

II. Mechanical templates (Transparencies 1-4)

A. General purpose

1. Circles
2. Squares
3. Arrows
4. Hexagons
5. Octagons
6. Triangles

B. Welding

C. Threaded fasteners

1. Nuts
2. Bolts
3. Screws
4. Threads
D. Sprites

E. Three dimensional
   1. Projection ellipses
   2. Isometric ellipses
   3. Isometric hexagon bolt heads and nuts
   4. Projection hexagon bolt heads and nuts

III. Machinist precision measuring instruments and functions (Transparencies 5-19)

(NOTE: Machinist precision measuring instruments are expensive and should be handled with care and stored properly.)

A. Rules—Distance measurements

B. Outside micrometer—Accurate outside measurements

C. Inside micrometer—Accurate inside measurements

D. Depth micrometer—Depth of slots of holes from datum surfaces

E. Caliper—Approximate internal and external measurements

F. Vernier caliper—Both inside and outside measurements

G. Dial caliper—Continuous reading and dial test indicators for gaging
   (NOTE: The dial on this caliper may be metric.)

H. Height transfer gage for surfaces—Accurate parallel surface measurements

I. Sine bar—Accurate angle measurements

J. Dial indicator gage—Alignment, eccentricity, or deviations on surfaces

K. Snap gage—Plain external dimensions for "go" or "no go" gaging

L. Plug gage—Internal dimensions of holes for "go" or "no go" gaging

M. Divider—Dimension transfers and circle scribes

N. Optical comparator—Comparison of finished part to a master or lines on a screen
   (NOTE: These instruments are very accurate in measurement, location of datums, and gaging of surfaces and holes. These instruments may be calibrated in decimals of an inch or metric.)
INFORMATION SHEET

IV. Types of welding measuring instruments (Transparency 20)
   A. Combination square
   B. Steel rule
   C. Steel square
   D. Tapes
   E. Outside caliper
   F. Inside caliper

V. Types of scales used in mechanical drafting (Transparencies 21 and 22)
   A. Mechanical engineer scale
   B. Machinist steel rule
   C. Metric scale

VI. Primary metric unit of measurement used in mechanical drafting—Millimeter
    (NOTE: The meter and kilometer are secondary scales. The centimeter and decimeter are rarely used.)

VII. Scales used in mechanical drafting
    A. Mechanical engineer scale (Transparency 21)
       (NOTE: Review "Mechanical Engineer's Scale Usage," Unit VII, of Basic Drafting, Book One for use of these scales.)
       1. Fractions (scale ratio)—Open divided
          a. 1" = 1"—Full size
          b. 1/2" = 1"—Half size
          c. 1/4" = 1"—Quarter size
          d. 1/8" = 1"—One-eighth size
       2. Decimal—Full divided
          a. 10 parts per inch—Each division equals .1"
          b. 50 parts per inch—Each division equals .02"
INFORMATION SHEET

B. Machinist steel rule (common) (Transparency 22)

1. Fractions-English
   a. 32 parts per inch--Each division equals 1/32"
   b. 64 parts per inch--Each division equals 1/64"

2. Decimal-English
   a. 10 parts per inch--Each division equals .1"
   b. 50 parts per inch--Each division equals .02"

3. Metric-IS
   (NOTE: Review "Metric Scale Usage," Unit VIII, of Basic Drafting, Book One for use of these scales.)
   a. Millimeters (mm)--Each division equals 1mm
   b. 1/2 millimeters--Each division equals .5mm

   (NOTE: Machinist steel rules may be found in various combinations of fractions, decimals, and metrics in the common scales above or other scales.)

C. Metric scale

1. 1:1
2. 1:2
3. 1:3
4. 1:5
5. 1:10

VIII. Hand calculator functions (Transparency 23)

A. Primary

1. Add
2. Subtract
3. Multiply
4. Divide
INFORMATION SHEET

B. Secondary

1. Reciprocal
2. Square
3. Square root
4. Logarithm
5. Trigonometric
6. Storage (memory)
7. Antilogarithm
8. Angular mode (radians-degrees)
9. Hyperbolic

IX. Types of keyboard sequences used in hand calculators (Transparency 24)

A. Lukasciewicz

1. Is referred to as "reverse Polish"
2. Has operational stack
3. Usually takes fewer steps

B. Algebraic

1. Is easy to master
2. Sometimes takes more steps
Templates
General Purpose

Professional Arrow

General Purpose

Square Template

Circle Master

Triangles/Diamonds

Dimensioning Arrows

Courtesy of Chartpak-Pickett
Templates
Threaded Fasteners

Screw Threads

Nut, Bolt, and Screw Template

Hexagon Socket Screws

Springs and Screw Threads

Small Machine Screw Template

Standard Screw Heads

Courtesy of Chartpak-Pickett
Templates
Ellipses

Isometric Ellipse

Large Isometric Ellipse

Master Ellipse

Master Ellipse

Master Ellipse

Master Ellipse

Courtesy of Chartpak-Pickett
Templates
Miscellaneous

Welding Symbols

Tool Planner

Large Hexagon Bolts and Nuts

Hexagon Nuts

Involute Rack and Spur Gear

Isometric Hexagon Heads and Nuts

Isometric Springs

Courtesy of Chartpak-Pickett
Types of Machinist Rules

Narrow Flexible Rule

Steel Rule

Hook Rule

Dial Caliper

Short Rule with Holder

Slide Caliper Rule
Uses of Rules

MEASUREMENT TRANSFER

Outside Caliper

Inside Caliper

Hermaphrodite Caliper
Uses of Rules

Depth Gauge

Combination Square
Reading a Micrometer

**English**

- 0.184
- 0.086

**Metric**

- 15.05mm
- 11.40mm
Parts of the Inside Micrometer

- Lock Screw
- Body
- Rod
- Handle
- Thimble
- Anvil
Inside Micrometer Set

Extension Rods

Extension Collar

Height Gauge Base

Base Unit

Extension Handle

Wrenches
Uses of the Inside Micrometer

Height Gauge

Measurement Transfer

1.250”
Uses of the Inside Micrometer
(Continued)

Measuring Inside Diameters

Measuring Widths
Parts of a Depth Micrometer

- Ratchet Stop
- Thimble Cap
- Thimble
- Sleeve
- Base
- Measuring Rod
Uses of the Depth Micrometer

Measuring Depth of Milled Slot
Measuring Shallow Recess
Machinist Precision Instruments

Plug Gage for Checking a Hole Size

Adjustable Limit Snap Gage Set for Inspecting a Dimension

Height Transfer Gage for Surfaces

Machinist Precision Instruments
(Continued)

Sine Bar Setup on Gage Blocks for Measuring an Angle on a Workpiece

Dial Indicating Gage with Permanent Magnet Base

Dial and Vernier Calipers

Dial Caliper

Metric Dial

Vernier Caliper
Vernier Scales

25 Division Inch Caliper

50 Division Inch and Metric Caliper
Welding Measuring Instruments

Steel Square

Combination Square

Steel Rule

Inside Caliper

Outside Caliper

Tapes
Machinist Steel Rules

10ths, 50ths

Decimal

32nds, 64ths

Fractions

Full mm, ½ mm

Metric
Algebraic Keyboard

![Image of Algebraic Keyboard]

Courtesy of Texas Instruments, Inc.
# Hand Calculator Keyboard Sequences

<table>
<thead>
<tr>
<th>Problem</th>
<th>Lukasiewicz</th>
<th>Algebraic</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3×4) + (7×8)=?</td>
<td>3 4 x 7 8 + +</td>
<td>3 × 4 + 7 × 8 =</td>
</tr>
<tr>
<td>(3×4) × (7+8)=?</td>
<td>3 4 x 7 8 + x</td>
<td>3 + 4 ÷ STO 7 + 8 = x RCL =</td>
</tr>
<tr>
<td>(3+4) ÷ (7+8)=?</td>
<td>3 4 + 7 8 + ÷</td>
<td>3 + 4 ÷ STO 7 + 8 = ÷ RCL 4 ÷ =</td>
</tr>
</tbody>
</table>
ASSIGNMENT SHEET #1: READ MICROMETER SETTINGS

(Note: Students should complete Job Sheet #1 before attempting this assignment.)

Directions: Read the micrometer settings below, and place your answers in the blanks provided at the right of the page.

Problems:
A. Inch

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

Answers

1. ____________

2. ____________

3. ____________

4. ____________

5. ____________

6. ____________

7. ____________

8. ____________

9. ____________

10. ____________

11. ____________

12. ____________

13. ____________
ASSIGNMENT SHEET #2 - READ VERNIER CALIPERS

(NOTE: Students should complete Job Sheet #2 before attempting this assignment)

Directions. Read the vernier caliper settings below, and place your answers in the blanks provided at the right of the page.

Problems.

A. 25 graduations - inch

1. 

Answers

1. 

2. 

B. 50 graduations - inch

1. 

2. 

1.
ASSIGNMENT SHEET #2

2. 

1. 

2. 

C. Metric
TOOLS AND EQUIPMENT
UNIT II

ASSIGNMENT SHEET #3: MEASURE WITH SCALES

Directions: Measure the lines A through H using each of the scales indicated at the top of each column in the following tables. Place the scale readings in the appropriate spaces in the tables.

Example: Measure line "A" with a mechanical engineer scale with inches reading in 50ths. A reading of 3.89" is obtained. This dimension is placed under the decimal column of the mechanical engineer scale table.

Problems:

A. 

B. 

C. 

D. 

E. 

F. 

G. 

H. 


ASSIGNMENT SHEET #3

<table>
<thead>
<tr>
<th>MECHANICAL ENGINEER SCALE</th>
<th>METRIC SCALE (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECIMAL</td>
<td>FRACTIONS</td>
</tr>
<tr>
<td>1&quot; = 1&quot;</td>
<td>1/2&quot; = 1&quot;</td>
</tr>
<tr>
<td>(2 Places)</td>
<td>1/4&quot; = 1&quot; (Nearest 32nd)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.89</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MACTHINIST STEEL RULE

<table>
<thead>
<tr>
<th>FRACTIONS (NEAREST 1/64)</th>
<th>DECIMAL (NEAREST .02)</th>
<th>METRIC (NEAREST mm)</th>
<th>METRIC (NEAREST 1/2 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
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<td></td>
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<tr>
<td>C</td>
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<td>F</td>
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<td>G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
TOOLS AND EQUIPMENT
UNIT II

ASSIGNMENT SHEET #4 - COMPUTE MECHANICAL DRAFTING PROBLEMS USING A HAND CALCULATOR

Directions. On engineering grid paper, compute the mechanical drafting problems using a hand calculator with trigonometry functions. You are given an example for each type of problem to be used as a guideline. Each example is immediately followed by the specific problem(s) that you need to solve.

Example A: Make calculations for centering a drawing (Figure 1)

1. Find W
   \[ A + B + C = W, \text{ if } A = 60, B = 50, C = 30, \text{ then } 60 + 50 + 30 + = 140\text{mm} \]

2. Find K
   \[ \text{Horizontal dimension } W = K, \text{ if horizontal dimension } = 240, \text{ then } 240 - 140 = 100\text{mm} \]

3. Find X
   \[ K \div 2 = X = \text{left and right space, if } K = 100, \text{ then } X = 100 - 2 = 50\text{mm (space on both left and right)} \]

Problem A:

1. Find X in the following layout dimensions (Figure 2)

   **Figure 2**

   \[ X = \text{________________________} \]
ASSIGNMENT SHEET #4

2. Find X in the following layout dimensions (Figure 3)

(NOTE: Convert fractions to decimals by dividing top (numerator) by bottom (denominator.) Example: 5/8 = 5 ÷ 8 = .625.)

\[ X = \frac{16}{10} \]

3. Find X in the following layout dimensions (Figure 4)

\[ X = \frac{5.62}{13.75} \]

\[ X = \frac{4.32}{33} \]
Example B: Make triangle calculations

1. Find "R" distance using the following steps on the hand calculator: (Figure 5)

   ![Diagram of triangle with labels A, B, C, R, 90°, and sides 5, 12, and R.]

   a. \((AB)^2 = (BC)^2 + (CA)^2\)
   b. \(R^2 = (5)^2 + (12)^2\)
   c. \(R^2 = 25 + 144\)
   d. \(R^2 = 169\)
   e. \(R = \sqrt{169} = 13\)

2. Find "X" distance using the following steps on the hand calculator: (Figure 6)

   ![Diagram of triangle with labels A, B, X, C, 90°, and sides 13, 12, and X.]

   a. \((AB)^2 = (BC)^2 + (CA)^2\)
   b. \((13)^2 = (BC)^2 + (12)^2\)
   c. \(169 = (BC)^2 + 144\)
   d. \(169 - 144 = (BC)^2\)
   e. \(25 = (BC)^2\)
   f. \(\sqrt{25} = BC\)
   g. \(5 = BC = X\)
ASSIGNMENT SHEET #4

Problem B:

1. Calculate R (Figure 7) \[ R = \]

![Figure 7]

2. Calculate X (Figure 8) \[ X = \]

![Figure 8]

(NOTE: If you should need to find the area for triangles, use the following formula: Area = 1/2 x Opposite side x Adjacent side. See Figure 9.)

![Figure 9]
ASSIGNMENT SHEET #4

(NOTE: If you should need to find the area of an oblique triangle, use the following formula: Area = 1/2 x Base x Altitude. See Figure 10.)

Example C: Make circle calculations by using the following formulas:

- Area = \( \pi R^2 = \frac{\pi (D)^2}{4} \) and Circumference = \( \pi D = 2\pi R \) (Figure 11)

(NOTE: Use 3.1416 = \( \pi \).)

1. Find area
   a. Use area = \( \pi R^2 \) and radii = 2"
      
      \[
      \text{Area} = 3.1416 (2)^2 \\
      = 3.1416 (4) \\
      = 12.566
      \]
      (NOTE: Diameter = 2R.)
   b. Use area = \( \frac{\pi (D)^2}{4} \)
      
      \[
      \text{Area} = \frac{3.1416 (4)^2}{4} \\
      = 12.566
      \]

2. Find circumference
   a. Use circumference = \( 2\pi R \) and radii = 3"
      
      \[
      \text{Circumference} = 2 (3.1416) 3 \\
      = 18.850
      \]
   b. Use circumference = \( \pi D \)
      
      \[
      \text{Circumference} = 3.1416 (6) \\
      = 18.850
      \]
Problem C:

1. Calculate area of a 6.32" diameter circle

\[ A = \frac{\pi \times (6.32)^2}{4} \]

2. Calculate area of a 4.5" radius circle

\[ A = \pi \times (4.5)^2 \]

3. Calculate circumference of a 3 7/8" diameter circle

\[ C = \pi \times 3.875 \]

4. Calculate circumference of a 1.75" radius circle

\[ C = 2 \pi \times 1.75 \]

Example D: Make rectangle calculations by using the following formulas:

Area = Base x Height; Diagonal = \( \sqrt{\text{Base}^2 + \text{Height}^2} \)

(NOTE: Diagonal of the rectangle and hypotenuse of the triangle formed are the same. See Figure 12.)

[Figure 12: Diagram of a rectangle with a diagonal line and labels for base, height, and diagonal with a 90° angle]
1. Find area of rectangle
   a. Base is 4mm and height is 2mm
   b. Area = Base x height
      = 4mm x 2mm
      = 8mm²

2. Find diagonal of rectangle
   a. Base is 4mm and height is 2mm
   b. Diagonal = \sqrt{(Base)^2 + (Height)^2}
      = \sqrt{(4mm)^2 + (2mm)^2}
      = \sqrt{16mm^2 + 4mm^2}
      = \sqrt{20mm^2}
      = 4.4721mm

Problem D:
1. Calculate area of a rectangle 7.75" x 12.32"

A = 

2. Calculate diagonal of a rectangle 4.59" x 8.79"
TOOLS AND EQUIPMENT
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1. 0.871
   2. 0.226
   3. 0.184
   4. 0.291
   5. 0.086
   6. 0.023
   7. 0.500
   8. 0.342
   9. 0.047
  10. 0.125
  11. 0.613
  12. 0.250
  13. 0.012

B. 1. 6.75 mm
   2. 3.68 mm
   3. 8.78 mm
   4. 14.26 mm
   5. 10.61 mm
   6. 3.85 mm

Assignment Sheet #2

A. 1. .321
   2. 3.067

B. 1. 4.603
   2. 1.317

C. 1. 18.22
   2. 20.62
   3. 6.70
   4. 19.94
### MECHANICAL ENGINEER SCALE

<table>
<thead>
<tr>
<th></th>
<th>DECIMAL (2 Places)</th>
<th>FRACTIONS (Nearest 32nd)</th>
<th>1:1 (One place)</th>
<th>1:2 (Nearest mm)</th>
<th>1:5 (Nearest mm)</th>
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<tbody>
<tr>
<td>A</td>
<td>3.89</td>
<td>7 25/32</td>
<td>159/16</td>
<td>98.8</td>
<td>198</td>
</tr>
<tr>
<td>B</td>
<td>3.31</td>
<td>6 5/8</td>
<td>13 1/4</td>
<td>84.0</td>
<td>168</td>
</tr>
<tr>
<td>C</td>
<td>5.39</td>
<td>10 25/32</td>
<td>219/16</td>
<td>136.9</td>
<td>274</td>
</tr>
<tr>
<td>D</td>
<td>.36</td>
<td>23/32</td>
<td>1 7/16</td>
<td>9.2</td>
<td>18</td>
</tr>
<tr>
<td>E</td>
<td>2.41</td>
<td>4 13/16</td>
<td>9 5/8</td>
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<td>121</td>
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<tr>
<td>F</td>
<td>4.33</td>
<td>8 21/32</td>
<td>17 5/16</td>
<td>109.7</td>
<td>219</td>
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<td>G</td>
<td>4.98</td>
<td>10 31/32</td>
<td>19 15/16</td>
<td>125.6</td>
<td>251</td>
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<tr>
<td>H</td>
<td>1.38</td>
<td>2 3/4</td>
<td>5 1/2</td>
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<td>70</td>
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</table>

### METRIC SCALE (mm)

<table>
<thead>
<tr>
<th></th>
<th>METRIC (NEAREST mm)</th>
<th>METRIC (NEAREST 1/2 mm)</th>
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<td>99.0</td>
</tr>
<tr>
<td>B</td>
<td>84</td>
<td>84.0</td>
</tr>
<tr>
<td>C</td>
<td>137</td>
<td>137.0</td>
</tr>
<tr>
<td>D</td>
<td>9</td>
<td>9.0</td>
</tr>
<tr>
<td>E</td>
<td>61</td>
<td>60.5</td>
</tr>
<tr>
<td>F</td>
<td>110</td>
<td>109.5</td>
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<td>G</td>
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<td>125.5</td>
</tr>
<tr>
<td>H</td>
<td>35</td>
<td>35.0</td>
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### MACHINIST STEEL RULE

<table>
<thead>
<tr>
<th></th>
<th>FRACTIONS (NEAREST 1/64)</th>
<th>DECIMAL (NEAREST .02)</th>
<th>METRIC (NEAREST mm)</th>
<th>METRIC (NEAREST 1/2 mm)</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>3 57/64</td>
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<td>99</td>
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<tr>
<td>B</td>
<td>3 5/16</td>
<td>3.40</td>
<td>84</td>
<td>84.0</td>
</tr>
<tr>
<td>C</td>
<td>5 25/64</td>
<td>5.40</td>
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<td>D</td>
<td>23/64</td>
<td>.36</td>
<td>9</td>
<td>9.0</td>
</tr>
<tr>
<td>E</td>
<td>2 13/32</td>
<td>2.40</td>
<td>61</td>
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</tr>
<tr>
<td>F</td>
<td>4 21/64</td>
<td>2.32</td>
<td>110</td>
<td>109.5</td>
</tr>
<tr>
<td>G</td>
<td>4 63/64</td>
<td>4.98</td>
<td>126</td>
<td>125.5</td>
</tr>
<tr>
<td>H</td>
<td>1 3/8</td>
<td>1.38</td>
<td>35</td>
<td>35.0</td>
</tr>
</tbody>
</table>
Assignment Sheet #4

A. 1. $X = 68.5\,''$
    2. $X = 1.28$
    3. $X = 4.64$

B. 1. $R = 20.2485''$
    2. $X = 9.3808''$

C. 1. $A = 31.3707\,\text{in.}^2$
    2. $A = 63.6173\,\text{in.}^2$
    3. $C = 2.7489''$
    4. $C = 10.9956''$

D. 1. $A = 95.48\,\text{in.}^2$
    2. $D = 9.916$
TOOLS AND EQUIPMENT
UNIT II

JOB SHEET #1--USE A MICROMETER

I. Tools and equipment
A. Micrometers (plain)
   1. (0-1.000") size
   2. (1.000"-2.000") size
   (CAUTION: Handle instruments with care.)

B. Workpieces
   1. Assortment (5) fractional drill bits (new)
   2. Assortment (5) letter size drill bits (new)
   3. Assortment (5) pieces of cold rolled stock, machined parts, or hardened dowels
   4. One workpiece mounted stationary
   (NOTE: All workpieces should be numbered for reference.)

II. Procedure
A. Clean all workpieces to be measured and make sure they are free of burrs, nicks, or dents
B. Number all workpieces for reference
C. Clean the spindle and anvil of the micrometer (Figure 1)

Figure 1

CLEAN SPINDLE AND ANVIL

Cloth or Paper
JOB SHEET #1

D. Check the micrometer at zero reference

E. Hold the micrometer in the right hand and the workpiece in the left hand to measure non-stationary objects (Figure 2)

Figure 2

NON-STATIONARY OBJECT

F. Hold the micrometer in both hands to measure a stationary object (Figure 3)

Figure 3

STATIONARY OBJECT
JOB SHEET #1

G. Roll micrometer along palm of hand or forearm for quick adjustment (Figure 4)

H. Place the micrometer directly over the center of the workpiece to be measured.
   (NOTE: Use proper size micrometer for the job.)

I. Turn the thimble of the micrometer until the anvil and spindle contact the workpiece.

J. Hold the anvil steady, and move the spindle lightly over the workpiece to locate the true diameter (Figure 5)

WORK BACK AND FORTH TO FIND TRUE DIAMETER
JOB SHEET #1

K. Use ratchet stop or light sense of touch to determine exact measurement

L. Observe micrometer readings
   (NOTE: Lock nut can be turned to hold measurement if micrometer must be removed from workpiece. Spindle must be unlocked before resetting to a new measurement.)

M. List the readings according to the letter or number on the workpiece
   1. Workpiece #1________________________________________
   2. Workpiece #2________________________________________
   3. Workpiece #3________________________________________
   4. Workpiece #4________________________________________
   5. Workpiece #5________________________________________
   6. Stationary workpiece________________________________

N. Leave the spindle and anvil of the micrometer open

O. Return the micrometer to its correct storage

P. Hand in listed readings to the instructor for evaluation
TOOLS AND EQUIPMENT
UNIT II

JOB-SHEET #2--USE A VERNIER CALIPER

I. Tools and equipment
   A. Vernier caliper--Inch, 25 or 50 divisions
   B. Vernier caliper--Metric
      (NOTE: A combination inch and metric vernier caliper may be used.)
      (CAUTION: Handle instruments with care.)
   C. Workpieces
      1. Assortment (5) pieces of cold rolled stock, machine parts, or hardened dowels
      2. One workpiece mounted stationary
         (NOTE: All workpieces should be numbered for reference.)

II. Procedure
   A. Clean all workpieces to be measured and make sure they are free of burrs, nicks, or dents
   B. Number all workpieces for reference
   C. Clean the vernier caliper’s jaws
   D. Slide movable jaws by releasing clamp screws (Figure 1)

FIGURE 1

Clamp Screws

Vernier Caliper
E. Slide jaws over workpieces to be measured
   (NOTE: Use fine adjustment nut to get a more accurate reading.)

F. Tighten clamp screws with fingers and remove workpiece, or in the case
   of stationary workpiece, remove caliper

G. Read an inch vernier caliper--25 divisions (Figure 2)

FIGURE 2

1. Read to the left of the vernier scale zero the last large number above
   the main scale for the number of whole inches
   Example: 1.000"

2. Read to the left of the vernier scale zero the last small number above
   the main scale for the number in tenths
   Example: 4

3. Multiply this number by .100
   Example: 4 x .100 = .400"

4. Count the number of graduations from the small number to zero on
   the vernier scale
   Example: 1

5. Multiply this number by .025
   Example: 1 x .025 = .025"

6. Look at the graduations on the vernier scale and the graduations
   on the bar; find which two graduation lines line up

7. Count over from zero to where the two line up

8. Multiply this number by .001
   Example: 11 x .001 = .011
JOB SHEET #2

9. Add up each part

Example:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1.000</td>
<td>.400</td>
</tr>
<tr>
<td>.025</td>
<td>.011</td>
</tr>
</tbody>
</table>

Answer 1.436''

H. Read an inch vernier caliper—50 divisions (Figure 3)

FIGURE 3

1. Read to the left of the main inch vernier scale zero the last large number above the main inch vernier plate on the bar for the number of whole inches

Example: 1.000

2. Read to the left of the vernier scale zero the last small number above the main inch vernier plate on the bar for the number in tenths

Example: 0 x .1 = 0.0

3. Count the number of graduations from small number to zero on the vernier scale

4. Multiply this number by .050

Example: 1 x .050 = .050

5. Look at the graduations on the vernier scale and the graduations on the bar; find which two graduation lines line up

6. Count over from zero to where the two line up

7. Multiply this number by .001

Example: 14 x .001 = .014
JOB SHEET #2

8. Add up each part
Example:  

1.000  
.000  
.050  
.014  
Answer 1.064"

I. Read a metric vernier caliper (Figure 3)

1. Read to the left of the main metric vernier scale zero the number on the bar; the number represents the number of millimeters
Example: 20mm
(NOTE: In Transparency 19, the number must be multiplied by 10 to get the number of millimeters.)

2. Read the number of graduation lines from the number to zero

3. Multiply this number by 1mm
Example: 7 x 1 = 7mm

4. Look at the graduations on the main metric vernier scale and the graduations on the bar; find which two graduation lines line up

5. Count over from zero to where the two line up; each graduate is .02
Example:. .42

6. Add up each part
Example: 20. mm  
7. mm  
.42 mm  
Answer 27.42 mm

J. List the readings for the inch or metric vernier caliper according to the number on the workpiece

<table>
<thead>
<tr>
<th>INCH</th>
<th>METRIC</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tbody>
</table>

1. Workpiece #1
2. Workpiece #2
3. Workpiece #3
4. Workpiece #4
5. Workpiece #5
6. Stationary workpiece
JOB SHEET #2

K. Return calipers to their correct storage

L. Hand in listed readings to the instructor for evaluation
TOOLS AND EQUIPMENT
UNIT II

NAME __________________________

TEST

1. Match the terms on the right with the correct definitions.

   a. Instrument used as a standard of reference when drawing an object to a proportional size
   b. A thin, flat, plastic tool with various size openings of different shapes used to expedite the drawing of standard features
   c. Arrangement of a sequence of operations
   d. Instruments used by machinists to measure and gage products
   e. Calculating device to solve mathematical problems
   f. Preprinted letters, symbols, and shading that can be rubbed on or cut out for drawings to save drafting time
   g. Points, lines, or other geometric shapes assumed to be exact from which the location or geometric form of features of a part may be estimated

   1. Template
   2. Precision instruments
   3. Transfer artwork
   4. Datums
   5. Scale
   6. Hand calculator
   7. Logic

2. Complete the following list of mechanical templates.

   a. General purpose
      1. __________________________
      2. __________________________
   b. Welding
   c. Threaded fasteners
      1. __________________________
      2. __________________________
   d. Springs
   e. Three dimensional
      1. __________________________
      2. __________________________
3. Match the machinist precision measuring instruments on the right with the correct functions.

_____ a. Accurate inside measurements
_____ b. Depth of slots or holes from datum surfaces
_____ c. Plain external dimension for "go" or "no go" gaging
_____ d. Comparison of finished part to a master or lines on a screen
_____ e. Accurate angle measurements
_____ f. Alignment, eccentricity, or deviations on surfaces
_____ g. Dimension transfers and circle scribes
_____ h. Internal dimensions of holes for "go" or "no go" gaging

1. Snap gage
2. Plug gage
3. Inside micrometer
4. Depth micrometer
5. Sine bar
6. Divider
7. Dial indicator gage
8. Optical comparator

4. Identify types of welding measuring instruments.

   a. 
   b. 
   c. 

5. Identify types of scales used in mechanical drafting.

   a. 

32nds
64ths
6. Name the primary metric unit of measurement used in mechanical drafting.

7. Classify the scales used in mechanical drafting by placing an "MEF" for Mechanical Engineer, Fractions; "MED" for Mechanical Engineer, Decimal; "MSRD" for Machinist Steel Rule, Decimal; "MSRM" for Machinist Steel Rule, Metric; and "M" for Metric scale in the appropriate blanks.

   a. 1:3
   b. 50 parts per inch--Each division equals .02"
   c. 32 parts per inch--Each division equals 1/32"
   d. 1/4" = 1"
   e. 1:5
   f. 1/2 millimeter--Each division equals .5mm
   g. 64 parts per inch--Each division equals 1/64"
   h. 1:10
   i. 1:1
   j. 1/2" = 1"

8. Complete the following list of hand calculator functions.

   a. Primary
      1. Multiply
      2. Divide
      3. 
      4. 

b. Secondary
   1. Square
   2. Logarithm
   3. Trigonometric
   4. Storage
   5. Angular mode
   6. Hyperbolic

9. Distinguish between the types of keyboard sequences used in hand calculators by placing an "X" next to the characteristics of the Lukasiewicz keyboard sequence.
   ___ a. Is easy to master
   ___ b. Usually takes fewer steps
   ___ c. Is referred to as "reverse Polish"
   ___ d. Sometimes takes more steps
   ___ e. Has operational stack

10. Demonstrate the ability to:
    a. Read micrometer settings.
    b. Read vernier calipers.
    c. Measure with scales.
    d. Compute mechanical drafting problems using a hand calculator.
    e. Use a micrometer.
    f. Use a vernier caliper.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
# TOOLS AND EQUIPMENT

## UNIT II

## ANSWERS TO TEST

1. a. 5  
   b. 1  
   c. 7  
   d. 2  
   e. 6  
   f. 3  
   g. 4  

2. Any two of the following under each category:
   - a. 1. Circles  
      2. Squares  
      3. Arrows  
      4. Hexagons  
      5. Octagons  
      6. Triangles  
   - c. 1. Nuts  
      2. Bolts  
      3. Screws  
      4. Threads  
   - e. 1. Projection ellipses  
      2. Isometric ellipses  
      3. Isometric hexagon bolt heads and nuts  
      4. Projection hexagon bolt heads and nuts  

3. a. 3  
   b. 4  
   c. 1  
   d. 8  
   e. 5  
   f. 7  
   g. 6  
   h. 2  

4. a. Inside caliper  
   b. Tapes  
   c. Steel rule  

5. a. Machinist steel rule (fractions)  
   b. Mechanical engineer scale  

6. Millimeter  
   f. MSRM  
   g. MSRF  
   h. M  
   i. M  
   j. MEF  

8. List should include:  
   a. Under primary--add, subtract  
   b. Under secondary--reciprocal, square root, antilogarithm  

9. b, c, e  

10. Evaluated to the satisfaction of the instructor
REFERENCE MATERIALS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to read reference materials and ANSI standards. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to reference materials with the correct definitions.
2. List manufacturing catalogs that contain product information literature.
3. Complete a list of mechanical standards references.
4. Select mechanical drafter and designer handbooks.
5. Name standards found in an ANSI drafting manual.
6. List general types of standard parts specified by ANSI.
7. Distinguish between ANSI miscellaneous standards.
8. Select ANSI metric standard fasteners references.
9. Demonstrate the ability to:
   a. Determine manufacturer of mechanical components from Thomas Register.
   b. Write a letter requesting product literature for mechanical components.
   c. Write a technical report using reference materials.
REFERENCE MATERIALS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.
II. Provide student with information and assignment sheets.
III. Make transparency.
IV. Discuss unit and specific objectives.
V. Discuss information and assignment sheets.
VI. Have students go to their libraries and find out what reference indexes are available.
VII. Require that students list all reference books in drawing room.
VIII. Suggest that students go visit a welding shop and machine shop and find out what references are in use.
IX. Tour an engineering drafting room and have students take notes of references being used.
X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
A. Objective sheet
B. Information sheet
C. Transparency Master 1--Mechanical Standards References
D. Assignment sheets
   1. Assignment Sheet #1--Determine Manufacturer of Mechanical Components from Thomas Register
   2. Assignment Sheet #2--Write a Letter Requesting Product Literature for Mechanical Components
   3. Assignment Sheet #3--Write a Technical Report Using Reference Materials
E. Test
F. Answers to test
II. References:


D. *Oklahoma Directory of Manufacturers and Products.* Oklahoma City: Oklahoma Industrial Development Department, 1981.

(NOTE: Each state may have one available.)


III. Additional references:


I. Terms and definitions

A. ANSI (American National Standards Institute)—Organization which identifies industrial and public needs for national standards and which coordinates their development.

B. Product catalog—Compiled booklet of product literature information including specifications of parts and subassemblies and assemblies of products for consumers and manufacturers to order and/or specify on parts list.

C. Standard parts—Hardware such as bolts, screws, nuts, washers, keys, gears, and pins for use on subassemblies and assemblies specified on parts lists.


E. Standard—Specification; test method; definition; classification; publication, or practice that has been approved by a committee to regulate or control manufacturing.

II. Manufacturing catalogs that contain product information literature

A. Materials Selector Issue
   (NOTE: This catalog contains materials used in design engineering.)

B. Thomas Register
   (NOTE: This catalog contains products and service information.)

C. Mac Rae's Blue Book
   (NOTE: In this catalog products are classified.)

D. Directory of Manufacturers
   (NOTE: This catalog is available by individual states from the industrial development departments.)

III. Mechanical standards references (Transparency 1)

A. ANSI (American National Standards Institute)

B. ASME (American Society of Mechanical Engineers)

C. ASTM (American Society for Testing and Materials)

D. SAE (Society of Automotive Engineers)
INFORMATION SHEET

IV. Mechanical drafter and designer handbooks

(NOTE: Complete author and publication information is included in instructor's manual.)

A. American Machinist's Handbook
B. ASME Handbook
C. Chambers Technical Dictionary
D. Databook for Human Factors Engineering
E. Gear Handbook
F. The Human Body in Equipment Design
G. Human Engineering Guide to Equipment Design
H. Machinery's Handbook
I. Production Handbook
J. SAE Automotive Drafting Standards
K. SAE Handbook
L. Standard Handbook for Mechanical Engineers
M. SME Tool and Manufacturer's Engineer's Handbook
N. Welding Handbook

V. Standards found in an ANSI drafting manual

(NOTE: The numbers in parentheses are the numbers referred to by ANSI standards.)

B. Line Conventions and Lettering (Y14.2-1979)
C. Multi and Sectional View Drawings (Y14.3-1975)
D. Pictorial Drawings (Y14.4-1957)
E. Dimensioning and Tolerancing (Y14.5-1973)
F. Screw Threads (Y14.6-1978)
INFORMATION SHEET

G. *Gears, Splines, and Serrations* (Y14.7-1978)
H. *Gear Drawing Standards* (Y14.7.1-1971)
I. *Forgings* (Y14.9-1958)
J. *Metal Stampings* (Y14.10-1959)
K. *Plastics* (Y14.11-1958)
M. *Electrical and Electronics* (Y14.15-1966)
P. *Chassis Frames* (Y14.32.1-1974)
Q. *Digital Representation of Physical Object Shapes* (Y14, Report #1)
R. *Guideline for Documenting of Computer Systems Used in Computer-Aided Preparation of Product Definition Data--User Instructions* (Y14, Report #2)
S. *Guideline for Documenting of Computer Systems Used in Computer-Aided Preparation of Product Definition Data--Design Requirements* (Y14, Report #3)

(NOTE: Another common standard is *Abbreviations* (Y1.1-1974), but this is not commonly found in a manual of drafting standards.)

VI. General types of standard parts specified by ANSI

A. Bolts and screws

1. *Hexagon or Slotted Head Cap Screws, Square Head or Slotted Set Screws* (B18.6.2-1972)
3. *Round Head Bolts* (B18.5-1971)
5. *Slotted and Recessed Head Wood Screws* (B18.6.1-1972)
7. *Square and Hex Bolts and Screws* (B18.2.1-1972)
INFORMATION SHEET

8. Square and Hex Nuts (B18.2.2-1972)


B. Gears


C. Keys and pins

1. Machine Pins (B5.20-1958)

2. Woodruff Keys and Keyseats (B17.2-1967, R1972)

D. Rivets

1. Large Rivets (B18.1.2-1972)

2. Small Sbli Rivets (B18.1.1-1972)

E. Washers

1. Lock Washers (B18.21.1-1972)

2. Plain Washers (B18.22.2-1965)

VII. ANSI miscellaneous standards

A. Dimensioning and surface finish

1. Preferred Limits and Fits for Cylindrical Parts (B4.1-1967, R1974)


3. Scale to Use with Decimal-Inch Dimensioning (Z75.1-1955)

4. Surface Texture (B46.1-1962, R1971)

5. Decimal Inch (B97.1-1965)

6. Metric Practice (E380.76)

7. Tolerance for Metric Dimensional Products, General (B4.3-1978)
B. Small tools and machine elements
   1. Jig Bushings (B94.33-1974)
   3. Milling Cutters and End Mills (B94.19-1968)
   4. Reamers (B94.2-1971)
   5. T-Slots (B5.1-1975)
   6. Tops, Cut, and Ground Threads (B94.9-1971)
   7. Twist Drills, Straight Shank, and Taper Shank (B94.11-1967, R1972)

VIII. ANSI metric standard fasteners references,
   A. Hexagon Socket Head Shoulder Screws Metric (B18.3.3M-1979)
   B. Hex Socket Button Head Cap Screws Metric (B18.3.4N-1979)
   C. Metric Formed Hex Screws (B18.2.3.2M 1979)
   D. Metric Heavy Hex Bolts (B18.2.3.6M 1979)
   E. Metric Heavy Hex Screws (B18.2.3.3M 1979)
   F. Metric Heavy Hex Structural Bolts (B18.2.3.7M 1979)
   G. Metric Hex Bolt (B18.2.3.5M 1979)
   H. Metric Hex Cap Screws (B18.2.3.1M 1979)
   I. Metric Hex Lag Screws (B18.2.3.8M 1979)
   J. Metric Series Hexagon Keys and Bits (B18.3.2M 1979)
   K. Metric Series Hexagon Socket Set Screws (B18.3.6M 1979)
   L. Metric Screw Threads MJ Profile (B1.21M 1978)
   M. Retaining Rings (B27.8M 1978)
REFERENCE MATERIALS
UNIT III

ASSIGNMENT SHEET #1--DETERMINE MANUFACTURER OF MECHANICAL COMPONENTS FROM THOMAS REGISTER

Directions: Using the Thomas Register, write the name and address of one manufacturer for the following products and/or parts.

A. Electric motor
B. Machine screws
C. Cams
D. Spring lock washer
E. Gears
F. Solar collector
G. Shear for sheet metal
H. Pump
ASSIGNMENT SHEET #2--WRITE A LETTER REQUESTING PRODUCT LITERATURE FOR MECHANICAL COMPONENTS

Directions: Select one of the addresses from Assignment Sheet #1 or another address from the Thomas Register. Write a letter to the manufacturer requesting information concerning product specifications and cost. After instructor approves rough copy, type and mail. Those items in italics in the following example are what you should fill in with your information.

Example:

425 Elm Street
Stillwater, OK 74074

February 17, 1983

Enerpac
Sales Office
Butler, WI 53007

Sales Representative:

I am a student at Indian Meridian Area Vocational-Technical School. I am in the process of designing equipment. Please send me product literature, specifications, and cost for Hi-tonnage jacking cylinders. I am not interested in purchasing your product at this time, but may consider it in the future.

Thank you for your consideration.

Sincerely,

Joe Smith
REFERENCE MATERIALS
UNIT III

ASSIGNMENT SHEET #3: WRITE A TECHNICAL REPORT USING REFERENCE MATERIALS

Directions: Write a technical report in an area which interests you. Use reference materials found in available indexes. Restrict length to 5 handwritten (2-2 1/2 typed) pages. Report should include the following:

1. Title page (subject, your name, date)
2. Introduction (what your paper will cover, why you chose this area)
3. Body (logical presentation of information discovered while researching)
4. Conclusion (brief summary of what you have learned, final remarks)
5. References (at least three)

(Note: Books are categorized in the library according to the author, title, and subject in the card catalogs. Two good indexes to find articles in the library are Engineering Index and Applied Science and Technology Index.)
1. Match the terms on the right with the correct definitions.

   a. Hardware such as bolts, screws, nuts, washers, keys, gears, and pins for use on subassemblies and assemblies and specified on parts lists
   
   b. Organization which identifies industrial and public needs for national standards and which coordinates their development
   
   c. Reference book or manual containing directions, specifications, and tables to aid in the design and drafting of manufactured products
   
   d. Compiled booklet of product literature information including specifications of parts and subassemblies and assemblies of products for consumers and manufacturers to order and/or specify on parts lists
   
   e. Specification, test method, definition, classification, publication, or practice that has been approved by a committee to regulate or control manufacturing

2. List two manufacturing catalogs that contain product information literature.

   a.  
   
   b.  

3. Complete the following list of mechanical standards references.

   a. ASME
   
   b. SAE
   
   c.  
   
   d.  
4. Select mechanical drafter and designer handbooks by placing an "X" in the appropriate blanks.

   a. Chambers Technical Dictionary  
   b. Standard Handbook for Mechanical Engineers  
   c. Small Engine Repair  
   d. American Machinist Handbook  
   e. ASME Handbook  
   f. Four-Stroke Cycle Engine Mechanic Handbook  
   g. SAE Handbook  
   h. Databook for Human Factors Engineering

5. Name five standards found in an ANSI drafting manual.

   a. 
   b. 
   c. 
   d. 
   e. 

6. List four general types of standard parts specified by ANSI.

   a. 
   b. 
   c. 
   d. 

7. Distinguish between ANSI miscellaneous standards by placing an "X" next to the standards for dimensioning and surface finish and an "O" next to the standards for small tools and machine elements.

   a. Preferred Limits and Fits for Cylindrical Parts  
   b. Machine Tapers  
   c. T-Slots  
   d. Metric Practice  
   e. Tolerance for Metric Dimensional Products; General  
   f. Reamers
8. Select ANSI metric standard fasteners references by placing an "X" in the appropriate blanks.

   a. **Metric Heavy Hex Screws**
   b. **Retaining Rings**
   c. **Metric Hex-Lag Screws**
   d. **Slotted and Recessed Head Wood Screws**

9. Demonstrate the ability to:

   a. Determine manufacturer of mechanical components from *Thomas Register*.
   b. Write a letter requesting product literature for mechanical components.
   c. Write a technical report using reference materials.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
REFERENCE MATERIALS
UNIT III

ANSWERS TO TEST

1. a. 3  d. 2
   b. 1  e. 5
   c.  4

2. Any two of the following:
   a. Materials Selector Issue
   b. Thomas Register
   c. Mac Rae's Blue Book
   d. Directory of Manufacturers

3. c. ANSI
d. ASTM

4. a, b, d, e, g, h

5. Any five of the following:
   a. Drawing Sheet Size and Format
   b. Line Conventions and Lettering
   c. Multi and Sectional View Drawings
   d. Pictorial Drawings
   e. Dimensioning and Tolerancing
   f. Screw Threads
   g. Gears, Splines, and Serrations
   h. Gear Drawing Standards
   i. Forgings
   j. Metal Stampings
   k. Plastics
   l. Mechanical Assemblies
   m. Electrical and Electronics
   n. Fluid Power Diagrams
   o. Dictionary of Terms for Computer-Aided Preparation of Product Definition Data
   p. Chassis Frames
   q. Digital Representation of Physical Object Shapes
   r. Guideline for Documenting of Computer Systems Used in Computer-Aided Preparation of Product Definition Data--User Instructions
   s. Guideline for Documenting of Computer Systems Used in Computer-Aided Preparation of Product Definition Data--Design Requirements

6. Any four of the following:
   a. Bolts and screws
   b. Gears
   c. Keys and pins
   d. Rivets
   e. Washers
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<tr>
<th></th>
<th>X</th>
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<tbody>
<tr>
<td>7. a.</td>
<td>X</td>
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<td>7. b.</td>
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<td>7. c.</td>
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<tr>
<td>7. d.</td>
<td>X</td>
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<tr>
<td>7. e.</td>
<td>X</td>
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<td>7. f.</td>
<td>O</td>
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</tbody>
</table>

8. a, b, c

9. Evaluated to the satisfaction of the instructor
LAYOUTS AND WORKING DRAWINGS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to draw a design layout and draw a set of working drawings. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to layouts and working drawings with the correct definitions.
2. Distinguish between standard and additional information on a title form.
3. Identify information on a revision block.
4. List information on a bill of materials/parts list.
5. Arrange in order the stages of the design process.
6. Select true statements concerning design layouts.
7. List basic elements of a design layout sketch.
8. Name the three standard parts of a detail drawing.
9. Match parts of an assembly drawing with the correct functions.
10. Select information found on outline or installation assemblies.
11. Select information found on welding assembly drawings.
12. Select characteristics of forging drawings.
13. Select information found on a pattern or casting drawing.
14. Demonstrate the ability to:
   a. Draw a design layout.
   b. Draw a set of detail drawings.
   c. Draw an assembly drawing.
   d. Complete a detailed title block and revision block.
   e. Complete a parts list.
   f. Make a drawing revision.
LAYOUTS AND WORKING DRAWINGS
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Assign students appropriate projects that can be used for all assignment sheets.

VII. Select the title block that you want the students to use in this particular class, and give instructions on filling it out.

VIII. Make appropriate changes in the student's drawing sheets from Assignment Sheets #2, #3, or #4 to enable the students to make revisions for Assignment Sheet #6.

IX. Furnish a model or prototype for use in discussing objective V, item D, the design process.

X. Give test.

INSTRUCTIONAL MATERIALS

Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters
   1. TM 1-Engineering Change Notice
   2. TM 2-Title Forms
   3. TM 3-Revisions
   4. TM 4-Bill of Materials/Parts List
   5. TM 5-Design Process
   6. TM 6-Design Layout
7. TM 7--Detail Drawing
8. TM 8--Assembly Drawing
9. TM 9--Detail Assembly Drawing
10. TM 10--Outline or Installation Assembly
11. TM 11--Welding Assembly Drawing
12. TM 12--Forging Drawing
13. TM 13--Casting Drawing

D. Assignment sheets

1. Assignment Sheet #1--Draw a Design Layout
2. Assignment Sheet #2--Draw a Set of Detail Drawings
3. Assignment Sheet #3--Draw an Assembly Drawing
4. Assignment Sheet #4--Complete a Detailed Title Block and Revision Block
5. Assignment Sheet #5--Complete a Parts List
6. Assignment Sheet #6--Make a Drawing Revision

E. Test

F. Answers to test

II. References


LAYOUTS AND WORKING DRAWINGS
UNIT IV

INFORMATION SHEET

Terms and definitions

A. Title--Name of the object or project
   (NOTE: The title is the second most important size of lettering on the drawing.)

B. Title form--Standardized place to show all information not shown with notes and dimensions on the drawing

C. Revision--Change made on a drawing
   (NOTE: This change may be due to drafting error, design change or error, production change or error, or customer change or error.)

D. Revision form--Area to show all information related to a drawing revision

E. Zoning--Equal intervals along the margins labeled with numbers along the horizontal margin and with letters along the vertical margin for locating an area on a drawing

F. Bill of materials/parts list--Itemized list of parts shown with an assembly drawing
   (NOTE: Parts may be raw stock, purchased parts, or fasteners.)

G. Design process--Organized method to combine scientific principles, standard parts, and resources into the solution of a problem

H. Detail drawing--Drawing containing the necessary information to completely manufacture a single part or one stage of a single part

I. Design layout--Accurate drawing of all parts in working positions showing clearances of moving parts, ease of assembly, and ease of serviceability

J. Assembly drawing--Drawing showing all parts in their working position

K. Detail assembly drawing--Combined detail and assembly drawing used when the details are simple enough for all parts to be shown and dimensioned clearly while shown in assembled positions
   (NOTE: This drawing is used on aircraft subassemblies, drawings of jigs and fixtures, and welding drawings.)

L. Engineering change notice (ECN)--An approved change to a drawing caused by a change in design, tool changes, errors in design or production, and customer changes (Transparency 1)
   (NOTE: ECN's are reflected in the revision record on the drawing.)
INFORMATION SHEET

M. Forging drawing--A detail drawing of a workpiece to be forged in dies

N. Casting drawing--A detail drawing of a workpiece to be cast

II. Information on a title form (Transparency 2)

(NOTE: The following information is generally found in a title form as a title block or title strip.)

A. Standard information
   1. Name of the object represented
   2. Name and address of the industry
   3. Name and address of the client, if any
   4. Number of drawing which may include sheet letter size
   5. Revision letter
   6. Signature of drafter with date of completion
   7. Signature of checker with date of completion
   8. Signature of designer, engineer, or other official and date approved
   9. Predominant scale of drawing
   10. Sheet number for multiple sheets

B. Additional information
   1. Tolerances
   2. Material
   3. Heat treatment
   4. Quantity
   5. Finish
   6. Hardness
   7. Weight
   8. Superseding note
   9. Company logos
   10. Other peculiarities of the product
INFORMATION SHEET

III. Information on a revision block (Transparency 3)
   A. Letter or number of change(s)
   B. Description of correction or change
   C. Person making change
   D. Person checking change
   E. Date of change
   F. Zone for location of change

IV. Information on a bill of materials/parts list (Transparency 4)
   A. Standard information
      1. Item number referring to assembly drawing
         (NOTE: Item numbers are sometimes referred to as dash numbers.)
      2. Part name
      3. Number required
      4. Material from which part is made
   B. Additional information
      1. Stock number
      2. Description or nomenclature
      3. Address of vendor
      4. Unit of measure
         (NOTE: These units include grams, pieces, feet, pounds, or gallons.)
      5. Group subassembly where used
      6. Approval
      7. Release date
      8. Originator
      9. Revision
INFORMATION SHEET

10. Stock size
11. Pattern number
12. Weight

V. Stages of the design process (Transparency 5)

A. Problem identification

(NOTE: This stage is the plan of action which includes available information, parameters for time, cost, defined function, limits, and market potential.)

B. Preliminary ideas and concepts

(NOTE: This stage includes brainstorming from technical literature, reports, design and trade journals, patents, and existing products. A notebook should be started and up-dated to include signatures and dates of inventors and witnesses.)

C. Refinement of solutions

(NOTE: In this stage the design layouts, functional features, stress analysis, ease of assembly, serviceability, and manufacturability are refined for the most promising solutions.)

D. Model or prototype analysis

(NOTE: In this stage the design is analyzed, studied, and refined to prove that the design works. This is a very important step that may cause you to return to one of the other steps.)

E. Presentation/working drawings

(NOTE: This stage is the formal documented form for production which includes detail drawings, assembly drawings, and parts lists. The primary focus is to sell the idea or product to others.)

VI. Design layouts (Transparency 6)

A. Drawn by the designer as part of the design process

B. Amount of detail needed depends on the degree of competency of the drafter
   1. Requires very little detail if the drafter is well trained
   2. Requires a great deal of detail if the drafter is not well trained

C. May include the following:

   (NOTE: The following items represent the maximum detail a designer would place on a design layout.)
INFORMATION SHEET

1. Accurate to-scale details of each part
2. Strength calculations
3. Function calculations
4. Cost calculations
5. Weight calculations
6. Shape or form determinations
7. Stress analysis
8. Explanation of how parts fit together
9. Most dimensions
10. Notes for standard parts or special processes
11. Clearances for moving parts
12. Ease of assembly
13. Ease of serviceability
14. Standard parts recommended wherever possible
15. Special manufacturing problems

- Drawn accurately with thin lines
- Usually only critical dimensions are included

VII. Basic elements of a design layout sketch (Transparency 6)

(Note: Many drawings do not need to be drawn accurately to prove they work. A designer or engineer may simply make a sketch of his/her needs and the drafter can make a detail drawing.)

A. Projection (multiview, isometric)
B. Line symbols and darkness
C. Proportions
D. Strength calculations
E. Function calculations
F. Cost calculations
G. Weight calculations
INFORMATION SHEET

H. Shape or form determinations
I. Stress analysis
J. Way parts fit together
K. All critical dimensions
L. Notes for standard parts or special processes
M. Clearances for moving parts
N. Ease of assembly
O. Ease of serviceability
P. Standard parts recommended wherever possible
Q. Special manufacturing problems

VIII. Standard parts of a detail drawing (Transparency 7)
A. Shape description
   (NOTE: This includes multiview, auxiliary, sections, and/or pictorials.)
B. Dimensions
   (NOTE: These include size, location, and tolerances.)
C. Notes
   (NOTE: These may be general or specific.)

IX. Parts of an assembly drawing and functions (Transparency 8)
A. Views—Show relationship of parts
   (NOTE: Views do not show the shapes of individual parts but just how they fit together.)
B. Sections—Show the inside function or construction of the parts
C. Hidden lines—Shown only to promote clearness; unnecessary when several sections are used
   (NOTE: Hidden lines may not be necessary and in some cases would only confuse the reading of the drawing.)
INFORMATION SHEET

D. Dimensions—Show maximum or minimum sizes or locations of machine parts after assembly and overall size

(NOTE: Only certain dimensions and notes are given on an assembly drawing.)

E. Parts identification numbers—Allow for quick identification of physical shape and guide reader to the parts list (Figure 1)

(NOTE: An identification number should be 5mm high in a 12mm circle. The circle is connected to the part with an arrowhead, dot, or S.)

FIGURE 1

Leaders drawn radial to circle

(NOTE: Avoid vertical and horizontal leaders.)

X. Information found on outline or installation assemblies (Transparency 10)

A. Method for installing or erecting a machine or structure
B. Outline and relationships of external surfaces
C. Relationship of final positioning for subassemblies

XI. Information found on welding assembly drawings (Transparency 11)

A. Parts identification
B. Dimensioning

(NOTE: This includes the detailed or after-welded final dimensions. Proper jigs must be used to prevent distortion to maintain final dimensions.)
C. Standard welding symbols (ANSI Y 32.3-1969)
D. Parts list

(NOTE: Parts may be made from stock.)
E. Multiviews and auxiliary views, if used

(NOTE: Sections are not normally employed in welding assembly drawings.)

XII. Characteristics of forging drawings (ANSI Y14.9-1958) (Transparency 12)

A. Fillets and rounds—Minimum sizes (Figure 2)
INFORMATION SHEET

B. Parting line--Separation of upper and lower dies
C. Draft--Ease in removal from dies
D. Extra material not needed in final product

FIGURE 2

Opposing Ribs--Confined Metal in Web
Single Rib

FILLET RADII

<table>
<thead>
<tr>
<th>H</th>
<th>R1</th>
<th>R2</th>
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CORNER RADII

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<th>R2</th>
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<tr>
<td>7</td>
<td>1/2</td>
<td>11/16</td>
<td>1/2</td>
</tr>
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XIII. Information found on a pattern or casting drawing (Transparency 13)

A. Fillets and rounds--Minimum sizes
B. Parting line--Separation of one mold from the other
C. Extra material not needed in final product

(Note: A draft may be included by the pattern maker, but it is not shown on the drawing.)
# Engineering Change Notice

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<th>ENGINEERING CHANGE NOTICE</th>
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<tr>
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</tr>
<tr>
<td>SHEET NO</td>
<td></td>
</tr>
<tr>
<td>APPARATUS</td>
<td>SERIES AN</td>
</tr>
<tr>
<td>ENG PROD PLAN</td>
<td>CLASS OF CHG.</td>
</tr>
<tr>
<td>AFFECTED</td>
<td>NOT AFFECTED</td>
</tr>
<tr>
<td>IT</td>
<td>NAME OF PART</td>
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## Reason for Change/Problem

![Diagram](image)

## Summary of Change/Solution

![Diagram](image)

## Status of Material

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<th>RTBS</th>
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## Serial Numbers to Be Reworked

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## Issued By

<table>
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| TM 1 |
Title Forms

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<th>WEIGHT</th>
<th>TOLERANCES UNLESS OTHERWISE SPECIFIED</th>
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<td>INCH - METRIC</td>
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<tr>
<td>HT</td>
<td></td>
</tr>
<tr>
<td>FINISH</td>
<td></td>
</tr>
<tr>
<td>QTY</td>
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</tr>
<tr>
<td>ANGULAR</td>
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<tr>
<td>FRACTIONS</td>
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</thead>
<tbody>
<tr>
<td>SHEET SIZE</td>
<td>DRAWING NO.</td>
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Title Block

Title Strip

(Note: All lettering is 3mm high except Title and Drawing numbers which are 6mm high.)
Revisions

<table>
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<tr>
<th>ZONE</th>
<th>REV.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>APP.</th>
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<tr>
<td>2c</td>
<td>A</td>
<td>WAS .57</td>
<td>Jan 582</td>
<td>D</td>
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NOTE. See Basic Drafting, Book Two for dimensions.

Revision Form With Zones

Revision Form Without Zones
# Bill of Materials / Parts List

**Parts List--Short Form Over Title Block**

**Title Block**

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<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
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<tr>
<td>1</td>
<td>VISE BASE</td>
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</tr>
<tr>
<td>2</td>
<td>SLIDE JAW</td>
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**Drawing Codes**

1. VENDOR ITEM--SPEC CONTROL DWG
2. VENDOR ITEM--SOURCE CONTROL DWG
3. ALTERED OR SELECTED PART

**Unit of Measure Codes**

0. GRAMS
1. PIECES
2. FEET
3. POUNDS
4. GALLONS
5. SETS
6. OUNCES
7. INCHES
8. PINTS
9. AS REQ'D

**Parts List for**

<table>
<thead>
<tr>
<th>ITEM NO</th>
<th>DWG CODE</th>
<th>IDENTIFICATION NUMBERS</th>
<th>DESCRIPTION OR NOMENCLATURE</th>
<th>GROUP NO AND QUANTITY</th>
<th>UM</th>
<th>RTG</th>
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**Prints to**

<table>
<thead>
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<th>REVISION</th>
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**Cont on or Final**

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**Metric**

1. 15
2. 67
3. 15
4. 22

**Bill of Materials/Parts List**
Design Process

1. Problem Identification
2. Preliminary Ideas and Concepts
3. Refinement of Solutions
4. Models or Prototypes Analysis
5. Presentation/Working Drawing
Design Layout


Design Layout
Freehand Sketch
Assembly Drawing
Detail Assembly Drawing

Outline or Installation Assembly

Welding Assembly Drawing

```
<table>
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<th>DESCRIPTION</th>
<th>QTY</th>
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<tbody>
<tr>
<td>3</td>
<td>1</td>
<td>5(\frac{1}{2}) x (\frac{1}{2}) Plate 6(\frac{3}{4}) long</td>
<td>1020</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2 x (\frac{3}{4}) Bar - 7(\frac{3}{4}) long</td>
<td>1020</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>6 x (\frac{1}{2}) Plate - 6 long</td>
<td>1020</td>
</tr>
</tbody>
</table>
```

Bracket Assembly 158625

Approved by Bracket Assembly

Scale: 1:5
Forging Drawing

Casting Drawing

Drill C bore \( \frac{1}{8} \) D x \( \frac{1}{16} \) deep, 4 holes

Neck \( \frac{1}{8} \) wide
\( \frac{1}{8} \) deep

No. 7 SCREENER
LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #1: DRAW A DESIGN LAYOUT

Directions. For the project assigned by your instructor, sketch the desired layout to include standard parts and fixed dimensions. Tape drawing media to drawing surface, and draw your design layout. Letter in information in its proper place using correct lettering techniques.
ASSIGNMENT SHEET #2-DRAW A SET OF DETAIL DRAWINGS

Directions: Using the design layout of the project from Assignment Sheet #1, sketch each detail to include proper placement of dimensions, tolerances, and notes. Tape drawing media to drawing surface, and draw each detail on a separate sheet of paper of appropriate size. Letter information in its proper place using correct lettering techniques.
LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #3: DRAW AN ASSEMBLY DRAWING

Directions: For this assignment use details from either Assignment Sheet #2, the design layout of Assignment Sheet #1, or a different project appropriate to time. Sketch an assembly drawing to include appropriate sections, views, and dimensions. Tape drawing media to drawing surface, and draw an assembly drawing. Letter in information in its proper place using correct lettering techniques.
LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #4 - COMPLETE A DETAILED TITLE BLOCK AND REVISION BLOCK

Directions: With a lettering guide and the drawing media from Assignment Sheet #2 and #3, use the procedure in the following example to complete a detailed title block and revision block.

Example:

1. Tape drawing media to drawing surface
2. Select correct pencils
3. Select appropriate title block for detail information

(NOTE: Refer to the following examples of title strips and title blocks. Select one shown or devise one of your own which has been approved by the instructor.)

Example:

( NOTE: This title block can be used with "C," "D," and "E" size sheets.)
(NOTE: The title block can be used with "A" and "B" size sheets.)

4. Draw title block in lower right hand corner
5. Draw guidelines for lettering
6. Letter in information in its proper place using correct lettering techniques
7. Select revision block containing zone reference
8. Draw revision block in upper right hand corner
9. Letter in information in its proper place using correct lettering techniques
LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #5--COMPLETE A PARTS LIST

Directions: Tape either the drawing from Assignment Sheet #3 or a separate parts list (PL) form on drawing surface. Draw a parts list. Letter in information in the parts list using correct lettering techniques.
ASSIGNMENT SHEET #6: MAKE A DRAWING REVISION

Directions: In order to make a drawing revision, you will need the drawings from Assignment Sheets #2, #3, and #4 and an Engineering Change Notice (ECN) from your instructor. Now use the procedure in the following example to make the revision.

Example:

1. Letter revision on drawing
2. Letter revision in revision block
3. Sign and date revision block
4. Make a blueline print of revision
5. Turn in revision and print to instructor

NOTE: See Basic Drafting, Book Two for dimensions.
LAYOUTS AND WORKING DRAWINGS
UNIT IV

NAME ________________________

TEST

1. Match the terms on the right with the correct definitions.

   a. Change made on a drawing

   b. Equal intervals along the margins labeled with numbers along the horizontal margin and with
      letters along the vertical margin for locating an area on a drawing

   c. Drawing containing the necessary information to completely manufacture a single part or
      one stage of a single part

   d. Name of the object or project

   e. Area to show all information related to a drawing revision

   f. Organized method to combine scientific principles, standard parts, and resources into
      the solution of a problem

   g. Drawing showing all parts in their working position

   h. Standardized place to show all information not shown with notes and dimensions on the
      drawing

   i. Combined detail and assembly drawing used when the details are simple enough
      for all parts to be shown and dimensioned clearly while shown in assembled positions

   j. Accurate drawing of all parts in working positions showing clearances of moving
      parts, ease of assembly, and ease of service-ability

   k. Itemized list of parts shown with an assembly drawing

   l. A detail drawing of a workpiece to be cast
m. A detail drawing of a workpiece to be forged in dies

n. An approved change to a drawing caused by a change in design, tool changes, errors in design or production, and customer changes

2. Distinguish between standard and additional information on a title form by placing an "X" next to the standard information and an "O" next to the additional information.

   a. Tolerances
   b. Revision letter
   c. Signature of drafter with date of completion
   d. Hardness
   e. Heat treatment
   f. Predominate scale of drawing

3. Identify information on a revision block.

   a. __________________________
   b. __________________________
   c. __________________________
   d. __________________________
4. List information on a bill of materials/parts list.
   a. Standard information
      1) ____________________________
      2) ____________________________
   b. Additional information
      1) ____________________________
      2) ____________________________
      3) ____________________________
      4) ____________________________

5. Arrange in order the following stages of the design process by placing the correct sequence numbers in the appropriate blanks.
   a. Refinement of solutions
   b. Presentation/working drawings
   c. Problem identification
   d. Model or prototype analysis
   e. Preliminary ideas and concepts

6. Select true statements concerning design layouts by placing an "X" in the appropriate blanks.
   a. Drawn by the designer as part of the design process
   b. Requires a great deal of detail if the drafter is well trained
   c. May include strength calculations
   d. May include weight calculations
   e. Drawn with thick lines
   f. All dimensions are omitted
   g. May include clearances for moving parts
   h. May include ease of serviceability
7. List eight basic elements of a design layout sketch.
   a. 
   b. 
   c. 
   d. 
   e. 
   f. 
   g. 
   h. 

8. Name the three standard parts of a detail drawing.
   a. 
   b. 
   c. 

9. Match the parts of an assembly drawing on the right with the correct functions.
   _____ a. Shown only to promote clearness; unnecessary when several sections are used
   _____ b. Allow for quick identification of physical shape and guide reader to the parts list
   _____ c. Show maximum or minimum sizes or locations of machine parts after assembly and overall size
   _____ d. Show relationship of parts
   _____ e. Show the inside function or construction of the parts

10. Select information found on outline or installation assemblies by placing an "X" in the appropriate blanks.
    _____ a. Method for installing or erecting a machine or structure
    _____ b. Sections of internal detail of a machine
    _____ c. Outline and relationships of external surfaces
    _____ d. Detail dimensions of individual parts
    _____ e. Relationship of final positioning for subassemblies
11. Select information found on welding assembly drawings by placing an "X" in the appropriate blanks.

   ____ a. Parts identification
   ____ b. Dimensioning
   ____ c. Standard welding symbols
   ____ d. Parts list
   ____ e. Sections
   ____ f. Auxiliary views, if used

12. Select characteristics of forging drawings by placing an "X" in the appropriate blanks.

   ____ a. Fillets and rounds
   ____ b. Finish marks
   ____ c. Drilled holes
   ____ d. Parting line
   ____ e. Draft
   ____ f. Extra material not needed in final product

13. Select information found on a pattern or casting drawing by placing an "X" in the appropriate blanks.

   ____ a. Fillets and rounds
   ____ b. Finish marks
   ____ c. Drilled holes
   ____ d. Parting line
   ____ e. Draft
   ____ f. Extra material not needed in final product

14. Demonstrate the ability to:

   a. Draw a design layout.
   b. Draw a set of detail drawings.
   c. Draw an assembly drawing.
   d. Complete a detailed title block and revision block.
   e. Complete a parts list.
   f. Make a drawing revision.

(Note: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
LAYOUTS AND WORKING DRAWINGS
UNIT IV

ANSWERS TO TEST

1. a. 3  e. 5  i. 14  m. 13
   b. 6  f. 10  j. 9  n. 4
   c. 11  g. 12  k. 7
   d. 1  h. 2  l. 8

2. a. 0  
   b. X  
   c. X  
   d. 0  
   e. 0  
   f. X

3. a. Zone for location of change
   b. Letter of change
   c. Date of change
   d. Person checking change (approved by)

4. a. Any two of the following:
    1) Item number referring to assembly drawing
    2) Part name
    3) Number required
    4) Material from which part is made

   b. Any four of the following:
    1) Stock number
    2) Description or nomenclature
    3) Address of vendor
    4) Unit of measure
    5) Group subassembly where used
    6) Approval
    7) Release date
    8) Originator
    9) Revision
    10) Stock size
    11) Pattern number
    12) Weight

5. a. 3  
   b. 5  
   c. 1  
   d. 4  
   e. 2

6. a, c, d, g, h
7. Any eight of the following:
   a. Projection
   b. Line symbols and darkness
   c. Proportions
   d. Strength calculations
   e. Function calculations
   f. Cost calculations
   g. Weight calculations
   h. Shape or form determinations
   i. Stress analysis
   j. Way parts fit together
   k. All critical dimensions
   l. Notes for standard parts or special processes
   m. Clearances for moving parts
   n. Ease of assembly
   o. Ease of serviceability
   p. Standard parts recommended wherever possible
   q. Special manufacturing problems

8. a. Shape description
   b. Dimensions
   c. Notes

9. a. 3
   b. 5
   c. 4
   d. 4
   e. 2

10. a, c, e

11. a, b, c, d, f

12. a, d, e, f

13. a, d, f

14. Evaluated to the satisfaction of the instructor
UNIT OBJECTIVE

After completion of this unit, the student should be able to illustrate dimensioning tolerances to include surface quality, position and geometric form dimensions. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

(NOTE: Students are expected to review "Dimensioning Procedures" and "Basic Tolerancing" of Basic Drafting, Book Two before attempting this unit.)

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to dimensioning and tolerancing with the correct definitions.
2. Distinguish between size and location dimensions for a geometric shape.
3. Select mating dimensions in an assembly drawing.
4. Select true statements concerning numerical control dimensioning.
5. Distinguish between fits for inch units and fits for metric units.
6. Calculate limits in inch units using basic hole system.
7. Calculate limits in inch units using basic shaft system.
8. Calculate limits in metric units using basic hole system.
9. Determine the tolerance ranges for shop processes using the accompanying table.
10. Distinguish between clearance fit and interference fit of hole size limits for standard dowels.
11. Select true statements concerning limit dimensions for interchangeability of parts.
12. Arrange in order the steps for determining limit dimensions for intermediate parts to retain overall limits.
13. Complete a chart of characteristic symbols for tolerances of position and form.
14. Match terms with the correct supplementary symbols for tolerances of position and form.
15. Match position and form symbols with the correct descriptions.
16. Match the descriptions of position and form with the correct meaning of drawings.
17. Select true statements concerning positional tolerancing.
18. Distinguish between maximum material condition and regardless of feature size.
19. Select true statements concerning angular tolerances.
20. State the purpose of surface quality specifications.
21. Identify parts of a surface quality symbol.
22. Select true statements concerning surface quality notes.
23. Match lay symbols with the correct designations.
24. Differentiate between correct and incorrect placement of surface quality symbols.
25. Select true statements concerning surface roughness produced by common production methods using the accompanying table.
26. Select preferred recommended roughness, waviness, and roughness width cutoff values from tables.
27. Demonstrate the ability to:
   a. Dimension an object completely.
   b. Calculate and dimension clearance fit tolerances using standard fit tables.
   c. Calculate and dimension interference fit tolerances using standard fit tables.
   d. Calculate and assign tolerances to mating parts using standard fit tables.
   e. Calculate and dimension hole size limits for standard dowels.
   f. Dimension an object using position and form tolerances.
   g. Determine ranges of motion of limbs and spaces required for a person.
DIMENSIONING AND TOLERANCING
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.
II. Provide student with information and assignment sheets.
III. Make transparencies.
IV. Discuss unit and specific objectives.
V. Discuss information and assignment sheets.
VI. Develop a display of different types of gages with corresponding parts to be measured for size and location.
VII. Have students check a group of parts for correct dimensions by using gages.
VIII. Provide part drawings for students to see specified tolerances.
IX. Visit a manufacturing quality control department to see how they operate and inspect parts.
X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
A. Objective sheet
B. Information sheet
C. Transparency masters
   1. TM 1--Tolerancing Terms
      1A--Overlay
      1B--Overlay
   2. TM 2--Graphical Representation of Tolerance Zones (Metric)
   3. TM 3--Metric Tolerance Designation
   4. TM 4--Determining Limits for Hole and Shaft (Inch Units)
   5. TM 5--Determining Limits for Hole and Shaft (Metric Units)
   6. TM 6--Tolerances Related to Shop Processes
<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>TM 7--Hole Size for Standard Dowel (Fit Dimensions)</td>
</tr>
<tr>
<td>2.</td>
<td>7A--Overlay</td>
</tr>
<tr>
<td>3.</td>
<td>TM 8--Interchangeability of Mating Parts (Problem)</td>
</tr>
<tr>
<td>4.</td>
<td>TM 9--Interchangeability of Mating Parts (Calculations)</td>
</tr>
<tr>
<td>5.</td>
<td>TM 10 and Overlay 10A--Limits for Intermediate Parts</td>
</tr>
<tr>
<td>6.</td>
<td>TM 11--Symbols for Tolerances of Position and Form</td>
</tr>
<tr>
<td>7.</td>
<td>TM 12--Use of Symbols for Tolerances of Position and Form</td>
</tr>
<tr>
<td>8.</td>
<td>TM 13--Application of Symbols to Position and Form Tolerance Dimensions</td>
</tr>
<tr>
<td>9.</td>
<td>TM 14--No Specified Tolerance of Form</td>
</tr>
<tr>
<td>10.</td>
<td>TM 15--Straightness</td>
</tr>
<tr>
<td>11.</td>
<td>TM 16--Flatness</td>
</tr>
<tr>
<td>12.</td>
<td>TM 17--Roundness</td>
</tr>
<tr>
<td>13.</td>
<td>TM 18--Cylindricality</td>
</tr>
<tr>
<td>14.</td>
<td>TM 19--Profile of a Surface</td>
</tr>
<tr>
<td>15.</td>
<td>TM 20--Profile of a Surface Between Points</td>
</tr>
<tr>
<td>16.</td>
<td>TM 21--Angularity of a Plane Surface</td>
</tr>
<tr>
<td>17.</td>
<td>TM 22--Perpendicularity</td>
</tr>
<tr>
<td>18.</td>
<td>TM 23--Perpendicularity (Continued)</td>
</tr>
<tr>
<td>19.</td>
<td>TM 24--Parallelism</td>
</tr>
<tr>
<td>20.</td>
<td>TM 25--Concentricity</td>
</tr>
<tr>
<td>21.</td>
<td>TM 26--Symmetry</td>
</tr>
<tr>
<td>22.</td>
<td>TM 27--Positional Tolerancing</td>
</tr>
<tr>
<td>23.</td>
<td>TM 28--Tolerance Zones</td>
</tr>
<tr>
<td>24.</td>
<td>TM 29--Cylindrical Tolerance Zones</td>
</tr>
<tr>
<td>25.</td>
<td>TM 30--No Tolerance Accumulation</td>
</tr>
<tr>
<td>26.</td>
<td>TM 31--Maximum and Least Material Conditions</td>
</tr>
<tr>
<td>27.</td>
<td>TM 32--Regardless of Feature Size</td>
</tr>
<tr>
<td>28.</td>
<td>TM 33--Angular Tolerances</td>
</tr>
</tbody>
</table>
34. TM 34--Surface Quality Symbol
35. TM 35--Lay Symbols

D. Assignment sheets
   1. Assignment Sheet #1--Dimension an Object Completely
   2. Assignment Sheet #2--Calculate and Dimension Clearance Fit Tolerances Using Standard Fit Tables
   3. Assignment Sheet #3--Calculate and Dimension Interference Fit Tolerances Using Standard Fit Tables
   4. Assignment Sheet #4--Calculate and Assign Tolerances to Mating Parts Using Standard Fit Tables
   5. Assignment Sheet #5--Calculate and Dimension Hole Size Limits for Standard Dowels
   6. Assignment Sheet #6--Dimension an Object Using Position and Form Tolerances
   7. Assignment Sheet #7--Determine Ranges of Motion of Limbs and the Spaces Required for a Person

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:


Terms and definitions (Transparencies 1, 2, and 3)

A. Interchangeability--The condition that refers to a part made to limit dimensions so that it will fit any part similarly manufactured; the ability of mating parts to fit properly together.

B. Geometric shapes--Shapes such as prisms, cylinders, pyramids, cones, and spheres.

C. Size dimension--Any type of dimension that tells how large or small an object is.

D. Location dimension--Any type of dimension that locates a feature on an object.

E. Tolerance--The total amount of variation permitted in limit dimensioning of a part; the difference between the limit dimensions (Transparency 1).

F. Basic size--The size of a part determined by engineering and design requirements from which the limits of size are determined; the line of zero deviation.

G. Limits--The extreme permissible dimensions of a part resulting from the application of a tolerance; the maximum and minimum size indicated by a tolerance.

H. Maximum material condition (MMC)--Used when maximum material is present in a feature. (NOTE: This is the smallest hole, largest shaft.)

I. Least material condition (LMC)--Used when the least material is present in a feature. (NOTE: This is the largest hole, smallest shaft.)

J. Upper deviation--Difference between the maximum limit and the basic size.

K. Lower deviation--Difference between the minimum limit and the basic size.

L. International tolerance grade--Group of tolerances numbered 01 - 16. (NOTE: 01 thru 5 are used for gages, 6 thru 12 are used for fits, and 13 thru 16 are used for general dimensioning.)

M. Fundamental deviation--The deviation nearer the basic size for the hole and near the basic size for the shaft. (NOTE: The fundamental deviation is an upper case letter for holes and a lower case letter for shafts.)
INFORMATION SHEET

N. Tolerance zone-The association of a fundamental deviation (letter) with an international tolerance grade (IT number)

O. Basic hole system-The basic size of the hole is the design size (basic size) and the allowance is applied to the shaft

(NOTE: The fundamental deviation for a hole system is H.)

P. Basic shaft system-The basic size of the shaft is the design size and the allowance is applied to the hole

(NOTE: The fundamental deviation for a shaft system is h.)

Q. Clearance fit-Limits of size are determined so that a loose fit or positive allowance occurs between mating parts

R. Interference fit-Limits of size are determined so that a negative allowance or tight fit occurs between mating parts

S. Transition fit-Limits of size are determined so that the allowance may be either a clearance fit or an interference fit

T. Allowance-The minimum international difference in the dimensions of mating parts to provide for different classes of fits; the minimum clearance or maximum interference when parts are at maximum material condition (MMC)

U. Datums-Points, lines, or other geometric shapes assumed to be exact from which the location or geometric form of features of a part may be established

V. Positional tolerance-Exact theoretical position of a feature established by basic dimensions

(NOTE: The term "positional tolerancing" has the same meaning as "true position tolerancing.")

W. Form tolerances-Maximum allowable variations of a perfect geometric shape

X. Surface quality-Roughness, waviness, and lay of a surface which may include certain flaws

Y. Lay-Direction of the major surface pattern determined by manufacturing method used

Z. Roughness-Fine irregularities in surface texture

AA. Waviness-Widely spaced element of a surface texture

BB. Anthropometric data-Measurements of the human body and its parts
II. Size and location dimensions for geometric shapes

A. Size dimensions

1. Prisms

2. Cylinders

   (NOTE: Diameter is not recommended for circular view but ANSI does approve its use.)

3. Miscellaneous shapes
INFORMATION SHEET

4. Holes (negative cylinders)

(NOTE: These may be drilled, reamed, bored, punched, or cored specified by standard notes.)

B. Location dimensions

1. Rectangular shapes—Reference to their faces

2. Cylinders or holes—Reference to their center lines

(NOTE: Location dimensions are best located in circular view.)
III. Mating dimensions in an assembly drawing

A. Dimensions common to both parts

B. Single bracket assembly

(NOTE: Critical dimension "A" of frame must mate critical dimension "A" of bracket.)

"A" is critical dimension
"B" and "C" are not critical dimensions
INFORMATION SHEET

C. Double bracket assembly

(NOTE: With double bracket design, dimension "B" is critical dimension that must mate on both parts.)

IV. Numerical control dimensioning

A. Datum or reference planes must be selected that are mutually perpendicular in the X, Y, and Z axes

B. Dimensions originate from the three planes

C. Dimensions must be in decimals

D. Angles should be in degrees and decimal parts of degrees

E. Standard tools such as reamers, drills, and tapers should be specified wherever possible

F. Tolerances should be used based on design requirements rather than tolerances of manufacturing machines

V. Fits

A. Fits for inch units

1. Running and sliding fits
   a. RC 1 (Close sliding fits)
   b. RC 2 (Sliding fits)
   c. RC 3 (Precision running fits)
INFORMATION SHEET

d. RC 4 (Close running fits)
e. RC 5-RC 6 (Medium running fits)
f. RC 7 (Free running fits)
g. RC 8-RC 9 (Loose running fits)

2. Locational fits
   a. LC 1-LC 11 (Locational clearance fits)
   b. LT 1-LT 6 (Transition fits)
   c. LN 1-LN 2 (Locational interference fits)

3. Force fits
   a. FN 1 (Light drive fits)
   b. FN 2 (Medium drive fits)
   c. FN 3 (Heavy drive fits)
   d. FN 4-FN 5 (Force fits)

B. Fits for metric units (SI)

1. Clearance fits

<table>
<thead>
<tr>
<th>HOLES BASIS</th>
<th>SHAFT BASIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 11/c 11</td>
<td>C 11/h 11</td>
</tr>
<tr>
<td>H 9/d 9</td>
<td>D 9/h 9</td>
</tr>
<tr>
<td>H 8/f 7</td>
<td>F 8/h 7</td>
</tr>
<tr>
<td>H 7/g 6</td>
<td>G 7/h 6</td>
</tr>
<tr>
<td>H 7/h 6</td>
<td>H 7/h 6</td>
</tr>
</tbody>
</table>

2. Transition fits

<table>
<thead>
<tr>
<th>HOLES SHAFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 7/k 6</td>
</tr>
<tr>
<td>H 7/n 6</td>
</tr>
</tbody>
</table>
INFORMATION SHEET

3. Interference fits

HOLE SHAFT

a. H 7/p 6 P 7/h 6 (Locational interference fits)
b. H 7/s 6 S 7/h 6 (Medium drive fits)
c. H 7/u 6 U 7/h 6 (Force fits)

VI. Calculation of limits in inch units using basic hole system (Transparency 4)

A. Calculation of limits for clearance fit

1. Refer to tolerance fit table for inch units, and locate basic hole size in Nominal size range, inches column

(NOTE: Limits are in thousandths of an inch. Multiply limit by 0.001 for calculations.)

Example: Basic hole size 2.00 fit RC 6 --Go to table--

<table>
<thead>
<tr>
<th>Nominal size range, inches</th>
<th>Limits of clearance</th>
<th>Standards limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hole</td>
</tr>
<tr>
<td>1.97-3.15</td>
<td>2.5</td>
<td>+3.0</td>
</tr>
<tr>
<td></td>
<td>7.3</td>
<td>0</td>
</tr>
</tbody>
</table>

2. Calculate limits for the hole

Example: 2.000 + 3.0 (.001) = 2.003 Max. limit (LMC)--largest hole
2.000 - 0 = 2.000 Min. limit (MMC)--smallest hole

3. Calculate limits for the shaft

Example: 2.000 - 2.5 (.001) = 1.9975 Max. limit (MMC)--largest shaft
2.000 - 4.3 (.001) = 1.9957 Min. limit (LMC)--smallest shaft

4. Calculate allowance in inch units

a. Calculate tightest fit (MMC of hole--MMC of shaft)
   smallest hole--largest shaft

Example: 2.000 - 1.9975 = .0025

b. Look at table under limits of clearance and check your answer against table

Example: .0025/.001 = 2.5 which checks
INFORMATION SHEET

c. Calculate loosest fit (LMC of hole - LMC of shaft)
Example: 2.0030 - 1.9957 = .0073

d. Look at table under limits of clearance and check your answer against table
Example: \( \frac{.0073}{.001} = 7.3 \) which checks

5. Dimension

B. Calculation of limits for locational fit

1. Refer to fit table for inch units, and locate basic hole size in Nominal size range, inches column
Example: Basic size 2.00 fit LT 4 - Go to table

2. Calculate limits for the hole
Example: 
\[ 2.00 + 1.8 \times (.001) = 2.0018 \text{ LMC} \]
\[ 2.00 - 0 = 2.0000 \text{ MMC} \]

3. Calculate limits for the shaft
Example: 
\[ 2.00 + 1.3 \times (.001) = 2.0013 \text{ MMC} \]
\[ 2.00 + .1 \times (.001) = 2.0001 \text{ LMC} \]

4. Calculate fit
   a. Calculate tightest fit (MMC of hole - MMC of shaft)
Example: 2.0000 - 2.0013 = .0013
   b. Calculate loosest fit (LMC of hole - LMC of shaft)
Example: 2.0018 - 2.0001 = + .0017
C. Calculation of limits for force fit

1. Refer to fit table for inch units, and locate basic hole size in Nominal size range, inches column
   
   Example: Basic size 2.00 fit FN 3; --Go to table--

2. Calculate limits for the hole.
   
   Example: 2.00 + (1.2) (.001) = 2.0012 LMC
   2.00 - 0 = 2.0000 MMC

3. Calculate limits for the shaft.
   
   Example: 2.00 + 3.2 (.001) = 2.0032 MMC
   2.00 + 2.5 (.001) = 2.0025 LMC

4. Calculate limits of interference
   
   a. Calculate tightest interference (MMC of hole − MMC of shaft)
      
      Example: 2.0000 − 2.0032 = − .0032

   b. Calculate loosest interference (LMC of hole − LMC of shaft)
      
      Example: 2.0012 − 2.0025 = − .0013

      (NOTE: Notice both have negative values.)

   c. Check table under limits of interference to check your answer
VII. Calculation of limits in inch units using basic shaft system

A. Refer to fit table for inch units, and locate the basic shaft size

Example: Basic shaft size 2.00 fit RC 6 → Go to table

<table>
<thead>
<tr>
<th>Nominal size range, inches</th>
<th>Limits of clearance</th>
<th>Standards limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hole</td>
<td>Shaft</td>
</tr>
<tr>
<td>1.97-3.15</td>
<td>2.5</td>
<td>+3.0</td>
</tr>
<tr>
<td></td>
<td>7.3</td>
<td>-2.5</td>
</tr>
</tbody>
</table>

B. Calculate basic hole size by adding allowance at MMC to basic shaft size

Example: 2.000 + .0025 = 2.0025 basic hole size

(Note: Now use table as we did in basic hole system.)

C. Calculate limits for the hole

Example: 2.0025 + 3.0 (.001) = 2.0055 LMC
                        2.0025 - 0 = 2.0025 MMC

D. Calculate limits for the shaft

Example: 2.0025 - 2.5 (.001) = 2.0000 MMC
                        2.0025 - 4.3 (.001) = 1.9982 LMC

E. Calculate allowance

1. Calculate tightest fit (MMC of hole - MMC of shaft)

Example: 2.0025 - 2.0000 = .0025

2. Check allowance from table
INFORMATION SHEET

3. Calculate loosest fit (LMC of hole - LMC of shaft)

Example: 2.0055 - 1.9982 = .0073

4. Check allowance from table

VIII. Calculation of limits in metric units using basic hole system (Transparency 5)

A. Calculation of limits for clearance fit

1. Refer to fit table for metric units, and locate basic size in Basic Size column

Example: Basic hole size 40mm fit H7/g6 -- Go to fit table --

<table>
<thead>
<tr>
<th>Basic Size</th>
<th>Hole H7</th>
<th>Shaft g6</th>
<th>Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 Max.</td>
<td>40.025</td>
<td>39.991</td>
<td>0.050</td>
</tr>
<tr>
<td>Min.</td>
<td>40.000</td>
<td>39.975</td>
<td>0.009</td>
</tr>
</tbody>
</table>

2. Read from table hole limits

Example: H7 40.025 maximum hole LMC
         H7 40.000 minimum hole MMC

3. Read from table shaft limits

Example: g6 39.991 maximum shaft MMC
         g6 39.975 minimum shaft LMC

4. Calculate allowance

a. Calculate tightest fit (MMC of hole - MMC of shaft)
   smallest hole - largest shaft

Example: 40.000 - 39.991 = .009 mm

b. Check table under minimum fit to check this calculation

c. Calculate loosest fit (LMC of hole - LMC of shaft)
   largest hole - smallest shaft

Example: 40.025 - 39.975 = .050

d. Check table under maximum fit to check this calculation
B. Calculation of limits for transition fit

1. Refer to fit table for metric units (SI), and locate basic size in Basic Size column

Example: Basic size 40mm fit H7/k6 --Go to table--

2. Read from table hole limits

Example: H7 40.025 LMC
       H7 40.000 MMC

3. Read from table shaft limits

Example: k6 40.018 MMC
       k6 40.002 LMC

4. Calculate fit

   a. Calculate tightest fit (MMC of hole -- MMC of shaft)

      Example: 40.000 -- 40.018 = -.018

   b. Calculate loosest fit (LMC of hole -- LMC of shaft)

      Example: 40.025 -- 40.002 = + .023

5. Dimension

   40.018 40.025
   40.002 40.000
C. Calculation of limits for interference

1. Refer to fit table for metric units (SI), and locate basic size in Basic Size column
   Example: Basic size 50mm fit H7/u6 --Go to table--

2. Read from table hole limits
   Example: H7 50.025 LMC  
   H7 50.000 MMC

3. Read from table shaft limits
   Example: u6 50.086 MMC  
   u6 50.070 LMC

4. Calculate allowance
   a. Calculate tightest fit (MMC of hole – MMC of shaft)
      Example: 50.000 – 50.086 = .086
   b. Calculate loosest fit (LMC of hole – LMC of shaft)
      Example: 50.025 – 50.070 = .045

5. Dimension

IX. Tolerance ranges for shop processes

A. Processes (Transparency 6)
   1. Lapping and honing - smallest tolerance - most expensive
   2. Grinding, diamond turning, and boring
   3. Broaching
   4. Reaming
INFORMATION SHEET

5. Turning, boring, slotting, planing, and shaping
6. Milling
7. Drilling - largest tolerance - least expensive

B. Tolerance ranges
   1. Inch units
   2. Metric units - Multiply 25.4 times values in table

X. Hole size limits for standard dowels (Transparency 7)

A. Clearance fit - limits of clearance given
   1. Tightest fit = MMC hole - MMC shaft
   2. Loosest fit = LMC hole - LMC shaft
   3. Limits of clearance: smallest number is tightest fit; largest number is loosest fit

B. Interference fit - limits of interference given
   1. Tightest fit = MMC hole - MMC shaft
   2. Loosest fit = LMC hole - LMC shaft
   3. Limits of interference: largest number is tightest fit and is negative; smallest number is loosest fit and is negative

XI. Limit dimensions for interchangeability of parts

A. Parts should be tolerated to fit end-for-end to make assembly easier if function is not affected (Transparencies 8 and 9)
B. Find limit dimensions of each part and dimension so parts fit end-for-end

Example: Nominal size .500; .004 maximum accumulation of tolerance; clearance between each mating part .005; least fit not to exceed .015

---

C. Since parts must fit end-for-end, the limit dimensions must be the same on both ends.

D. Select the center dimension to be basic size

( NOTE: It could be yoke or clevis. Yoke was selected for the following example.)

Example:
- Yoke (B) MMC = .500
- Clearance = -.005
- Clevis (B) MMC = .495

---

E. Distribute maximum accumulation equally on each side of parts

( NOTE: As you can see in the following example, 3 does not divide into .004 evenly, so we give .002 to the center (B) and .001 to both sides A and C.)

Example:
- .002 tolerance distribution
- .001 tolerance distribution
- .001 tolerance distribution
- .004 maximum accumulation

---

F. Calculate LMC for center (B)

Example:
- Yoke (B) MMC = .500
  - (B) Tol = +.002
  - Yoke (B) LMC = .502
- Clevis (B) MMC = .495
  - (B) Tol = -.002
  - Clevis (B) LMC = .493

( NOTE: The + and - signs are for LMC; that is, if a feature is like a hole, LMC is "+"); if a feature is like a shaft, it is "-" )
INFORMATION SHEET

G. Calculate MMC for sides (A or C)

1. Use LMC of yoke (B) for LMC of clevis (A) or (C)

Example: Clevis (A) or (C) LMC = 0.502
Tol. dist. = -0.001
Clevis (A) or (C) MMC = 0.501

2. Use LMC of clevis (B) for LMC of yoke (A) or (C)

Example: Yoke (A) or (C) LMC = 0.493
Tol. dist. = +0.001
Yoke (A) or (C) MMC = 0.494

H. When each part is toleranced, an accumulation of tolerances must be checked

1. Add up maximum and minimum values

Example:

<table>
<thead>
<tr>
<th>Max. of yoke</th>
<th>Min. of yoke</th>
</tr>
</thead>
<tbody>
<tr>
<td>.494</td>
<td>.493</td>
</tr>
<tr>
<td>.502</td>
<td>.500</td>
</tr>
<tr>
<td>.494</td>
<td>.493</td>
</tr>
<tr>
<td>1.490</td>
<td>1.486</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Max. of clevis</th>
<th>Min. of clevis</th>
</tr>
</thead>
<tbody>
<tr>
<td>.502</td>
<td>.501</td>
</tr>
<tr>
<td>.495</td>
<td>.493</td>
</tr>
<tr>
<td>.502</td>
<td>.501</td>
</tr>
<tr>
<td>1.499</td>
<td>1.495</td>
</tr>
</tbody>
</table>

2. Subtract minimum of each part from the maximum of mating part

Example:

Max. of yoke - Min. of clevis = clearance (overall)
Max. of clevis - Min. of yoke = loosest fit

\[ 1.490 - 1.495 = 0.005 \text{ (checks for clearance)} \]
\[ 1.499 - 1.486 = 0.013 \text{ (checks within loosest fit)} \]
XII. Steps for determining limit dimensions for intermediate parts to retain overall limits (Transparency 10)

(NOTE: Always use largest possible tolerance.)

A. Find limit dimensions

Example:

BASIC SIZES

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.375</td>
<td>B</td>
<td>1.250</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>.002</td>
<td></td>
<td>.002</td>
<td></td>
</tr>
<tr>
<td>1.377</td>
<td>1.252</td>
<td>1.752</td>
<td>1.502</td>
<td></td>
</tr>
</tbody>
</table>

B. Subtract upper and lower limits of overall dimension to get total tolerance accumulation

Example: 10.639 - 10.625 = .014 total tolerance accumulation

C. Divide total tolerance accumulation by number of toleranced parts to get tolerance per part

Example: \( \frac{.014}{7} = .002 \) tolerance per part

D. Add tolerance per part to each basic size to get upper limit of each part

Example:

\[
\begin{align*}
1.750 & \pm .002 \\
2.000 & \pm .002 \\
1.000 & \pm .002
\end{align*}
\]

(NOTE: The lower limit is basic size.)
E. Check by adding upper limits together to get upper limit of overall dimension


XIII. Characteristic symbols for tolerances of position and form (Transparency 11)
XIV. Terms and supplementary symbols for tolerances of position and form (Transparency 11)

A. Maximum material condition (MMC) -- M
B. Regardless of feature size (RFS) -- S
C. Diameter (DIA) -- Ø
D. Reference (Ref) -- ( )
E. Basic (BSC) --
F. Projected tolerance zone -- P

XV. Position and form symbols (Transparencies 12 and 13)

A. Basic dimension symbol .
B. Datum symbol with datum reference
C. Feature control symbols’
   1. Geometric characteristic symbol
   2. Tolerance
   3. Modifier
D. Feature control symbols with datum references
   1. Symbol
   2. Datum reference to one or two datums
   3. Tolerance
   4. Modifier
      a. Of datum
      b. Of tolerance

XVI. Descriptions of position and form
A. No specified tolerance of form (Transparency 14)
B. Straightness (Transparency 15)
C. Flatness (Transparency 16)
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D. Roundness (Transparency 17)
E. Cylindricity (Transparency 18)
F. Profile of a surface (Transparency 19)
G. Profile of a surface between points (Transparency 20)
H. Angularity (Transparency 21)
I. Perpendicularity (Transparencies 22 and 23)
J. Parallelism (Transparency 24)
K. Concentricity (Transparency 25)
L. Symmetry (Transparency 26)

XVII. Positional tolerancing (Transparency 27)
A. Tolerance zones (Transparency 28)
   1. Conventional limit location dimensions have a square tolerance zone
   2. Positional tolerancing allows a circular tolerance zone
B. Cylindrical tolerance zones (Transparency 29)--Positional tolerancing allows more tolerance than conventional limit dimensions
C. No tolerance accumulation is found in positional tolerancing (Transparency 30)
D. Extreme angular variation in drilling a hole under positional tolerancing is possible

XVIII. Maximum material condition (MMC) and regardless of feature size (RFS)
A. MMC--Less restrictive (Transparency 31)
B. RFS--More restrictive (Transparency 32)

XIX. Angular tolerances (Transparency 33)
A. Bilateral angular tolerances--Cause a larger tolerance zone as you move from the vertex
B. Basic angular tolerances--Using angular feature controls causes a parallel tolerance zone

XX. Purpose of surface quality specifications--Used where heavy loads and high speeds with less friction are needed
Example: Aerospace, automotive, and aircraft industries
XXI. Parts of a surface quality symbol (Transparency 34)

A. Roughness height
B. Waviness height
C. Waviness width
D. Roughness width cutoff
E. Lay
F. Roughness width

XXII. Surface quality notes

A. Values are in micrometers or microinches
B. Higher number of micrometers or inches indicates rougher surface
C. Symbol is always made in the standard upright position
D. The roughest surface that will satisfy function and form is the ideal finish

XXIII. Lay symbols (Transparency 35)

A. — Parallel to surface
B. ⊥ Perpendicular to surface
C. X Angular to surface
D. M Multidirectional
E. C Circular
F. R Radial
G. P3 Particulate, non-directional, or protuberant

XXIV. Placement of surface quality symbols

A. Placed on edge of surface
B. Read from bottom of sheet
C. Typical placement

XXV. Surface roughness produced by common production methods

<table>
<thead>
<tr>
<th>ROUGHNESS HEIGHT RATING. MICROMETERS (MICROINCHES)</th>
<th>50 (2000)</th>
<th>12.5 (500)</th>
<th>3.2 (125)</th>
<th>1.6 (63)</th>
<th>0.8 (32)</th>
<th>0.4 (16)</th>
<th>0.2 (8)</th>
<th>0.1 (2)</th>
<th>0.05 (0.5)</th>
<th>0.025</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROCESS</td>
<td>25 (1000)</td>
<td>6.3 (250)</td>
<td>1.6 (63)</td>
<td>0.4 (16)</td>
<td>0.2 (8)</td>
<td>0.1 (2)</td>
<td>0.05 (0.5)</td>
<td>0.025</td>
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<td>Flame cutting</td>
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<td>Perm mold casting</td>
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<td>Investment casting</td>
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<tr>
<td>Cold rolling, Drawing</td>
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<td>Die casting</td>
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</tbody>
</table>

KEY: ★★ Average application  ★★★ Less frequent application

The ranges shown above are typical of the processes listed. Higher or lower values may be obtained under special conditions.
**INFORMATION SHEET**

**XXVI. Recommended values for surface quality symbols**

**A. Roughness average rating values--Preferred values in boldface type**

**Recommended Roughness Average Rating Values**

<table>
<thead>
<tr>
<th>Micrometers (Microinches)</th>
<th>µm</th>
<th>µin.</th>
<th>µm</th>
<th>µin.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.025</td>
<td>(1)</td>
<td>1.25</td>
<td>(50)</td>
<td></td>
</tr>
<tr>
<td>0.050</td>
<td>(2)</td>
<td>1.6</td>
<td>(63)</td>
<td></td>
</tr>
<tr>
<td>0.075</td>
<td>(3)</td>
<td>2.0</td>
<td>(80)</td>
<td></td>
</tr>
<tr>
<td>0.100</td>
<td>(4)</td>
<td>2.5</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>0.125</td>
<td>(5)</td>
<td>3.2</td>
<td>(125)</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>(6)</td>
<td>4.0</td>
<td>(160)</td>
<td></td>
</tr>
<tr>
<td>0.20</td>
<td>(8)</td>
<td>5.0</td>
<td>(200)</td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>(10)</td>
<td>6.3</td>
<td>(250)</td>
<td></td>
</tr>
<tr>
<td>0.32</td>
<td>(13)</td>
<td>8.0</td>
<td>(320)</td>
<td></td>
</tr>
<tr>
<td>0.40</td>
<td>(16)</td>
<td>10.0</td>
<td>(400)</td>
<td></td>
</tr>
<tr>
<td>0.50</td>
<td>(20)</td>
<td>12.5</td>
<td>(500)</td>
<td></td>
</tr>
<tr>
<td>0.63</td>
<td>(25)</td>
<td>15.0</td>
<td>(600)</td>
<td></td>
</tr>
<tr>
<td>0.80</td>
<td>(32)</td>
<td>20.0</td>
<td>(800)</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>(40)</td>
<td>25.0</td>
<td>(1000)</td>
<td></td>
</tr>
</tbody>
</table>

**B. Waviness height values--Preferred values in boldface type**

**Recommended Waviness Height Values, Millimeters (Inches)**

<table>
<thead>
<tr>
<th>mm</th>
<th>in.</th>
<th>mm</th>
<th>in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0005</td>
<td>(.00002)</td>
<td>0.025</td>
<td>(.0010)</td>
</tr>
<tr>
<td>0.0008</td>
<td>(.00003)</td>
<td>0.05</td>
<td>(.002)</td>
</tr>
<tr>
<td>0.0012</td>
<td>(.00005)</td>
<td>0.08</td>
<td>(.003)</td>
</tr>
<tr>
<td>0.0020</td>
<td>(.00008)</td>
<td>0.12</td>
<td>(.005)</td>
</tr>
<tr>
<td>0.0025</td>
<td>(.00010)</td>
<td>0.20</td>
<td>(.008)</td>
</tr>
<tr>
<td>0.005</td>
<td>(.0002)</td>
<td>0.25</td>
<td>(.010)</td>
</tr>
<tr>
<td>0.008</td>
<td>(.0003)</td>
<td>0.38</td>
<td>(.015)</td>
</tr>
<tr>
<td>0.012</td>
<td>(.0005)</td>
<td>0.50</td>
<td>(.020)</td>
</tr>
<tr>
<td>0.020</td>
<td>(.0008)</td>
<td>0.80</td>
<td>(.030)</td>
</tr>
</tbody>
</table>

**C. Roughness width cutoff values--Preferred values in boldface type**

**Recommended Standard Roughness Width Cutoff Values, Millimeters (Inches)**

<table>
<thead>
<tr>
<th>mm</th>
<th>in.</th>
<th>mm</th>
<th>in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.08</td>
<td>(.03)</td>
<td>2.50</td>
<td>(.100)</td>
</tr>
<tr>
<td>0.25</td>
<td>(.013)</td>
<td>8.0</td>
<td>(.300)</td>
</tr>
<tr>
<td>0.80</td>
<td>(.030)</td>
<td>25.0</td>
<td>(.1000)</td>
</tr>
</tbody>
</table>
Tolerancing Terms

[Diagram showing the relationship between upper and lower fundamental deviations, with terms labeled as follows:
- Lower Deviation
- Fundamental Deviation (Letter)
- Upper Deviation
- Fundamental Deviation (Letter)
- Lower Deviation]

Zero line or line of zero deviation
International Tolerance Grade (IT Number)

Maximum DIA Limit (MMC)

Minimum DIA Limit (LMC)

Hole
Maximum DIA Limit (MMG) - Minimum Limit (LMC)

International Tolerance Grade (IT Number)

Shaft
Graphical Representation of Tolerance Zones (Metric)

Holes

Fundamental Deviation

Zero Line

Basic Size

Fundamental Deviation

Shafts

Zero Line

Basic Size

Fundamental Deviation

Fundamental Deviation

Fundamental Deviation

Fundamental Deviation
Metric Tolerance Designation

Internal Dimensions
Hole
Basic Size
External Dimensions
Shaft

Fundamental Deviation (POSITION LETTER)
International Tolerance Grade (IT NUMBER)
Tolerance Zone
International Tolerance Grade (IT NUMBER)
Fundamental Deviation (POSITION LETTER)

Designations of Tolerances on Drawings

(a) 50H8

(b) 50H8 50.039 50.000

(c) 50.039 (50H8) 50.000
### Determining Limits for Hole and Shaft (Inch Units)

#### Tolerance Fit Table

<table>
<thead>
<tr>
<th>Basic Size Range in Inches</th>
<th>Class RC 5</th>
<th>Class RC 6</th>
<th>Class LT 3</th>
<th>Class LT 4</th>
<th>Nominal Size Range in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over To</td>
<td>Hole HB</td>
<td>Hole H7</td>
<td>Shaft kW</td>
<td>Shaft k6</td>
<td>Hole HB</td>
</tr>
<tr>
<td>0.0000</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.0000</td>
</tr>
<tr>
<td>0.0004</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.004</td>
</tr>
<tr>
<td>0.0008</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.008</td>
</tr>
<tr>
<td>0.0012</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Basic hole system limits are in thousands of an inch.

**Problem:** Find limits for shaft and hole

**Basic Size = 3.75**

**RC 5 Fit**

**Solution:**

1. **From tol fit table**
   - Hole + 2.2
   - Shaft -3.0

2. **Hole**
   - 3.7500
   - 3.7500
   - +0.0022
   - 3.7522
   - 3.7500

3. **Shaft**
   - 3.7500
   - 3.7500
   - -0.0030
   - 3.7470
   - 3.7456

4. **Check Clearance**
   - Tightest fit MMC
   - 3.7500 Hole
   - -3.7470 Shaft
   - .0030

   - Loosest fit LMC
   - 3.7522 Hole
   - -3.7456 Shaft
   - .0066

5. **Check table under limits of fit**

---

**Diagram:**

- Hole: 3.7470 - 3.7522
- Shaft: 3.7456 - 3.7500
## Determining Limits for Hole and Shaft (Metric Units)

### Tolerance Fit Table

<table>
<thead>
<tr>
<th>BASIC SIZE</th>
<th>LOOSE RUNNING Hole Shaft Fit</th>
<th>FREE RUNNING Hole Shaft Fit</th>
<th>CLOSE RUNNING Hole Shaft Fit</th>
<th>SLIDING Hole Shaft Fit</th>
<th>LOCATIONAL CLEARANCE Hole Shaft Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 MAX</td>
<td>40.180 39.880 0.440</td>
<td>40.062 39.920 0.204</td>
<td>40.039 39.975 0.089</td>
<td>40.025 39.991 0.050</td>
<td>40.025 40.000 0.041</td>
</tr>
<tr>
<td></td>
<td>40.000 39.720 0.120</td>
<td>40.000 39.858 0.080</td>
<td>40.000 39.950 0.025</td>
<td>40.000 39.975 0.009</td>
<td>40.000 39.984 0.000</td>
</tr>
<tr>
<td>50 MAX</td>
<td>50.180 49.870 0.450</td>
<td>50.062 49.920 0.204</td>
<td>50.039 49.975 0.089</td>
<td>50.025 49.991 0.050</td>
<td>50.025 50.000 0.041</td>
</tr>
<tr>
<td></td>
<td>50.000 49.710 0.130</td>
<td>50.000 49.858 0.080</td>
<td>50.000 49.950 0.025</td>
<td>50.000 49.975 0.009</td>
<td>50.000 49.984 0.000</td>
</tr>
<tr>
<td>60 MAX</td>
<td>60.190 59.860 0.520</td>
<td>60.074 59.900 0.248</td>
<td>60.046 59.970 0.106</td>
<td>60.030 59.990 0.050</td>
<td>60.030 60.000 0.049</td>
</tr>
<tr>
<td></td>
<td>60.000 59.700 0.140</td>
<td>60.000 59.826 0.100</td>
<td>60.000 59.940 0.030</td>
<td>60.000 59.971 0.010</td>
<td>60.000 59.984 0.000</td>
</tr>
<tr>
<td>80 MAX</td>
<td>80.190 79.850 0.530</td>
<td>80.074 79.900 0.248</td>
<td>80.046 79.970 0.106</td>
<td>80.030 79.990 0.050</td>
<td>80.030 80.000 0.049</td>
</tr>
<tr>
<td></td>
<td>80.000 79.650 0.150</td>
<td>80.000 79.826 0.100</td>
<td>80.000 79.940 0.030</td>
<td>80.000 79.971 0.010</td>
<td>80.000 79.984 0.000</td>
</tr>
<tr>
<td>100 MAX</td>
<td>100.220 99.830 0.610</td>
<td>100.087 99.880 0.294</td>
<td>100.054 99.964 0.125</td>
<td>100.035 99.984 0.065</td>
<td>100.035 100.000 0.057</td>
</tr>
<tr>
<td></td>
<td>100.000 99.610 0.170</td>
<td>100.000 99.793 0.120</td>
<td>100.000 99.928 0.036</td>
<td>100.000 99.956 0.012</td>
<td>100.000 99.978 0.000</td>
</tr>
<tr>
<td>120 MAX</td>
<td>120.220 119.820 0.620</td>
<td>120.087 119.880 0.294</td>
<td>120.054 119.964 0.125</td>
<td>120.035 119.988 0.065</td>
<td>120.035 120.000 0.057</td>
</tr>
<tr>
<td></td>
<td>120.000 119.600 0.180</td>
<td>120.000 119.793 0.129</td>
<td>120.000 119.929 0.036</td>
<td>120.000 119.956 0.012</td>
<td>120.000 119.978 0.000</td>
</tr>
<tr>
<td>160 MAX</td>
<td>160.250 159.790 0.710</td>
<td>160.100 159.855 0.346</td>
<td>160.063 159.957 0.146</td>
<td>160.043 159.984 0.079</td>
<td>160.043 160.000 0.065</td>
</tr>
<tr>
<td></td>
<td>160.000 159.540 0.210</td>
<td>160.000 159.755 0.145</td>
<td>160.000 159.917 0.043</td>
<td>160.000 159.961 0.014</td>
<td>160.000 159.975 0.000</td>
</tr>
</tbody>
</table>

**Solution:**

1. From table fit tables, locate 40mm basic size.
2. Hole limits
   - H7: 40.025 LMC (Max hole)
   - 40.000 MMC (Min hole)
3. Shaft limits
   - g6: 39.991 MMC (Max shaft)
   - 39.975 LMC (Min shaft)
4. Check Clearance
   - Tightest fit MMC
     - 40.000 Hole
     - -39.991 Shaft
     - .009
   - Loosest fit LMC
     - 40.025 Hole
     - -39.975 Shaft
     - .050
5. Check table under limits of fit
# Tolerances Related to Shop Processes

## Table of Tolerances

<table>
<thead>
<tr>
<th>Range of Sizes From</th>
<th>To &amp; Incl</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>.000</td>
<td>.599</td>
<td>.00015</td>
</tr>
<tr>
<td>.600</td>
<td>.999</td>
<td>.00015</td>
</tr>
<tr>
<td>1.000</td>
<td>1.499</td>
<td>.0002</td>
</tr>
<tr>
<td>1.500</td>
<td>2.799</td>
<td>.00025</td>
</tr>
<tr>
<td>2.800</td>
<td>4.499</td>
<td>.0003</td>
</tr>
<tr>
<td>4.500</td>
<td>7.799</td>
<td>.0004</td>
</tr>
<tr>
<td>7.800</td>
<td>13.599</td>
<td>.0005</td>
</tr>
<tr>
<td>13.600</td>
<td>20.999</td>
<td>.0006</td>
</tr>
</tbody>
</table>

## Diagram of Processes

- Lapping & Honing
- Grinding, Diamond
- Turning & Boring
- Broaching
- Reaming
- Turning, Boring
- Slotting, Planing & Shaping
- Milling
- Drilling
Hole Size for Standard Dowel (Fit Dimensions)

Directions: Determine Hole Limits for Each Mating Situation with Defined Dowel & Fit Limits.

Problem 1
Dowel .2502 MMC .2500 LMC
RC3 Fit
Limits of Clearance .0005, -.0015

Problem 2
Dowel .2502 MMC .2500 LMC
FN2 - Fit
Limits of Interference .0004, -.0014
Tightest Fit = MMC of Hole – MMC of Shaft
- .0005 = MMC of Hole – .2502
- .2507 = MMC of Hole

Loosest Fit = LMC of Hole – LMC of Shaft
- .0015 = LMC of Hole – .2500
- .2515 = LMC of Hole

Tightest Fit = MMC of Hole – MMC of Shaft
- .0014 = MMC of Hole – .2502
- .2488 = MMC of Hole

Loosest Fit = LMC of Hole – LMC of Shaft
- .0004 = LMC of Hole – .2500
- .2496 = LMC of Hole
Interchangeability of Mating Parts

(Problem)

Data:

A. Basic sizes are as indicated.
B. Maximum accumulation of tolerance is .004 which may be X or Y.
C. Required clearance allowance between each set of mating components is .005.
D. Loosest fit not to exceed .015.
E. Dimension each component on the yoke and also on the clevis, in limit form so that the fit requirements are maintained.
F. Dimension so that yoke can be turned end-for-end and the parts will assemble with required clearance values.
Interchangeability of Mating Parts

(Calculations)

1. Yoke (B) MMC = .625
   Clearance = -.005
   Clevis (B) MMC = .620

2. (B) .002 Tol dist.
   (A) .001 Tol dist.
   (C) .001 Tol dist.
   .004 Max Accum

3. Yoke (B) MMC = .625
   (B) Tol = +.002
   Yoke (B) LMC = .627

4. Clevis (B) MMC = .620
   (B) Tol = -.002
   Clevis (B) LMC = .618

5. Clevis (A) or (B) LMC
   6. Clevis (A) or (B) LMC = .627
      Tol dist. = -.001
      (From Yoke [B] LMC)
      Clevis (A) or (B) MMC = .626

7. Yoke (A) or (B) LMC
   8. Yoke (A) or (B) LMC = .618
      Tol dist. = +.001
      Yoke (A) or (B) MMC = .619

9. Check Maximum and Minimum
   Max of Yoke Min of Yoke Max of Clevis Min of Clevis
   .619 .618 .627 .626
   .627 .625 .620 .618
   .619 .618 .627 .626
   1.865 1.861 1.874 1.870

   1.870 - 1.865 = .005 (Within Overall Clearance)
   1.874 - 1.861 = .013 (Within Loosest Fit)
Limits for Intermediate Parts

A. Dimension the Intermediate Parts to Retain Overall Limits.

B. Use Largest Possible Tolerance.

C. Give Dimensions in Limit Form.

Basic Size

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.500</td>
<td>1.350</td>
<td>1.500</td>
<td>2.000</td>
<td>3.750</td>
</tr>
</tbody>
</table>

Limits

A. \hspace{2cm} B. \hspace{2cm} C. \\
D. \hspace{2cm} E.
## ANSWERS

<table>
<thead>
<tr>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.502</td>
<td>1.352</td>
<td>1.502</td>
</tr>
<tr>
<td>1.500</td>
<td>1.350</td>
<td>1.500</td>
</tr>
<tr>
<td>2.002</td>
<td>3.752</td>
<td></td>
</tr>
<tr>
<td>2.000</td>
<td>3.750</td>
<td></td>
</tr>
</tbody>
</table>
### Symbols for Tolerances of Position and Form

<table>
<thead>
<tr>
<th>Characteristic Symbols</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Straightness</td>
<td></td>
</tr>
<tr>
<td>Flatness</td>
<td></td>
</tr>
<tr>
<td>Roundness; Circularity</td>
<td></td>
</tr>
<tr>
<td>Cylindricity</td>
<td></td>
</tr>
<tr>
<td>Profile of a line</td>
<td></td>
</tr>
<tr>
<td>Profile of a surface</td>
<td></td>
</tr>
<tr>
<td>Angularity</td>
<td></td>
</tr>
<tr>
<td>Perpendicularity</td>
<td></td>
</tr>
<tr>
<td>Parallelism</td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td></td>
</tr>
<tr>
<td>Concentricity</td>
<td></td>
</tr>
<tr>
<td>Symmetry</td>
<td></td>
</tr>
<tr>
<td>Circular</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
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</table>

#### Supplementary Symbols

<table>
<thead>
<tr>
<th>MMC</th>
<th>Maximum material condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFS</td>
<td>Regardless of feature size</td>
</tr>
<tr>
<td>DIA</td>
<td>Diameter</td>
</tr>
<tr>
<td>REF</td>
<td>Reference</td>
</tr>
<tr>
<td>BSC</td>
<td>Basic</td>
</tr>
</tbody>
</table>

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Use of Symbols for Tolerances of Position and Form

(a) Basic Dimension Symbol

(b) Datum Symbol

(c) Feature Control Symbols

(d) Feature Control Symbols with Datum References

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No Specified Tolerance of Form

This on the drawing . . . . .

... Means this

Acceptable

(Note: Tolerance zone or boundary within which forms may vary when no tolerance of form is given.)

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Straightness

This on the drawing . . . .

\[ \phi .605 - .615 \]
\[ - .003 \]

\[ \phi .615 \]
\[ .605 \]

Means this

\[ .003 \text{ wide tolerance zone} \]
\[ \phi .630 \]
\[ \phi .615 (\text{Max}) \]

\[ \phi .605 (\text{Min}) \]

(Note: Each longitudinal element of the surface must be within the specified tolerance size of the perfect form at MMC and lie between two parallel lines (.003 apart) where the two lines and the nominal axis share a common plane.)

(Note: Each circular element of the figure must be within the specified tolerance of size. The centerline of the feature must lie within a cylindrical tolerance zone of .015 at MMC. The allowed straightness tolerance increases equal to the amount the feature departs from MMC.)

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Flatness

This on the drawing . . . .

. . . . Means this

.010 wide tolerance zone

(NOTE: The surface must be within the specified tolerance of size and must lie between two parallel planes .010 apart.)

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Roundness

This on the drawing . . . .

\[ \Phi_{0.010} \]

Cylinder

. . . . Means this

\[ \Phi_{0.010} \] .010 wide tolerance zone

Cone

Section A-A

(NOTE: Each circular element of the surface in any plane perpendicular to a common axis must be within the specified tolerance of size and must lie between two concentric circles -- one having a radius .010 larger than the other.)

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Cylindricity

This on the drawing . . . .

\[ \Phi.010 \]

. . . . Means this

.010 wide tolerance zone

(NOTE: The cylindrical surface must be within the specified tolerance of size and must lie between two concentric cylinders -- one having a radius .010 larger than the other.)

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Profile of a Surface

This on the drawing . . . .

Means this

Datum plane A

.020 wide
tolerance zone

( NOTE: Surfaces all around must lie within two parallel boundaries .020 apart equally disposed about the true profile which are perpendicular to datum plane A. Radii of part corners must not exceed .005 R.)

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Profile of a Surface Between Points

This on the drawing . . . .

7 STEPS EACH .250

.688

844 .906

.938

.781 .906

.895

2.312±.005

BETWEEN X & Y

.340 ±.005

2.312±.005

UNTOLERANCED DIMENSIONS ARE BASIC

Means this

Datum plane C

.010 wide tolerance zone

Datum plane B

Datum plane A

90°

NOTE: The surface between points X and Y must lie between the two profile boundaries .010 apart, equally disposed about the true profile, which are perpendicular to datum plane A and positioned with respect to datum planes B and C.)

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Angularity of a Plane Surface

This on the drawing . . . .

\[ \angle A = 0.015 \]

30°

Means this

0.015 wide tolerance zone.

Possible attitude of the surface

30°

Datum plane

(NOTE: The surface must be within the specified tolerance of size and must lie between two parallel planes .015 apart which are inclined at 30° to the datum plane.)

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Perpendicularity

This on the drawing . . . .

\[ \phi.624-625 \]

\[ \perp A \] .002

Means this

\[ \phi.627 \]

\[ \phi.002 \]

\[ \phi.003 \]

\[ \phi.625 \]

\[ \phi.624 \]

\[ \phi.627 \]

(Note: The feature axis must be within the specified tolerance of location. Where the feature is at MMC (.625), the maximum perpendicularity tolerance is .002 diameter. Where the feature departs from its MMC size, an increase in the perpendicularity tolerance is allowed which is equal to the amount of such departure.)

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Perpendicularity
(Continued)

This on the drawing . . . . . Means this

Possible attitude of the surface

\[ \perp A .005 \]

.005 wide tolerance zone

For a Plane Surface

Possible attitude of the feature median plane

\[ \perp A .003 \]

.003 wide tolerance zone

For a Median Plane

Possible attitude of the feature axis

\[ \perp A .005 \]

.005 wide tolerance zone

For an Axis

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Parallelism

This on the drawing . . . . . Means this

For a Plane Surface

For an Axis

For an Axis - Feature at MMC

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Concentricity

This on the drawing . . . .

\[\text{\(\bigcirc A \ \varnothing 0.003\)}\]

... Means this

- \text{Extreme offset variation}
- \text{Extreme angular variation}
- \text{.003 diameter tolerance zone}
- \text{Axis of datum A}

\text{(NOTE: The feature axis must be within a cylindrical zone whose diameter is equal to the concentricity tolerance and whose axis coincides with the datum axis.)}

From ANSI 14.5-1973 Reprinted with permission of ASME
Symmetry

This on the drawing ....

.306-.316
\[= A \: B \: .005\]

.615-.625
\[-B-\]

... Means this

- CENTER PLANE OF DATUM FEATURE B IS PERPENDICULAR TO DATUM PLANE A

-005 wide tolerance zone

- CENTER PLANE OF SLOT MUST LIE BETWEEN PARALLEL PLANES .005 APART, REGARDLESS OF FEATURE SIZE, WHICH ARE EQUALLY DISPOSED ABOUT THE CENTER PLANE OF DATUM B

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Positional Tolerancing

Hole Position May Vary as Shown but No Point on its Surface Shall be Inside Cylinder A

True Position

Cylinder A
Minimum Diameter of Hole (MMC) Minus the Positional Tolerance

Positional Tolerance Interpretation
Tolerance Zones

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XXX - XXX DIA

MAXIMUM TOLERANCE ALLOWED
.010 x 1.4 = .014

.010 SQUARE TOL ZONES

.010 TOLERANCE INDICATED
Cylindrical Tolerance Zones

Cylindrical Tolerance Zone
Equal to positional tolerance

Axis of Hole
at True Position

Extreme Positional Variation

Extreme Angular Variation

Primary Datum

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No Tolerance Accumulation

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Maximum and Least Material Conditions

NOTE: When holes are large, an extra tolerance causes 2.007 to increase to 2.012 and 1.993 to 1.988. The extra positional tolerance is acceptable and desirable. When not specified, MMC applies to positional tolerances and related datums.
Regardless of Feature Size

25.40 Thru
25.38
6 Holes
⊕ B S ø 0.05 S

152.40

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Angular Tolerances

(a) Bilateral Angular Tolerances

(b) Basic Angular Tolerances

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Surface Quality Symbol

- Roughness Height
- Waviness Height
- Roughness Width
- Waviness Width
- Lay Direction
- Roughness Width Cutoff
- Waviness Width Cutoff
- Roughness Height (Arithmetical Average)

Dimensions:
- 0.051-50
- 2.54
- 1.6
- 0.51
## Lay Symbols

<table>
<thead>
<tr>
<th>Lay Symbol</th>
<th>Meaning</th>
<th>Example Showing Direction of Tool Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Lay approximately parallel to the line representing the surface to which the symbol is applied.</td>
<td></td>
</tr>
<tr>
<td>( \perp )</td>
<td>Lay approximately perpendicular to the line representing the surface to which the symbol is applied.</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>Lay angular in both directions to line representing the surface to which the symbol is applied.</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Lay multidirectional.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Lay approximately circular relative to the center of the surface to which the symbol is applied.</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>Lay approximately radial relative to the center of the surface to which the symbol is applied.</td>
<td></td>
</tr>
<tr>
<td>P(^3)</td>
<td>Lay, particulate, non-directional, or protuberant.</td>
<td></td>
</tr>
</tbody>
</table>
DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #1 - DIMENSION AN OBJECT COMPLETELY

Directions: With drafting tools and machine, dimension the objects below using proper dimensioning rules and techniques.

Problems:

A. Full size - inch system - fractions

B. Half size - metric system
ASSIGNMENT SHEET #1

C. 1/4" = 1" - inch system - decimal
DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #2 CALCULATE AND DIMENSION CLEARANCE
FIT TOLERANCES USING STANDARD FIT TABLES

Directions: Calculate and dimension the following clearance fit tolerances using standard fit tables.

Problems:

A. Inch system using ANSI B 4.1 - 1967, R 1974

Fit RC 4
Basic Size 1.00
Check fit

B. Metric system using ANSI B 4.2 - 1978

Fit H7/g6
Basic Size 40
Check fit

Fit D9/h9
Basic Size 2.5
Check fit
ASSIGNMENT SHEET #8--CALCULATE AND DIMENSION INTERFERENCE FIT TOLERANCES USING STANDARD FIT TABLES

Directions: Calculate and dimension the following interference fit tolerances using standard tables.

Problems:

A. Inch system using ANSI B 4.1 -1967, R 1974

1. Fit FN 4
   Basic Size 3.00
   Check fit

2. Fit LN 2
   Basic Size .5
   Check fit

B. Metric system using ANSI B 4.2 -1978

3. Fit U7/h6
   Basic Size 10
   Check fit

4. Fit P7/h6
   Basic Size 1.2
   Check fit
ASSIGNMENT SHEET #4: CALCULATE AND ASSIGN TOLERANCES TO MATING PARTS USING STANDARD FIT TABLES

Directions: Calculate and assign tolerances to mating parts using standard fit tables for the pulley assembly below.

Problems
A. Metric system

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Show calculations below</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHAFT-BRACKET FIT</td>
<td>SHAFT-BUSHING FIT</td>
</tr>
<tr>
<td>12mm Nominal diameter</td>
<td>12mm Nominal diameter</td>
</tr>
<tr>
<td>Fit D9/h9</td>
<td>Fit F8/h9</td>
</tr>
<tr>
<td>BUSHING-PULLEY FIT</td>
<td>BUSHING-BRACKET FIT</td>
</tr>
<tr>
<td>20mm Nominal diameter</td>
<td>50mm Nominal length</td>
</tr>
<tr>
<td>Fit H7/p6</td>
<td>Fit H11/c11</td>
</tr>
</tbody>
</table>

Graphical representation of the pulley assembly.
ASSIGNMENT SHEET #4

B. Inch system

Specifications

<table>
<thead>
<tr>
<th>SHAFT-BRACKET FIT</th>
<th>SHAFT-BUSHING FIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>.75 Nominal diameter</td>
<td>.75 Nominal diameter</td>
</tr>
<tr>
<td>Fit RC7</td>
<td>Fit RC4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BUSHING-PULLEY FIT</th>
<th>BUSHING-BRACKET FIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25 Nominal diameter</td>
<td>3 Nominal length</td>
</tr>
<tr>
<td>Fit LN1</td>
<td>Fit RC8</td>
</tr>
</tbody>
</table>
Directions: Calculate and dimension hole size limits for standard dowels using basic shaft system. You should use the appropriate tolerance tables for the following problems.

Dowel limits = \( \frac{.7502}{.7500} \)

Problems:

A. For a sliding fit with limits of possible clearance from .0003-.0012

B. For an interference fit with limits of interference from .0006-.0019
DIMENSIONING AND TOLERANCING  
UNIT V  

ASSIGNMENT SHEET #6: DIMENSION AN OBJECT USING POSITION AND FORM TOLERANCES  

Directions: Dimension an object using position and form tolerances to completely describe it.  
(NOTE: Instructor or student may select datums as assigned.)  

Problem:
Assignment Sheet #7-Determine Ranges of Motion of Limbs and Spaces Required for a Person

Directions: With the anthropometric data included at the end of this assignment sheet, solve the following problems by using the examples provided as guidelines.

Example #1: Find the width of the head of an adult in the 50 percentile group
   a. Go to anthropometric data-Standing adult male
   b. Go to 50 percentile drawing of man on chart
   c. Locate head and read dimension above it
   d. Answer 6.1"

Example #2: Find the reach radius of 50 percentile male
   a. Go to anthropometric data-Adult male, seated at console
   b. Go to view of man showing his reach radius
   c. The reach radius is shown as:
      30.7
      28.5
      26.5
   d. The first number 30.7 is for the 97.5 percentile, the 28.5 is for the 50 percentile, and the 26.5 is for the 2.5 percentile
   e. Answer 28.5"

Problems

A. Find the width of the shoulders of a 97.5 percentile adult male.
ASSIGNMENT SHEET #7

B. Find the height of a 50 percentile adult female.

C. Find the total visual limit in degrees from up to down.

D. Find the maximum cylinder hand grasp for a 97.5 percentile adult male.

E. Find the average hand breadth of an 11 year-old child.

F. Find the average thumb length of a 50 percentile woman.
ASSIGNMENT SHEET #7

ANTHROPOMETRIC DATA — STANDING ADULT, MALE
ACCOMODATING 95% OF U.S. ADULT MALE POPULATION

25th percentile

50th percentile

97th percentile

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HAND MEASUREMENTS OF MEN, WOMEN AND CHILDREN

HAND DATA

<table>
<thead>
<tr>
<th>Hand Data</th>
<th>Men</th>
<th>Women</th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>hand length</td>
<td>25%tile</td>
<td>50%tile</td>
<td>75%tile</td>
</tr>
<tr>
<td>hand breadth</td>
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<td>38</td>
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<tr>
<td>3rd finger lg</td>
<td>40</td>
<td>45</td>
<td>50</td>
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<tr>
<td>dorsum lg</td>
<td>28</td>
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<td>thumb length</td>
<td>24</td>
<td>27</td>
<td>30</td>
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</table>

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ASSIGNMENT SHEET #7

ANTHROPOMETRIC DATA — ADULT MALE SEATED AT CONSOLE

EASY HEAD MOVEMENT

35° lmax
30° ov
34° tmax

50° max
but avoid
movements

50°/tile

5°-tile

2° normal

Lights below cause glare

color limit

opt viewing zone

max eye rotation

opt eye rotation

visual limit

rt eye

0-20°

54° max — emergency controls

52 min to avoid seeing top

std sight line

0°

45° max see over ht

Reach radius

Normal sight line

15°

CONTROL LOCATIONS

A set-up & emergency
B displays & set-up
C display & assoc controls
D controls & misc equip
E set-up & adjust controls
start & light sw (recess)

REACH INCREASE

arm pos

0°-45°

80°

shoulder extended

shoulder extended &

trunk rotated

shoulder extended,

trunk rotated &

trunk bent

REACH DECREASE

push buttons

foggles

small rotary selectors

large rotary selectors

hand grasp

0°

17°

compressed

seat ht

to fit 80%

rise & lower

1° to fit 95%

15 max

475°

55°

6°

29°-26°

range

248-173 range

23

12

16

4

5

0° datum

18 min

24 min

27.6-18.5 range

2675 knee clear NYC bus

6.8-9% left handed, 35-6% color blind, 45% hard of hearing, 293% wear glasses

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DIMENSIONING AND TOLERANCING
UNIT V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1--Evaluated to the satisfaction of the instructor

Assignment Sheet #2
A.

| 0.9992 | 2.4996 |
| 0.9984 | 2.4991 |
| 1.0008 | 2.5007 |
| 1.0000 | 2.5000 |

B.

| 39.991 | 2.500 |
| 39.975 | 2.475 |

Assignment Sheet #3
A.

| 3.0047 | 0.5011 |
| 3.0040 | 0.5007 |
| 3.0012 | 0.5007 |
| 3.0000 | 0.5000 |

B.

| 10.000 | 1.200 |
| 9.991  | 1.194 |
| 9.978  | 1.194 |
| 9.963  | 1.184 |

Assignment Sheet #4
A. Metric system
B. Inch system

Assignment Sheet #5
A. Clearance 0.512
B. Interference 0.7494

Assignment Sheet #6 Evaluated to the satisfaction of the instructor

Assignment Sheet #7
A. 19.8"
B. 69.1"
C. 120°
D. 4.5"
E. 2.8"
F. 2.4"
1. Match the terms on the right with the correct definitions.

   a. The condition that refers to a part made to limit dimensions so that it will fit any part similarly manufactured; the ability of mating parts to fit properly together

   b. Shapes such as prisms, cylinders, pyramids, cones, and spheres

   c. Any type of dimension that tells how large or small an object is

   d. Any type of dimension that locates a feature on an object

   e. The total amount of variation permitted in limiting dimensioning of a part; the difference between the limit dimensions

   f. The size of a part determined by engineering and design requirements from which the limits of size are determined; the line of zero deviation

   g. The extreme permissible dimensions of a part resulting from the application of a tolerance; the maximum and minimum size indicated by a tolerance

   h. Used when maximum material is present in a feature

   i. Used when the least material is present in a feature

   j. Difference between the maximum limit and the basic size

   k. Difference between the minimum limit and the basic size

   l. Group of tolerances numbered 01 - 16

   m. The deviation nearer the basic size for the hole and near the basic size for the shaft
n. The association of a fundamental deviation with an international tolerance grade

o. The basic size of the hole is the design size and the allowance is applied to the shaft

p. The basic size of the shaft is the design size and the allowance is applied to the hole

q. Limits of size are determined so that a loose fit or positive allowance occurs between mating parts

r. Limits of size are determined so that a negative allowance or tight fit occurs between mating parts

s. Limits of size are determined so that the allowance may be either a clearance fit or an interference fit

The minimum international difference in the dimensions of mating parts to provide for different classes of fits; the minimum clearance or maximum interference when parts are at maximum material condition.

u. Points, lines, or other geometric shapes assumed to be exact from which the location or geometric form of features of a part may be established

v. Exact theoretical position of a feature established by basic dimensions

w. Maximum allowable variations of a perfect geometric shape

x. Roughness, waviness, and lay of a surface which may include certain flaws.

y. Direction of the major surface pattern determined by manufacturing method used

z. Fine irregularities in surface texture

aa. Widely spaced element of a surface texture

bb. Measurements of the human body and its parts
2. Distinguish between size and location dimensions for the following geometric shape by placing an "X" next to the size dimensions.

   a. Dimension "A"
   b. Dimension "B"
   c. Dimension "C"
   d. Dimension "D"
   e. Dimension "E"
   f. Dimension "F"
   g. Dimension "G"
   h. Dimension "H"
   i. Dimension "I"
   j. Dimension "J"
   k. Dimension "K"
   l. Dimension "L"
   m. Dimension "M"
   n. Dimension "N"
   o. Dimension "O"

3. Select mating dimensions in the following assembly drawing by placing an "X" in the appropriate blanks.

   a. Dimension "A"
   b. Dimension "B"
   c. Dimension "C"
4. Select true statements concerning numerical control dimensioning by placing an "X" in the appropriate blanks.

   a. Datum or reference planes must be selected that are mutually perpendicular in the X, Y, and Z axes
   b. Dimensions originate from two planes
   c. Dimensions must be in fractions
   d. Standard tools such as reamers, drills, and tapers should be specified whenever possible

5. Distinguish between fits for inch units and fits for metric units by placing an "X" next to the fits for inch units and an "O" next to the fits for metric units.

   a. RC 2
   b. H9/d9
   c. H7/h6
   d. FN 3
   e. LT 1
   f. N7/h6
   g. P7/h6
   h. U7/h6
   i. LC 1
6. Calculate the limits for clearance fit in inch units using basic hole system for basic hole size of 2.25" and RC 4 fit. Place answers on drawing.

<table>
<thead>
<tr>
<th>NOMINAL SIZE RANGE, INCHES</th>
<th>CLEARANCE OF HOLE</th>
<th>CLEARANCE OF SHAFT</th>
<th>LIMITS</th>
<th>STANDARD LIMITS</th>
<th>RC 3</th>
<th>RC 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.19 - 1.97</td>
<td>-1.0</td>
<td>+1.0</td>
<td>-1.0</td>
<td>1.0</td>
<td>0</td>
<td>-1.0</td>
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<tr>
<td></td>
<td>-0.26</td>
<td>+0.16</td>
<td>+0.0</td>
<td>1.0</td>
<td>-1.0</td>
<td></td>
</tr>
<tr>
<td>1.97 - 3.15</td>
<td>1.2</td>
<td>+1.2</td>
<td>1.2</td>
<td>+1.8</td>
<td>-1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.1</td>
<td>0</td>
<td>1.9</td>
<td>4.2</td>
<td>0</td>
<td>-2.4</td>
</tr>
</tbody>
</table>

7. Calculate the limits for clearance fit in inch units using basic shaft system for basic shaft size of 1.75 and RC 3 fit. Place answers on drawing.

(NOTE: Use table in question 6.)
8. Calculate the limits for an interference fit in metric units using basic hole system for basic hole size of 60 mm and H7/u6 fit. Place answers on drawing.

<table>
<thead>
<tr>
<th>BASIC SIZE</th>
<th>HOLE H7</th>
<th>SHAFT u6</th>
<th>FIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>60.030</td>
<td>60.106</td>
<td>-0.057</td>
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<tr>
<td></td>
<td>60.000</td>
<td>60.087</td>
<td>-0.106</td>
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<tr>
<td>80</td>
<td>80.030</td>
<td>80.121</td>
<td>-0.072</td>
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<tr>
<td></td>
<td>80.000</td>
<td>80.102</td>
<td>-0.121</td>
</tr>
</tbody>
</table>

9. Determine the tolerance ranges for the following shop processes using the accompanying table.

<table>
<thead>
<tr>
<th>Range of Sizes</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00015</td>
</tr>
<tr>
<td>----------------</td>
<td>------------</td>
</tr>
<tr>
<td>600</td>
<td>0.0025</td>
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<tr>
<td>1000</td>
<td>0.003</td>
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<tr>
<td>1500</td>
<td>0.004</td>
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<tr>
<td>2000</td>
<td>0.005</td>
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<td>2500</td>
<td>0.006</td>
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<td>3000</td>
<td>0.007</td>
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<td>3500</td>
<td>0.008</td>
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<tr>
<td>4000</td>
<td>0.009</td>
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<tr>
<td>4500</td>
<td>0.010</td>
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<td>5000</td>
<td>0.011</td>
</tr>
<tr>
<td>5500</td>
<td>0.012</td>
</tr>
<tr>
<td>6000</td>
<td>0.013</td>
</tr>
</tbody>
</table>

a. Milling of a 1.5 to 2.799 part
b. Reaming of a .6 to .999 part
c. Drilling of a 4.5 to 7.799 part
d. Honing of a .000 to .599 part
10. Distinguish between clearance fit and interference fit of hole size limits for standard dowels by placing an "X" next to the characteristic of clearance fit.
   a. Largest number is tightest fit and is negative; smallest number is loosest fit and is negative
   b. Smallest number is tightest fit; largest number is loosest fit

11. Select true statements concerning limit dimensions for interchangeability of parts by placing an "X" in the appropriate blanks.
   a. Parts should be tolerated to fit end-for-end to make assembly easier if function is not affected
   b. Select the center dimension to be basic size
   c. Maximum accumulation should be added to center
   d. When each part is tolerated, it is not necessary to check the accumulation of tolerance

12. Arrange in order the steps for determining limit dimensions for intermediate parts to retain overall limits by placing the correct sequence numbers in the appropriate blanks.
   a. Divide total tolerance accumulation by number of tolerated parts to get tolerance per part
   b. Subtract upper and lower limits of overall dimension to get total tolerance accumulation
   c. Add tolerance per part to each basic size to get upper limit of each part
   d. Find limit dimensions
   e. Check by adding upper limits together to get upper limit of overall dimension
13. Complete the following chart of characteristic symbols for tolerances of position and form.

<table>
<thead>
<tr>
<th>Characteristic Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straightness</td>
</tr>
<tr>
<td>Flatness</td>
</tr>
<tr>
<td>Cylindricity</td>
</tr>
<tr>
<td>Profile of a line</td>
</tr>
<tr>
<td>Profile of a surface</td>
</tr>
<tr>
<td>Angularity</td>
</tr>
<tr>
<td>Perpendicularity</td>
</tr>
<tr>
<td>Position</td>
</tr>
<tr>
<td>Concentricity</td>
</tr>
<tr>
<td>Symmetry</td>
</tr>
<tr>
<td>Circular</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

14. Match the terms on the right with the correct supplementary symbols for tolerances of position and form.

- a. \( \circ \)  
- b. \( \mathbb{M} \)  
- c.  
- d. ()  
- e.  
- f. \( \mathbb{P} \)  

4. Basic  
2. Diameter  
3. Maximum material condition  
4. Projected tolerance zone  
5. Regardless of feature size  
6. Reference
15. Match position and form symbols in the drawing with the correct descriptions below.

- **3.875**
  1. Basic dimension symbol

- **_B_**
  2. Modifier of datum

- **.005**
  3. Geometric characteristic symbol
  4. Modifier of tolerance

- **[@](A)[\(\pm\)]0.002**
  5. Datum reference
  6. Tolerance

16. Match the descriptions of position and form on the right with the correct meaning of drawings.

- **Extreme angular variation**
  1. Flatness

- **Axis of datum A**
  2. Angularity

- **0.10 wide tolerance zone**
  3. Concentricity
  4. Profile of a surface

- **Perpendicular to the surface**
  5. Perpendicularity
17. Select true statements concerning positional tolerancing by placing an "X" in the appropriate blanks.

   a. Conventional limit locational dimensions have a square tolerance zone

   b. Positional tolerancing allows a circular tolerance zone

   c. Positional tolerancing allows more tolerance than conventional limit dimensions

   d. Extreme angular variation in drilling a hole under positional tolerancing is not possible

   e. No tolerance accumulation is found in positional tolerancing

18. Distinguish between maximum material condition and regardless of feature size by placing an "X" next to the characteristic of maximum material condition.

   a. More restrictive

   b. Less restrictive

19. Select true statements concerning angular tolerances by placing an "X" in the appropriate blanks.

   a. Bilateral angular tolerances cause a smaller tolerance zone as you move from the vertex

   b. Basic angular tolerances using angular feature controls cause a parallel tolerance zone

20. State the purpose of surface quality specifications.
21. Identify parts of a surface quality symbol.

22. Select true statements concerning surface quality notes by placing an "X" in the appropriate blanks.

- a. Values are in decimeters
- b. Lower number of values indicate rougher surface
- c. Symbol is always made in the standard upright position
- d. The smoothest surface that will satisfy function and form is the ideal finish

23. Match lay symbols on the right with the correct designation.

- a. Angular to surface
- b. Radial
- c. Particulate, nondirectional, or protuberant
- d. Parallel to surface
- e. Multidirectional
- f. Perpendicular to surface
- g. Circular
24. Differentiate between correct and incorrect placement of surface quality symbols by placing an "X" in the blanks which correspond to symbols placed correctly.

25. Select true statements concerning surface roughness produced by common production methods by placing an "X" in the appropriate blanks by using the accompanying table.

<table>
<thead>
<tr>
<th>ROUGHNESS HEIGHT RATING, MICROMETERS (MICROINCHES)</th>
<th>AA</th>
<th>(5000)</th>
<th>(2500)</th>
<th>(125)</th>
<th>(32)</th>
<th>(8)</th>
<th>(2)</th>
<th>(0.5)</th>
</tr>
</thead>
<tbody>
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<td>25</td>
<td>6.3</td>
<td>1.6</td>
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<td>0.05</td>
<td>0.025</td>
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<td>Cold rolling, Drawing</td>
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</tr>
</tbody>
</table>

**KEY**
- **Average application**
- **Less frequent application**
26. Select preferred recommended roughness, waviness, and roughness width cutoff values from table by placing an "X" in the appropriate blanks.

<table>
<thead>
<tr>
<th>Recommended Roughness</th>
<th>Recommended Waviness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Rating Values</td>
<td>Height Values,</td>
</tr>
<tr>
<td>Micrometers (Microinches)</td>
<td>Millimeters (Inches)</td>
</tr>
<tr>
<td>µm</td>
<td>µm</td>
</tr>
<tr>
<td>0.025</td>
<td>(1)</td>
</tr>
<tr>
<td>0.050</td>
<td>(2)</td>
</tr>
<tr>
<td>0.075</td>
<td>(3)</td>
</tr>
<tr>
<td>0.100</td>
<td>(4)</td>
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<tr>
<td>0.125</td>
<td>(5)</td>
</tr>
<tr>
<td>0.15</td>
<td>(6)</td>
</tr>
<tr>
<td>0.20</td>
<td>(8)</td>
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<tr>
<td>0.25</td>
<td>(10)</td>
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<tr>
<td>0.32</td>
<td>(13)</td>
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<td>0.40</td>
<td>(16)</td>
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<tr>
<td>0.50</td>
<td>(20)</td>
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<tr>
<td>0.63</td>
<td>(25)</td>
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<tr>
<td>0.80</td>
<td>(32)</td>
</tr>
<tr>
<td>1.00</td>
<td>(40)</td>
</tr>
</tbody>
</table>

| a. | .075 µm Roughness |
|    | 0.06 | (0.03) | 2.50 | (100) |
|    | 0.25 | (0.13) | 8.0 | (300) |
|    | 0.80 | (0.30) | 25.0 | (1000) |

b. .20 mm Waviness height

c. .80 mm Roughness width cutoff

d. Demonstrate the ability to:
   a. Dimension an object completely.
   b. Calculate and dimension clearance fit tolerances using standard fit tables.
   c. Calculate and dimension interference fit tolerances using standard fit tables.
   d. Calculate and assign tolerances to mating parts using standard fit tables.
   e. Calculate and dimension hole size limits for standard dowels.
   f. Dimension an object using position and form tolerances.
   g. Determine ranges of motion of limbs and spaces required for a person.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
DIMENSIONING AND TOLERANCING
UNIT: V

ANSWERS TO TEST

1. a. 8 h. 10 o. 16 v. 6
   b. 27 i. 24 p. 5 w. 26
   c. 13 j. 44 q. 15 x. 21
   d. 22 k. 4 r. 2 y. 7
   e. 20 l. 25 s. 9 z. 17
   f. 11 m. 12 t. 18 aa. 3
   g. 1 n. 28 u. 23 bb. 19

2. a, b, c, f, g, h, i, j, k, o

3. a, b, c, d, e

4. a, d

5. a. X f. O
   b. O g. O
   c. O h. O
   d. X i. X
   e. X

6. 2.2488 2.2500
    2.2476 2.2518

7. 1.7488 1.7500
    1.7481 1.7512

8. 60.106 60.030
    60.087 60.000

9. a. .0025 .010
    b. .0004 .0025
    c. .006 .015
    d. .08015 .0003
10. b
11. a, b
12. a. 3  
    b. 2  
    c. 4  
    d. 1  
    e. 5
13. 

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<tr>
<th>Characteristic Symbols</th>
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<th>Inspection Features</th>
<th>Related Features</th>
<th>Runout Tolerances</th>
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<td>Profile of a surface</td>
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14. a. 5  
      b. 3  
      c. 1  
      d. 6  
      e. 2  
      f. 4
15. a. 3  
      b. 6  
      c. 2  
      d. 1  
      e. 4  
      f. 5
16. a. 3  
b. 1  
c. 2  
d. 4  
e. 5

17. a, b, c, e

18. b

19. b

20. Used where heavy loads and high speeds with less friction are needed

21. a. Roughness height  
b. Waviness height  
c. Waviness width  
d. Roughness width cutoff  
e. Roughness width  
f. Lay

22. c

23. a. 3  
b. 6  
c. 7  
d. 1  
e. 4  
f. 2  
g. 5

24. a, b, d, e

25. a, b, d

26. c

27. Evaluated to the satisfaction of the instructor
FASTENERS AND HARDWARE
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify fasteners and symbols and construct symbols and hardware drawings. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to fasteners and hardware with the correct definitions.
2. Name two general types of fasteners.
3. Name three basic applications of screw threads.
4. Identify screw thread nomenclature.
5. Identify screw thread profiles.
6. Compute lead of thread.
7. Identify screw thread symbols.
8. Match classes of fit for unified threads with the correct uses.
9. List two classes of fit for metric threads.
10. Identify parts of thread notes.
11. Distinguish between conventional representations of pipe threads.
12. List types of threaded removable fasteners.
13. Name two shapes of bolts and nuts.
14. Select types of locknuts and locking devices.
15. Name types of standard cap screws.
16. Complete a list of types of machine screws.
17. Identify set screw heads and points.
18. Identify miscellaneous bolts and screws.
19. Identify standard large and small rivets.
20. Match conventional rivet symbols with the correct identifications.
21. List advantages of plastic fasteners over metal fasteners.
22. Select devices to lock components on a shaft.
23. List types of springs.
24. Identify types of springs according to notes and dimensions.
25. Name types of spring clips.
26. Select types of keys to prevent relative motion between wheel and shaft.
27. Identify types of machine pins.
28. Select true statements concerning washers.
29. List two applications of inserts.
30. Distinguish between types of lock washers.
31. Name uses for spring washer designs.
32. Identify quick opening and locking devices.
33. Match miscellaneous machine elements with the correct uses.
34. Name advantages of welding over threaded fasteners.
35. Identify types of welded joints.
36. Label parts of a welding symbol.
37. Identify basic arc and gas weld symbols.
38. Identify supplementary welding symbols.
39. Determine welding dimensions for a fillet weld.
40. Identify resistance welding symbols.
41. Name classifications of methods of using adhesives for bonding materials.
42. List two joint design considerations for adhesive bonding.
43. Select joint designs for adhesive bonding.
44. Demonstrate the ability to:
   a. Construct thread symbols.
   b. Construct bolts, screws, and nuts.
c. Construct an assembly containing various fasteners.
d. Construct a welded assembly drawing.
e. Construct spring drawings to include specifications.
f. Construct keys in assembled positions.
g. Write specifications for hardware from vendor catalogs.
FASTENERS AND HARDWARE
UNIT VI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Have students tour a hardware store searching out various fasteners. A display of various fasteners in the classroom would improve learning of this unit.

VII. Have students tour a welding lab to see how parts are welded together.

VIII. Assemble a display of various hardware items obtainable from a hardware store and discuss their possible uses.

IX. Have various springs for the students to see.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

   1. TM 1--Screw Thread Nomenclature
   2. TM 2--Screw Thread Profiles
   3. TM 3--Screw Thread Symbols
   4. TM 4--Combined Screw Thread Symbols
   5. TM 5--American National Thread Note for Holes
   6. TM 6--American National Thread Notes for Threaded Shaft
   7. TM 7--American Standard Unified Thread Notes
   8. TM 8--Metric Thread Notes
<p>| | |</p>
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<thead>
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<tr>
<td>9.</td>
<td>TM 9--Pipe Threads</td>
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<td>10.</td>
<td>TM 10--Removable Fasteners</td>
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<td>11.</td>
<td>TM 11--Locknuts and Locking Devices</td>
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<td>12.</td>
<td>TM 12--Standard Cap Screws</td>
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<td>TM 13--Machine Screws</td>
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<td>14.</td>
<td>TM 14--Set Screws</td>
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<td>15.</td>
<td>TM 15--Miscellaneous Bolts and Screws</td>
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<td>16.</td>
<td>TM 16--Miscellaneous Bolts and Screws (Continued)</td>
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<td>TM 17--Standard Large Rivets</td>
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<td>18.</td>
<td>TM 18--Small Rivets</td>
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<td>19.</td>
<td>TM 19--Rivet Symbols</td>
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<tr>
<td>20.</td>
<td>TM 20--Design with Rivets</td>
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<td>TM 21--Shaft Locking Hardware</td>
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<td>TM 22--Springs</td>
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<td>23.</td>
<td>TM 23--Schematic Spring Drawing Representative</td>
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<td>TM 28--Tooth Lock Washers</td>
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<td>TM 29--Quick Locking Devices</td>
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<td>TM 30--Attaching Resistance Weld Fasteners</td>
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<td>TM 31--Welding Advantages</td>
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<td>32.</td>
<td>TM 32--Types of Welded Joints</td>
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<td>TM 33--Parts of a Welding Symbol</td>
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<td>TM 34--Basic Arc and Gas Welding Symbol</td>
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<td>35.</td>
<td>TM 35--Supplementary Symbols</td>
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<td>36.</td>
<td>TM 36--Dimensioning of Welds</td>
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37. TM 37-Resistance Welding Symbols
38. TM 38-Stresses on Bonded Joints
39. TM 39-Joint Design for Adhesive Bonding

D. Assignment sheets
   1. Assignment Sheet #1-Construct Thread Symbols
   2. Assignment Sheet #2-Construct Bolts, Screws, and Nuts
   3. Assignment Sheet #3-Construct an Assembly Containing Various Fasteners
   4. Assignment Sheet #4-Construct a Welded Assembly Drawing
   5. Assignment Sheet #5-Construct Spring Drawings to Include Specifications
   6. Assignment Sheet #6-Construct Keys in Assembled Positions
   7. Assignment Sheet #7-Write Specifications for Hardware from Vendor Catalogs

E. Test

F. Answers to test

II. References:


E. American National Standards Institute, 1430 Broadway, New York, NY 10018.


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FASTENERS AND HARDWARE
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. Fastener--Mechanical device for holding two or more parts in a set position

B. Finished fastener--Fastener made to close tolerance having a high grade finish

C. High strength fastener--Fastener having high tensile and shear strength

D. Semi-finished fastener--Fastener made with greater tolerances than a finished fastener and having only the bearing surface and threads finished

E. Unfinished fastener--Fastener with wide tolerances and all surfaces in their formed conditions

F. Slotted head--Head having a slot centered across the top

G. Recessed head--Head having a specially formed indentation centered in its top

H. Screw thread form--Profile of the thread

I. Detailed threads--Close approximation to actual appearance

J. Schematic threads--More detailed than simplified but faster to draw than detailed threads

K. Simplified threads--Least amount of drawing information necessary to convey information without confusion

L. External thread--Thread on the outside of a shaft

M. Internal thread--Thread on the inside of a hole

N. Lead--Distance a screw travels in one rotation
INFORMATION SHEET

O. Series of thread--Number of threads per inch based on standard nominal diameters

P. Single thread--Thread having one start, and the lead is equal to the pitch

Q. Multiple threads--Thread having multiple starts, and the lead is equal to a multiple of the pitch

Example: Double thread has a lead of twice the pitch

R. Right-hand thread--Advances when turned clockwise

S. Left-hand thread--Advances when turned counterclockwise

T. Welding--Joining parts by melting base metal to form a unit structure to support loads

U. Adhesive--Chemical bonding between parts

V. Hardware--Small parts such as fasteners, springs, and washers

W. Springs--Used for storage of mechanical energy

X. Keys--Used to attach wheels, pulleys, and gears to shafts

Y. Washers--Designed to insulate, lubricate, span large holes, and distribute stress over a larger area

Z. Nuts--Designed for fastening, adjusting, and transmitting motion or power

AA. Pins--Designed for semi-permanent attachment or location

BB. O-Rings--Used to seal along a shaft

CC. Retaining ring--Has a removable shoulder to accurately retain, locate, or lock components in bases and housings or on shafts

(NOTE: This is also called a snap ring.)

II. General types of fasteners

A. Removable

Example: Bolts, keys, screws

B. Permanent

Example: Rivets, welds, adhesives.
III. Basic applications of screw threads
   A. Holding parts together
   B. Adjustment
   C. Power transmission

IV. Screw thread nomenclature (Transparency 1)
   A. Crest
   B. Root
   C. Side
   D. Major diameter
   E. Pitch diameter
   F. Minor diameter
   G. Depth
   H. Axis
   I. Thread angle
   J. Pitch

V. Screw thread profiles (Transparency 2)
   A. Sharp V-Adjustments

   B. American National-General purpose
INFORMATION SHEET

C. Unified
   ![Diagram of a Unified thread with notations: H = 0.86P, 60°, 12H, Rounded Root, Flat or Rounded Crest.]

D. Metric
   ![Diagram of a Metric thread with notations: 12P, 60°, 54P.]

E. Square
   ![Diagram of a Square thread with notations: P.]

F. Acme-General purpose
   ![Diagram of an Acme thread with notations: 37P, 29°, 15P, 29°, 15P.]

G. Acme-Stub
   ![Diagram of an Acme-Stub thread with notations: 15P, 29°, 15P.]

H. Whitworth Standard
   ![Diagram of a Whitworth thread with notations: r = 0.137P, 55°.]

I. Knuckle
   ![Diagram of a Knuckle thread with notations: P, 5P, 5P.]

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VI. Computing lead of thread

A. Single thread lead = Pitch
B. Double thread lead = (2)(Pitch)
C. Triple thread lead = (3)(Pitch)
D. Multi-threads lead = (Number of threads)(Pitch)

(NOTE: Pitch = \( \frac{1}{\text{Number of threads per inch}} \))

Example: 12 threads per inch

Pitch = \( \frac{1}{12} \)

Lead = \( \frac{1}{12} \) for single thread

Lead = \( \frac{2}{12} \) or \( \frac{1}{6} \) for double thread

VII. Screw thread symbols (Transparencies 3 and 4)

A. Simplified
B. Schematic
C. Detailed
D. Combined

VIII. Classes of fit for unified threads and uses

A. Classes 1A and 1B—For parts that are easy to assemble; ordinance and other special uses; quick assembly

B. Classes 2A and 2B—For general purposes and most common uses

C. Classes 3A and 3B—For close tolerance screw thread

(NOTE: "A" refers to internal and "B" refers to external.)
IX. Classes of fit for metric threads
   A. Coarse (general purpose)
   B. Fine

X. Parts of thread notes
   A. American National Screw Threads (Transparencies 5 and 6)
      1. Major diameter
      2. Threads per inch
      3. Profile
      4. Series
      5. Class of fit
      6. Left hand
      7. Thread depth
   B. American National Standard Unified (Transparency 7)
      1. Major diameter
      2. Threads per inch
      3. Series
      4. Class of fit
      5. Internal or external thread
      6. Left hand
   C. Metric thread (Transparency 8)
      1. Metric thread form
      2. Major-diameter of thread
      3. Pitch
      4. Class of fit
      5. Internal-external
      6. Left hand
INFORMATION SHEET

XI. Conventional representations of pipe threads (Transparency 9)
   A. Schematic
   B. Simplified

XII. Types of threaded removable fasteners (Transparency 10)
   A. Bolts
   B. Studs
   C. Cap screws
   D. Machine screws
   E. Set screws

XIII. Shapes of bolts and nuts
   A. Square head
   B. Hexagon head

   (NOTE: Bolt specifications would include nominal size, thread type, length of bolt, finish of bolts, style of head, and name.)

XIV. Types of locknuts and locking devices (Transparency 11)
   A. Jam nuts
   B. Lock washer
   C. Cotter pin
   D. Set screw
   E. Hex slotted nut
   F. Hex castle nut
   G. Stop nut
   H. Elastic stop nut
   I. Spring head
   J. Wire rap nuts
   K. Serrated face nut
   L. Captive washer
INFORMATION SHEET

XV. Types of standard cap screws (Transparency 12)
   A. Hexagon head
   B. Flat head
   C. Round head
   D. Fillister head
   E. Hex socket head

XVI. Types of machine screws (Transparency 13)
   A. Round head
   B. Flat head
   C. Oval head
   D. Fillister head

XVII. Set screw heads and points (Transparency 14)
   A. Heads
      1. Slotted
      2. Hex socket
      3. Fluted socket
      4. Square
   B. Points
      1. Cup
      2. Flat
      3. Oval
      4. Full dog
      5. Half dog
      6. Cone

XVIII. Miscellaneous bolts and screws (Transparencies 15 and 16)
   A. Stove bolt
   B. Collar bolt
   C. Hanger bolt
INFORMATION SHEET

D. Step bolt
E. Track bolt
F. Square neck bolt
G. Fin neck bolt
H. Countersunk-square neck bolt
I. Ribbed neck bolt
J. Countersunk bolt
K. Roundhead bolt
L. Turnbuckle
M. Clevis
N. Thumb screw
O. Wing nut
P. T-head bolt
Q. Plow bolt
R. Eye bolt
S. U-bolt
T. Hook bolt
U. Askew-head bolt
V. J-bolt
W. Lag screw
X. Square head bolt
Y. Hexagon head bolt
Z. Aircraft bolt
AA. Lab bolt
BB. Tapping screw
CC. Tamper proof fasteners
   1. Spanner
   2. One-way
INFORMATION SHEET

XIX. Standard large and small rivets
   A. Standard large rivets (Transparency 17)
      1. Button head
      2. High button head (acorn)
      3. Cone head
      4. Pan head
      5. Flat top countersunk head
      6. Round top countersunk head
   B. Small rivets (Transparency 18)
      1. Pan head
      2. Truss or wagon box head
      3. Flat head
      4. Countersunk head
      5. Button head

XX. Conventional rivet symbols and identification (Transparency 19)
   A. Shop rivets
      Far Side    Near Side
      1. - Two-full heads
      2. - Countersunk and chipped; near side
      3. - Countersunk and chipped; far side
      4. - Countersunk and chipped; both sides
      5. - Countersunk not over 1/8" high; near side
      6. - Countersunk not over 1/8" high; far side
      7. - Countersunk not over 1/8" high; both sides
      8. - Flattened to 1/4", 1/2" and 5/8" rivets; near side
      9. - Flattened to 1/4", 1/2" and 5/8" rivets; far side
     10. - Flattened to 1/4", 1/2" and 5/8" rivets; both sides
     11. - Flattened to 3/8", 3/4" rivets and over; near side
INFORMATION SHEET

12. Field rivets

13. --Flattened to 3/8", 3/4" rivets and over; far side

B. Field rivets

1. --Two full heads

2. --Countersunk; near side

3. --Countersunk; far side

4. --Countersunk; both sides

XXI. Advantages of plastic fasteners over metal fasteners

A. Lightweight

B. Thermal and electrical insulators

C. Corrosion resistant

D. Easy to color

XXII. Devices to lock components on a shaft (Transparencies 20 and 21)

A. Sunk key (Pratt & Whitney)

B. Woodruff key

C. Square key

D. Flat plain parallel key

E. Square type taper key

F. Flat type taper key

G. Square gib head key

H. Flat gib head key

I. Taper pins

J. Cotter key

K. Retaining rings-internal

L. Retaining rings-external

M. Self-locking rings
INFORMATION SHEET

XXIII. Types of springs (Transparency 22)
   A. Compression (To absorb or cushion forces)
   B. Extension (Designed to stretch and pull back to original position)
   C. Torsion (Many different shapes that involve twisting)
   D. Flat (Any desired shape that absorbs energy)

XXIV. Notes and dimensions for types of springs (Transparency 23)
   A. Compression
      1. Free length
      2. Pitch
      3. Diameter ID or OD
      4. Type of end
      5. Direction of coil
      6. Material
      7. Wire gage
   B. Extension
      1. Length
      2. Free length
      3. Diameter OD
      4. Pitch
      5. Direction of coil
      6. Material
      7. Wire gage
   C. Torsion
      1. Length
      2. Number of coils
      3. Diameter of wire OD
      4. Type of end
      5. Length of end and angle
INFORMATION SHEET

6. Direction of coil
7. Material
8. Gage

XXV: Types of spring clips (Transparency 24)
A. Spring molding
B. Stud-receiver
C. Cable, wire, and tube
D. Dart-type
E. U-shaped, S-shaped, and C-shaped

XXVI. Types of keys to prevent relative motion between wheel and shaft (Transparency 25)
A. Square
B. Flat
C. Gib head
D. Pratt and Whitney
E. Woodruff
F. Round

(Note: Keys are ordered by size except Woodruff keys which are ordered by number.)

XXVII. Types of machine pins (Transparency 26)
A. Dowel
B. Tapered
C. Clevis
D. Spirally coiled
E. Grooved
F. Knurled
G. Quick release
H. Cotter
I. Wire
INFORMATION SHEET

J. Split
K. Drive

XXVIII. Washers (Transparency 27)
   A. Flat washers—Bearing surface
      (NOTE: The two types include heavy and standard.)
   B. Conical washers—Spring action
   C. Helical spring washers—Locking
   D. Tooth lock washers—Locking
   E. Spring washers—Built-in pressure
   F. Special purpose washers—Decoration and other functions
      (NOTE: These are available in plated and unplated finishes.)

XXIX. Applications of inserts
   A. In light alloys and plastics for higher strength
   B. In ferrous alloys for permanent threads
   C. In thin parts for internal locking of threaded holes
   D. In reassembly of mating screw without damage to metal

XXX. Types of lock washers (Transparency 28)
   A. Helical spring
      1. Plain
      2. Nonlink positive
   B. Tooth lock
      1. Internal
      2. External
      3. Countersunk
      4. External-internal
      5. Dome
      6. Dished
      7. Pyramidal
INFORMATION SHEET

XXXI. Uses for spring washer designs
   A. Provide pressure on adjacent parts
   B. Act as take-up devices in an assembly
   C. Control end pressure
   D. Eliminate end play

XXXII. Quick opening and locking devices (Transparency 29)
   A. Link lock
   B. Hinge lock
   C. Hook lock
   D. Quarter turn
   E. Spring lock
   F. Trigger lock

XXXIII. Miscellaneous machine elements and uses
   A. Quick release pins--To rapidly assemble and disassemble parts
   B. Resistance welded fasteners (Transparency 30)
      1. Projection weld--To weld nuts to a surface
      2. Spot weld--To weld studs to a surface
   C. Stud welded fasteners--To prevent leaks at joints
   D. Self-tapping screws--To cut mating thread in metal or plastic
   E. Captive nuts--To prevent rotation of nuts
   F. Wing nuts--To allow fastening with fingers
   G. Screw and washer assembles--To save time at assembly

XXXIV. Advantages of welding over threaded fasteners (Transparency 31)
   A. Fast and relatively simple process
   B. Savings in time and expense
   C. Less weight than casting or forged part in most cases
   D. Neater appearance
   E. Less noisy
INFORMATION SHEET

F. Painting simplified
G. Small quantity jobs

XXXV. Types of welded joints (Transparency 32)
A. Lap
B. Butt
C. -Tee
D. Corner
E. Edge

XXXVI. Parts of a welding symbol (Transparency 33)
A. Finish symbol
B. Contour symbol
C. Groove angle
D. Specification, process, or other reference
E. Tail
   (NOTE: This may be omitted when a reference is not used.)
F. Reference line
G. Size or strength for certain welds
H. Basic weld symbol
I. Root opening, depth of filling for certain welds
J. Number of spot or projection welds
K. Length of welds
L. Pitch of welds
M. Weld-all-around symbol
N. Field weld symbol
O. Arrow
P. Multiple welds
INFORMATION SHEET

XXXVII. Basic arc and gas weld symbols (Transparency 34)

A. Fillet
B. Plug or slot
C. Arc-spot or arc-seam
D. Groove
   1. Square
   2. V
   3. Bevel
   4. U
   5. J
   6. Flare V
   7. Flare bevel
E. Back or backing
F. Surfacing
G. Flange
   1. Edge
   2. Corner

XXXVIII. Supplementary welding symbols (Transparency 35)

A. Weld-all-around
B. Field weld
C. Contour
   1. Flush
   2. Convex
D. Melt thru

XXXIX. Dimensioning of welds (Transparency 36)

A. Weld-all-around
B. Staggered
INFORMATION SHEET

C. Near side-opposite side

D. Combined welds

XL. Resistance welding symbols (Transparency 37)

(Note: Students will be responsible for new symbols.)

A. Resistance spot

B. Projection

C. Resistance seam

D. Flash or upset

XLI. Classifications of methods of using adhesives for bonding materials

A. Functional
   1. Structural
   2. Holding
   3. Sealing

B. Chemical
   1. Thermosetting
   2. Thermoplastic
   3. Repetitive structure
      a. Epoxies
      b. Polyamides
      c. Polyurethanes
      d. Polyacrylates

C. Method of application
   1. Solvent
   2. Hot melt
   3. Two part
INFORMATION SHEET

D. Nature of properties
   1. Metal to metal
   2. Metal to plastic
   3. Plastic to glass

XLII. Joint design considerations for adhesive bonding
   A. Consider type of stresses on bonded joint (Transparency 38)
      Example: Shear, tension, compression, cleavage, and peel
   B. Use as large of contact areas as possible for maximum strength

XLIII. Joint designs for adhesive bonding (Transparency 39)
   A. Lap joint
   B. Joggle joint
   C. Double butt lap
   D. Tapered lap
   E. Double scarf lap
   F. Corner joint
   G. T-section stiffener
   H. End lap joint
   I. Mortise and tenon
Pitch = \frac{1}{\text{Number of Threads Per Inch}}
Screw Thread Profiles

- **Sharp V**
- **American National**
- **Unified (External)**
- **Metric**
- **Square**
- **General Purpose Acme**
- **Whitworth Standard**
- **Knuckle**
- **Buttress**
- **Acme-Stub**

(NOTE: Dimensions may be used to approximate the threads for detail drawings.)
Screw Thread Symbols

Simplified Representation of Threads

Schematic Representation of Threads

Detailed Representation of Threads

From ANSI 14.6-1978 Reprinted with permission of ASME
Combined Screw Thread Symbols

Multiple Thread Representations of Assembled Parts

From ANSI 14.6-1978 Reprinted with permission of ASME
American National Thread Note for Holes

49/64 DRILL 1.38 DEEP

7/8 9NC-2 LH-1.00 DEEP

Thread Depth
Left Hand
Class of Fit
Course Thread Series
National (Profile)
Threads Per Inch (Series)
Major Dia of Thread

Interpretation of Note

NOTE: Obtain tap drill size from thread chart.
American National Thread Notes for Threaded Shaft

5/8 - 18 NF - 2
National Fine

1 1/8 - 5 ACME - 2G
Class of Fit - General Purpose
American Standard Unified Thread Notes

\[
\frac{3}{8} - 16 \text{ UNC-2B LH}
\]

- Left Hand
- Internal Thread
- Class of Fit
- Unified Form
- Coarse Series
- Threads Per Inch
- Major Dia of Thread (Nominal)

\[
\frac{1}{4} - 28 \text{ UNF - 2 A}
\]

- External
- Class of Fit
- Unified Form
- Fine Series
- Threads Per Inch
- Major Dia
Pipe Threads

2 - NPT

Schematic

1 1/2 - NPT

Simplified
Removable Fasteners

Bolt

Cap Screw

Stud

Machine Screw

Set Screw
Locknuts and Locking Devices

- Cotter Pin Hex Semi-Finished Thick Nut
- Nut With Set Screw
- Hex Unfinished Slotted Nut With Cotter Pin
- Semi-Finished Castle Nut With Cotter Pin
- Hexagon Nut with Lock
- Stop Nut
- Lock Washer
- Hex Semi-Finished Jam Nut
- Hex Unfinished Jam Nut
- Hexagon Head Screw and Spring Lock Washer
- Truss Head Screw and External Tooth Lock Washer
- Pan Head Screw and Conical Spring Washer

Screw and Washer Assemblies

- Plate Nut
- Stamped Nut
- Flange Nut
- Knurled Nut
- Weld Nut
Standard Cap Screws

Hexagon Head

Flat Head

Spline Socket

Flat Head

Round Head

Fillister Head

Hex Socket
Machine Screws

D = Body Dia

Oval Head

Fillister Head

Round Head

Flat Head

(NOTE: These are approximate dimensions for drawing purposes. Use hardware catalog for accurate dimensions.)
Set Screws

Square Head

Cup Point

Flat Point

Oval Point

Full Dog Point

Half Dog Point

Cone Point

D = Thread Diameter
L = Length

(NOTE: These are approximate dimensions for drawing purposes. Use hardware or standards catalogs for accurate dimensions.)
Miscellaneous Bolts and Screws

- Step Bolt
- One-Way Head Screw
- Meter Bolt
- Tapping Screw
- Oval Head Truck Bolt
- Connecting Rod Bolt
- U-Bolt, Round Bend
- Round Head Short Square Neck Bolt
- Turnbuckle
- Round Head Square Neck Bolt
- Thumb Screw
- Wing Nut
- Clevis Bolt
- Boiler Patch Bolt
- Clevis
Miscellaneous Bolts and Screws
(Continued)

- Round Head Fin Neck Bolt
- Collared Eye Bolt
- Square Neck
- Round Head Ribbed Neck Bolt
- Square Head Bolt
- Aircraft Drilled Head Bolt
- Hexagon Head
- Eye Bolt, Open Anchor Ring
- Stove Bolt
- Hood Latch Bolt
- Lag Bolt
- Rivet Bolt
- Strut Bolt
- Round Countersunk Head Square Neck Plow Bolt
- T-Bolt
Standard Large Rivets

- Button Head
- High Button Head (Acorn)
- Cone Head
- Pan Head
- Flat Top Countersunk HD
- Round Top Countersunk HD
Small Rivets

- Flat Head
- Countersunk Head
- Button Head
- Pan Head
- Truss or Wagon Box Head
### Rivet Symbols

<table>
<thead>
<tr>
<th>Two Full Heads</th>
<th>Countersunk and Chipped</th>
<th>Countersunk Not Over 1/8&quot; High</th>
<th>Flattened to 1/4&quot;, 1/2&quot;, and 5/8&quot; Rivets</th>
<th>Flattened to 3/8&quot; 3/4&quot; Rivets and Over</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near Side</td>
<td>Far Side</td>
<td>Both Sides</td>
<td>Near Side</td>
<td>Far Side</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Both Sides</td>
<td>Both Sides</td>
</tr>
</tbody>
</table>

#### Shop Rivets

<table>
<thead>
<tr>
<th>Two Full Heads</th>
<th>Countersunk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near Side</td>
<td>Far Side</td>
</tr>
<tr>
<td>Both Sides</td>
<td>Both Sides</td>
</tr>
</tbody>
</table>

#### Field Rivets

<table>
<thead>
<tr>
<th>Countersunk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far Side</td>
</tr>
<tr>
<td>Both Sides</td>
</tr>
</tbody>
</table>

---

**MD - 431**
Design with Rivets

Clearance Problems

Placement Problems
Shaft Locking Hardware

- Round End Key (Pratt and Whitney)
- Woodruff Key
- Square Key
- Flat Key
- Taper Key
- Gib Head Key
- Taper Pin
- Cotter Pin
- Retaining Ring Internal
- Retaining Ring External
- Self Locking External
- Self Locking Triangular
- Self Locking Internal
Springs

Compression

Extension

Torsion

Flat
Schematic Spring Drawing Representative

<table>
<thead>
<tr>
<th>Type of End</th>
<th>Dia of Wire</th>
<th>Number of Coils</th>
<th>OD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression</td>
<td>Free Length</td>
<td>Pitch</td>
<td>ID or OD</td>
</tr>
<tr>
<td>Extension</td>
<td>Length</td>
<td>Pitch</td>
<td>Free Length</td>
</tr>
<tr>
<td>Torsional</td>
<td>Length</td>
<td>Dia of Wire</td>
<td>OD</td>
</tr>
</tbody>
</table>

Direction of Coil
Material
Gage

Type of End
Number of Coils
Direction of Coil
Material
Gage
Clips

Dart Type Spring Clips

Cable, Wire, and Tubing Clips

Spring Molding Clip

Stud Receiver Clips

Note: These must be identified by using vendors catalog.

"U"-Shaped, "S"-Shaped and "C"-Shaped Clips
Keys

Round

Square

Flat

Woodruff

Pratt and Whitney

Gib Head
Pins

- Dowel
- Tapered
- Clevis
- Split
- Spirally Coiled
- Drive
- Grooved
- Knurled
- Quick Release
- Wire
- Cotter
Washers

- Flat
- Conical
- Helical Spring
- Tooth Lock
- Spring Type
- Finishing
Tooth Lock Washers

- External
- Internal
- External-Internal
- Countersunk
- Pyramidal
Quick Locking Devices

- Link Lock
- Hinge Lock
- Quarter Turn
- Hook Lock
Attaching Resistance Weld Fasteners

Projection Welded

Spot Welded
Welding Advantages

1. Is Fast and Relatively Simple
2. Saves Time and Expense
3. Causes Less Weight Than Casting or Forging the Part in Most Cases
4. Has a Neater Appearance
5. Is Less Noisy
6. Simplifies Painting Process
7. Is Good for Small Quantity Jobs
Types of Welded Joints

- Lap Joint
- Butt Joint
- Tee Joint
- Corner Joint
- Edge Joints
Parts of a Welding Symbol

Finish Symbol
Contour Symbol
Root Opening; Depth of Filling for Plug and Slot Welds
Size; Size or Strength for Resistance Welds
Reference Line

Groove Angle or Angle of Countersink for Plug Welds
Length of Weld
Pitch (Center to Center Spacing) of Welds
Arrow Connecting Reference Line to Arrow Side or Arrow-Side Member of Joint

Specification, Process, or Other Reference Tail (May be Omitted When Reference is Not Used)

Basic Weld Symbol or Detail Reference

Field Weld Symbol
Weld All Around Symbol
Number of Spot or Projection Welds
Basic Arc and Gas Welding Symbols

<table>
<thead>
<tr>
<th>Fillet</th>
<th>Plug or Slot</th>
<th>Arc - Spot or Arc - Seam</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Fillet Symbol]</td>
<td>![Plug or Slot Symbol]</td>
<td>![Arc - Spot or Arc - Seam Symbol]</td>
</tr>
</tbody>
</table>

Groove

<table>
<thead>
<tr>
<th>Square</th>
<th>V</th>
<th>Bevel</th>
<th>U</th>
<th>J</th>
<th>Flare V</th>
<th>Flare Bevel</th>
</tr>
</thead>
</table>

Back or Backing

<table>
<thead>
<tr>
<th>Surfacing</th>
<th>Flange</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Surfacing Symbol]</td>
<td>![Flange Symbol]</td>
</tr>
</tbody>
</table>

Flange

<table>
<thead>
<tr>
<th>Edge</th>
<th>Corner</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Edge Symbol]</td>
<td>![Corner Symbol]</td>
</tr>
</tbody>
</table>
### Supplementary Symbols

<table>
<thead>
<tr>
<th>Weld All Around</th>
<th>Field Weld</th>
<th>Melt Thru</th>
<th>Contour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flush</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Convex</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Concave</td>
</tr>
</tbody>
</table>

- **M** - Machine
- **G** - Grind

#### Combined Welds

- 60°
- 5/16
- T-2
Dimensioning of Welds

- Staggered
- Weld All Around
- Combination Weld

Near Side - Opposite Side

[Diagram with measurements]
# Resistance Welding Symbols

<table>
<thead>
<tr>
<th>Type of Weld</th>
<th>Resistance Spot</th>
<th>Projection</th>
<th>Resistance Seam</th>
<th>Flash or Upset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old</td>
<td>Old</td>
<td>Old</td>
<td>Old</td>
<td>Old</td>
</tr>
<tr>
<td>New</td>
<td>New</td>
<td>New</td>
<td>New</td>
<td>New</td>
</tr>
<tr>
<td>Old</td>
<td>Old</td>
<td>New</td>
<td>Old</td>
<td>Old</td>
</tr>
<tr>
<td>New</td>
<td>New</td>
<td>New</td>
<td>New</td>
<td>New</td>
</tr>
</tbody>
</table>

- **Resistance Spot**: Old symbol represents old weld, New symbol represents new weld.
- **Projection**: Old symbol represents old weld, New symbol represents new weld.
- **Resistance Seam**: Old symbol represents old weld, New symbol represents new weld.
- **Flash or Upset**: Old symbol represents old weld, New symbol represents new weld.
Stresses on Bonded Joints

- Shear
- Tension
- Compression
- Cleavage
- Peel
Joint Design for Adhesive Bonding

- Lap Joint
- Joggle Lap
- Double Butt Lap
- Tapered Lap
- T Section Stiffener
- Corner Joint
- End Lap Joint
- Mortise and Tenon
ASSIGNMENT SHEET #1: CONSTRUCT THREAD SYMBOLS

Directions: Using the screw thread tables included with this assignment sheet, draw on "B" size vellum or other media to a full or proper scale the thread symbols indicated in the problems. Use the correct type of symbol, and letter the correct thread note as shown in the following example.

Example:

5/8-18 UNF - 2A

Schematic

Circular View

Section
ASSIGNMENT SHEET #1

Problems:
A. Simplified external thread M 10 x 1.5 - 6gA
B. Simplified internal thread M 10 x 1.5 - 6HB thru 3/4, 10NC - 2LH 1.00 deep
C. Simplified external thread 3/4-10NC - 2LH
D. Simplified internal thread 3/4-10NC - 2LH - 1.00 deep
E. Schematic external thread M3 x .5C+A
F. Schematic internal thread M3 x .5C-B
G. Schematic external thread 1/4-20 UNC - 2A
H. Schematic internal thread 1/4-20 UNC - 2B thru
### TABLE 1-A

**AMERICAN NATIONAL STANDARD UNIFIED AND AMERICAN NATIONAL SCREW THREADS**

<table>
<thead>
<tr>
<th>Nominal Diameter</th>
<th>Course UNC</th>
<th>Fine NF</th>
<th>Extra Fine NF</th>
<th>8 Pitch Series 8N and BUN</th>
<th>12 Pitch Series 12N and 12UN</th>
<th>16 Pitch Series 16N and 16UN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thds per Inch</td>
<td>Tap Drill</td>
<td>Thds per Inch</td>
<td>Thds per Inch</td>
<td>Tap Drill</td>
<td>Thds per Inch</td>
</tr>
<tr>
<td>0.060</td>
<td>64</td>
<td>No 53</td>
<td>80</td>
<td>3/64</td>
<td>12</td>
<td>27/64</td>
</tr>
<tr>
<td>0.073</td>
<td>56</td>
<td>No 50</td>
<td>72</td>
<td>No 53</td>
<td></td>
<td>31/64</td>
</tr>
<tr>
<td>0.086</td>
<td>48</td>
<td>No 47</td>
<td>64</td>
<td>No 45</td>
<td></td>
<td>35/64</td>
</tr>
<tr>
<td>0.112</td>
<td>40</td>
<td>No 43</td>
<td>56</td>
<td>No 42</td>
<td></td>
<td>39/64</td>
</tr>
<tr>
<td>0.125</td>
<td>32</td>
<td>No 38</td>
<td>48</td>
<td>No 37</td>
<td></td>
<td>No 42</td>
</tr>
<tr>
<td>0.136</td>
<td>24</td>
<td>No 29</td>
<td>40</td>
<td>No 26</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>0.160</td>
<td>24</td>
<td>No 25</td>
<td>32</td>
<td>No 21</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>0.216</td>
<td>20</td>
<td>No 16</td>
<td>28</td>
<td>No 14</td>
<td>32</td>
<td>11/16</td>
</tr>
<tr>
<td>0.5</td>
<td>10</td>
<td>No 13</td>
<td>8</td>
<td>No 6</td>
<td>32</td>
<td>13/32</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>No 10</td>
<td>8</td>
<td>No 6</td>
<td>32</td>
<td>9/32</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>No 9</td>
<td>8</td>
<td>No 6</td>
<td>32</td>
<td>11/32</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>No 8</td>
<td>8</td>
<td>No 6</td>
<td>32</td>
<td>11/32</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>No 5</td>
<td>8</td>
<td>No 6</td>
<td>32</td>
<td>11/32</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>8</td>
<td>8</td>
<td>No 6</td>
<td>32</td>
<td>11/32</td>
</tr>
<tr>
<td>1/2</td>
<td>2</td>
<td>8</td>
<td>8</td>
<td>No 6</td>
<td>32</td>
<td>11/32</td>
</tr>
</tbody>
</table>

**ANSI B1.1**

- Classes 1A, 2A, 3A, 4B, 5B, 6B, 7B, 2 and 3
- Classes 2A, 3A, 4B, 5B, 6B, 7B, 2 and 3
- For approximate 75% full depth of thread
### TABLE 1B

**METRIC SCREW THREADS**

<table>
<thead>
<tr>
<th>Coarse general purpose</th>
<th>Fine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nominal Size &amp; Thd Pitch</strong></td>
<td><strong>Tap Drill Diameter, mm</strong></td>
</tr>
<tr>
<td>M1.6 X 0.35</td>
<td>1.25</td>
</tr>
<tr>
<td>M1.8 X 0.35</td>
<td>1.45</td>
</tr>
<tr>
<td>*M2 X 0.4</td>
<td>1.6</td>
</tr>
<tr>
<td>M2.2 X 0.45</td>
<td>1.75</td>
</tr>
<tr>
<td>*M2.5 X 0.45</td>
<td>2.05</td>
</tr>
<tr>
<td>*M3 X 0.5</td>
<td>2.50</td>
</tr>
<tr>
<td>*M3.5 X 0.6</td>
<td>2.90</td>
</tr>
<tr>
<td>*M4 X 0.7</td>
<td>3.30</td>
</tr>
<tr>
<td>M4.5 X 0.75</td>
<td>3.75</td>
</tr>
<tr>
<td>*M5 X 0.8</td>
<td>4.20</td>
</tr>
<tr>
<td>*M6 X 1</td>
<td>5.30</td>
</tr>
<tr>
<td>M7 X 1</td>
<td>6.00</td>
</tr>
<tr>
<td>M8 X 1.25</td>
<td>6.80</td>
</tr>
<tr>
<td>M9 X 1.25</td>
<td>7.75</td>
</tr>
<tr>
<td>*M10 X 1.5</td>
<td>8.50</td>
</tr>
<tr>
<td>M11 X 1.5</td>
<td>9.50</td>
</tr>
<tr>
<td>*M12 X 1.75</td>
<td>10.30</td>
</tr>
<tr>
<td>*M14 X 2</td>
<td>12.00</td>
</tr>
<tr>
<td>*M16 X 2</td>
<td>14.00</td>
</tr>
<tr>
<td>M18 X 2.5</td>
<td>15.50</td>
</tr>
<tr>
<td>*M20 X 2.5</td>
<td>17.50</td>
</tr>
<tr>
<td>M22 X 2.5</td>
<td>19.50</td>
</tr>
<tr>
<td>M24 X 3</td>
<td>21.00</td>
</tr>
<tr>
<td>M27 X 3</td>
<td>24.00</td>
</tr>
<tr>
<td>M30 X 3.5</td>
<td>28.50</td>
</tr>
<tr>
<td>M33 X 3.5</td>
<td>29.50</td>
</tr>
<tr>
<td>M36 X 4</td>
<td>32.00</td>
</tr>
<tr>
<td>M39 X 4</td>
<td>35.00</td>
</tr>
<tr>
<td>M42 X 4.5</td>
<td>37.50</td>
</tr>
<tr>
<td>M45 X 4.5</td>
<td>40.50</td>
</tr>
<tr>
<td>*M48 X 5</td>
<td>43.00</td>
</tr>
<tr>
<td>M52 X 5</td>
<td>47.00</td>
</tr>
<tr>
<td>M56 X 5.5</td>
<td>50.50</td>
</tr>
<tr>
<td>M60 X 6</td>
<td>54.50</td>
</tr>
<tr>
<td>M64 X 6</td>
<td>58.00</td>
</tr>
<tr>
<td>*M68 X 6</td>
<td>62.00</td>
</tr>
<tr>
<td>M72 X 6</td>
<td>66.00</td>
</tr>
<tr>
<td>*M80 X 6</td>
<td>74.00</td>
</tr>
<tr>
<td>M90 X 6</td>
<td>84.00</td>
</tr>
<tr>
<td>M100 X 6</td>
<td>94.00</td>
</tr>
</tbody>
</table>

Metric Fasteners Standards IFI 500 (1976).

*Preferred sizes for commercial threads and fasteners*
Directions: Using bolt, screw, and nut tables, draw on "B" size vellum or other media to a full or proper scale the fasteners indicated in the problems. Each fastener is to be drawn holding parts together. Letter correct description abbreviated below each symbol as shown in the following example.

Example:
Problems

(NOTE All tap drill sizes should be specified for external.)

A. M6.3 x 1.40 mm long hexagon head cap screw
B. 3/4 x 2 1/2 hexagon head cap screw
C. 5/8 11 unc - 2B square nut
D. M 6.3 x 1 hexagon nut
E. 3/4 - 10UNC - 2A 2 1/2 long hexagon cap screw
F. No. 10 (.1900) - 32NF - 3, 5/8 long fillister head machine screw
G. M8 x 1.25, 30mm long slotted pan head machine screws
H. 3/8 16 UNC - 2A, 3/4 long square head flat point set screw
I. M10 x 1.5 12mm long hexagon socket head set screw full dog point
J. #204 woodruff key
FASTENERS AND HARDWARE
UNIT VI

ASSIGNMENT SHEET #3: CONSTRUCT AN ASSEMBLY CONTAINING VARIOUS FASTENERS

Directions: Using fastener tables, draw on "B" size vellum or other media an assembly drawing with the following fasteners:

1. 3/8 x 1" hexagon cap screw and American Standard regular lockwasher
2. 3/8 x 1/2 slotted pan head machine screw and special washer
3. No. 10 x 1/2 slotted round head machine screw
4. 3/8 x 1/2 slotted headless cup point set screw
5. #606 Woodruff key
6. #10 x 1/2 slotted oval head machine screw
7. 3/4 pipe tap

Correct fastener descriptions in parts list directly above title block. Complete the sectioned assembly as specified by instructor.
FASTENERS AND HARDWARE
UNIT VI

ASSIGNMENT SHEET #4-CONSTRUCT A WELDED ASSEMBLY DRAWING

Directions: Select problem A or B and make into a welded drawing on a "B" size sheet of vellum or other media. Use proper welding symbols as shown in a welding symbol chart, and completely dimension.

Problems:

A Bracket - Metric
   Scale 1:10
   \[ \phi 40 \text{ REAM} \]
   \[ \phi 19 \text{ 2 HOLES} \]

B Stop base: Inch
   Scale 1/4" = 1"
   \[ 8.00 \]
   \[ 4.00 \]
   \[ 1.75 \]
   \[ 3.00 \]
   \[ 1.75 \]
   \[ 0.68 \]
   \[ 1.38 \]
   \[ 1.50 \]

\[ 62 \text{ DRILL} \]

\[ 1.26 \]

\[ 2.50 \text{ R} \]

\[ 997 \]

\[ 1000 \text{ REAM} \]
ASSIGNMENT SHEET #5 - CONSTRUCT SPRING DRAWINGS TO INCLUDE SPECIFICATIONS

Directions: On "A" size vellum or other media, construct spring drawings to include the specifications listed for each problem.

Problems:

A. Detail drawing representation of a compressed spring with the following specifications:
   1. 2" free length
   2. 10 gage diameter of wire
   3. 3/4" OD
   4. 1/4 pitch

B. Schematic drawing of an extension spring with the following specifications:
   1. 3" length
   2. 2 1/2" free length
   3. 5/8" OD
   4. 1/4 pitch

C. Schematic drawing of a torsion spring with the following specifications:
   1. 4" length
   2. 15 coils
   3. 1/8" OD
   4. Length of ends 1 1/4"
   5. Angle 50°
ASSIGNMENT SHEET #6 - CONSTRUCT KEYS IN ASSEMBLED POSITIONS

Directions: Using the tables included with this assignment sheet, construct keys for the problems given by using the procedure in the following example.

Example: Construct an assembled detailed drawing of a 1 1/8" shaft square-keyed to a wheel. Only show detail of the key, shaft, and wheel.

1. Using Table 6-C, find shaft diameter range for 1 1/8" shaft.
   - Answer is 15/16" to 1 1/4"

2. Reading across the line, square stock key says W = 1/4 and H = 1/4

3. Draw detail based on dimensions in illustration.

---

**DRAWING INFORMATION**

**DRAWING**
ASSIGNMENT SHEET #6

Problems

A. Construct an assembled detailed drawing of a 1 1/2" diameter shaft square keyed to a wheel. Only show detail of the key, shaft, and wheel. Draw in 1/2" = 1" scale in the upper left quarter of the "A" size vellum. Letter title and scale under detail.

B. Construct an assembled detailed drawing of a 4 3/4" diameter shaft flat keyed to a wheel. Only show detail of the key, shaft, and wheel. Draw in 1/4" = 1" scale in the upper right quarter of the "A" size vellum. Letter title and scale under detail.

C. Construct an assembled detailed drawing of a 9/16" diameter shaft Woodruff keyed to a pulley. Only show detail of the key, shaft, and pulley. Draw in 2 X scale in the lower left quarter of the "A" size vellum. Letter title and scale under detail.

(Note: Table 6-A will locate the Woodruff key size and Table 6-B will give the drawing details.)

D. Construct an assembled detailed drawing of a 1 3/4" diameter shaft Woodruff keyed to a hub. Only show detail of the key, hub, and shaft. Draw in full size in the lower right quarter of the "A" size vellum. Letter title and scale under detail.
# TABLE 6-A

Woodruff Keys\(^1\), American National Standard

<table>
<thead>
<tr>
<th>Key No.</th>
<th>Nominal Sizes</th>
<th>Maximum Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>204</td>
<td>1/16 X 1/2</td>
<td>3/64</td>
</tr>
<tr>
<td>304</td>
<td>3/32 X 1/2</td>
<td>3/64</td>
</tr>
<tr>
<td>305</td>
<td>3/32 X 5/8</td>
<td>1/16</td>
</tr>
<tr>
<td>404</td>
<td>1/8 X 1/2</td>
<td>3/64</td>
</tr>
<tr>
<td>405</td>
<td>1/8 X 5/8</td>
<td>1/16</td>
</tr>
<tr>
<td>406</td>
<td>1/8 X 3/4</td>
<td>1/16</td>
</tr>
<tr>
<td>505</td>
<td>5/32 X 5/8</td>
<td>1/16</td>
</tr>
<tr>
<td>506</td>
<td>5/32 X 3/4</td>
<td>1/16</td>
</tr>
<tr>
<td>907</td>
<td>5/32 X 7/8</td>
<td>1/16</td>
</tr>
<tr>
<td>606</td>
<td>3/16 X 3/4</td>
<td>1/16</td>
</tr>
<tr>
<td>607</td>
<td>3/16 X 7/8</td>
<td>1/16</td>
</tr>
<tr>
<td>608</td>
<td>3/16 X 1</td>
<td>1/16</td>
</tr>
<tr>
<td>609</td>
<td>3/16 X 1 1/8</td>
<td>5/64</td>
</tr>
<tr>
<td>807</td>
<td>1/4 X 3/4</td>
<td>1/16</td>
</tr>
<tr>
<td>808</td>
<td>1/4 X 1</td>
<td>1/16</td>
</tr>
<tr>
<td>809</td>
<td>1/4 X 1 1/8</td>
<td>5/64</td>
</tr>
<tr>
<td>810</td>
<td>1/10 X 1 1/4</td>
<td>5/64</td>
</tr>
<tr>
<td>811</td>
<td>1/4 X 1 3/8</td>
<td>3/32</td>
</tr>
<tr>
<td>812</td>
<td>1/4 X 1 1/4</td>
<td>7/64</td>
</tr>
<tr>
<td>1008</td>
<td>5/16 X 1</td>
<td>1/16</td>
</tr>
<tr>
<td>1009</td>
<td>5/16 X 1 1/8</td>
<td>5/64</td>
</tr>
<tr>
<td>1010</td>
<td>5/16 X 1 1/4</td>
<td>5/64</td>
</tr>
<tr>
<td>1012</td>
<td>5/16 X 1 1/2</td>
<td>7/64</td>
</tr>
<tr>
<td>1210</td>
<td>3/8 X 1 1/4</td>
<td>8/64</td>
</tr>
<tr>
<td>1212</td>
<td>3/8 X 1 1/2</td>
<td>7/64</td>
</tr>
</tbody>
</table>

\(^1\)ANSI B18.2-1967, R1972

\(^2\)Key numbers indicate nominal key dimensions. The last two digits give the nominal diameter B in eights of an inch, and the digits before the last two give the nominal width A in thirty-seconds of an inch.
### TABLE 6-B
Woodruff Key Sizes for Different Shaft Diameters

<table>
<thead>
<tr>
<th>Shaft Diameter</th>
<th>5/16 to 1/2</th>
<th>7/16 to 3/8</th>
<th>9/16 to 15/16</th>
<th>11/16 to 11/16</th>
<th>13/16 to 1 1/16</th>
<th>1 1/2 to 1 1/2</th>
<th>2 1/8 to 2 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Numbers</td>
<td>204</td>
<td>304</td>
<td>505</td>
<td>606</td>
<td>807</td>
<td>870</td>
<td>1011</td>
</tr>
<tr>
<td>Numbers</td>
<td>305</td>
<td>405</td>
<td>506</td>
<td>607</td>
<td>808</td>
<td>811</td>
<td>812</td>
</tr>
</tbody>
</table>

*Suggested sizes, not standard

### TABLE 6-C
Keys Square Flat Plain Taper and Gib Head

<table>
<thead>
<tr>
<th>Shaft Diameter</th>
<th>Square Key</th>
<th>Flat Stock Key</th>
<th>Gib Head Taper Stock Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>W H</td>
<td>W X H</td>
<td>C F E</td>
</tr>
<tr>
<td>1/2 to 9/16</td>
<td>1/8</td>
<td>1.8 X 3.32</td>
<td>1/4 7/32</td>
</tr>
<tr>
<td>5/8 to 7/8</td>
<td>3/16</td>
<td>3.16 X 1.78</td>
<td>5/16 9.32</td>
</tr>
<tr>
<td>15/16 to 1 1/4</td>
<td>1/4</td>
<td>1/4 X 1.16</td>
<td>7/16 11.32</td>
</tr>
<tr>
<td>1 5/16 to 1 3/8</td>
<td>5/16</td>
<td>5.16 X 1.4</td>
<td>9/16 13.32</td>
</tr>
<tr>
<td>1 7/16 to 1 3/4</td>
<td>3/8</td>
<td>3.8 X 1.4</td>
<td>11/16 15.32</td>
</tr>
<tr>
<td>1 13/16 to 2 1/4</td>
<td>1/2</td>
<td>1.2 X 3.8</td>
<td>7/8 19.32</td>
</tr>
<tr>
<td>2 7/8 to 3 1/4</td>
<td>3/4</td>
<td>3.4 X 1.2</td>
<td>11/4 23/32</td>
</tr>
<tr>
<td>3 3/8 to 3 3/4</td>
<td>7/8</td>
<td>7.8 X 5.8</td>
<td>1/1 2/2</td>
</tr>
<tr>
<td>3 7/8 to 4 1/2</td>
<td>1</td>
<td>1.3 X 3.8</td>
<td>1/3 2/2</td>
</tr>
<tr>
<td>4 3/4 to 5 1/2</td>
<td>1 1/4</td>
<td>1.1 X 3.8</td>
<td>1/3 2/2</td>
</tr>
<tr>
<td>5 3/4 to 6</td>
<td>1 1/2</td>
<td>1.2 X 2.1</td>
<td>1/3 2/2</td>
</tr>
</tbody>
</table>

*Plain taper square and flat keys have the same dimensions as the plain parallel stock keys, with the addition of the taper on top. Gib head taper square and flat keys have the same dimensions as the plain taper keys, with the addition of the gib head.

Stock lengths for plain taper and gib head taper keys. The minimum stock length equals 4V, and the maximum equals 16V. The increments of increase of length equal 2V.

---

**Note:** The above tables are excerpts from a technical reference guide and provide specific dimensions for woodruff keys and related components, including their sizes and stock lengths for different shaft diameters.
FASTENERS AND HARDWARE
UNIT VI

ASSIGNMENT SHEET #7: WRITE SPECIFICATIONS FOR HARDWARE FROM VENDOR CATALOGS

Directions: Find the hardware items for each problem in vendor catalogs of hardware such as the Thomas Register. Select a specific size or type for each problem. Write a specification to include vendor's name and address, cost, material, and specific specification (size, length, type, etc.) of each hardware item selected. Letter answer on "A" size vellum converting sheet to a parts list to include part number, description (vendor's name, address, and specification), cost, and material.

Problems:
A. Compression spring
B. Tension spring
C. Woodruff key
D. Internal tooth washer
E. Dart-type spring clip
F. Spring washer to control end pressure
G. Hook lock fastener – quick operating
H. Weld nut
1. Match the terms on the right with the correct definitions.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Head having a slot centered across the top</td>
<td>1. Fastener</td>
</tr>
<tr>
<td>b. Fastener having high tensile and shear strength</td>
<td>2. Keys</td>
</tr>
<tr>
<td>c. Thread on the inside of a hole</td>
<td>3. Finished fastener</td>
</tr>
<tr>
<td>d. Thread having one start, and the lead is equal to the pitch</td>
<td>4. High strength fastener</td>
</tr>
<tr>
<td>e. Least amount of drawing information necessary to convey information without confusion</td>
<td>5. Semi-finished fastener</td>
</tr>
<tr>
<td>f. Chemical bonding between parts</td>
<td>6. Hardware</td>
</tr>
<tr>
<td>g. Mechanical device for holding two or more parts in a set position</td>
<td>7. Unfinished fastener</td>
</tr>
<tr>
<td>h. Fastener with wide tolerances and all surfaces in their formed conditions</td>
<td>8. Slotted head</td>
</tr>
<tr>
<td>i. Head having a specially formed indentation centered in its top</td>
<td>9. Recessed head</td>
</tr>
<tr>
<td>j. Fastener made to close tolerance having a high grade finish</td>
<td>10. Nuts</td>
</tr>
<tr>
<td>k. Advances when turned clockwise</td>
<td>11. Screw thread form</td>
</tr>
<tr>
<td>l. Distance a screw travels in one rotation</td>
<td>12. Schematic threads</td>
</tr>
<tr>
<td>m. Close approximation to actual appearance</td>
<td>13. Simplified threads</td>
</tr>
<tr>
<td>n. More detailed than simplified but faster to draw than detailed threads</td>
<td>14. Detailed threads</td>
</tr>
<tr>
<td>o. Fastener made with greater tolerances than a finished fastener and having only the bearing surface and threads finished</td>
<td>15. O-Rings</td>
</tr>
<tr>
<td>p. Profile of the thread</td>
<td>16. External thread</td>
</tr>
<tr>
<td></td>
<td>17. Internal thread</td>
</tr>
<tr>
<td></td>
<td>18. Retaining ring</td>
</tr>
<tr>
<td></td>
<td>19. Lead</td>
</tr>
<tr>
<td></td>
<td>20. Series of thread</td>
</tr>
<tr>
<td></td>
<td>21. Single thread</td>
</tr>
<tr>
<td></td>
<td>22. Multiple threads</td>
</tr>
<tr>
<td></td>
<td>23. Pins</td>
</tr>
<tr>
<td></td>
<td>24. Springs</td>
</tr>
</tbody>
</table>

NAME

TEST
q. Thread on the outside of a shaft

r. Number of threads per inch based on standard nominal diameters

s. Thread having multiple starts, and the lead is equal to a multiple of the pitch

t. Joining parts by melting base metal to form a unit structure-to support loads

u. Advances when turned counterclockwise

v. Small parts such as fasteners, springs, and washers

w. Used for storage of mechanical energy

x. Used to attach wheels, pulleys, and gears to shafts

y. Designed to insulate, lubricate, span large holes, and distribute stress over a larger area

z. Designed for fastening, adjusting, and transmitting motion or power

aa. Designed for semi-permanent attachment or location

bb. Used to seal along a shaft

cc. Has a removable shoulder to accurately retain, locate, or lock components in bases and housings or on shafts

2. Name two general types of fasteners.

a. 

b. 

3. Name three basic applications of screw threads.

a. 

b. 

c. 

25. Right hand thread

26. Left hand thread

27. Welding

28. Washers

29. Adhesive
4. Identify screw thread nomenclature.

5. Identify screw thread profiles.
6. Compute lead of thread for the following problems.
   a. Single thread, 10 threads per inch
      \[ L = \ldots \]
   b. Double thread, 18 threads per inch
      \[ L = \ldots \]
   c. Triple thread, 24 threads per inch
      \[ L = \ldots \]

7. Identify screw thread symbols.
   a. \[ \ldots \]
   b. \[ \ldots \]
   c. \[ \ldots \]
8. Match classes of fit for unified threads on the right with the correct uses.
   a. For general purposes and most common uses  1. Classes 1A and 1B
   b. For close tolerance screw thread  2. Classes 2A and 2B
   c. For parts that are easy to assemble; ordinance-  3. Classes 3A and 3B
       and other special uses; quick assembly

9. List two classes of fit for metric threads.
   a. 
   b. 

10. Identify parts of thread notes.
   7/8 - 9 NC - 2 LH - 1.00 DEEP

   M 6.3 X 1 6H B LH

   a.  
   b.  
   c.  
   d.  
   e.  
   f.  
   g.  
   h.  
   i.  
   j.  

11. Distinguish between conventional representations of pipe threads by placing an "X" next to the thread drawn in schematic and an "O" next to the thread drawn in simplified.

   a.  
   b.  

12. List four types of threaded removable fasteners.
   a. 
   b. 
   c. 
   d. 

13. Name two shapes of bolts and nuts.
   a. 
   b. 

14. Select types of locknuts and locking devices by placing an "X" in the appropriate blanks.
   _____ a. Fillister head
   _____ b. Cotter pin
   _____ c. Set screw
   _____ d. Fluted socket
   _____ e. Welding
   _____ f. Hex slotted nut

15. Name four types of standard cap screws.
   a. 
   b. 
   c. 
   d. 

16. Complete the following list of types of machine screws.
   a. Round head
   b. 
   c. Oval head
   d. Fillister head
17. Identify set screw heads and points.

a. 

b. 

c. 

d. 

18. Identify miscellaneous bolts and screws.

a. 

b. 

c. 

d. 

e. 

19. Identify standard large and small rivets.

Large rivets.

a. 

b. 

c. 

d. 

Small rivets

e. 

f. 

20. Match conventional rivet symbols on the right with the correct identifications.

____ a. Field rivet--Two full heads

____ b. Shop rivet--Countersunk and chipped; far side

____ c. Shop rivet--Flattened to 1/4", 1/2" and 5/8" rivets; far side

____ d. Field rivet--Countersunk; near side

____ e. Field rivet--Countersunk; both sides
21. List three advantages of plastic fasteners over metal fasteners.
   a. 
   b. 
   c. 

22. Select devices to lock components on a shaft by placing an "X" in the appropriate blanks.
   ___ a. Woodruff key
   ___ b. Cleavage pin
   ___ c. Cotter key
   ___ d. Joggle clamp

23. List three types of springs.
   a. 
   b. 
   c. 

24. Identify types of springs according to notes and dimension.

25. Name two types of spring clips.
   a. 
   b. 
26. Select types of keys to prevent relative motion between wheel and shaft by placing an "X" in the appropriate blanks.

   a. Flat  
   b. Square  
   c. Knurled  
   d. Torsion  
   e. Dart-type  
   f. Woodruff

27. Identify types of machine pins.

   a.  
   b.  
   c.  
   d.  

28. Select true statements concerning washers by placing an "X" in the appropriate blanks.

   a. Conical washers have spring action  
   b. Spring washers have built-in pressure  
   c. Tooth lock washers are used mainly for bearing surface  
   d. Helical spring washers are locking
29. List two applications of inserts.
   a. 
   b. 

30. Distinguish between types of lock washers by placing an "X" next to the helical spring washers and an "O" next to the tooth lock washers.
   a. Plain
   b. Dome
   c. External
   d. Countersunk
   e. Nonlink positive
   f. Dished

31. Name two uses for spring washer designs.
   a. 
   b. 

32. Identify quick opening and locking devices.
   a. 
   b. 

---

Diagram:

- Two illustrations showing mechanical components, possibly with labels for identification.
33. Match the miscellaneous machine elements on the right with the correct uses.

   a. To allow fastening with fingers   1. Quick release pins
   b. To weld studs to a surface   2. Projection weld fasteners
   c. To rapidly assemble and disassemble parts   3. Spot weld fasteners
   d. To prevent rotation of nuts   4. Stud welded fasteners
   e. To weld nuts to a surface   5. Self-tapping screws
   f. To prevent leaks at joints   6. Captive nuts
   g. To cut mating thread in metal or plastic   7. Wing nuts

34. Name four advantages of welding over threaded fasteners.
   a. 
   b. 
   c. 
   d. 

35. Identify types of welded joints.
   a. 
   b. 
   c. 
   d. 

36. Label parts of a welding symbol.

a. 

b. 

c. 

d. 

e. 

f. 

g. 

37. Identify basic arc and gas weld symbols.

a. 

b. 

c. 

d. 

38. Identify supplementary welding symbols.

a. 

b. 

39. Determine welding dimensions for the following fillet weld.

40. Identify resistance welding symbols.

41. Name two classifications of methods of using adhesives for bonding materials.
   a. 
   b. 

42. List two joint design considerations for adhesive bonding.
   a. 
   b. 

43. Select joint designs for adhesive bonding by placing an "X" in the appropriate blanks.
   a. Lap joint
   b. Joggle joint
   c. Resistance joint
   d. Corner joint
   e. Simplified joint

44. Demonstrate the ability to:
   a. Construct thread symbols.
   b. Construct bolts, screws, and nuts.
c. Construct an assembly containing various fasteners.
d. Construct a welded assembly drawing.
e. Construct spring drawings to include specifications.
f. Construct keys in assembled positions.
g. Write specifications for hardware from vendor catalogs.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
FASTENERS AND HARDWARE
UNIT VI

ANSWERS TO TEST

1. a. 8  i. 9  p. 11  w. 24
   b. 4   j. 3  q. 16  x. 2
   c. 17  k. 25  r. 20  y. 28
   d. 21  l. 19  s. 22  z. 10
   e. 13  m. 14  t. 27  aa. 23
   f. 29  n. 12  u. 26  bb. 15
   g. 1   o. 5  v. 6  cc. 18
   h. 7

2. a. Removable
     b. Permanent

3. a. Holding parts together
     b. Adjustment
     c. Power transmission

4. a. Depth
     b. Crest
     c. Root
     d. Side
     e. Minor diameter
     f. Pitch diameter
     g. Major diameter
     h. Pitch
     i. Thread angle

5. a. Sharp V
     b. American National
     c. Unified
     d. Square
     e. Acme
     f. Whitworth Standard
     g. Metric
     h. Knuckle
     i. Buttress

6. a. \( L = \frac{1}{10} \)
     b. \( L = \frac{2}{18} = \frac{1}{9} \)
     c. \( L = \frac{3}{24} = \frac{1}{8} \)

7. a. Detailed
     b. Schematic
     c. Simplified

8. a. 2
     b. 3
     c. 1

9. a. Coarse
     b. Fine
10. a. Major diameter
    b. Threads per inch
    c. Class of fit
    d. Left hand
    e. Thread depth
    f. Metric
    g. Major diameter in mm
    h. Pitch in mm
    i. Class of fit
    j. Internal thread

11. a. O
    b. X

12. Any four of the following:
    a. Bolts
    b. Studs
    c. Cap screws
    d. Machine screws
    e. Set screws

13. a. Hexagon head
    b. Square head

14. b, c, f

15. Any four of the following:
    a. Hexagon head
    b. Flat head
    c. Round head
    d. Fillister head
    e. Hex socket head

16. b. Flat head

17. a. Flat point
    b. Hex socket head
    c. Full dog point
    d. Half dog point

18. a. Eye bolt
    b. Step bolt
    c. Square neck bolt
    d. Clevis
    e. Wing nut
    f. Tapping screw

19. a. Button head
    b. Cone head
    c. Countersunk head
    d. Button head
20. a. 4  
b. 2  
c. 5  
d. 1  
e. 3  

21. Any three of the following:  
a. Lightweight  
b. Thermal and electrical insulators  
c. Corrosion resistant  
d. Easy to color  

22. a, c  

23. Any three of the following:  
a. Compression  
b. Flat  
c. Extension  
d. Torsion  

24. a. Extension  
b. Compression  

25. Any two of the following:  
a. Spring molding  
b. Stud receiver  
c. Cable, wire, and tube  
d. Dart-type  
e. U-shaped, S-shaped, and C-shaped  

26. a, b, f  

27. a. Clevis  
b. Drive  
c. Knurled  
d. Cotter  

28. a, b, d  

29. Any two of the following:  
a. In light alloys and plastics for higher strength  
b. In ferrous alloys for permanent threads  
c. In thin parts for internal locking of threaded holes  
d. In reassembly of mating screw without damage to metal  

30. a. X  
b. O  
c. O  
d. O  
e. X  
f. O
31. Any two of the following:
   a. Provide pressure on adjacent parts
   b. Act as take-up devices in an assembly
   c. Control end pressure
   d. Eliminate end play

32. a. Link lock
    b. Hinge lock

33. a. 7  e. 2
    b. 3  f. 4
    c. 1  g. 5
    d. 6

34. Any four of the following:
   a. Fast and relatively simple process
   b. Savings in time and expense
   c. Less weight than casting or forged part in most cases
   d. Neater appearance
   e. Less noisy
   f. Painting simplified
   g. Small quantity jobs

35. a. Butt
    b. Lap
    c. Corner
    d. Edge

36. a. Finish symbol
    b. Size or strength for resistance welds
    c. Basic weld symbol
    d. Weld-all-around symbol
    e. Field weld symbol
    f. Pitch of welds
    g. Groove angle

37. a. Fillet
    b. Plug or slot
    c. J groove
    d. Square groove

38. a. Weld-all-around
    b. Convex contour

39. Diagram of a weld symbol with dimensions 1.5.
40. a. Resistance seam  
    b. Flash or upset  

41. Any two of the following:  
   a. Functional  
   b. Chemical  
   c. Method of application  
   d. Nature of properties  

42. a. Consider type of stresses on bonded joint  
    b. Use as large of contact areas as possible for maximum strength  

43. a, b, d  

44. Evaluated to the satisfaction of the instructor
PRESENTATION DRAWINGS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to sketch and draw presentation drawings. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

(NOTE: Students should review "Axonometrics," "Oblique," and "Perspective" of Basic Drafting, Book Two before attempting this unit.)

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to presentation drawings with the correct definitions.
2. Name three types of presentation sketches.
3. Arrange in order the steps of sketching.
4. Select true statements concerning ellipse construction.
5. List places where presentation drawings are found.
6. Complete a list of shading techniques for presentation drawings.
7. Distinguish between the types of axonometric drawings.
8. Select true statements concerning oblique drawings.
9. Match parts of exploded assembly presentation drawings with the correct uses.
10. Select special requirements for patent drawings.
11. Demonstrate the ability to:
   a. Shade pictorials.
   b. Construct conceptual presentation sketches.
   c. Construct design sketches.
   d. Construct a dimetric presentation drawing.
   e. Construct an oblique presentation drawing.
   f. Construct a two point presentation perspective of an object.
   g. Construct an exploded assembly presentation drawing.
PRESENTATION DRAWINGS
UNIT VII

SUGGESTED ACTIVITIES

I. Provide students with objective sheet.

II. Provide students with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Suggest alternate problems for use in Assignment Sheet #1.

VII. Allow students to select projects they have an interest in for the conceptual sketches.

VIII. Allow students to show and discuss their ideas in front of the class.

IX. Several solutions could be submitted for each problem by each student in Assignment Sheet #2.

X. Have students discuss advantages and disadvantages of each problem in Assignment Sheet #2.

XI. Recommend that students work in teams and trace other students' parts for the exploded assembly. This will allow larger projects to be completed if time is a problem.

XII. Impose a time limit to force students to think fast and draw fast.

XIII. Have students construct three point perspectives after they have constructed two point perspectives.

XIV. Have students select problems for Assignment Sheet #7 from past set of assembly drawings.

XV. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit

A. Objective sheet

B. Information sheet
C. Transparency masters
   1. TM 1--Reduction Ratios
   2. TM 2--Sketching Order
      2A--Overlay
      2B--Overlay
   3. TM 3--Ellipses
   4. TM 4--Catalog Presentation Drawings
   5. TM 5--Sales Literature Presentation Drawings
   6. TM 6--Technical Report Presentation Drawings
   7. TM 7--Shades and Shadows
   8. TM 8--Shades and Shadows (Continued)
   9. TM 9--Shades and Shadows (Continued)
 10. TM 10--Axonometric Drawings
 11. TM 11--Oblique Drawings
 12. TM 12--Leaders and Overlapping Parts
 13. TM 13--Exploded Assembly Drawing
 14. TM 14--Exploded Assembly Drawing (Continued)
 15. TM 15--Patent Drawing

D. Assignment sheets
   1. Assignment Sheet #1--Shade Pictorials
   2. Assignment Sheet #2--Construct Conceptual Presentation Sketches
   3. Assignment Sheet #3--Construct Design Sketches
   4. Assignment Sheet #4--Construct a Dimetric Presentation Drawing
   5. Assignment Sheet #5--Construct an Oblique Presentation Drawing
   6. Assignment Sheet #6--Construct a Two Point Presentation Perspective of an Object
   7. Assignment Sheet #7--Construct an Exploded Assembly Presentation Drawing

E. Test

F. Answers to test
II. References:


C. Spence, William P. *Drafting Technology and Practice*. Peoria, IL 61614: Charles A. Bennett Co., Inc.


(NOTE: This book is out of print and may be difficult to find.)


(NOTE: This can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

PRESENTATION DRAWINGS
UNIT VII

INFORMATION SHEET

I. Terms and definitions

A. Freehand technical sketching—Freehand drawing of technical ideas without instruments

B. Conceptual sketches—Recording and communicating technical ideas that are in the process of development

C. Design sketches—Carefully drawn sketches prepared to be given to someone else to make detail drawings

D. Presentation sketch or drawing—Sketch, mechanical drawing, or rendering designed to illustrate a technical subject and help sell or clarify its idea to a client

E. Pictorial drawing—Three dimensional drawing in axonometric, oblique, or perspective to imitate a picture of an object

F. Shading—Simple exterior embellishments utilizing light effects to enhance the pictorial qualities of an object

G. Exploded assembly drawing—Drawing showing all parts in relationship with each other and how they fit together

H. Photodrafting—A simplified drafting technique to reduce drafting time that combines photographs and line drawing on a standard sheet layout

I. Paste-up drafting—A simplified drafting technique in which drawing segments are pasted or typed in position on a drawing form and photographically reproduced

J. Patent drafting—Drawing an invention in pictorial and explanatory form to convey the correct interpretation

K. Airbrushing—A method of touching up photographs and adding shading to line drawings by blowing ink or paint pigments through an air cap onto the drawing

L. Reduction ratios—To reduce a drawing proportionally using a ratio (Transparency 1)

II. Types of presentation sketches

A. Conceptual

B. Design

C. Presentation
III. Steps of sketching (Transparency 2)

A. Sketch light construction of an enclosing box or cylinder in proportion

Example:

B. Block in object proportionately with light construction lines

Example:
C. Clean up unnecessary construction lines with an eraser and darken final visible lines

Example:

IV. Ellipse construction (Transparency 3)

A. On horizontal (top) plane, major axis is horizontal

Example:

B. On right side plane, major axis is 60° from horizontal

Example:
INFORMATION SHEET

C. On left side plane, major axis is 60° from horizontal
   Example:

D. Diameter of circle is boxed in, and ellipse is sketched
   Example:
INFORMATION SHEET

E. Perpendicular bisector of each side of box is found and drawn mechanically with straight edge and compass

Example:

V. Places where presentation drawings are found (Transparencies 4, 5, and 6)

A. Catalogs
B. Sales literature
C. Proposals
D. Technical reports
E. Patents
F. Parts books

VI. Shading techniques for presentation drawings (Transparencies 7, 8, and 9)

A. Lines
B. Dots-stippling
C. Smudge
D. Transfer sheets
E. Air brush
F. Shadows
INFORMATION SHEET

VII. Types of axonometric drawings (Transparency 10)
A. Isometric
   1. Width, height, and depth on equal scale
   2. All angles are equal
   3. 120° between axes
B. Dimetric
   1. Width and height full scale
   2. Two angles are equal
   3. Two dimensions are equal
C. Trimetric
   1. Width, height, and depth are unequal
   2. All axes are at different angles
   3. All angles are unequal
   4. Dimensions are unequal

VIII. Oblique drawings (Transparency 11)
A. Cavalier—True length on all axes
B. Cabinet—Half scale on depth axis
C. General—Depth axis at any scale
   (NOTE: Circular view is normally drawn in front view—true size view.)

IX. Parts of exploded assembly presentation drawings and uses (Transparencies 12, 13, and 14)
A. Methods of identification of parts
   1. Numbers—Used if tied to parts list
   2. Part names—Used if immediate identification is important
   (NOTE: Either method may be used on exploded assembly presentation drawings. If the numbers method is used, there must be a corresponding parts list.)
INFORMATION SHEET

B. Flow lines--Indicate where parts fit
C. Shading--Used to differentiate one part from another
D. Standard hardware--Can be duplicated and pasted up on drawing to save time
E. Axis--Should be in natural position rather than just to fit the paper
F. Parts list (PL)--Should be on same sheet directly above title block
G. Overlapping parts--Lines in front take precedence over lines in back by gapping back lines for front lines

(NOTE: For best results drawing should be inked and reduced for final copy.)

X. Special requirements for patent drawings (Transparency 15)
A. Draw mechanically correct to help understand the invention
B. Do not dimension or detail as working drawings
C. Illustrate each claim
D. Omit center lines and notes
E. Draw in India-ink or equivalent
F. Use heavy, smooth, white paper 8 1/2 by 14" (21.6 by 35.6 cm) or 21.0 by 29.7 cm (DIN size A4); two ply or three ply bristol board is preferred
G. Line shade and surface shade to improve readability
Reduction Ratios

Diagonal Line Method to Enlarge or Reduce

Circular Proportional Scale
Sketching Order

Sketch Enclosing Box
Block in With Light Construction Lines
Erase Unnecessary Construction Lines, and Darken Final Visible Lines.
Ellipses

Ellipse Orientation

Sketch Box

4 Point Approximate Ellipse

Perpendicular Bisectors of each side
Catalog Presentation Drawing

PLOW FRAME

Courtesy of Charles Machine Works, Perry, Oklahoma
Sales Literature Presentation Drawing
Technical Report Presentation Drawing

Solar Hut and Earth Coil Reservoir

Courtesy of Dr. James Bose, Oklahoma State University
Shades and Shadows

Line Shading

Smudge Shading

Dots

Press on Materials
Shades and Shadows (Continued)
Shades and Shadows (Continued)
Axonometric Drawings

Isometric
- $\angle a = \angle b = \angle c$
- $OX = OY = OZ$

Dimetric
- $\angle a = \angle c$
- $OX = OY$

Trimetric
- $a, b, c$ are unequal
- $OX, OY, OZ$ are unequal
Oblique Drawings

Cavalier Oblique

Cabinet Oblique

General Oblique
Leaders and Overlapping Parts

 Identification Numbers

 Arrow (To Object)  Dot (On Object)  "S" (On Object)  Line (On Object)

 Leaders

 Overlapping Parts

 Gap
Exploded Assembly Drawing
(Continued)

HYDRAULIC SYSTEM
Collapsible Trailer Apparatus

Melin C. Wertness, Santa Cruz, and Arnold E. Lyle, Capitola, both of Calif., assignors to Bermaco Enterprises, San Jose, Calif.

Filed Dec. 11, 1969. Ser. No. 884,240

Int. Cl. B62d 23/00

U.S. Cl. 280 106

12 Claims

Electric Scissors

John K. Miles, Columbus, Ind., and Jack F. Baker, Glenview, Ill., assignors to Arvin Industries, Inc., Columbus, Ind.

Filed Aug. 12, 1970, Ser. No. 24,433

Term of patent 14 years

Int. Cl. D8—03

U.S. Cl. D8—61
PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #1: SHADE PICTORIALS

Directions: On "B" size vellum or other media selected by instructor, construct an isometric drawing of one of the problems below to appropriate scale using pencil or ink. Make four quality blueline prints, and shade each blueline print using a different shading technique.

(NOTE: These techniques are outlined in the information sheet, and include lines, stipple, and smudging.)

Shade the original drawing using the best shading technique on the prints. Make a blueline print of the completed drawing, and turn in all blueline prints to instructor.

Problems:

(NOTE: Your instructor may wish to assign an alternate problem.)

A.

B.

LOCATOR

CENTER BRACKET
PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #2 - CONSTRUCT CONCEPTUAL PRESENTATION SKETCHES

Directions: On "A" size vellum or other media selected by instructor, construct conceptual sketches of one of the problems below to include the following: 1) applicable dimensions and notes, 2) parts identification, and 3) shape description.

Problems:

(NOTE: Your instructor may wish to assign an alternate problem.)

A. Design safety or security devices for fire or theft to help save lives and prevent injury
B. Design a new or improved educational aid for your instructor
C. Design an improvement in vehicle transportation or racing
D. Design a home improvement product
PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #3--CONSTRUCT DESIGN SKETCHES

Directions: Using two sheets of "A" size vellum or other media selected by instructor, construct design sketches of two parts for one of the problems below or a problem from Assignment Sheet #2 to include the following: 1) shape description such as multiview and/or pictorial, 2) estimated size dimensions and notes, and 3) estimated material specifications.

(NOTE: Make sketches complete enough so a drafter can make detailed drawings.)

Problems:

(NOTE: Your instructor may wish to assign an alternate problem.)

A.  

B.  

Diagram of designs A and B.
PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #4: CONSTRUCT A DIMETRIC PRESENTATION DRAWING

Directions: On "B" size vellum or other media selected by instructor, construct a dimetric drawing of one of the problems from Assignment Sheet #1 to appropriate scale using pencil or ink. You will need to select your own dimetric axis. Make two quality blueline prints, and shade each dimetric print with a different type of shading. Shade original dimetric with best shading, and turn in blueline prints and original to instructor.

(NOTE: Your instructor may wish to assign an alternate problem.)
PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #5--CONSTRUCT AN OBLIQUE PRESENTATION DRAWING

Directions: On "B" size vellum or other media selected by instructor, construct an oblique drawing of one of the problems from Assignment Sheet #1 to appropriate scale using pencil or ink. You will need to select your type of oblique such as cavalier, cabinet, or general. Make two quality blueline prints of your oblique, and shade oblique prints with different types of shading. Shade original with best shading, and turn in blueline prints and original to instructor.

(NOTE: Your instructor may wish to assign an alternate problem.)
PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #6: CONSTRUCT A TWO POINT PRESENTATION PERSPECTIVE OF AN OBJECT

Directions: On "B" size vellum or other media selected by instructor, construct a two point perspective of one of the problems from Assignment Sheet #1 to appropriate scale using pencil or ink. You will need to select your own vanishing and station points. Make two quality blueline prints, and shade each perspective print with a different type of shading. Shade original with best shading, and turn in blueline prints and original to instructor.

(NOTE: Your instructor may wish to assign an alternate problem.)
PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #7 - CONSTRUCT AN EXPLODED ASSEMBLY PRESENTATION DRAWING

Directions: On "D" size vellum or other media selected by instructor, construct an exploded assembly drawing of a problem assigned by instructor to scale using pencil or ink as instructed to include the following: 1) selected shading, 2) parts identifications, 3) parts list, and 4) flow lines. You will need to select appropriate scale and the type of pictorial (axonometric, oblique, or perspective) you wish to draw. Make a blueline print of your completed drawing, and turn in blueline print and original to instructor.

(NOTE: You may be divided into teams to work on a large problem.)
1. Match the terms on the right with the correct definitions.

   a. Simple exterior embellishments utilizing light effects to enhance the pictorial qualities of an object
   1. Freehand technical sketching

   b. Sketch, mechanical drawing, or rendering designed to illustrate a technical subject and help sell or clarify its idea to a client
   2. Photodrafting

   c. Freehand drawing of technical ideas without instruments
   3. Conceptual sketches

   d. Carefully drawn sketches prepared to be given to someone else to make detail drawings
   4. Reduction ratios

   e. Drawing showing all parts in relationship with each other and how they fit together
   5. Design sketches

   f. Recording and communicating technical ideas that are in the process of development
   6. Presentation sketch or drawing

   g. Three-dimensional drawing in axonometric, oblique, or perspective to imitate a picture of an object
   7. Airbrushing

   h. A simplified drafting technique to reduce drafting time that combines photographs and line drawing on a standard sheet layout
   8. Pictorial drawing

   i. A simplified drafting technique in which drawing segments are pasted or typed in position on a drawing form and photographically reproduced
   9. Shading

   j. Drawing an invention in pictorial and explanatory form to convey the correct interpretation
   10. Paste-up drafting

   k. A method of touching up photographs and adding shading to line drawings by blowing ink or paint pigments through an air cap onto the drawing
   11. Exploded assembly drawing

   l. To reduce a drawing proportionally using a ratio
   12. Patent drafting
2. Name three types of presentation sketches.
   a. ____________________________
   b. ____________________________
   c. ____________________________

3. Arrange in order the following steps of sketching by placing the correct sequence numbers in the appropriate blanks.

   a. Block in object proportionately with light construction lines
   b. Clean up unnecessary construction lines with an eraser and darken final visible lines
   c. Sketch light construction of an enclosing box or cylinder in proportion

4. Select true statements concerning ellipse construction by placing an "X" in the appropriate blanks.

   a. On horizontal plane, major axis is horizontal
   b. On right side plane, major axis is 60° from horizontal
   c. On left side plane, major axis is 45° from horizontal
   d. Diameter of circle is boxed in, and ellipse is sketched
   e. 45° bisector of each side of box is found and drawn mechanically with straight edge and compass

5. List three places where presentation drawings are found.

   a. ____________________________
   b. ____________________________
   c. ____________________________

6. Complete the following list of shading techniques for presentation drawings.

   a. Smudge
   b. Transfer sheets
   c. Shadows
   d. ____________________________
   e. ____________________________
   f. ____________________________
7. Distinguish between the types of axonometric drawings by placing an "1" next to the characteristics of isometric, a "D" next to the characteristic of dimetric, and a "T" next to the characteristic of trimetric.

   a. 120° between axes
   b. All angles are unequal
   c. All axes are at different angles
   d. Two angles are equal
   e. All angles are equal
   f. Width and height full scale
   g. Width, height, and depth are unequal

8. Select true statements concerning oblique drawings by placing an "X" in the appropriate blanks.

   a. Cabinet obliques are drawn half scale on the depth axis
   b. General obliques can be drawn full scale on the depth axis or other scales
   c. Cavalier obliques are drawn half scale on the depth axis

9. Match the parts of exploded assembly presentation drawings on the right with the correct uses.

   a. Used to differentiate one part from another
   b. Should be on same sheet directly above title block
   c. Used if tied to parts list
   d. Can be duplicated and pasted up on drawing to save time
   e. Indicate where parts fit
   f. Lines in front take precedence over lines in back by gapping back lines for front lines
   g. Used if immediate identification is important
   h. Should be in natural position rather than just to fit the paper
10. Select special requirements for patent drawings by placing an "X" in the appropriate blanks.

   a. Draw mechanically correct to help understand the invention.
   b. Dimension and detail as working drawings
   c. Illustrate each claim
   d. Use center lines and notes
   e. Use poster paper 4" by 5"
   f. Line shade and surface shade to improve readability
   g. Draw in pencil so changes can be made

11. Demonstrate the ability to:

   a. Shade pictorials.
   b. Construct conceptual presentation sketches.
   c. Construct design sketches.
   d. Construct a dimetric presentation drawing.
   e. Construct an oblique presentation drawing.
   f. Construct a two point presentation perspective of an object.
   g. Construct an exploded assembly presentation drawing.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
**PRESENTATION DRAWINGS**

**UNIT VII**

**ANSWERS TO TEST**

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<td>c. 1</td>
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2. a. Conceptual  
b. Design  
c. Presentation

3. a. 2  
b. 3  
c. 1

4. a, b, d

5. Any three of the following:  
a. Catalogs  
b. Sales literature  
c. Proposals  
d. Technical reports  
e. Patents  
f. Parts books

6. d. Lines  
e. Dots-stippling  
f. Air brush

7. a. I  
b. T  
c. T  
d. D  
e. I  
f. D  
g. T

8. a, b

9. a. 4  
b. 7  
c. 1  
d. 5  
e. 3  
f. 8  
g. 2  
h. 6

10. a, c, f

11. Evaluated to the satisfaction of the instructor
MATERIALS AND SPECIFICATIONS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to specify materials and write specifications for working drawings to include materials, heat treatment, and standard shapes. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to materials and specifications with the correct definitions.
2. List specifications sometimes found on mechanical drawings.
3. Match general heat treatments for metals with the correct definitions.
4. Match surface hardening treatments for metals with the correct definitions.
5. Select forms of carbon steel.
6. Complete a list of categories of pipe based on end use.
7. List three specifications for tubing callouts.
8. Match structural steel shapes with the correct specifications.
10. Match metal properties with the correct definitions.
11. List factors to consider in selecting materials.
12. Distinguish between physical and manufacturing characteristics of metals.
13. Complete a list of types and kinds of ferrous manufacturing metals.
14. Identify parts of the steel numbering system.
15. Select primary copper type metals.
16. Match the designations of condition of aluminum with the correct definitions.
17. Distinguish between advantages and disadvantages of aluminum.
18. Distinguish between advantages and disadvantages of zinc.
19. Distinguish between types of plastic materials.

20. Distinguish between advantages and disadvantages of plastics.

21. Match refractory materials with the correct uses.

22. Demonstrate the ability to:
   a. Determine wire and sheet metal size from gage number.
MATERIALS AND SPECIFICATIONS

UNIT VIII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.
II. Provide student with information and assignment sheets.
III. Make transparencies.
IV. Discuss unit and specific objectives.
V. Discuss information and assignment sheets.
VI. Have students look through ASM's Metals Handbook and SME's Tool and Manufacturing Handbook to see the full depth of this subject.
VII. Take a field trip to a smelter, foundry, or other metal producing plant.
VIII. Take a field trip to a metal fabricator to observe stock materials in the as received condition.
IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Metal Properties
      2. TM 2--Steel Numbering System
      3. TM 3--Aluminum Alloy Numbering System
      4. TM 4--Aluminum Classification System
   D. Test
   E. Answers to test

II. References:


G. *Shapes and Plates*, United States Steel, Pittsburgh, Pennsylvania 15230.

H. *Metals Stock List*, Ducommun Metals Company, P. O. Box 82356, 2101 South Villa, Oklahoma City, OK 73108.


J. *Patterson Steel Company Reference Book*, Metal Service Center, 801 North Xanthus, P. O. Box 2620, Tulsa, OK 74101.

K. *Steel Sales Stock List*, Steel Sales Corp., 3348 S. Pulaski Rd., Chicago, IL 60623.

L. *Steel and Aluminum Stock List and Reference Book*, #76, Earle M. Jorgensen Co., P. O. Box 18065, Denver, Colorado 80216.
MATERIALS AND SPECIFICATIONS
UNIT VIII

INFORMATION SHEET

Terms and definitions

A. Toughness--Ability of a metal to resist rough treatment

B. Ductility--Ability of a metal to stretch and flow under pressure without breaking

C. Machinability--Relative difficulty of machining a metal

D. Ferrous metals--Metals primarily composed of iron

E. Nonferrous metals--Metals not composed of iron

F. Organic material--Substance containing animal, vegetable, or carbon
   Example: Leather and wood

G. Inorganic materials--Substance not containing animal, vegetable, or carbon
   Example: Cement, glass, and graphite

H. AISI (American Iron and Steel Institute)--Issues steel specifications for steel-working industry

I. ASME (American Society of Mechanical Engineers)--Issues steel plate specifications

J. ASTM (American Society for Testing and Materials)--Writes specifications for all materials

K. ANSI (American National Standards Institute)--Coordinates standards development and resolves standards problems for the United States

L. SAE (Society of Automotive Engineers)--Issues steel bar specifications

M. UNS--Unified National Standard for metals

N. Materials classification system--Standard designation system by AISI, SAE, ASTM, ASME, or UNS

O. Heat treatment--Operation or combined operations of heating a metal and cooling it to obtain certain specifications

P. Thermosetting--Plastic which permanently hardens (sets) after heating

Q. Thermoplastic--Plastic which repeatedly softens with heat
INFORMATION SHEET

II. Specifications sometimes found on mechanical drawings
   A. Material
   B. Finish
   C. General tolerances
   D. Color
   E. Heat treatment
   F. Number required
   G. Hardness
   H. Weight
   I. Manufacturing process or operation
      (NOTE: Specifications may be required depending on the organizational structure of the manufacturing department.)

III. General heat treatments for metals and definitions
   A. Annealing--To soften metal and release stresses
   B. Hardening--To harden metal by dipping in oil, water, air, or brine
   C. Tempering--To reduce internal stresses
   D. Surface hardening--To harden surface while leaving inside soft

IV. Surface hardening treatments for metals and definitions
   A. Carburizing--Introduction of carbon to surface
   B. Cyaniding--Introduction of carbon and nitrogen to surface
   C. Nitriding--Introduction of nitrogen to surface
   D. Induction hardening--Electrical heating of surface before quench
   E. Flame hardening--Flame heating of surface before quench

V. Forms of carbon steel
   A. Cold-rolled sheets
      (NOTE: These are available in commercial quality for bending, forming, and welding, and in drawing quality for severe forming or drawing.)
INFORMATION SHEET

B. Plates

1. Rectangles

2. Coils

(NOTE: Coils are rarely used due to the difficulty of flattening the plate for processing.)

C. Bars

1. Hot-rolled

(NOTE: These are rounds, squares, flats, half rounds, and half ovals, and are available in merchant quality and special quality.)

2. Cold-rolled

(NOTE: These are rounds, hexagons, squares, and flats.)

VI Categories of pipe based on end

A. Pressure pipe

B. Structural and mechanical pipe

C. Standard pipe

VII Specifications for tubing callouts

A. Outside diameter

B. Inside diameter

C. Wall thickness

VIII Structural steel shapes and specifications

A. Beams, columns, and channels—Depth of the section and by weight

B. Angles—Length of legs and weight per foot

C. Tees—Width of flange, overall depth of stem, and weight per foot

D. Zees—Depth of section, flange width, and weight per foot

E. Wide-flange sections—Depth of section, flange width, and weight per foot
IX. Standard mill forms of materials

A. Foil (.0002" to .0055" thick, 7" to 36" wide)

B. Strip (1/16" thick, 1/4" to 12" wide)

C. Sheet (18 gage [.0478] to 7 gage [.1793], 24" to 72" wide)

D. Plates (3/16 to 12" thick, 9" to 120" wide)

E. Bar (1/4 to 6" square, 1/4 to 4" hexagon, up to 12' length)

F. Rod (7/32 to 4 7/16 diameter)

G. Wire (.004 to .625 diameter)

H. Tubing (1/32 to 24 OD, .004" to 3" thick walls)

I. Angle (Legs 1/2" to 9", up to 80 ft. long)

J. Channel (Depth 3" to 18", 4.1#/foot to 42.7#/Foot, 20' to 60' long)

K. I Beam (Depth 3" to 24", 5.7#/foot to 100#/foot, 20' to 60' long)

L. Expanded sheet (36 gage to 22 gage, up to 72" by 144")

M. Perforated sheet (24 gage, to 14 gage up to 48" x 120")

N. Coils (.001 to .1793 thick general use-1/4, 1/2-coiled for special material handling equipment-6"-60" wide)

(NOTE: Refer to a materials selector guide for reference to finished stock sizes. Standard mill sizes indicated in parentheses are for general reference only and to give you a feeling for material size and shape.)

X. Metal properties and definitions (Transparency 1)

A. Tensile strength--Maximum load divided by cross sectional area just before straining when tensile loading a specimen

B. Compressive strength--Maximum stress that a material can withstand during compression just before deformation

C. Torsional strength--Maximum load in twisting action just before deformation

D. Modulus of elasticity--Measure of the rigidity of a metal; ratio of stress to the strain
E. Shear strength--Stress required to produce a fracture across a plane perpendicular to the cross section, the direction of forces and resistance being opposite and parallel with the paths offset a small amount

F. Bend strength--Maximum stress at which fracture occurs during bending

(NOTE: This is also known as modulus of rupture.)

XI. Factors to consider in selecting materials

A. Costs
   1. Per ton
   2. Per pound
   3. Per piece
   4. Per unit of strength

(NOTE: You want to select materials with the lowest cost and the highest number of desirable characteristics.)

B. Strength

C. Rigidity

D. Space filling

E. Surface finish

F. Manufacturability

G. Machinability

H. Weldability

I. Weight

J. Corrosion resistance

XII. Characteristics of metals

A. Physical characteristics
   1. Toughness (shock loading)
   2. Rigidity (resist forces)
   3. Loading (weight - stress)
   4. Strength (great forces)
   5. Ductility (can be drawn or rolled without breaking)
B. Manufacturing characteristics

1. Machinability (ease or difficulty for chip removal)
2. Formability (ease of plastic flow)
3. Joinability (ease of joining by welding, adhesives, or mechanical fasteners)
4. Castability (formed into parts)

XIII. Types and kinds of ferrous manufacturing metals

A. Cast iron
   1. Gray cast iron
   2. White cast iron
   3. Malleable iron
   4. Ductile (nodular) iron
   5. Alloy cast iron

B. Carbon steel
   1. Low carbon steel—.05% to .30% carbon (mild steel)
   2. Medium carbon steel—.30% to .60% carbon
   3. High carbon steel—.60% to 1.5% carbon

C. Alloy steel
   1. Low alloy steel
   2. Medium alloy steel

XIV. Parts of the steel numbering system (Transparency 2)

A. Classification body
B. Process
C. Approximate alloying element
D. Carbon content

Example: .4% carbon = 40
INFORMATION SHEET

XV. Primary copper type metals
A. Copper
B. Brass
C. Leaded brass
D. Phosphor bronze
E. Aluminum bronze
F. Silicon bronze
G. Beryllium
H. Cupro nickel
I. Nickel silver

XVI. Designations of condition of aluminum (Transparencies 3 and 4)
A. F--Fabricated
B. O--Annealed
C. H--Strain hardened
D. W--Solution treated
E. T (T3-T10)--Special conditions

XVII. Advantages and disadvantages of aluminum
A. Advantages
   1. Corrosion resistance
   2. Electrical and thermal conductivity
   3. Attractive appearance
   4. Light compared to steel, brass, nickel, or copper
   5. Load carrying capacities based on equal weight of material compares very favorably with steel
   6. Ease of fabrication
   7. Non-sparking and non-magnetic
INFORMATION SHEET

B. Disadvantages

1. Loses part of strength at elevated temperatures
2. Galvanic corrosion possible when in contact with other metals
3. Alkalis are corrosive to aluminum
4. Lower mechanical properties than those of steel when of equal cross-section (not weight)

XVIII. Advantages and disadvantages of zinc

A. Advantages

1. Easier to cast than aluminum because of lower melting point
   (NOTE: Zinc is used in the automotive industry and general manufacturing because it is so easy to cast.)
2. Low cost
3. High production rate
4. Resistance to atmospheric corrosion
5. Ability to provide galvanic protection to steel

B. Disadvantages

1. Two to three times heavier than aluminum in equivalent die castings
2. Not as dimensionally stable as aluminum castings
3. Toxic--Cannot be used for food packaging

XIX. Types of plastic materials

(NOTE: Only more common plastics are listed.)

A. Thermosetting (reheating will not soften)

1. Epoxides--Esters and straight epoxies
   (NOTE: These are used for fastening, molding, casting, laminating, potting (encasing of electronic parts), and manufacturing press dies for metal forming.)
2. Amino resins--Urea and Melamine--formaldehyde
   (NOTE: These are used in tableware, knobs, and electrical appliances.)
INFORMATION SHEET

3. Phoholics.
   (NOTE: These are used in missiles, dials, and electrical parts.)

4. Polyesters
   (NOTE: These are used in skylights, sports car bodies, and aircraft parts.)

B. Thermoplastics (may be reheated to soften)

1. Acrylonitrile-butadiene-styrene-ABS
   (NOTE: This is used in tool handles and automotive parts.)

2. Acetals-Copolymer and homopolymer
   (NOTE: These are used in plumbing valves, pumps, faucets, toys, gears, and cams.)

3. Acrylic resin-Methyl methacrylate
   (NOTE: This is used for outdoor signs, sunscreens, windows, and canopies.)

4. Polyethylene-Also known as polythene
   (NOTE: This is used for packaging material, bottles, and insulation.)

5. Polycarbonate
   (NOTE: This is used for safety glass, housings, and electrical appliances.)

6. Polyethylene resins
   (NOTE: These are used for garden hose, toys, ice trays, and packaging.)

7. Polypropylene
   (NOTE: This is used for textiles, furniture, and toys.)

8. Celluloses-Acetate, acetate butyrate, ethyl-cellulose
   (NOTE: These are used for knobs, toys, and extruded tubes.)

9. Polystyrenes
   (NOTE: These are used for tumblers, toys, and housings.)

10. Polysulfones
    (NOTE: These are used for switch gears and appliances.)
INFORMATION SHEET

11. Vinyl resins-Polyyinyl butyrate, polyvinyl chloride (PVC), polyvinylidene chloride, and cellular-vinyl

(NOTE: These are used in safety glass, raincoats, pipe, and floats.)

12. Synthetic rubber

(NOTE: This is used in tires, hose, shoe soles, and shock absorbing pads.)

XX. Advantages and disadvantages of plastics

A. Advantages

1. Often outlast metal equivalent parts at reasonable speed and load
2. Often outlast metals in corrosive environments
3. Dampen shock vibration and noise
4. Can operate with little or no lubricant
5. Machine easier and faster

B. Disadvantages

1. Are more dimensionally sensitive to temperature changes
2. Cannot be produced to as high precision tolerance as most metals
3. Have lower load carrying capacity

XXI. Refractories

A. Concrete-Structures

B. Glass-Windows

C. Aluminum-Rocket nozzles and furnace parts

D. Graphite-Heat shields for re-entry vehicles

E. Ceramics-Normal and high temperatures
Metal Properties

Tensile Strength

Force

Torsional or Twisting Strength

Force

Compressive Strength

Force

Bend Strength

Force

Shear Strength

Force
Steel Numbering System

Classification Body
- AISI
- SAE
- UNS
- ASTM
- ASME
- Most Used

Steel Manufacturing Process (Optional)
- B - Bessemer Steel
- C - Open Hearth Steel
- D - Electric Furnace Steel

AISI C 13 40 0

Approximate Percentage of Main Alloying Element
- 10XX - Plain Carbon
- 11XX - Lead-Free Machining Steel
- 13XX - Manganese
- 2XXX - Nickel
- 3XXX - Nickel and Chromium
- 4XXX - Molybdenum
- 5XXX - Chromium
- 6XXX - Chromium-Vanadium
- 7XXX - Tungsten
- 8XXX - Nickel-Chromium-Molybdenum
- 9XXX - Manganese-Silicon

UNS Only
Carbon Content (Hundredths of One Percent)
- 4% Carbon
Aluminum Alloy Numbering System

Group (Zinc) (See Transparency 4)

Minimum Aluminum Percentage (99.78% Alum)

7178-T6

Original Alloy: Modifications (Numbers 1-9)

Condition (Solution Treated, and Artificially Aged)
### Aluminum Classification System

(Modifiers)

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<th>Description</th>
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MATERIALS AND SPECIFICATIONS
UNIT VIII

ASSIGNMENT SHEET #1: DETERMINE WIRE AND SHEET METAL SIZE FROM GAGE NUMBER

Directions: Using the standard wire and sheet gage charts included with this assignment sheet, determine wire and sheet metal size from gage number. The following example can be used as a guideline.

Example: Find the size of a Birmingham wire #0000 gage

1. Go to standard wire gage chart attached
2. Read down "Gage No." column until 4-0's is reached, the 4-0's means 0000
3. Read across Birmingham column to where it intersects 4-0's column
4. Answer is 454

Problems.

A. Find the size of a Birmingham wire #9 gage

B. Find the size of a steel manufacturers' sheet #23 gage

C. Find the size of a Brown and Sharpe for nonferrous metals wire #36 gage

D. Find the size of an American S and W Co.'s std steel wire #36 gage
### STANDARD WIRE & SHEET GAGES

#### WIRE GAGES

| Decimals Inch Equivalent | 0.000 | 0.005 | 0.010 | 0.015 | 0.020 | 0.025 | 0.030 | 0.035 | 0.040 | 0.045 | 0.050 | 0.055 | 0.060 | 0.065 | 0.070 | 0.075 | 0.080 | 0.085 | 0.090 | 0.095 |
|--------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0.000                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.005                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.010                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.015                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.020                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.025                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.030                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.035                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.040                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.045                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.050                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.055                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.060                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.065                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.070                    | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

#### SHEET GAGES

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1. Used for tubing wall thicknesses and certain strip and spring steel products
2. Used by virtually all manufacturers of steel wire in U.S.
3. Used for copper, brass, aluminum, and other nonferrous metals
4. Aluminum sheets use the same gage numbers as American Wire gage—order aluminum by thickness not gage
MATERIALS AND SPECIFICATIONS
UNIT VIII

ASSIGNMENT SHEET #2 - SELECT MATERIALS FROM A MATERIALS STOCK BOOK

Directions: Using the Steel and Aluminum Stock List and Reference Book or any comparable materials stock book, solve the problems which follow for selecting materials. The following example can be used as a guideline.

Example:
Select the standard sheet size length and width for 14 gage hot-rolled steel sheet ASTM A570, Grade A to fit a design 57" by 143". Consider the least amount of wasted material in your selection. Also find the estimated weight per sheet.

1. Go to standard materials stock book
2. Read index of stock book for steel sheets
3. Locate ASTM A570, Grade A Hot Rolled Flat sheets
4. Locate 14 gage thickness
5. Locate sheet size a 57" by 143" would fit
6. Answer is 60" by 144"
7. Estimated lbs. per sheet is 187.5#

Problems:
A. Select the standard purchased sheet size length and width for 22 gage cold rolled commercial quality ASTM A366 steel sheet to fit a design 31" by 97". Consider the least amount of wasted material in your selection. Also find the estimated weight per sheet.

1. Sheet size length and width
2. Estimated weight per sheet

B. Select the standard purchased sheet size length and width for .063 thick 5052 aluminum flat sheets Spec QQ-A250/8 with 1+32 mill finish to fit a design 45" by 85". Consider the least amount of wasted material in your selection. Also find weight per sheet.

1. Sheet size length and width
2. Estimated weight per sheet
ASSIGNMENT SHEET #2

C. Select the standard purchased sheet size length and width for .032 thick zinc alloy sheets QQ-Z100A to fit a design 29\" x 115\". Consider the least amount of wasted materials in your selection. Also find weight per sheet.

1. Sheet size length and width
2. Estimated weight per sheet

D. Select the standard purchased estimated weight per foot 1018 hexagon cold finished bar ASTM A108 of 11/16 inches across flats. Also find the stock length.

1. Estimated weight per foot
2. Stock length

E. Select a bar size angle ASTM A36 to fit a design need of 2 1/2\" by 2\" by 5/16 thick. What is the estimated weight per foot, and what lengths are available?

1. Estimated weight per foot
2. Lengths available

F. Select a wide flange structural beam ASTM A36 with a depth of 18.12\", flange width 7.532\" and web thickness of .390\". Find the AISI designation and estimated weight per foot.

1. AISI designation
2. Estimated weight per foot

G. Select a carbon steel tubing-round seamless mechanical tubing cold drawn outside diameter (OD) 2 7/8 and inside diameter 2.125\". Find the wall thickness and estimated weight per foot.

1. Wall thickness
2. Estimated weight per foot
MATERIALS AND SPECIFICATIONS
UNIT VIII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1
A. .148
B. .0269
C. .00500
D. .0090

Assignment Sheet #2
(NOTE: Answers may vary slightly according to the stock book used.)
A. 1. 36" by 120"
2. 37.5 #
B. 1. 48" by 96"
2. 28.06 #
C. 1. 36" by 120"
2. 36 #
D. 1. 1.39 #
2. 10' to 12' 
E. 1. 4.50 #
2. 20', 30', 40'
F. 1. W18 x 55
2. 55.0 #
G. 1. .375"
2. 10.01.#
1. Match the terms on the right with the correct definitions.

   a. Ability of a metal to resist rough treatment
   b. Ability of a metal to stretch and flow under pressure without breaking
   c. Relative difficulty of machining a metal
   d. Metals primarily composed of iron
   e. Metals not composed of iron
   f. Substance containing animal, vegetable, or carbon
   g. Substance not containing animal, vegetable, or carbon
   h. Issues steel specifications for steel-working industry
   i. Issues steel plate specifications
   j. Writes specifications for all materials
   k. Coordinates standards development and resolves standards problems for the United States
   l. Issues steel bar specifications
   m. Unified National Standard for metals
   n. Standard designation system by AISI, SAE, ASTM, ASME, or UNS
   o. Operation or combined operations of heating a metal and cooling it to obtain certain specifications
   p. A plastic which permanently hardens after heating
   q. Plastic which repeatedly softens with heat

1. SAE
2. Machinability
3. AISI
4. Organic material
5. Thermosetting
6. ANSI
7. Ductility
8. Nonferrous metals
9. Heat treatment
10. Toughness
11. Thermoplastic
12. UNS
13. Ferrous metals
14. Inorganic material
15. ASME
16. ASTM
17. Materials classification system
2. List four specifications sometimes found on mechanical drawings.
   a. 
   b. 
   c. 
   d. 

3. Match general heat treatments for metals on the right with the correct definitions.
   _____ a. To soften metal and release stresses 1. Tempering
   _____ b. To harden metal by dipping in oil, water, 2. Annealing
       air, or brine
   _____ c. To reduce internal stresses 3. Surface hardening
   _____ d. To harden surface while leaving inside soft 4. Hardening

4. Match surface hardening treatments for metals on the right with the correct definitions.
   _____ a. Introduction of carbon to surface 1. Induction hardening
   _____ b. Introduction of carbon and nitrogen to surface 2. Carburizing
   _____ c. Introduction of nitrogen to surface 3. Cyaniding
   _____ d. Electrical heating of surface before quench 4. Flame hardening
   _____ e. Flame heating of surface before quench 5. Nitriding

5. Select forms of carbon steel by placing an "X" in the appropriate blanks.
   _____ a. Warm-rolled sheets
   _____ b. Coil plates
   _____ c. Hot-rolled bars
   _____ d. Rectangle particles
   _____ e. Liquid
   _____ f. Cold-rolled bars

6. Complete the following list of categories of pipe based on end use.
   a. Pressure pipe
   b. Structural and mechanical pipe
   c. 

480
7. List three specifications for tubing callouts.
   a.
   b.
   c.

8. Match structural steel shapes on the right with the correct specifications.
   a. Depth of the section and by weight
   b. Length of legs and weight per foot
   c. Width of flange, overall depth of stem, and weight per foot
   d. Depth of section, flange width, and weight per foot

9. List five standard mill forms of materials.
   a.
   b.
   c.
   d.
   e.

10. Match the metal properties on the right with the correct definitions.
    a. Maximum load in twisting action just before deformation
    b. Maximum stress at which fracture occurs during bending
    c. Maximum stress that a material can withstand during compression just before deformation
    d. Maximum load divided by cross sectional area just before straining when tensile loading a specimen
    e. Measure of the rigidity of a metal; ratio of stress to the strain
    f. Stress required to produce a fracture across a plane perpendicular to the cross section, the direction of forces and resistance being opposite and parallel with the paths offset a small amount

   1. Tensile strength
   2. Compressive strength
   3. Torsional strength
   4. Modulus of elasticity
   5. Shear strength
   6. Bend strength
11. List six factors to consider in selecting materials.
   a. 
   b. 
   c. 
   d. 
   e. 
   f. 

12. Distinguish between physical and manufacturing characteristics of metals by placing an "X" next to the physical characteristics.
   - a. Strength
   - b. Castability
   - c. Rigidity
   - d. Ductility
   - e. Machinability
   - f. Toughness
   - g. Formability

13. Complete the following list of types and kinds of ferrous manufacturing metals.
   a. Cast iron
      1) 
      2) 
   b. 
      1) 
      2) Low carbon steel
   c. Alloy steel
      1) 
      2)
14. Identify the parts of the steel numbering system.

SAE C 5 40

a. b. c. d.

15. Select primary copper type metals by placing an "X" in the appropriate blanks.
   a. Zinc
   b. Lead brass
   c. Beryllium
   d. Cupro nickel
   e. Cast iron
   f. Nickel silver
   g. Silicon bronze

16. Match the designations of condition of aluminum on the right with the correct definitions.
   a. Solution treated
   b. Annealed
   c. Special conditions
   d. Fabricated
   e. Strain hardened

17. Distinguish between advantages and disadvantages of aluminum by placing an "X" next to the advantages.

- a. Alkalis are corrosive to aluminum
- b. Electrical and thermal conductivity
- c. Ease of fabrication
- d. Loses part of strength at elevated temperatures
- e. Light compared to steel
- f. Non-sparking and non-magnetic

18. Distinguish between advantages and disadvantages of zinc by placing an "X" next to the advantages.

- a. High production rate
- b. Toxic—Cannot be used for food packaging
- c. Easier to cast than aluminum because of a lower melting point
- d. Resistance to atmospheric corrosion
- e. Two to three times heavier than aluminum equivalent die castings

19. Distinguish between types of plastic materials by placing an "X" next to the thermosetting plastics and an "O" next to the thermoplastics.

- a. Polyethylene
- b. Amino resins
- c. Acrylic
- d. Vinyl resins
- e. Polysters
- f. Polypropylene
- g. Epoxides
- h. Acetals

20. Distinguish between advantages and disadvantages of plastics by placing an "X" next to the advantages.

- a. Are more dimensionally sensitive to temperature changes
- b. Machine easier and faster
- c. Often outlast metals in corrosive environments
- d. Have lower load carrying capacity
- e. Dampen shock vibration and noise
21. Match the refractory materials on the right with the correct uses.

_____ a. Heat shields for re-entry vehicles 1. Concrete
_____ b. Windows 2. Glass
_____ c. Rocket nozzles and furnace parts 3. Aluminum
_____ d. Normal and high temperatures 4. Graphite
_____ e. Structures 5. Ceramics

22. Demonstrate the ability to:

a. Determine wire and sheet metal size from gage number.


(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
MATERIALS AND SPECIFICATIONS
UNIT VIII

ANSWERS TO TEST

1. a. 10  f. 4   k. 6-
p.
   b. 7  g. 14   l. 1
   c. 2  h. 3    m. 12
   d. 13 i. 15   n. 17
   e. 8  j. 16   o. 9

2. Any four of the following:
   a. Material
   b. Finish
   c. General tolerances
   d. Color
   e. Heat treatment
   f. Number required
   g. Hardness
   h. Weight
   i. Manufacturing process or operation

3. a. 2
   b. 4
   c. 1
   d. 3

4. a. 2
   b. 3
   c. 5
   d. 1
   e. 4

5. b, c, f

6. c. Standard pipe

7. a. Outside diameter
   b. Inside diameter
   c. Wall thickness

8. a. 2
   b. 1
   c. 4
   d. 3

9. Any five of the following:
   a. Foil
   b. Strip
   c. Sheet
   d. Plates
   e. Bar
   f. Rod
   g. Wire
   h. Tubing
   i. Angle
   j. Channel
   k. I beam
   l. Expanded sheet
   m. Perforated sheet
   n. Coils
10. a. 3
b. 6
c. 2
d. 1
e. 4
f. 5

11. Any six of the following:
   a. Costs
   b. Strength
   c. Rigidity
   d. Space filling
   e. Surface finish
   f. Machinability
   g. Weldability
   h. Weight
   i. Corrosion resistance

12. a, c, d, f

13. a. Any two of the following:
    1) Gray cast iron
    2) White cast iron
    3) Malleable iron
    4) Ductile iron
    5) Alloy cast iron
   b. Carbon steel
   c. Any one of the following:
      1) Medium carbon steel
      2) High carbon steel
   d. Any two of the following:
      1) Low alloy steel
      2) Medium alloy steel

14. a. Classification body
    b. Process
    c. Approximate alloying element
    d. Carbon content

15. b, c, d, f, g

16. a. 4
   b. 2
c. 5
d. 1
e. 3

17. b, c, e, f

18. a, c, d

19. a. 0 e. X
    b. X f. 0
    c. 0 g. X
    d. 0 h. 0

20. b, c, e
21. a. 4  
     b. 2  
     c. 3  
     d. 5  
     e. 1

22. Evaluated to the satisfaction of the instructor.
MANUFACTURING PROCESSES
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to design parts for manufacturing processes. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to manufacturing processes with the correct definitions.
2. State three purposes of manufacturing processes.
3. Identify principal types of drawings for manufacturing processes.
4. Match casting terms with the correct definitions.
5. Select true statements concerning design procedures for a casting.
6. Distinguish between pattern and machine dimensions.
7. Match forging terms with the correct definitions.
8. Select true statements concerning design procedures for a forging.
9. Match welding terms with the correct definitions.
10. Select true statements concerning design procedures for a welded assembly.
11. Match machines with the correct processes.
12. Name advantages of numerical control machinery.
13. Match plastic manufacture terms with the correct definitions.
15. Select true statements concerning design procedures for plastics.
16. Match sheet metal processing terms with the correct definitions.
17. Identify sheet metal hems and joints.
18. Calculate bend allowance for sheet metal.
19. Demonstrate the ability to:
   a. Design a casting part.
   b. Design a forging part.
   c. Design a welded part.
   d. Design a thermoplastic part.
MANUFACTURING PROCESSES
UNIT IX

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Tour several manufacturing plants such as welding, foundry, machine shop, or sheet metal plants, and explain the processes in use.

VII. Tour the welding shop, foundry, machine shop, or plastic shop in your school or school district, and ask the instructors to explain the processes in use. Discuss the differences and similarities between the school shops and the actual manufacturing plants.

VIII. Discuss the major difference between the types of drawings for various manufacturing processes.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
A. Objective sheet
B. Information sheet
C. Transparency masters
   1. TM 1--Sahd Casting Drawing
   2. TM 2--Machining Drawing
   3. TM 3--Welding Drawing
   4. TM 4--Sheet Metal Drawing
   5. TM 5--Forging Drawing
   6. TM 6--Sand Mold Pattern
   7. TM 7--Starting to Make the Sand Mold
   8. TM 8--After Rolling Over the Drag
9. TM 9 - Preparing to Ram Molding Sand in Cope

10. TM 10 - Complete Mold Separated

11. TM 11 - Completed Mold

12. TM 12 - Design of Castings

13. TM 13 - Design of Castings (Continued)

14. TM 14 - Pattern and Machine Dimensions

15. TM 15 - Sheet Metal Joints and Joints

16. TM 16 - Bend Allowance

D. Assignment sheets

1. Assignment Sheet #1 - Calculate Bend Allowance for Sheet Metal

2. Assignment Sheet #2 - Design a Casting Part

3. Assignment Sheet #3 - Design a Forging Part

4. Assignment Sheet #4 - Design a Welded Part

5. Assignment Sheet #5 - Design a Thermoplastic Part

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:


MANUFACTURING PROCESSES
UNIT IX

INFORMATION SHEET

I. Terms and definitions

A. Casting--Metal object formed by pouring molten metal into a mold until solidified.

B. Pattern--Form used to make a cavity in sand mold.

C. Core--Special body designed to produce a special cavity in or on a casting.

D. Permanent mold casting--Casting produced with metal molds plus hydrostatic pressure.

E. Die casting--Process of forcing hot metal into a metal mold or die.

F. Centrifugal casting--Process of pouring metal into a revolving mold.

G. Investment casting--"Lost wax" process of pouring a sand mixture (investment) around a wax pattern; the casting is made by pouring molten metal into the hardened sand shell melting and forcing the wax out.

H. Shell molding--Process using thin sand resin shells molded of the pattern and molten metal is poured into the cavity.

(Note: This process produces close tolerance parts.)

I. Hot working metal--Metal in plastic state formed by mechanical working.

(Note: Mechanical workings include rolling and forging.)

J. Cold working metal--Forming or plastic deforming metals while metal is cold.

K. Machining operations--To change the shape, finish, and size by removing material from the workpiece.

L. Electroplating--Covering a metal by electro-deposits of a thin coating of the same or other metal.

M. Chemical milling--Chemical removal of a metal from the workpiece.

N. Flame spraying--Process of melting materials and blowing the melted metal on a surface.

O. Laser machining--Precise removal of small amounts of metal by a concentrated focus of intense heat.

P. Ultrasonic machining--Bombardment of a workpiece by grit driven by linear oscillation of the tool.
### INFORMATION SHEET

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q.</td>
<td>Electron beam machining—Pulsing technique by accelerated electrons that heat and cool an area</td>
</tr>
<tr>
<td>R.</td>
<td>Electronic discharge machining—Removal of metal by spark in the presence of a coolant</td>
</tr>
<tr>
<td>S.</td>
<td>Electro-chemical machining—Reverse plating process of material removal</td>
</tr>
<tr>
<td>T.</td>
<td>Chemical machining—Use of an acid to dissolve metal in areas except where acid resist is used</td>
</tr>
<tr>
<td>U.</td>
<td>Numerical control (NC) machining—Operation of machine tools by automatic programmed cutting sequences using numerical data stored on paper, magnetic tape, tabulating cards, computer storage, or direct information to produce accurate machining of complex geometrical surfaces</td>
</tr>
<tr>
<td>V.</td>
<td>Injection molding—Ramming of hot plastic into a mold</td>
</tr>
<tr>
<td>W.</td>
<td>Fusion—The process of melting or melting together materials</td>
</tr>
<tr>
<td>X.</td>
<td>Extrusion—The process of pushing (forcing) metal through a shape-formed die</td>
</tr>
<tr>
<td>Y.</td>
<td>Surface preparation—A mechanical or chemical process to improve part appearance, surface hardness, coatability, and resistance to wear</td>
</tr>
<tr>
<td></td>
<td>Examples: Sand blasting, deburring, shot peening, electropolishing</td>
</tr>
<tr>
<td>Z.</td>
<td>Computer numerical control (CNC) machining—A numerical control system using a special purpose computer to operate machine tools</td>
</tr>
<tr>
<td>AA.</td>
<td>Automation—An NC machine or system of machines that control the sequence of operations, tool movement, or material movement with very little, if any, assistance from the operator</td>
</tr>
<tr>
<td>BB.</td>
<td>Transfer machine—A machine that has the capability to transfer a workpiece from one operation to another operation within the machine or to another machine</td>
</tr>
<tr>
<td></td>
<td>(NOTE: Transfer machines permit the maximum number of production operations to be performed on workpieces at a maximum production rate.)</td>
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</tbody>
</table>

### II. Purposes of manufacturing processes

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Removing material from original part</td>
</tr>
<tr>
<td>B.</td>
<td>Adding material to original part</td>
</tr>
<tr>
<td>C.</td>
<td>Spreading material to other areas</td>
</tr>
</tbody>
</table>
INFORMATION SHEET

III. Principal types of drawings for manufacturing processes (Transparencies 1-5)
A. Casting
B. Machining
C. Welding
D. Sheet metal
E. Forging

IV. Casting terms and definitions (Transparencies 6-11)
A. Riser--Relief for air and molten metal to rise
B. Flask--Complete mold
C. Sprue--Tapered hole in the cope of a casting mold to pour molten metal into the mold cavity
D. Parting line--Line of separation
E. Draft--Pattern taper for easy removal of pattern from mold
F. Drag--Bottom half of the flask
G. Cope--Top half of the flask
H. Cheek--Middle part of the flask
I. Gate--Opening for the molten metal to flow between the sprue and the mold cavity
J. Alignment pins--Devices to align drag and cope

V. Design procedures for a casting (Transparencies 12 and 13)
A. Avoid abrupt changes in section
B. Keep wall thickness of sections uniform
C. Avoid internal stresses
D. Use minimum number of adjoining sections
E. Fillet radii should be equal to rib thicknesses
F. Thicker thin members when they approach a thick member
G. Odd number of spokes is better than even number to prevent stresses along opposite spokes
H. Allow room for withdrawing of pattern from sand
FORMATION SHEET

I. Use a shrink rule to lay out patterns

(NOTE: Each material has a different shrinkage factor. For example, a cast iron shrinkage rule is 1/8" longer per foot than a standard rule and an aluminum shrinkage rule is 5/32" longer per foot than a standard rule.)

J. A draft or taper must be added to the pattern to allow for removal from the mold

(NOTE: This is usually 1/8" to 1/4" per foot.)

K. A finish allowance or extra metal must be included for machining

(NOTE: This is normally 1/8" (3.2 mm) for small and average castings.)

L. Use a boss, a cylindrical projection on a casting, to give a bearing surface for a fastener

(NOTE: A boss requires less machining.)

VI. Pattern and machine dimensions

A. Pattern dimensions--Dimensions needed only by a pattern maker to make a pattern

B. Machine dimensions--Dimensions needed only by a machinist to machine the part

VII. Forging terms and definitions

A. Parting line (flash line)--Line where dies meet and separate

B. Die closure--Added amount to the die when dies do not close

C. Parting plane--Plane perpendicular to the direction of pressure

D. Die--Device used in shaping or stamping an object or flat material

E. Flash--Slight excess thin fin of material surrounding a forging at the parting line

F. Draft--Taper of surfaces to allow easy removal from the die

G. Match tolerance--Measurement of displacement of two opposing dies in the direction parallel to the parting line of the dies
INFORMATION SHEET

VIII. Design procedures for a forging

A. Avoid sharp corner fillets
   (NOTE: if material is flowing away, fillets may be sharper.)

B. Have large fillet if material is flowing toward fillet

C. Use strippers and ejectors when little or no draft is used

D. Allow generous tolerances for dies in areas of greatest pressure and flow
   (NOTE: Generous tolerances in these areas will make dies last longer.)

IX. Welding terms and definitions

A. Arc welding—Most common process which uses electric arc to melt edges and melted electrode as additional material

B. Forge welding—Heated metal is forced together under pressure

C. Induction welding—Parts are heated by electric current to melt and fuse parts together
   (NOTE: Induction welding is an economical mass production method.)

D. Resistance welding—A heavy current is passed through parts in contact which melts and fuses the parts together

E. Gas welding—Heating of metal by hot flame and melting of welding rod as a fillet metal

F. Thermit welding—Chemical reaction between powdered aluminum and powdered metal oxide which causes them to be welded together

G. TIG—Gas tungsten inert shielding arc welding using a metal electrode

H. MIG—Gas metal inert shielding arc welding using a metal electrode

I. Plasma welding—An arc welding process in which the arc is constricted in a hot ionized gas flowing through an orifice

J. Nondestructive testing—A method of testing materials without impairing the usefulness of the material
   Examples: Visual, magnetic particle, liquid penetrant, and X-ray

K. Destructive testing—A method of testing materials, usually samples, that destroys their usefulness
   Examples: Chemical tests, hardness tests, mechanical tests, and notched bar impact test
INFORMATION SHEET

X. Design procedures for a welded assembly
   A. Use standard rolled shapes such as I beams, channels, zees, and tees
   B. Design for calculated load to avoid wasting materials
   C. Use deep sections to avoid bending
   D. Proper use of stiffeners will provide rigidity with less weight
   E. Use closed sections or diagonal bracing for torsion (twisting)
   F. Provide maintenance accessibility
   G. Design with minimum number of pieces
   H. Eliminate beveling if deep-penetrating arc can be used
   I. Use minimum root opening to avoid excess filler metal
   J. Place welds on shortest seams

XI. Machines and processes
   A. Turning machines—Cutting the workpiece by rotating the workpiece against
      the edge of the tool
   B. Milling machines—Cutting the workpiece by a rotating tool; the workpiece is
      then moved back into position for the next cut
   C. Drill press—Cutting circular holes in the workpiece by a rotating tool
   D. Shaper and planer—Cutting by tools going back and forth on workpiece,
      while workpiece is automatically advanced
   E. Sawing machines—Making straight or circular outs in a workpiece
   F. Broaching machines—Pulling or pushing a broaching tool over the work-
      piece surface to machine simple or complex contours
      (NOTE: Broaching is one of the most productive precision machining
      processes known to produce precision finishes, hold small tolerances, and
      eliminate the need for highly skilled machine operators.)
   G. Grinding machines—Removing tiny particles from the surface of the work-
      piece by abrasive action

XII. Advantages of numerical control machinery
   A. Greater control over the manufacturing process
   B. Higher cutting rates
   C. Large time savings
INFORMATION SHEET

D. Reduction of inventory
E. Fewer machines and operators required
F. Less skill required by operators
G. Reduced scrap and rework
H. Improved product design

XIII. Plastic manufacture terms and definitions
A. Thermoplastic welding—Fusing together of thermoplastic materials
B. Compression molding—Pressure and heat cause material to flow in a mold
C. Transfer molding—Plunger and high frequency preheating mold plastic in a mold cavity
D. Injection molding—Thermoplastic material is injected into a mold and cooled
E. Extrusion—Plastic is forced through die of the desired shape
F. Blow molding—Air is blown into heated plastic forcing it against the mold sides
G. Thermoforming—Preheating plastic sheets until limp, followed by vacuum forming over a mold
H. Rotational molding—Process in which plastisol plastic is fused while in a rotating mold
I. Laminating—Combination of materials by heat and pressure to form a single piece

XIV. Methods of fabricating plastics
A. Machining—Used on rigid plastics
B. Forming—Used on flexible thermoplastics
C. Welding—Used for joining rigid sheets of plastic

XV. Design procedures for plastics
A. Any wall or rib should be between a minimum of 3/32" to 5/32" thick
B. Any wall thickness should not exceed 1/8" thick
C. Draft or taper of 1° to 2° is desirable
D. Fillets should be added to facilitate molding with minimum distortion and breakage
INFORMATION SHEET

E. Ribs and bosses must have 5° tapers

F. Holes smaller than 1/16" in diameter must be drilled or formed after molding

(NOTE: These procedures are not exhaustive of the plastic industry. Please consult specific references for more details.)

XVI. Sheet metal processing terms and definitions

A. Metal spinning--Forming a sheet of metal over a mandrel while the sheet is rotating

B. Stretch forming--Stretching sheet metal and then forming by dies

C. High energy forming--Using high energy to shape metal such as explosive or magnetic forming

D. Shearing--Cutting metal by shearing action

E. Drawing--Stretching sheet over die in the form of the final product

F. Development--A pattern or shape in two dimensions for sheet metal

G. Bending--To form corners, edges, and seams in sheet metal

H. Bend relief holes--Holes drilled or punched at intersection of bends to relieve strain which would cause metal to crack or buckle

I. Spring back--An overbending operation to allow for the material to spring back into the desired shape

XVII. Sheet metal hems and joints (Transparency 15)

A. Single flange

B. Double flange

C. Rolled flange
D. Single hem
E. Double hem
F. Wired edge
G. Lap seam
H. Plain flat seam
I. Grooved seam
J. Single seam
K. Double seam
XVIII. Calculating bend allowance for sheet metal (Transparency 16)

A. $BA = \text{Bend allowance}$
B. $R = \text{Radius of bend}$
C. $T = \text{Metal thickness}$
D. $N = \text{Number of degrees in bend}$
E. $BA = (0.017453R + 0.0078T)N$
F. $\text{Length} = L_1 + L_2 + BA$

(NOTE: Bend allowance tables have been tabulated for many industries based on experimental data. As a rule of thumb BA equals 1/3 thickness for soft metals and 1/2 thickness for hard metals.)
Sand Casting Drawing

For "Machining" see Dwg 87343.

Rounds $\frac{1}{4}$ R. Fillets $\frac{1}{8}$ R.

Machining Drawing

Heat treatment:
1. Carbonize at 1650° to 1700° F
2. Quench direct
3. Draw at 275°

Protect threads during hardening.

Welding Drawing

Cut from 2/3" CRS

1/3" Drill after welding

1/3" Drill, 2 holes

Limits unless otherwise noted

Fractional ± 1/64, Decimal ± .001, Angular ± 1°

Material: SAE 1020

Stock Size: 1/2 Size

Scale: 1/8" = 1'

Company Name: Diesel Assy

Drawing No: 93521

City: Cleveland

Date: 6-7-77

Name: TCD L K D

Part No: 137-8

Assy No: 93624

Revision: 4

Operation: Welding Assy

Company Name: Diesel Assy
Sheet Metal Drawing

L.H. Bracket shown
Make R.H. opposite
Bend radii 1/8

Forging Drawing

Sand Mold Pattern

Aligning Dowel

Cope Half

Drag Half

Fig. A

Fig. B

Cope Half
Starting to Make the Sand Mold

Drag Half of Pattern (With Dowel Holes)

Molding Sand

Drag Flask

Alignment Pins

Mold Board
After Rolling Over the Drag

Parting Surface

Bottom Board
Preparing to Ram Molding Sand in Cope

Gate Sprue Pin

Riser Pin

Cope Flask

Lug

Parting Line
Complete Mold - Separated

- Riser
- Guide Pin
- Gate
- Molding Board
- Follow Board
- Cope
- Sprue
- Drag
- Core Box
- Core Print
- Split Pattern
- Core (Halves)
Parting Line

Sprue

Riser

Flask

Cope

Drag
Design of Castings

Preferred

Poor

Preferred

Preferred

Preferred

Often Done

Preferred

Often Done

Preferred
Design of Castings
(Continued)

Hole machined from solid casting

Preferred

Hole cored; then machined

Preferred

Cored hole

Preferred

Preferred
Pattern and Machine Dimensions

KEY
Pattern -- P
Machine -- M
Sheet Metal Hems and Joints

Single Flange  Double Flange  Rolled Edge

Lap Seam  Plain Flat Seam  Grooved Seam

Single Hem  Double Hem  Wired Edge

Single Seam  Double Seam  Standing Seam
Bend Allowance

BA = Bend Allowance

R = Radius

T = Metal Thickness

N° = Number of Degrees in Bend

Length = L₁ + L₂ + BA

BA = (0.017453R + 0.0078T)N°

Example: If R = .5, T = .10, N° = 120° --

BA = (0.017453R + 0.0078T)N°
   = [.017453(.5) + .0078(.10)]120
   = .1872
MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #1-Calculate Bend Allowance for Sheet Metal

Directions: Calculate bend allowances for these problems using the following formula:

\[ BA = (0.017453R + 0.0078T) N \]

Problems:

A. Radius: 4"
   Thickness: .75"
   Number of degrees of bend: 90°
   \[ BA = \]

B. Radius: 6"
   Thickness: .60"
   Number of degrees of bend: 120°
   \[ BA = \]

C. Radius: .75"
   Thickness: .25"
   Number of degrees of bend: 90°
   \[ BA = \]

D. Radius: .25"
   Thickness: .125"
   Number of degrees of bend: 85°
   \[ BA = \]

E. Radius: 1.5"
   Thickness: .50"
   Number of degrees of bend: 30°
   \[ BA = \]

F. Radius: 1.25"
   Thickness: .25"
   Number of degrees of bend: 120°
   \[ BA = \]
ASSIGNMENT SHEET #2 - DESIGN A CASTING PART

Directions: Select a workpiece assigned below that has been welded or a workpiece selected by instructor. Redesign the workpiece into a casting drawing on "B" size vellum or other media assigned by instructor. Include all dimensions and notes necessary for a pattern maker.

Problems:

A. Include the following changes:

1. 1/8" high by 1 1/4" DIA boss on holes "A"
2. Finish "V" bottom surface, bosses, and left side
3. Fillets and rounds 1/8" radius
4. Add 1/4" high by 1 1/2" DIA boss to front and back of hole "B"
5. Finish boss surfaces
## ASSIGNMENT SHEET #2

<table>
<thead>
<tr>
<th>ID</th>
<th>PE 2D</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>$6 \times \frac{1}{2} \Phi - 6$ LG</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>$2 \times \frac{3}{4}$ BAR - 8 LG</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>$5 \frac{1}{2} \times \Phi - 6\frac{3}{4}$ LG</td>
</tr>
</tbody>
</table>

![Diagram of a structure with dimensions and annotations]

- OK: 1-8 UNISON 2B
- 45°
ASSIGNMENT SHEET #2

B. Include the following changes.

1. Finish front and back surfaces
2. Use 1/4" radius for rounds
3. Use 3/8" radius for fillets
MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #3--DESIGN A FORGING PART

Directions: Select a workpiece assigned below that has been cast or a workpiece selected by instructor. Redesign the workpiece into a forging drawing on "B" size vellum or other media assigned by instructor. All draft angles are to be 7°. If necessary, redesign shape, but hold bearing surfaces true. Include all dimensions and notes necessary for a forging design.

Problems:

A

[Diagram with dimensions and notes: 2, 6, 1/4 drill-2 holes in line, 1.249-1.250 ream fillets and rounds 1/8R, 1/16 saw]
MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #4: DESIGN A WELDED PART

Directions: Select a workpiece assigned below that has been cast or a workpiece selected by instructor. Redesign the workpiece into a welded assembly on "B" size vellum or other media assigned by instructor. Include all dimensions, symbols, and notes for the welded assembly. Also include a parts list of raw stock.

Problems

A.
MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #5: DESIGN A THERMOPLASTIC PART

Directions: Select a workpiece below or a workpiece selected by instructor. Design a thermoplastic workpiece to be injection molded on "B" size vellum or other media selected by instructor. Draw four parts attached to a common core. These four parts will be injection molded at one time.

Problems

A.
MANUFACTURING PROCESSES
UNIT IX

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. \([0.017453 \times 4 + 0.0078 \times 0.75] \times 90 = 6.81\]
B. \([0.017453 \times 6 + 0.0078 \times 0.60] \times 120 = 13.13\]
C. \([0.017453 \times 0.75 + 0.0078 \times 0.25] \times 90 = 1.35\]
D. \([0.017453 \times 0.25 + 0.0078 \times 0.125] \times 85 = 0.45\]
E. \([0.017453 \times 1.5 + 0.0078 \times 0.50] \times 30 = 0.90\]
F. \([0.017453 \times 1.25 + 0.0078 \times 0.25] \times 120 = 2.85\]

Assignment Sheets 2-5: Evaluated to the satisfaction of the instructor
MANUFACTURING PROCESSES
UNIT IX

NAME __________________________

TEST

1. Match the terms on the right with the correct definitions.

   a. Bombardment of a workpiece by grit driven by linear oscillation of the tool
   b. Process of melting materials and blowing the melted metal on a surface
   c. Removal of metal by spark in the presence of a coolant
   d. "Lost wax" process of pouring a sand mixture around a wax pattern; the casting is made by pouring molten metal into the hardened sand shell melting and forcing the wax out
   e. Metal in plastic state formed by mechanical working
   f. Special body designed to produce a special cavity in or off a casting
   g. Metal object formed by pouring molten metal into a mold until solidified
   h. Reverse plating process of material removal
   i. Use of an acid to dissolve metal in areas except where acid resist is used
   j. Pulsing technique by accelerated electrons that heat and cool an area
   k. Chemical removal of a metal from the workpiece
   l. Process using thin sand resin shells molded of the pattern and molten metal is poured into the cavity
   m. Forming or plastic deforming metals while metal is cold
   n. Precise removal of small amounts of metal by a concentrated focus of intense heat

   1. Casting
   2. Pattern
   3. Permanent mold casting
   4. Extrusion
   5. Die casting
   6. Centrifugal casting
   7. Automation
   8. Investment casting
   9. Shell molding
   10. Injection molding
   11. Hot working metal
   12. Cold working metal
   13. Machining operations
   14. Electroplating
o. Operation of machine tools by automatic programmed cutting sequences using numerical data stored on paper, magnetic tape, tabulating cards, computer storage, or direct information to produce accurate machining of complex geometrical surfaces

p. Ramming of hot plastic into a mold

q. Covering a metal by electro-deposits of a thin coating of the same or other metal

r. To change the shape, finish, and size by removing material from the workpiece

s. Process of pouring metal into a revolving mold

t. Form used to make a cavity in sand mold

u. Process of forcing hot metal into a metal mold or die

v. Casting produced with metal molds plus hydrostatic pressure

w. The process of melting or melting together materials

x. The process of pushing metal through a shape-formed die

y. A mechanical or chemical process to improve part appearance, surface hardness, coating ability, and resistance to wear

z. A numerical control system using a special purpose computer to operate machine tools

aa. An N/C machine or system of machines that control the sequence of operations, tool movement, or material movement with very little, if any, assistance from the operator

bb. A machine that has the capability to transfer a workpiece from one operation to another operation within the machine or to another machine

2. State three purposes of manufacturing processes.

a. 

b. 

c. 

3. Identify principal types of drawings for manufacturing processes.

4. Match the casting terms on the right with the correct definitions.

   a. Complete mold
   b. Top half of the flask
   c. Middle part of the flask
   d. Relief for air and molten metal to rise
   e. Tapered hole in the cope of the casting mold to pour molten metal into the mold cavity
   f. Bottom half of the flask
   g. Pattern taper for easy removal of pattern from mold
   h. Line of separation
   i. Devices to align drag and cope
   j. Opening for the molten metal to flow between the sprue and the mold cavity

   1. Riser
   2. Flask
   3. Sprue
   4. Parting line
   5. Draft
   6. Drag
   7. Cope
   8. Cheek
   9. Gate
   10. Alignment pins
5. Select true statements concerning design of a casting by placing an "X" in the appropriate blanks.

   a. Abrupt changes in sections aid in the design of castings
   b. Keep wall thickness of sections uniform
   c. Avoid internal stresses
   d. Use maximum number of adjoining sections
   e. Fillet radii should be larger than rib thicknesses
   f. A finish allowance or extra metal must be included for machining
   g. Even number of spokes is better than odd number so all stress will be along opposite spokes

6. Distinguish between pattern and machine dimensions in the illustration by placing a "P" for pattern dimension and an "M" for machine dimensions in the corresponding blanks.

   a. 
   b. 
   c. 
   d. 
   e. 
   f. 
   g. 
   h. 
   i. 
   j. 

7. Match the forging terms on the right with the correct definitions.

   a. Plane perpendicular to the direction of pressure
   b. Line where dies meet and separate
   c. Added amount to the die when dies do not close
   d. Measurement of displacement of two opposing dies in the direction parallel to the parting line of the dies

   1. Parting line
   2. Die
   3. Die closure
   4. Draft
e. Slight excess thin fin of material surrounding a forging at the parting line

f. Taper of surfaces to allow easy removal from the die

g. Device used in shaping or stamping an object or flat material

8. Select true statements concerning design of a forging by placing an "X" in the appropriate blanks.

a. Sharp corners should be designed in castings
b. Use strippers and ejectors when little or no draft is used
c. Have small fillet if material is flowing toward fillet
d. Allow generous tolerances for dies in areas of greatest pressure and flow

9. Match the welding terms on the right with the correct definitions.

a. Heating of metal by hot flame and melting of welding rod as a filler metal
b. Heated metal is forced together under pressure
c. Most common process which uses electric arc to melt edges and melted electrode as additional material
d. Chemical reaction between powdered aluminum and powdered metal oxide which causes them to be welded together
e. A heavy current is passed through parts in contact which melts and fuses the parts together
f. Parts are heated by electric current to melt and fuse parts together
g. A method of testing materials, usually samples, that destroys their usefulness
h. An arc welding process in which the arc is constricted in a hot ionized gas flowing through an orifice
i. Gas tungsten inert shielding arc welding using a metal electrode
j. Gas metal inert shielding arc welding using a metal electrode
k. A method of testing materials without impairing the usefulness of the material

1. Arc welding
2. Destructive testing
3. Forge welding
4. Induction welding
5. MIG
6. Resistance welding
7. Plasma welding
8. Gas welding
9. Nondestructive testing
10. Thermit welding
11. TIG
10 Select true statements concerning design procedures for a welded assembly by placing an "X" in the appropriate blanks.
   _____ a. Use standard rolled shapes such as I-beams, channels, zees, and tees
   _____ b. Design for calculated load to avoid wasting materials
   _____ c. Use shallow sections so bending will be needed
   _____ d. Design with maximum number of pieces
   _____ e. Eliminate beveling if deep penetrating arc can be used
   _____ f. Use maximum root opening so a great deal of filler metal can be used
   _____ g. Place welds on longest seams

Match the machines on the right with the correct processes.
   _____ a. Making straight or circular cuts in a workpiece
   _____ b. Cutting the workpiece by rotating the workpiece against the edge of the tool
   _____ c. Cutting circular holes in the workpiece by a rotating tool
   _____ d. Removing tiny particles from the surface of the workpiece by abrasive action
   _____ e. Cutting the workpiece by a rotating tool; the workpiece is then moved back into position for the next cut
   _____ f. Cutting by tools going back and forth on workpiece while workpiece is automatically advanced
   _____ g. Pulling or pushing a broaching tool over the workpiece surface to machine simple or complex contours

12 Name four advantages of numerical control machinery.
   a. ___________________________
   b. ___________________________
   c. ___________________________
   d. ___________________________
13. Match plastic manufacture terms on the right with the correct definitions.

- a. Air is blown into heated plastic forcing it against the mold sides
- b. Pressure and heat cause material to flow in a mold
- c. Fusing together of thermoplastic materials
- d. Plastic is forced through die of the desired shape
- e. Plunger and high frequency preheating mold plastic in a mold cavity
- f. Thermoplastic material is injected into a mold and cooled
- g. Preheating plastic sheets until limp, followed by vacuum forming over a mold
- h. Combination of materials by heat and pressure to form a single piece
- i. Process in which plastisol plastic is fused while in a rotating mold


- a. Machining is used on flexible thermoplastics
- b. Welding is used for joining rigid sheets of plastic
- c. Forming is used on rigid plastics
- d. Forming is used on flexible thermoplastics

15. Select true statements concerning design procedures for plastics by placing an "X" in the appropriate blanks.

- a. Any wall thickness should not exceed 1/8" thick
- b. Draft or taper of 7° to 10° is desirable
- c. Holes larger than 1/8" in diameter must be drilled or formed after molding
- d. Ribs and bosses must have 5° tapers
Match sheet metal processing terms on the right with the correct definitions.

_____ a. Stretching sheet over die in the form of the final product
_____ b. Stretching sheet metal and then forming by dies
_____ c. A pattern or shape in two dimensions for sheet metal
_____ d. Cutting metal by shearing action
_____ e. Using high energy to shape metal such as explosive or magnetic forming
_____ f. Forming a sheet of metal over a mandrel while the sheet is rotating
_____ g. An overbending operation to allow for the material to spring back into the desired shape
_____ h. To form corners, edges, and seams in sheet metal
_____ i. Holes drilled or punched at intersection of bends to relieve strain which would cause metal to crack or buckle

Identify the following sheet metal hems and joints.

a. b. c. d.

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18 Calculate bend allowance for 5 gage thick (.1819) sheet metal. Radius = 5\"; Number of degrees in bend = 75\".

BA = \((.017453R + .0078T)N\)

19. Demonstrate the ability to:

a. Design a casting part.

b. Design a forging part.

c. Design a welded part.

d. Design a thermoplastic part.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
### MANUFACTURING PROCESSES

**UNIT IX**

**ANSWERS TO TEST**

|   | a | b | c | d | e | f | g | h | i | j | k | l | m | n | o | p | q | r | s | t | u | v | w | x | y | z | aa | bb |
| 1.| 20 | 16 | 2 | 17 | 9 | 5 | 22 | 12 | 3 | 8 | 19 | 15 | 11 | 26 | 4 | 29 | 28 | 27 | 1 | 14 | 25 | 23 | 9 | 19 | 5 | 24 | 6 | 18 |
| 2.| Removing material from original part | Adding material to original part | Spreading material to other areas |
| 3.| a. Casting | b. Welding | c. Forging | d. Sheet metal |
| 4.| a. 2 | f. 6 | b. 7 | g. 5 | c. 8 | h. 4 | d. 1 | i. 10 | e. 3 | j. 9 |
| 5.| b, c, f |
| 7.| a. 5 | e. 6 | b. 1 | f. 4 | c. 3 | g. 2 | d. 7 |
| 8.| b, d |
| 9.| a. 8 | g. 2 | b. 3 | h. 7 | c. 1 | i. 11 | d. 10 | j. 5 | e. 6 | k. 9 | f. 4 |

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10. a, b, e

11. a.  5 e.  2
    b.  1 f.  4
c.  3 g.  6
d.  7

12. Any four of the following:
   a. Greater control over the manufacturing process
   b. Higher cutting rates
   c. Large time savings
   d. Reduction of inventory
   e. Fewer machines and operators required
   f. Less skill required by operators
   g. Reduced scrap and rework
   h. Improved product design

13. a.  8 f.  5
    b.  3 g.  9
c.  1 h.  2
d.  7 i.  6
e.  4

14. b, d

15. a, d

16. a.  7 f.  2
    b.  3 g.  5
c.  9 h.  8
d.  6 i.  1
e.  4

17. a. Plain flat seam
    b. Standing seam
    c. Single seam
    d. Double flange

18. BA = (.017453R + .0078T)N
     BA = [(.017453(.5) + .0078 (.1819)](75)
     BA = [.0087265 + .00141882] 75
     BA = .760

19. Evaluated to the satisfaction of the instructor
UNIT OBJECTIVE

After completion of this unit, the student should be able to identify true lengths and true sizes of surfaces, construct true lengths and true sizes by rotation, and construct intersections of surfaces and sheet metal developments. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

(NOTE: Review "Orthographic Views," "Geometric Construction," and "Auxiliary Views" from Basic Drafting, Book Two before attempting this unit.)

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to sheet metal developments with the correct definitions.
2. Distinguish between visualization of near and far points and planes.
3. Arrange in order the steps for constructing an auxiliary view.
4. Identify true length lines and true sizes of three view drawings.
5. Identify point views of lines and edge views of planes.
6. Select true statements concerning important characteristics of rotation.
7. Select elements of single curved surfaces.
9. Name three general groups of developments.
10. Calculate bend allowance.
11. Demonstrate the ability to:
   a. Label points, lines, and planes in views.
   b. Identify true lengths and types of lines.
   c. Identify true sizes and types of planes.
   d. Construct true lengths of lines and true sizes of planes using auxiliary views.
   e. Construct true lengths of lines by rotation.
f. Construct true sizes of planes by rotation.
g. Locate elements of single curved surfaces.
h. Construct intersections of surfaces.
i. Construct intersections of surfaces using two-view method.
j. Construct radial line developments.
k. Construct parallel line developments.
l. Construct special developments using triangulation.
SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparency masters.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Tour a sheet metal fabrication plant.

VII. If possible, have students construct models from sheet metal or cardboard.

(Note: Used aluminum plates from the local newspaper could be a source of metal. Caution the students that sheet metal can cut hands very easily.)

VIII. Give test.

INSTRUCTIONAL MATERIALS

Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Near and Far Points and Planes

2. TM 2--Observing Points and Planes

3. TM 3--Labeling Points, Lines, and Planes

4. TM 4--Steps for Constructing Auxiliary Views

5. TM 5--True Lengths of Lines

6. TM 6--Identifying True Lengths

7. TM 7--Observing True Size Planes

8. TM 8--Identifying True Sizes

9. TM 9--Point Views of Lines
10. TM 10--Edge Views of Planes
11. TM 11--Rotation of a Point
12. TM 12--True Lengths by Rotation
13. TM 13--True Sizes by Rotation
14. TM 14--Elements of Single Curved Surfaces
15. TM 15--Intersections With Edge View Given
16. TM 16--Intersections Using Auxiliary Views
17. TM 17--Intersections of Cylinders
18. TM 18--Developments
19. TM 19--Radial Line Developments--Pyramids
20. TM 20--Radial Line Developments--Cones
21. TM 21--Parallel Line Developments--Prisms
22. TM 22--Parallel Line Developments--Cylinders
23. TM 23--Triangulation

D. Assignment Sheets

1. Assignment Sheet #1--Label Points, Lines, and Planes in Views
2. Assignment Sheet #2--Identify True Lengths and Types of Lines
3. Assignment Sheet #3--Identify True Sizes and Types of Planes
4. Assignment Sheet #4--Construct True Lengths of Lines and True Sizes of Planes Using Auxiliary Views
5. Assignment Sheet #5--Construct True Lengths of Lines by Rotation
6. Assignment Sheet #6--Construct True Sizes of Planes by Rotation
7. Assignment Sheet #7--Locate Elements of Single Curved Surfaces
8. Assignment Sheet #8--Construct Intersections of Surfaces
9. Assignment Sheet #9--Construct Intersections of Surfaces Using Two-View Method
10. Assignment Sheet #10--Construct Radial Line Developments
11. Assignment Sheet #11--Construct Parallel Line Developments
12. Assignment Sheet #12--Construct Special Developments Using Triangulation
E. Answers to assignment sheets

F. Test

G. Answers to test

II. References


SHEET METAL DEVELOPMENTS
UNIT X

INFORMATION SHEET

I. Terms and definitions

A. True length of a line--The exact measurable view of the exact length of a line found by observation, projection, or calculation

B. True size of a surface--The exact measurable view of the exact size of a surface found by observation, projection, or calculation

C. Development--A pattern of the true sizes of unfolded or unrolled surfaces arranged to be folded to the desired shape

D. Bend allowance (BA)--An additional amount of material necessary when making a bend

(NOTE: Usually BA is calculated for material over .65 mm.)

E. Radial line development--The development of objects that can be developed due to elements radiating from a single point or vertex

Examples: Cones, pyramids

F. Parallel line development--The development of objects that can be developed due to parallel elements on these surfaces

Examples: Cylinders, prisms

G. Triangulation--A method of developing surfaces not possible by the parallel line or radial line methods

Examples: Transition pieces, hoppers

H. Warped surface--A ruled surface that cannot be developed

Examples: Oblique helicoid, cylindroid, many exterior surfaces on an airplane, approximation developments are possible

I. Right section--A cutting plane perpendicular to an axis of a three dimensional form

(NOTE: The axis may be the center line of a cylinder, cone, or true lengths of a prism, square, or hexagon shape.)

J. True length diagram--A diagram of the true lengths projected from the normal views

K. Elements of a surface--Ruled lines on the surface of geometric shapes

L. Single curved surface--A ruled surface generated by a straight line that can be developed

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INFORMATION SHEET

M. Double curved surface--A surface which has no straight line elements and cannot be developed

Examples: Sphere, cone, paraboloid, hyperboloid, approximation developments are possible

N. Ruled surface--Any surface generated by straight lines

(NOTE: This may be a plane, single curved surface, or a warped surface.)

O. Conic section--The intersection of a circular cone and a plane

P. Stretch out line--A line that is perpendicular to each element on which a parallel line development is unrolled or unfolded

Q. Transition piece--A piece that connects two differently shaped conductors

R. Master layouts--Original and complete developments of parts used for reference and checking

S. Contour templates--Templates to exact contour of part used for checking parts at production stages

T. Shrink templates--Contour templates made with a shrink scale for die maker and foundry

U. Bend line--Where bend starts

V. Mold line (ML)--The intersection of two adjacent surfaces

(NOTE: Inside surface intersections are called "inside mold lines" [IML] and outside surface intersections are called "outside mold lines" [OML].)

W. Relief holes--Drilled or routed holes at intersection of bends to relieve strain which would cause metal to crack or buckle

X. Rotation--A method of projection in which the observer stays stationary and the object is rotated for different views of the object

Formed View

Developed View

Set Back

Bend Allowance

Mold Lines

Bend Lines

Bend Lines
Y. Folding line--A reference line normally between two views representing the edge of a plane of projection

II. Visualization of near and far points and planes (Transparencies 1, 2, and 3)

A. Near points and planes (Transparency 1)

1. Top view--Points or planes are near you when they are observed in the front view closest to line of sight (LOS)
2. Front view--Points or planes are near you when they are observed in the top or side view closest to the line of sight (LOS)
3. Side view--Points or planes are near you when they are observed in the front view closest to the line of sight (LOS)

B. Far points and planes (Transparency 1)

1. Top view--Points or planes are far from you when they are observed in the front view far away from or on the other side of the line of sight
2. Front view--Points or planes are far from you when they are observed in the top or side view far away from or on the other side of the line of sight
3. Side view--Points or planes are far from you when they are observed in the front view far away from or on the other side of the line of sight

C. Points are observed when: (Transparency 2)

1. Line of sight is parallel to a true length line
2. Two lines intersect

D. Planes are observed when: (Transparency 2)

1. Line of sight is perpendicular to an edge view in which case the observed plane is in true size
2. Line of sight is inclined to edge view in which case the surface is not in true size
   (NOTE: In principal views, the surface is inclined if LOS is inclined to the edge view.)
3. Line of sight is oblique to edge view in which case the surface is not in true size
   (NOTE: In principal views, the surface is oblique if an edge view of the plane is not observed. In other words, the plane appears not in true size in all of the principal planes, and no edge view is observed.)
INFORMATION SHEET

E. Label points, lines, and planes (Transparency 3)

1. Use lower case letters for points
2. Use T for top, F for front, and S for side view

III. Steps for constructing an auxiliary view (Transparency 4)

A. Label points of entire object or certain lines or certain planes where an auxiliary view is needed

Example: Find TS of plane abcde

B. Select line of sight to get desired view

Example: Line of sight is perpendicular to edge view of plane abcde that is to be drawn true size
C. Locate reference or folding line in the adjacent view in either of the following places—back, middle, front, or between views.

(NOTE: When line is between views, it is called a folding line. When line is on the object, it is called a reference line.)

Example: The back is selected in the top view.

D. Draw reference or folding line in an auxiliary view perpendicular to line of sight at an adequate distance from edge of front view.
E. Draw light projection lines from the points of the view parallel to the line of sight

(Note: Projection lines will be perpendicular to reference line.)

Example: Draw projection lines

F. Transfer distances from adjacent view in relation to reference plane using dividers

Example: Transfer points a, e, d. Since b and c are on reference line, mark the points on the reference line.

G. Connect points in auxiliary view that are connected in adjacent view; darken lines

Example: Connect points abcde and back to a

(Note: Notice the similar shape of the surface has 5 lines in the top view and 5 lines in the auxiliary view.)
IV. True length lines and true size planes (Transparencies 5, 6, and 7)

A. True length lines are observed when:

1. The line of sight is perpendicular to a line—an oblique line

\[ \text{Diagram:} \]

2. The folding line is parallel to a line and line of sight is perpendicular to line—an inclined line

\[ \text{Diagram:} \]
3. The line of sight points to the point view of a line.

4. Both lines are parallel to the folding line—a normal line.
B. True size of a plane is observed when: (Transparencies 7 and 8)

1. The line of sight is perpendicular to the edge view of the plane—an inclined plane

2. The folding line is parallel to an edge view—a normal plane
V. Point views of lines and edge views of planes (Transparencies 9 and 10)

A. Point views (PV) of lines are observed when: (Transparency 9)
   1. The line of sight is parallel to true length (TL) lines

   ![Diagram showing point view (PV) of lines]

   2. The folding line is perpendicular to the true length line

   ![Diagram showing point view (PV) of lines with folding line]

B. Edge views (EV) of planes are observed when: (Transparency 10)
   1. The line of sight is parallel to a true length line in the plane

   ![Diagram showing edge view (EV) of planes]
2. The line of sight points to any view of a true size plane, and the results will be edge views.

VI. Rotation characteristics (Transparencies 11, 12, and 13)

(NOTE: Rotation is an easier way to find TL and TS.)

A. The path of rotation of any point not on the axis appears as a circle in a view showing the axis of rotation as a point.

Point "a" is revolved 130° to "a".

Point view of axis

Path of rotation is ⊥ to axis

EV of path of rotation

Axis
INFORMATION SHEET

B. The plane of the path of rotation of any point appears in edge view (EV) and perpendicular to the axis in a view showing the axis of rotation in true length.

C. True lengths by rotation (Transparency 12)

1. A line may be rotated until it is parallel to a principal plane.

2. The line is projected onto the adjacent plane.

3. Since it is parallel to the folding line, it is in true length in the adjacent plane.
INFORMATION SHEET

D. True sizes by rotation (Transparency 13)

1. An edge view may be rotated until it is parallel to an orthographic plane.
2. The edge view is then projected onto the plane and is in true size.

(NOTE: In this example, edge view is found by constructing horizontal line ax in front view and projecting TL line in top view.)

VII. Elements of single curved surfaces (Transparency 14)

A. Cones--Vertex to base
INFORMATION SHEET

Example: Locate point b on surface of cone in side view

1. Project from vertex OF through b to base of cone point W to make element OWF

2. Project point W to side view to base of cone WS and connect OS to WS to make element OWS

3. Project point bF to find answer at element OWS

B. Cylinders-Parallel to center
INFORMATION SHEET

Example: Locate point "a" on surface of cylinder

1. Project element xy through "a" intersecting circles in side view

2. Project intersection of X and Y to adjacent edge view of circles and connect to form element in front view.

   (NOTE: One line is all that is necessary because element is parallel to center of cylinder.)

3. Project point "as" from side view to find answer to problem at element XYF in front view
Methods for finding intersections of surfaces

A. Edge view given (Transparency 15)

Example:

1. When edge views are given, existing piercing points can be readily located and projected.

2. Visibility requires logical thinking of the position of the line of sight and what is near the observer and what is far from the observer.

3. Points 5 and 8 can be observed in top view where line xy intersects the two edge views.

4. Points 8 and 9 can be observed in the side view where the edges of the planes are intersected by cd and kw.
B. Auxiliary view method (Transparency 16)

Example:

1. Construct an auxiliary view to give edges of surfaces
   a. Line zw is in TL in top view
   b. LOS is parallel to TL to give edge views of the planes in the auxiliary view

2. When edges are constructed, piercing points may be readily located and projected

   (NOTE: The two view method can be used to find additional piercing points.)

3. The two view method of piercing points is used to find where line zw and line xy intersect the planes adc and adb

4. Visibility requires logical thinking of the position of the line of sight and what is near the observer and what is far from the observer
C. Cylinders intersecting (Transparency 17)

1. Locate elements on surface of cylinders
2. Find their intersection
3. Use correct visibility

D. Approximate intersections

1. Large diameters--Use radius of larger cylinder

Do not project $x_F$ -- use radius of larger diameter
INFORMATION SHEET

2. Small diameters—Ignore intersection

IX. General groups of developments (Transparency 18)
   A. Radial line (Transparencies 19 and 20)
      Example: Cone, pyramids
   B. Parallel line (Transparencies 21 and 22)
      Example: Cylinders, prisms
   C. Triangulation (Transparency 23)
      Example: Transition pieces, hoppers

X. Bend allowance calculation

   (NOTE: Refer to "Manufacturing Processes", Unit IX of this book for a review of bend allowance.)

Bend allowance measured on neutral axis

A. Calculate for materials thicker than .65 mm
B. Use formula:

$$BA = (.017453R + .0078T)N$$

BA = Bend allowance
R = Radius of bend IML
T = Metal thickness
N = Number of degrees of bend

Example: Radius = .75"
Thickness = .25"
Number of degrees = 130°

$$BA = (0.17453R + .0078T)N$$

$$BA = .017453(.75) + .0078(.25)(130°)$$

$$BA = 1.96"$$
Near and Far Points and Planes
(Observer Looking Down On Top View)

A - Near observer
B - Near observer
C - Far from observer

(Observer Looking On Right Side of Object)

Points a b c d e f g h are near observer
Points x y z w are far from observer
Observing Points and Planes

Point View (a)
Point is what you see of a line

Point View (b)
as a Corner of an Object

Edge View (EV) of Plane

Not True Size

True Size Plane

Observing Points and Planes
Labeling Points, Lines, and Planes

(NOTE: The labeling of points, lines, and planes on this transparency are meant to be supplied by the instructor.)
Steps for Constructing Auxiliary Views

Folding Line Method

1. Line of Sight–LOS
2. Folding Line $\perp$ to LOS
3. Project $\perp$ to Folding Line
4. Transfer Distances
5. Complete the View
True Lengths of Lines

From Line of Sight Being ⊥ to Line

From Folding Line Being Parallel to Line

From Point View
Identifying True Lengths

Normal Line

Inclined Line

Oblique Line
Observing True Size Planes

Line of Sight \( \perp \) To Edge View

Folding Line Parallel to Edge View
Identifying True Sizes

Normal Surface

Inclined Surface

Oblique Surface
Point Views of Lines

Point View of Line

LOS Parallel to TL Line

Folding Line ⊥ to TL Line
Edge Views of Planes

1. Construct TL line af in one view.
2. Find point view of TL line.
3. The result is an edge view of the plane.
Rotation of a Point

Point a rotated 130° counterclockwise about line xy

Edge of path of rotation

Perpendicular to axis

Point view of axis
True Lengths by Rotation

(a) [Diagram showing a rotation for true length calculations]

(b) [Diagram showing another rotation for true length calculations]
True Sizes By Rotation
Elements of Single Curved Surfaces
Intersections With Edge View Given
Intersections Using Auxiliary Views
Intersections of Cylinders

Projection

Small Intersections

Ignore

Approximate
Developments

Bend Lines

True Size

Development

Inside Up

Final Shape

(A) Radial Line

(B) Parallel Line

(C) Triangulation
Radial Line Developments
Pyramids
Radial Line Developments, Cones

"A" Distance may be stepped off, or use the formula

\[ \Theta = \frac{R}{B} \cdot 360^\circ \]
Parallel Line Developments
Prisms

Stretch Out Line
Parallel Line Developments
Cylinders
Triangulation

True Length Diagram

Half Development
ASSIGNMENT SHEET #1 - LABEL POINTS, LINES, AND PLANES IN VIEWS

Directions: Using the drawings accompanying each problem, label all points on the view indicated, and answer the questions. Refer to Transparency 3 for examples.

Problems:

A. Label points on front view

1. How many surfaces are normal?

2. What surface is inclined?
ASSIGNMENT SHEET #1

B. Label points on top view

1. What surfaces are inclined?

2. Do you see the similar surfaces of the inclined surfaces?
   (NOTE: If you don't, ask your instructor for assistance.)

3. Is surface hgutfe normal, inclined, or oblique?

4. Is surface abcdef normal, inclined, or oblique?
C. Label lines indicated

Example:

1. 

2. 

3. 

4.
D. Label projected surfaces indicated

Example:
ASSIGNMENT SHEET #2--IDENTIFY TRUE LENGTHS AND TYPES OF LINES

Directions: Identify true lengths and types of lines for the following problems. An example is included and is to be used as a review of the material covered in the information sheet and Transparencies 4 and 6.

Example:

1. Normal line--Is in its true length in two views and a point view in a third view

2. Inclined line--Is in true length in one view and not in true length in the other two views

3. Oblique or skewed line--Is not in true length in any view
**ASSIGNMENT SHEET #2**

**Problems:** Complete the tables by identifying all true length lines and non-true length lines, and indicate if line is normal, inclined, or oblique.

<table>
<thead>
<tr>
<th>LINE</th>
<th>VIEW TL IS LOCATED</th>
<th>NON-TL</th>
<th>TYPE OF LINE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NORMAL</td>
</tr>
<tr>
<td>ab</td>
<td>Top &amp; Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ef</td>
<td>Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nf</td>
<td>Top &amp; Front</td>
<td></td>
<td></td>
</tr>
<tr>
<td>oj</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>gf</td>
<td>Top &amp; Side</td>
<td></td>
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<tr>
<td>hj</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>id</td>
<td>Front</td>
<td>Top &amp; Side</td>
<td></td>
</tr>
<tr>
<td>eim</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>lm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>og</td>
<td>Top &amp; Front</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
### ASSIGNMENT SHEET #2

<table>
<thead>
<tr>
<th>LINE</th>
<th>VIEW TL IS LOCATED</th>
<th>NON-TL</th>
<th>TYPE OF LINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>cb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>go</td>
<td>Front &amp; Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>he</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>fg</td>
<td>Front &amp; Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fb</td>
<td></td>
<td>Top, Front, &amp; Side</td>
<td></td>
</tr>
<tr>
<td>ab</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gb</td>
<td></td>
<td>Top &amp; Front</td>
<td></td>
</tr>
<tr>
<td>hi</td>
<td></td>
<td>Top &amp; Side</td>
<td></td>
</tr>
<tr>
<td>tu</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ASSIGNMENT SHEET #3-IDENTIFY TRUE SIZES
AND TYPES OF PLANES

Directions: Identify true sizes and types of planes for the following problems. An example is included and is to be used as a review of the material covered in the information sheet and Transparencies 5 and 6.

Example:

1. Normal plane-Is in true size in one view and in edge view in the other two views
ASSIGNMENT SHEET #3

2. Inclined plane: Is not in true size in any regular view but can be observed as two similar surfaces in two views and as an edge in the other view.

\(\text{NOTE: Observe the similar surface with the same number of points and lines. The similar surfaces are not in true size.}\)
ASSIGNMENT SHEET #3

3. Oblique plane - is not in true size in any regular view; it can be observed in three views as similar surfaces.
(NOTE: Observe similar surfaces in all three views.)
Problems: Complete the tables by identifying all true size (TS) planes and non-true size planes, and indicate if plane is normal, inclined, or oblique.

<table>
<thead>
<tr>
<th>PLANE</th>
<th>VIEW TS IS LOCATED</th>
<th>VIEW NON-TS IS LOCATED</th>
<th>VIEW EDGE IS LOCATED</th>
<th>TYPE OF PLANE</th>
</tr>
</thead>
<tbody>
<tr>
<td>cbf</td>
<td></td>
<td></td>
<td>Top</td>
<td></td>
</tr>
<tr>
<td>abcde</td>
<td>Top</td>
<td></td>
<td>Front &amp; Side</td>
<td></td>
</tr>
<tr>
<td>deh</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>tmlu</td>
<td>Top</td>
<td></td>
<td>Top &amp; Side</td>
<td></td>
</tr>
<tr>
<td>bfg</td>
<td>Top &amp; Front</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ASSIGNMENT SHEET #3

<table>
<thead>
<tr>
<th>PLANE</th>
<th>VIEW TS IS LOCATED</th>
<th>VIEW NON-TS IS LOCATED</th>
<th>VIEW EDGE VIEW IS LOCATED</th>
<th>TYPE OF PLANE</th>
</tr>
</thead>
<tbody>
<tr>
<td>abcde</td>
<td></td>
<td></td>
<td>Front &amp; Side</td>
<td></td>
</tr>
<tr>
<td>bgfc</td>
<td></td>
<td></td>
<td>Top &amp; Side</td>
<td>Front</td>
</tr>
<tr>
<td>rst</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mpni</td>
<td>Top</td>
<td></td>
<td>Front &amp; Side</td>
<td></td>
</tr>
<tr>
<td>end</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**

- Top View
- Side View
- Front View
- Plan View

**Legend:**
- TS: True Size
- NON-TS: Non-True Size
- EDGE VIEW: Edge View

**Types of Planes:**
- NORMAL
- INCLINED
- OBLIQUE

---

\[615\]
ASSIGNMENT SHEET #4: CONSTRUCT TRUE LENGTHS OF LINES AND TRUE SIZES OF PLANES USING AUXILIARY VIEWS

Directions: When a line is oblique to any principal view, an auxiliary view is required to find the true length. When a plane is inclined or oblique to any principal view, an auxiliary view is required to find the true size. Construct true lengths of lines and true sizes of planes and label the points.

(NOTE: Refer to "Auxiliary Views", Unit VI of Basic Drafting, Book Two for specific examples.)

Problems:

A. Construct true lengths of the lines marked AB below using auxiliary view method. Label the points, and label the true length lines with TL.

1.  
   ![Diagram 1]

2.  
   ![Diagram 2]

3.  
   ![Diagram 3]

4.  
   ![Diagram 4]
ASSIGNMENT SHEET #4

B. Construct true sizes of planes marked below using auxiliary views. Label the points, and label the true size with TS.

1. 

2. 

3. 

4.
Introduction: In your previous study of orthographic projection and auxiliary views, the related principal views of an object are found by changing the position of the observer. This is the same as saying change the position of the line of sight. Different views of an object can also be obtained by rotating the object while the observer (LOS) stays stationary. This is the same as a fixed-viewing direction (see Transparency 12). Rotation eliminates some of the auxiliary views previously needed. Rotation also adds the problem of confusion from overlapping views. This confusion can be reduced by using different colored pencils, by using overlays, or as in the case of developments, by using true length diagrams.

Directions: Construct true lengths of lines by rotation as outlined in the procedure of the following example.

Example:

1. Select axis of rotation
   a. Any one of the following could be chosen: A, B, C, or D; it must be perpendicular to the folding line
   b. Your choice depends on what view you want TL in and what point you want rotated
   c. In this example, axis "C" was chosen so TL will be in front view
ASSIGNMENT SHEET #5

2. Construct path of rotation perpendicular to axis through the point to be rotated

3. In the adjacent view, construct a path of rotation from "b" to a position where "ab" will be parallel to the folding line; mark new point b' and project to adjacent view

4. Connect "a" to the new b' in the front view; mark it TL

(NOTE: Line ab' is in TL because it has been rotated parallel to the front plane or perpendicular to the LOS.)
Problems:

A. Find TL in front view

B. Find TL in top view

C. Find TL in side view

D. Find TL in front view
E. Find TL of ab and ac

F. Find TL of ab, ac, and ad

TL of ab =  
TL of ac =  

TL of ab =  
TL of ac =  
TL of ad =  
ASSIGNMENT SHEET #6-CONSTRUCT TRUE SIZES OF PLANES BY ROTATION

Directions: Construct true sizes of planes by rotation using the procedure in the following example as a guideline.

Example:

1. Construct or identify edge view of plane as shown in a and b.

2. Select axis of rotation
   a. Any axis could be chosen, but it must be perpendicular to the folding line next to the edge view.
   b. Your choice depends on what points you want to rotate.
ASSIGNMENT SHEET #6

3. Construct the edge of the path of rotation perpendicular to axis through the points to be rotated

![Diagram of path of rotation](image)

a. 

b. 

4. In the edge view, construct a path of rotation from center point to a position parallel to folding line, and mark new point

5. Connect all points forming true size of plane

Problems:

A. 

B. 

623
Directions: Locate elements on the surfaces of the following single curved surfaces to locate point "a" in both views.

Problems:

A. Cones

1. 

2. 

3. 

4. 

(Note: Two answers are possible for problems 3 and 4.)
ASSIGNMENT SHEET #7

B. Cylinders

(NOTE: Two solutions are possible for these problems.)

1.

2.

3.

4.
Assignment Sheet #8: Construct Intersections of Surfaces

Directions: Construct intersections of surfaces using edge views. The procedure in the following example is to be used as a guideline for solving the problems.

Example:

1. Identify and label all edge views (EV) and label all points

   (Note: If edge views are not given, use auxiliary views to find them.)
ASSIGNMENT SHEET #8

2. Observe edge views and circle points at the end of lines that intersect the edge views; these are called piercing points.
   a. Since all three piercing points are not on the same plane, line "be" should also be circled to make the line of intersection continuous.
   b. Circle piercing points where "be" intersects the edges in the side view.

3. Follow the line of intersection between the two objects numbering them as you go.
   a. 1 and 2 are on the same top surface
      (NOTE: Point 5 is hidden and is on the bottom surface.)
   b. Line 2-3 is on the top surface
   c. Line 3-4 is on the bottom surface
   d. Line 4-5 is on the bottom surface
   e. Line 5-1 is on the bottom surface
   f. The line of intersection is continuous ending with the same start point; your ability to visualize is very important in this process.
ASSIGNMENT SHEET #8

4. Project piercing points to front view intersecting corresponding lines; circle intersections

5. Connect piercing points to form line of intersection; use visualizing skills to determine visibility and if lines are near the observer or far from the observer

(NOTE: Points 2 and 4 must be projected from the side view. Another method for finding the piercing point of a line and a plane is the two-view method which will be covered in Assignment Sheet #9.)
Problems:

Construct line of intersection between the parts shown. Circle piercing points and number line of intersection on all views.

A.

B.
ASSIGNMENT SHEET #9: CONSTRUCT INTERSECTIONS OF SURFACES USING TWO-VIEW METHOD

Directions: Use the following example as a guideline for solving the problems of constructing intersections using the two-view method.

Example:

1. Identify and label all edge views if given and label all points

   ![Diagram](image1)

2. Take each line independently and locate its piercing point on the surface

   a. Extend the line until it crosses two lines cb and bd on the plane you expect it to intersect; label intersections #1 and #2

   (NOTE: In this method, the line is marked EV to indicate the edge of an imaginary cutting plane.)

   ![Diagram](image2)
b. Project points 1 and 2 to adjacent front view to intersect lines cb and bd

c. Draw a line between 1 and 2 where it intersects the line Y—that is a piercing point, mark piercing point, and project back to the one that we marked EV
d. Use the same process to locate all piercing points

e. Connect piercing points to form line of intersection; use visualizing skills to determine visibility and if lines are near the observer or far from the observer.
ASSIGNMENT SHEET #9

Problems: Construct line of intersection between the parts shown. Use two-view method where appropriate. Circle piercing points and number line of intersection on all views.

A.

B.
Introduction: The objective of constructing sheet metal developments is to draw a true size flat pattern of the surface to be folded to the desired form. Edges are joined by seams, rivets, welding, soldering, and other means. Edge lengths should be kept to a minimum for economy and ease of handling. (Transparencies 19 and 20)

Directions: Construct radial line developments of pyramids, truncated pyramids, right circular cones, and oblique cones. An example is included for each of these.

Example A: Pyramids

1. Label all points, true length lines, and true size surfaces

2. Find the true lengths of each inclined or oblique lines by rotation using the vertex as the axis

3. Decide where the seams will be located

4. Layout the surfaces in true size inside out
5. Complete the development making bend lines thin lines

(NOTE: Notice the use of the diagonal distance "K" to transfer the rectangle.)

Example B: Truncated pyramids

1. Label all points, true length lines, and true size surfaces

2. Find the true lengths of each inclined or oblique line by rotation using the vertex as center

3. Since the object does not go to the vertex, project the intermediate distances perpendicular to the axis of rotation to obtain correct true lengths
ASSIGNMENT SHEET #10

4. In more complicated drawings a true length diagram is used to keep the drawing from becoming confusing.

5. Layout the largest surfaces in true size inside up.

6. Layout the smaller true lengths on the true length lines on the development.

7. Complete the development making bend lines thin lines.
ASSIGNMENT SHEET #10

Example C: Right circular cones

1. Label all points, true length lines, and true size surfaces
   (NOTE: This example does not have any true size surfaces.)

2. Divide circular base into equal parts (normally every 15° or 30°) and draw the cone elements to the vertex; number each point

3. Project elements to the front view and draw to the vertex

4. Using the true length of the side of the cone as the radius, construct a semi-circle
5. Use the following formula to compute the number of degrees of the semi-circle for a half development

\[ \theta = \frac{1}{2} \left( \frac{R}{B} \right) \times 360° \]

(Note: In this example, \( R = 10 \); \( B = 20 \).

\[ \theta = \frac{1}{2} \left( \frac{10}{20} \right) \times 360° \]

\[ \theta = 90° \]

(Note: When the formula is used, the elements must be stepped off with dividers to divide the arc equally.)

6. An alternate method, not as accurate, can be used:
   a. Step the chord distance from 0 to 1, etc. around the semi-circle
   b. Construct the larger circle with a bow compass
   c. Layout the smaller true lengths on the developed true length lines
   d. Connect all points with an irregular curve
   e. Complete the development by darkening all lines
Example D  Oblique cones

1. Label all points, true length lines, and true size surfaces
   (NOTE: This example does not have any true size surfaces.)

2. Divide circular base into equal parts and draw the cone elements to the vertex; number each point

3. Construct a true length diagram by rotating points on the right side of the drawing
   (NOTE: This helps to prevent confusion.)
ASSIGNMENT SHEET #10

4. Project all elements intersection of the inclined surface to the TL diagram; this will give the correct length for the cut.

5. Layout one true length element at a time and one circular radius between elements at a time.

6. Connect all points using an irregular curve.
ASSIGNMENT SHEET #10

7. Layout the smaller true lengths on the developed true length lines

8. Connect all points with an irregular curve

9. Complete the development by darkening all lines

Problems:

1. Construct each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing and the development. Add dimensions as instructed.

2. Make a blueline print of the drawing and cut the pattern out with scissors.

3. Tape or glue development together to form three dimensional part.

   (NOTE: This is a good time to check your work.)

4. Hand in both the original and the object to your instructor.
ASSIGNMENT SHEET #10

A.

60mm

40mm

10mm
Directions: Construct parallel line developments of right prisms, oblique prisms, right circular cylinders, and oblique cylinders on "B" size media. Examples for each of these are included to be used as guidelines for solving the problems.

Example A: Right prisms

1. Label all points, true length lines, and true size surfaces

(Note: All lines are in true length except the inclined lines. Since the base is perpendicular to the octagon shaft, the corners formed on the planes are 90°. The top view is a right section of the base. When you have a right section, the solution to the problem is to transfer distances from the right section on a stretch out line.)
ASSIGNMENT SHEET #11

2. Project from the right section to the right hand area all true length vertical lines.

3. On the EV of the right section, mark off the true lengths of the base; this line is called stretch out line.

(Note: If a right section is not given, construct a right section perpendicular to the true length lines.)

4. Draw the lines from the points on the base until they connect to the common points such as 2 connects to K.

5. Complete the development making bend lines thin lines.
Example B: Oblique prisms

1. Label all points, true length lines, and true size surfaces

   (NOTE: This example has no true length lines or true size surfaces.)

2. To develop an oblique prism that has no true length sides given, construct an auxiliary view to find the true lengths of the parallel sides
3. Construct a true right section at a convenient location perpendicular to the TL of the parallel lines

(NOTE: This view is an edge view of the section.)

4. Construct the true size of the right section by constructing the line of sight parallel to the true length lines
ASSIGNMENT SHEET #11

5. In a convenient location draw a horizontal stretch out line
6. Transfer the true lengths of the sides from the TS right section view
7. Construct vertical lines through the points
8. Transfer true lengths of sides from the EV of the right section to the vertical lines
9. Complete the development making bend lines thin lines
Example C Right circular cylinders

1. Label all points, true length lines, and true size surfaces

2. By observation, the base of the cylinder is in true size in the top view

3. Divide circular base into equal parts (normally every 15° or 30°)

4. Project points (actually end view of elements) to front view and draw the elements parallel to the center line

5. Project horizontal stretch out line from EV of right section

6. Transfer distances from top view from point 0 to stretch out line

(Note: The distance laid out is 1/2 circumference.)
7. Project vertical lines from each point on stretch out line

8. Project points from inclined top edge of elements in front view to corresponding elements in development area

9. Complete the developments by connecting points with an irregular curve

Example D: Oblique cylinders

1. Label all points, true length lines, and true size surfaces

2. To develop an oblique prism that has no true length center line given, construct an auxiliary view to find the true length of the center line
3. Construct a true right section at a convenient location perpendicular to the TL of the center line.

(NOTE: This view is an edge view of the section.)

4. Construct the true size of the right section by constructing the line of sight parallel to the TL of the center line.

5. Divide the ellipse right section into equal parts and project back to view with TL center line; these lines are elements of the cylinder and are in TL.
ASSIGNMENT SHEET #11

6. In a convenient location, draw a horizontal stretch out line

7. Transfer the distances between the point view of the elements in the TS right section view to the stretch out line

8. Project vertical lines from each point on the stretch out line.

9. Transfer TL of elements from the EV of the right section to the vertical lines.

10. Complete the view using an irregular curve.

Problems

1. Construct a development for each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing with all construction lines and the development. Add dimensions as required by instructor.

2. Make a blueline print of the drawing and cut the pattern out with scissors.

3. Tape or glue development together to form three dimensional part.

(NOTE: This is a good time to check your work.)

4. Hand in both the original and the object to your instructor.
B. Transfer dimensions to "B" size media. Part is inclined at an angle of 25° to wall.

Opening in wall

Floor

Opening in floor

Wall

Floor

2.5mm

50mm

4mm

90°
INTRODUCTION: Many surfaces cannot be developed by the radial line or parallel line methods. Some of these other surfaces can be developed or approximately developed using triangulation. As the name triangulation implies, this method divides surfaces into triangles which can be easily constructed. (Transparency 22)

EXAMPLE: Is this four-sided figure ABCD a flat plane? It looks to be, but when we examine the diagonal lines, we find they do not intersect!

The plane constructed in Figure 1 is not a true flat plane but is, in fact, a warped plane.

To construct a four or more sided plane, we must first divide the surface into triangles, then project the triangles to the adjacent view including the intersection of the diagonals. Line ax is extended to locate point C. The resulting four-sided figure is a flat plane.

This concept is important when constructing drawings. The optical illusion of a flat plane with four or more sides is easy to draw. Always construct oblique planes with three or more sides using this triangulation method.
Directions: Construct plane surfaces and transition pieces using triangulation on "B" size media. Examples are included to be used as guidelines for solving the problems.

Example A. Plane surfaces by triangulation

1. Label all points, true length lines, and true size surfaces

![Diagram of plane surface hopper](image)

(NOTE: This plane surface hopper is not part of a pyramid and cannot be developed using radial line or parallel line methods.)

2. Divide each surface into triangles

![Diagram of divided surfaces](image)

3. Set up a true length diagram next to the front view to prevent confusion in the front view

![Diagram of true length diagram](image)

4. Project the height (H) directly to the true length diagram; this is the same as saying, project the edge view of the path of rotation

![Diagram of true length projection](image)
ASSIGNMENT SHEET #12

5. Transfer directly to the true length diagram the distance (W) that is normally rotated until it is parallel to the folding line.

6. Label all lines correctly on the TL diagram for future use.

7. Select an open area on the drawing to start the development; allow lots of space.

8. Take true length dimensions of each triangle from those given and those of the TL diagram.

9. Construct the triangles forming the sides of the surfaces; always start with the shortest side.

10. Complete the development adding bend lines.

Example B: Transition piece by triangulation

1. Label all points, true length lines, and true sizes.

(Note: This transition piece goes from a circular part to a rectangular part.)
2. Divide the circle into equal parts (normally 15° to 30° increments)

3. Draw common elements in both views forming triangle surfaces from the circle to the rectangle

4. Observe the number of true lengths that must be found

5. Determine where seam will be, this should be the shortest connection

6. Construct TL of all elements by using a TL diagram or other means
7. Select an open area to start the development

8. Starting with the seam, develop inside out by constructing triangles of each surface

9. Take true length dimensions of each triangle from the chord distance on the circle, those TL given, and those found on the TL diagram

10. Complete the development adding bend lines
ASSIGNMENT SHEET #12

Problems:

1. Construct each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing and the development. Add dimensions as instructed.

2. Make a blue line print of the drawings and cut the pattern out with scissors.
   (NOTE: Half patterns will need to be doubled.)

3. Tape or glue development together to form three dimensional part.
   (NOTE: This is a good time to check your work.)

4. Hand in both the original and the object to your instructor.
Assignment Sheet #1

The labeling of all problems should be evaluated to the satisfaction of the instructor.

A. 1. 12
2. abcdef

B. 1. yzvj, abcdef, klminop, ghdc
2. Yes
3. Normal
4. Inclined

C. D Evaluated to the satisfaction of the instructor.

Assignment Sheet #2

A.

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Assignment Sheet #3

### A.

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(NOTE: All other assignment sheets are to be evaluated to the satisfaction of the instructor.)
1. Match the terms on the right with the correct definitions.

   a. The exact, measurable view of the exact length of a line found by observation, projection, or calculation
   b. The exact measurable view of the exact size of a surface found by observation, projection, or calculation
   c. A pattern of the true sizes of unfolded or unrolled surfaces arranged to be folded to the desired shape
   d. An additional amount of material necessary when making a bend
   e. The development of objects that can be developed due to elements radiating from a single point or vertex
   f. The development of objects that can be developed due to parallel elements on these surfaces
   g. A method of developing surfaces not possible by the parallel line or radial line methods
   h. A ruled surface that cannot be developed
   i. A cutting plane perpendicular to an axis of a three dimensional form
   j. A diagram of the true lengths projected from the normal views
   k. Ruled lines on the surface of geometric shapes
   l. A surface which has no straight line elements and cannot be developed
   m. Any surface generated by straight lines
   n. A ruled surface generated by a straight line that can be developed
   o. The intersection of a circular cone and a plane

   1. Mold line
   2. Radial line development
   3. Double curved surface
   4. Transition piece
   5. Folding line
   6. True length diagram
   7. Shrink templates
   8. Bend line
   9. Rotation
   10. True size of a surface
   11. Single curved surface
   12. Development
   13. Right section
   14. Triangulation
   15. Stretch out line
p. A line that is perpendicular to each element on which a parallel line development is unrolled or unfolded
q. A piece that connects two differently shaped conductors
r. Original and complete developments of parts used for reference and checking
s. Contour templates made with a shrink scale for die maker and foundry
t. Templates to exact contour of part used for checking parts at production stages
u. Where bend starts
v. The intersection of two adjacent surfaces
w. Drilled or routed holes at intersection of bends to relieve strain which would cause metal to crack or buckle
x. A method of projection in which the observer stays stationary and the object is rotated for different views of the object
y. A reference line normally between two views representing the edge of a plane of projection

2. Distinguish between visualization of near and far points and planes by placing an "X" next to the near points and planes.

Figure 1

---

Observer looking on right side view

\[ \text{842} \]
3. Arrange in order the steps for constructing an auxiliary view by placing the correct sequence numbers in the appropriate blanks.

   a. Draw reference or folding line in auxiliary view perpendicular to line of sight at an adequate distance from edge of front view

   b. Connect points in auxiliary view that are connected in adjacent view; darken lines

   c. Label points of entire object or certain lines or certain planes where an auxiliary view is needed.

   d. Locate reference or folding line in the adjacent view in either of the following places—back, middle, front, or between views

   e. Draw light projection lines from the points of the view parallel to the line of sight

   f. Transfer distances, from adjacent view in relation to reference plane using dividers

   g. Select line of sight to get desired view
Identify true length lines and true sizes of three-view drawings by marking TL on true lengths and TS on true sizes.
5. Identify point views of lines and edge views of planes by marking PV on point view and EV on edge view.

6. Select true statements concerning important characteristics of rotation by placing an "X" in the appropriate blanks.

(NOTE: All parts of the statement must be true before you place an "X" by that statement. If one part is false, the whole statement is considered false.)

a. The path of rotation of any point not on the axis appears as a rectangle in a view showing the axis of rotation as a point

b. The plane of the path of rotation of any point appears in edge view (EV) and perpendicular to the axis in a view showing the axis of rotation in true length

c. In true lengths by rotation,
   1) A line may be rotated until it is parallel to a principal plane
   2) The line is projected onto the adjacent plane
   3) Since it is parallel to the folding line, it is in true length in the adjacent plane

d. In true sizes by rotation,
   1) An edge view may be rotated until it is parallel to an orthographic plane
   2) The edge view is then projected onto the plane and is foreshortened in size
7. Select elements of single curved surfaces by placing an "X" next to those that are elements.

[Diagrams of curved surfaces with labeled elements]

8. List two methods for finding intersections of surfaces.
   a. ____________________________________________
   b. ____________________________________________

9. Name three general groups of developments.
   a. ____________________________________________
   b. ____________________________________________
   c. ____________________________________________

10. Calculate bend allowance when a metal has a thickness of .45", radius of .80", and the number of degrees is 125°. Use the following formula and show all calculations.

    \[ BA = (0.017453R + 0.0078T) N \]

    \[ BA = \]
11. Demonstrate the ability to:
   a. Label points, lines, and planes in views.
   b. Identify true lengths and types of lines.
   c. Identify true sizes and types of planes.
   d. Construct true lengths of lines and true sizes of planes using auxiliary views.
   e. Construct true lengths of lines by rotation.
   f. Construct true sizes of planes by rotation.
   g. Locate elements of single curved surfaces.
   h. Construct intersections of surfaces.
   i. Construct intersections of surfaces using two-view method.
   j. Construct radial line developments.
   k. Construct parallel-line developments.
   l. Construct special developments using triangulation.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
SHEET METAL DEVELOPMENTS
UNIT X

ANSWERS TO TEST

1. a. 17  h. 25  n. 11  t. 21
   b. 10  i. 13  o. 23  u. 8
   c. 12  j. 6  p. 15  v. 1
   d. 16  k. 19  q. 4  w. 18
   e. 2  l. 3  r. 24  x. 9
   f. 22  m. 20  s. 7  y. 5
   g. 14

2. a, c, e, f

3. a. 4  e. 5
   b. 7  f. 6
   c. 1  g. 2
   d. 3

4. a.

b.

c.

d.
5. a.

6. b, c

7. a, c

8. Any two of the following:
   a. Edge view given
   b. Auxiliary view method
   c. Cylinders intersecting
   d. Approximate intersections

9. a. Radial line
   b. Parallel line
   c. Triangulation

10. BA = 2.18"

11. Evaluated to the satisfaction of the instructor
POWER TRANSMISSION
UNIT XI

UNIT OBJECTIVE

After completion of this unit, the student should be able to construct various gear and cam drawings. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:
1. Match terms related to power transmission with the correct definitions.
2. Distinguish between advantages of chain drives and gear drives.
3. Distinguish between advantages of chain drives and belt drives.
4. Arrange in order the steps for selecting a V-belt drive.
5. Complete a list of major types of power transmission chains.
6. Match axes positions with the correct types of gears.
7. Identify parts of gear teeth.
8. Identify parts of pinion and gear.
9. Name cutting data needed for spur gear drawings.
10. Identify parts of a bevel gear.
11. Complete a list of cutting data needed for bevel gears.
12. Distinguish between cutting data needed for worm and cutting data needed for worm wheel.
13. Calculate gear ratio.
15. Calculate gear speed.
16. List two types of couplings.
17. Distinguish between types of bearings.
18. Identify cam nomenclature.
19. Identify types of cam followers.

20. Select types of cam motions.

21. Match hydraulic nomenclature with the correct definitions.

22. Match basic pneumatic components with the correct functions.

23. Distinguish between air circuit components.

24. Demonstrate the ability to:
   a. Construct a spur gear drawing.
   b. Construct a bevel gear.
   c. Construct a worm and worm gear.
   d. Calculate gear ratios.
   e. Determine gear rotation.
   f. Calculate gear speeds.
   g. Construct a cam drawing.
   h. Select a chain drive.
   i. Select a V-belt drive.
   j. Select types of bearings from handbooks.
POWER TRANSMISSION
UNIT XI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.
II. Provide student with information and assignment sheets.
III. Make transparencies.
IV. Discuss unit and specific objectives.
V. Discuss information and assignment sheets.
VI. Set up a display of various power transmission elements.
VII. Allow students to assemble elements where practical.
VIII. Visit and tour a power transmission manufacturing plant. Observe the manufacture of various components such as cams, gears, and chains.
IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet
B. Information sheet
C. Transparency masters
   1. TM 1-Outside Diameter of Small V-Pulley
   2. TM 2-RPM and Diameter of Driven V-Pulley
   3. TM 3-Belt Length
   4. TM 4-Types of Gears
   5. TM 5-Gear Tooth Terms
   6. TM 6-Parts of Pinion and Gear
   7. TM 7-Working Drawing of a Spur Gear
   8. TM 8-Bevel Gear Nomenclature
   9. TM 9-Working Drawing of Bevel Gear
  10. TM 10-Worm and Worm Gear
11. TM 11-Working Drawings of Worm and Worm Gear
12. TM 12-How Gears Change Direction of Rotation
13. TM 13-A Diagram of Gears Used to Change Speed
14. TM 14-Cam Nomenclature
15. TM 15-Types of Cam Followers
16. TM 16-Uniform Motion
17. TM 17-Uniform Motion-Cam Profile
18. TM 18-Modified Motion
19. TM 19-Parabolic Motion
20. TM 20-Parabolic Motion-Cam Profile
21. TM 21-Parabolic Motion-Construction Method
22. TM 22-Harmonic Motion
23. TM 23-Harmonic Motion-Cam Profile
24. TM 24-Combination of Motions
25. TM 25-Basic Hydraulic and Pneumatic Components

D. Assignment sheets
1. Assignment Sheet #1-Construct a Spur Gear Drawing
2. Assignment Sheet #2-Construct a Bevel Gear
3. Assignment Sheet #3-Construct a Worm and Worm Gear
4. Assignment Sheet #4-Calculate Gear Ratios
5. Assignment Sheet #5-Determine Gear Rotation
6. Assignment Sheet #6-Calculate Gear Speeds
7. Assignment Sheet #7-Construct a Cam Drawing
8. Assignment Sheet #8-Select a Chain Drive
9. Assignment Sheet #9-Select a V-Belt Drive
10. Assignment Sheet #10-Select Types of Bearings from Handbooks.

E. Answers to assignment sheets
F. Test
G. Answers to test
II. References:


III. Additional references:


POWER TRANSMISSION
UNIT XI

INFORMATION SHEET

I. Terms and definitions
A. Gear drive--Toothed wheel/meshing with another toothed wheel
B. Belt drive--Endless flexible belt on pulleys
C. Chain drive--Endless chain on sprockets
D. Couplings--Devices for joining shafts together
E. Clutches--Devices for stopping or starting a machine without stopping the prime mover
F. Brakes--Devices for slowing or stopping power driven shafts
G. Flexible shafts--Devices used to transmit power around corners and different angles when the driver and driven shafts are not lined up
H. Speed reducer--Any device used to reduce the speed of the output device (driver)
I. Bearings--Machine parts used to lessen friction
J. Cams--Machine elements designed to produce a specific motion
K. Linkages--Motion and function generators
L. Hydraulics--Liquid is used as power transmission
M. Pneumatics--Compressed air is used as power transmission
N. Idler--As a gear it serves to fill up space and reverse direction; as a pulley it serves to take up slack
O. Countershaft (Jack shaft)--A second motion or intermediate shaft in a power transmission system
P. Seals--Parts used to protect ball or roller bearings from loss of lubricant and entrance of dust and dirt on bearings
Q. Bushing--A liner forced in a hole to provide a better wearing or bearing surface and to provide for easy renewal
   (NOTE: Bushings are commonly made from brass or bronze and are sometimes called bearings.)
R. Power train--Revolving components involved in the transmission of power from the engine to the drive wheel
S. Gear ratio--The number of revolutions the drive gear must make to turn the driven gear one revolution
INFORMATION SHEET

T. Splines—Multiple keys in the general form of internal and external gear teeth, used to prevent rotation of a shaft

U. Gear reduction—A combination of gears used to reduce the input speed to a lower output speed

II. Advantages of chain drives and gear drives

A. Advantages of chain drive over gear drive
   1. Center to center distance is not restricted
   2. Easy to install due to greater tolerances
   3. Ease of changes in design
   4. Better shock absorbing
   5. Wear is reduced
   6. Faster changing

B. Advantages of gear drive over chain drive
   1. Where space limitations are important, center to center of gears can be shortest distance
   2. Maximum speed ratio can be greater
   3. Higher RPM can be obtained
   4. Generally more practical at higher RPM and higher horsepower

III. Advantages of chain drives and belt drives

A. Advantages of chain drive over belt drive
   1. Does not slip or creep; no power lost
   2. Lower loads on bearings due to slack
   3. Occupies less overall space
   4. Easier to install
   5. Better for synchronism for several shafts
   6. No static electricity; thus no fire hazard
   7. Does not deteriorate with age
   8. Operates at higher temperature
   9. Slower elongation due to wear
INFORMATION SHEET

B. Advantages of belt drive over chain drive
   1. No lubrication except belt dressing for flexibility
   2. Generally operates with less noise
   3. For extremely long distances, flat belts work well
   4. For extremely high speeds, belts can be used
   5. Less vibration

IV. Steps for selecting a V-belt drive
   A. Decide whether belt will be used on light, normal, or heavy duty equipment
      1. If belt is for light duty, multiply horsepower rating by 1.20; then use normal duty tables
         Example: Light duty equipment include dishwashers, clotheswashers, fans, blowers
      2. If belt is for normal duty, use normal duty tables
         Example: Normal duty equipment include drill presses, power lawn mowers, heating and ventilating fans, generators, buffers
      3. If belt is for heavy duty, multiply horsepower rating by .85; then use normal duty tables
         Example: Heavy duty equipment include metal working machines, compressors, lathes, grinders, industrial machines
   B. Select outside diameter of small V-pulley (Transparency 1)
   C. Select driven V-pulley diameter (Transparency 2)
   D. Determine belt length (Transparency 3)

V. Major types of power transmission chains
   A. Roller
   B. Offset sidebar
   C. Double pitch
   D. Pintle
   E. Detachable
   F. Bead
   G. Inverted tooth
INFORMATION SHEET

VI. Axes positions and types of gears (Transparency 4)

A. Axes intersect
   1. Spiral bevel (miter) gear
   2. Plain (straight) bevel gear
   3. Hypoid gear

B. Axes are parallel
   1. Spur gear
   2. Helical gear
   3. Planetary (internal) gear
   4. Herringbone gear

C. Axes do not intersect
   1. Worm and worm gear
   2. Helical gear

D. Axes do not intersect and straight line motion converts to circular motion and vice versa—Rack and pinion gear

VII. Parts of gear teeth (Transparency 5)

A. Face width
B. Circular pitch
C. Circular thickness
D. Dedendum
E. Addendum
F. Whole depth
G. Chordal addendum
H. Root diameter
I. Pitch diameter
J. Outside diameter
VIII. Parts of pinion and gear (Transparency 6)
A. Line of action
B. Pressure angle
C. Clearance
D. Working depth
E. Center distance
F. Pitch circle

IX. Cutting data needed for spur gear drawings (Transparency 7)
A. Number of teeth
   Formula: Number of teeth = Pitch diameter x Diametral pitch
B. Pitch diameter
   Formula: Pitch diameter = \( \frac{\text{Number of teeth}}{\text{Diametral pitch}} \)
C. Diametral pitch
   Formula: Diametral pitch = \( \frac{\text{Number of teeth}}{\text{Pitch diameter}} \)
D. Pressure angle
   Formula: Pressure angle = 14 1/2° or 20°
E. Whole depth
   Formula: Whole depth = \( \frac{2.157}{\text{Diametral pitch}} \)
F. Chordal addendum
   Formula: Chordal addendum = Addendum + \( \frac{(1.57/\text{Diametral pitch})^2}{4 \times \text{Pitch diameter}} \)
G. Chordal thickness
   Formula: Chordal thickness = Pitch diameter \( \frac{(\sin 90°)}{\text{No. of teeth}} \)
INFORMATION SHEET

X. Parts of a bevel gear (Transparency 8)
   A. Cone distance
   B. Face
   C. Back angle
   D. Pitch diameter
   E. Crown backing
   F. Backing
   G. Mounting distance
   H. Addendum angle
   I. Dedendum angle
   J. Outside DIA
   K. Pitch angle
   L. Root angle
   M. Face angle
   N. Addendum
   O. Whole depth
   P. Dedendum
   Q. Pinion—Smaller of mating gears
      (NOTE: See ANSI B6.13: 1965 for more details.)

XI. Cutting data needed for bevel gears (Transparency 9)
   A. Number of teeth in pinion—n
   B. Number of teeth in gear—N
   C. Diametral pitch—P
   D. Pressure angle and form—Basic is 20° = φ
      (NOTE: 14 1/2° pressure angle can be used, but certain combinations of
      teeth must be used to avoid undercutting.)
   E. Addendum for gear = \( \frac{1}{Diametral \ pitch} \) or select from table
      (NOTE: Use Machinery’s Handbook for table.)
INFORMATION SHEET

F. Addendum--for pinion = Working depth x Addendum for gear

G. Addendum = \frac{1}{\text{Diametral pitch}}

H. Root angle--R = Pitch angle - Dedendum angle

I. Face angle--F = Pitch angle - Addendum angle

J. Whole depth--W = Addendum + Dedendum

(Note: This is the same for pinion and gear.)

K. Chordal Addendum for Pinion--C_p = Addendum for Pinion +
Circular thickness for pinion x Cosine of pitch angle of pinion
\frac{4 \times \text{Pitch diameter of pinion}}{4 \times \text{Pitch diameter of pinion}}

L. Chordal Addendum for Gear--C_g = Addendum for gear +
Circular thickness for gear - Cosine of pitch angle of pinion
\frac{4 \times \text{Pitch diameter of gear}}{4 \times \text{Pitch diameter of gear}}

M. Chordal Thickness--C_t = Circular thickness of Pinion --
\left(\frac{\text{Circular thickness of Pinion}}{6\text{(Pitch diameter of Pinion)}}\right)^2 - \frac{\text{Select from Table}}{2}

(Note: Select value from table in Machinery's Handbook.)

XII. Cutting data needed for worm and worm wheel (gear) (Transparencies 10 and 11)

A. Cutting data for worm

1. Number of threads--n

2. Pitch--P

3. Pitch diameter--D = (2.4 x Pitch) + 1.1

(Note: This is a recommended value.)

4. Lead and direction--Distance thread moves in one revolution; RH or LH

(Note: In a single thread, lead = pitch; in a double thread, lead = 2 pitch.)

5. Lead angle--Tangent = \frac{\text{Lead}}{(\text{Pitch diameter})}

6. Pressure angle--20° or 14 1/2°

7. Whole depth--W = 0.686 x Pitch
INFORMATION SHEET

8. Outside diameter--OD = Pitch diameter + .636 x Pitch

9. Face length--F = Pitch (4.5 + \( \frac{\text{Numbers of teeth on gear}}{50} \))

B. Cutting data for worm wheel (gear)

1. Number of teeth--n

2. Pitch--P

3. Pitch diameter--D = Pitch \( \frac{\text{number of teeth}}{\pi} \)

4. Addendum--a = .3183 x Pitch

5. Whole depth--W = .686 x Pitch

6. Number of threads = t

7. Lead and direction--Distance thread moves in one turn; RH or LH

8. Lead angle--tangent \( \theta = \frac{\text{Lead}}{\pi(Pitch \text{ diameter})} \)

9. Pressure angle--20° or 14 1/2°

10. Throat diameter--TD = Pitch diameter + .636 x Pitch

11. Outside diameter--OD = Throat diameter + .4775 x Pitch

12. Face radius--R_f = 1/2 Pitch diameter of worm - .318 x Pitch

13. Rim radius--R_r = 1/2 Pitch diameter of worm + Pitch

14. Face width--F = 2.38 x Pitch + .25

15. Center distance--C = 1/2 (Pitch Diameter of wheel + Pitch diameter of worm)

XIII. Calculating gear ratios

A. Count number of teeth on driving gear and teeth on driven gear

B. Divide the number of teeth of the driven gear by the number of teeth of the driving gear

Example: If a driven gear has 60 teeth and a driving gear has 20 teeth, the gear ratio is \( \frac{60}{20} = 3 \), or driving gear turns 3 times to one turn of driven gear.
INFORMATION SHEET

XIV. Determining gear rotation (Transparency 12)
   A. Gears are used to change the direction of power transmitted
   B. Gear rotation is determined by a driving gear turning in one direction (clockwise) which turns a driven gear in the opposite direction (counterclockwise)

XV. Calculating gear speed (Transparency 13)
   A. A small gear will drive a large gear more slowly but with greater torque
   B. A large gear will drive a small gear faster but with less torque
   C. Formula to find gear speed: R.P.M. x No. of Teeth of driving gear = R.P.M. x No. of Teeth of driven gear

Example: If a gear with 20 teeth revolves at 500 R.P.M. and drives a gear with 40 teeth, how many R.P.M. would the gear with 40 teeth make?

\[
500(20) = X(40) \\
10,000 = 40X \\
250 = X \quad \text{Answer is 250 R.P.M.}
\]

XVI. Types of couplings
   A. Permanent
      Example: Flexible, solid, universal, and fluid
   B. Clutches
      Example: Mechanical, electric, and hydraulic

XVII. Types of bearings
   A. Plain bearings
      1. Radial
      2. Thrust
      3. Guide or slipper
   B. Antifriction bearings
      1. Ball
      2. Roller
      3. Needle
      4. Thrust
INFORMATION SHEET

XVIII. Cam nomenclature (Transparency 14)
A. Follower
B. Base circle
C. Pressure angle
D. Trace point
E. Prime circle
F. Pitch circle
G. Direction of motion

XIX. Types of cam followers (Transparency 15)
A. Pointed
B. Roller
C. Flat face
D. Special
E. Swinging

XX. Types of cam motions (Transparencies 16-24)
A. Uniform
B. Modified
C. Parabolic
   1. Uniformly accelerated and retarded method
   2. Construction method
D. Harmonic
E. Combination
F. Cycloidal

XXI. Hydraulic nomenclature and definitions (Transparency 25)
A. Tank--Reservoir to hold fluid
B. Pump--Device to force liquid through system
C. Valves--Parts to control flow and pressure
D. Cylinder or motor--Device to convert fluid energy into mechanical force
E. Filters and strainers--Parts to clean fluid
F. Accumulator--A cylinder in which fluid is stored under pressure and used to meet fluctuating demands
G. Gages--Instruments to measure pressure, temperature, or flow

XXII. Basic pneumatic components and functions (Transparency 25)
A. Pressure gage--Indicates pressure
B. Filter--Removes dirt and water
C. Compressor--Compresses the air
INFORMATION SHEET

D. Receiving tank--Stores compressed air
E. Regulator--Keeps air pressure within an acceptable range
F. Lubricator--Lubricates the operating components of a system

XXIII. Air circuit components

A. Control elements (power valves)
   1. 2-way
   2. 3-position

B. Power elements
   1. Cylinders
   2. Air motors
# Outside Diameter of Small V-Pulley

## HORSEPOWER RATINGS

<table>
<thead>
<tr>
<th>RPM of small pulley</th>
<th>outside diameter of small v-pulley— inches</th>
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<tbody>
<tr>
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<td>1.75</td>
</tr>
<tr>
<td>200</td>
<td></td>
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**NOTE:** This table incorporates a service factor of 1.3. For heavy duty, multiply normal duty horsepower rating by .85. For light duty, multiply normal duty horsepower rating by 1.20.

Courtesy of T. B. Wood's Sons Company
### RPM and Diameter of Driven V-Pulley

#### Driven Speeds for 1160 RPM Motors

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<tr>
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<th>1.50</th>
<th>1.75</th>
<th>2.00</th>
<th>2.25</th>
<th>2.50</th>
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*Courtesy of T. B. Wood's Sons Company*
### Belt Length

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<th>Take-Up</th>
<th>Belt Length</th>
<th>sum of both V-belt pulley diameters</th>
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**Belt Length**

*Courtesy of T. B. Wood's Sons Company*
Types of Gears

- Straight Spur
- Helical Spur
- Herringbone
- Plain Bevel
- Spiral Bevel
- Hypoid
- Planetary
- Worm
- Rack and Pinion

Courtesy of Deere & Company, Moline, IL
Gear Tooth Terms

- Chordal Thickness
- Face Width
- Circular Pitch
- Circular Thickness
- Dedendum
- Addendum
- Whole Depth
- Chordal Addendum
- Root Dia
- Pitch Dia
- Outside Dia
Working Drawing of a Spur Gear

CUTTING DATA

| NO. OF TEETH | 48  |
| PITCH DIAMETER | 12.00 |
| DIA PITCH | 4.00 |
| PRESSURE ANGLE | 14\(\frac{1}{2}\)° |
| WHOLE DEPTH | .5395 |
| CHORDAL ADD | .25 |
| CHORDAL THICK | .3927 |
| WORKING DEPTH | .5000 |
| CIRCULAR THICK | .3927 |
Bevel Gear Nomenclature

- Addendum
- Whole Depth
- Dedendum
- Face
- Cone Distance
- Pitch Angle
- Root Angle
- Face Angle
- Pitch Diameter
- Web Thickness
- Hub Projection
- Backing
- Crown Height
- Mounting Distance
Working Drawing of Bevel Gear

CUTTING DATA

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<td>CHORD THICK</td>
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Worm and Worm Gear

Face Length
Addendum
Whole Depth

Pitch Dia
Outside Dia
Center Distance

Outside Dia
Throat Dia
Pitch Dia

Face
Rim
Radius
Radius
Working Drawings of Worm and Worm Gear

Worm

MILL TO 50% THREAD WIDTH
FAO - GRIND THREAD FLANKS

CUTTING DATA

| NO. OF THREADS | 2 |
| PITCH DIA     | 2.533 |
| AXIAL PITCH   | 0.625 |
| LEAD - RH     | 1.250 |
| LEAD - ANGLE  | 8°56' |
| PRESSURE ANGLE| 14½° |
| WHOLE DEPTH   | 0.429 |

Worm Gear

CUTTING DATA

| NO. OF TEETH | 30 |
| PITCH DIA    | 5.967 |
| ADDENDUM     | 0.199 |
| WHOLE DEPTH  | 0.429 |
| NO. of THREADS| 2 |
| AXIAL PITCH  | 0.625 |
| LEAD - RH    | 1.250 |
| LEAD ANGLE   | 8°56' |
| PRESS. ANGLE | 14½° |
How Gears Change Direction of Rotation

Clockwise (C) Counter Clockwise (CC)

Driver

Input Power

Output Power

Clockwise (C) Counter Clockwise (CC) Clockwise (C)
A Diagram of Gears Used to Change Speed

Driver

56 Teeth

1200 RPM

1292.3 RPM

52 Teeth

1527.3 RPM

44 Teeth
Cam Nomenclature

- Base Circle
- Cam Profile
- Pitch Circle
- Trace Point
- Direction of Motion
- Follower
- Pressure Angle
- Normal
- Tangent
- Pitch Point
- Pitch Circle

Diagram showing the components of cam nomenclature.
Types of Cam Followers

Pointed  Roller  Flat Face  Special

Cams with Swinging Followers
Uniform Motion

Cam Displacement Angle

Follower Displacement "y"

0° 30° 60° 90° 120° 150° 180°

0 1 2 3 4 5 6
Uniform Motion - Cam Profile

$R = \frac{1}{4}$ to $\frac{1}{2}$ DP

Modified True Uniform

Follower Displacement

Base Circle

Followed Displacement

Base Circle

$0^\circ$, $60^\circ$, $120^\circ$, $180^\circ$, $240^\circ$, $300^\circ$, $360^\circ$
Modified Motion

NOTE: Radius (R) varies between 1/3 to full rise depending upon how sharp the rise is.
Parabolic Motion

Uniformly Accelerated & Retarded Method

Cam Displacement Angle

Follower Displacement "y"

0°  30°  60°  90°  120°  150°  180°

0  1  2  3  4  5  6

1°  30°  60°  90°  120°  150°  180°

3  5  1  3  5  1
Parabolic Motion

Construction Method

Follower Displacement, \( Y \)

Cam Displacement Angle

\[
\frac{Y}{6}
\]
Harmonic Motion

Cam Displacement Angle

Follower Displacement “Y”
Harmonic Motion - Cam Profile

Base Circle

Follower Displacement
Combination of Motions

Harmonic Motion  Dwell  Uniform Motion  Dwell

Base Circle

Cam Profile  Harmonic Motion  Dwell  Base Circle

Uniform Motion

Dwell

90°  120°  150°  180°  210°  240°  270°  300°  330°  360°
Basic Hydraulic and Pneumatic Components

Hydraulic

4-Way Valve

Pressure Instrument

Electric Motor

Hydraulic Pump

Filter

Reservoir

Pneumatic

Compressor

Airline

Air Receiving Tank (Raw Air)

Filter

Lubricator

Pressure Gage

To Tools or Cylinders

Conditioned Air Out

Drain

Regulator
POWER TRANSMISSION
UNIT XI.

ASSIGNMENT SHEET #1--CONSTRUCT A'SPUR GEAR DRAWING

Directions: Select one of the following problems, and construct a spur gear drawing as shown in the example. Use "B" size vellum or other media assigned by instructor. Include cutting data table and dimensions. Use the following formulas to solve the incomplete cutting data in the problems:

1. No. of teeth = Pitch diameter x Diametral pitch

2. Pitch diameter = \( \frac{\text{No. of teeth}}{\text{Diametral pitch}} \)

3. Diametral pitch = \( \frac{\text{No. of teeth}}{\text{Pitch diameter}} \)

4. Whole depth = \( \frac{2.157}{\text{Diametral pitch}} \)

5. Chordal addendum = Addendum + \( \frac{(1.57/\text{Diametral pitch})^2}{4(\text{Pitch diameter})} \)

6. Chordal thickness = Pitch diameter \( \frac{(\sin 90^\circ)}{\text{No. of teeth}} \)

(NOTE: Your instructor may wish for you to do both problems or assign another problem.)
Example:

![Diagram of a gear with dimensions and cutting data](image)

**CUTTING DATA**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Teeth</td>
<td>48</td>
</tr>
<tr>
<td>Pitch Diameter</td>
<td>12.00</td>
</tr>
<tr>
<td>Dia. Pitch</td>
<td>4.00</td>
</tr>
<tr>
<td>Pressure Angle</td>
<td>14°</td>
</tr>
<tr>
<td>Whole Depth</td>
<td>5395</td>
</tr>
<tr>
<td>Chordal Add</td>
<td>25</td>
</tr>
<tr>
<td>Chordal Thick</td>
<td>3927</td>
</tr>
<tr>
<td>Working Depth</td>
<td>5000</td>
</tr>
<tr>
<td>Circular Thick</td>
<td>3927</td>
</tr>
</tbody>
</table>
ASSIGNMENT SHEET #1

Problems:

A. Spur gear
   1. Hub thickness - 1.5"
   2. Hub diameter - 2.19" at crown
   3. Hub diameter - 2" at face
   4. Web thickness - .31"
   5. Web width at hub - .75"
   6. Outside diameter - 6.4
   7. Inside diameter - 5.0
   8. Req - 1.000/1.002 and keyway - 1/4 x 1/8
   9. Cutting data
      a. Number of teeth - 30
      b. Pitch diameter - 6.000
      c. Diametral pitch - 5.0
      d. Pressure angle - 14 1/2°
      e. Whole depth - .431
      f. Chordal addendum

B. Spur gear
   1. Hub thickness - 2.00
   2. Hub diameter - 3.00 at crown
   3. Hub diameter - 2.85 at face
   4. Web thickness - .50
   5. Web width at hub - 1.50
   6. Web width at gears - .88
   7. Outside diameter - 12.25
   8. Inside diameter - 8.5
ASSIGNMENT SHEET #1

9. Cutting data
   a. Number of teeth - 96
   b. Pitch diameter
   c. Diametral pitch - 8
   d. Pressure angle - 14 1/2°
   e. Whole depth
   f. Chordal addendum
POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #2: CONSTRUCT A BEVEL GEAR

Directions. On "B" size vellum or other media assigned by instructor, construct a bevel
gear drawing from the information in problem A. Include a cutting data table and dimen-
sions as shown in the example. On a second sheet of vellum or other media, complete the
information in problem B. Use the following formulas to complete the data in problem B.

1. Number of teeth in pinion—n
2. Number of teeth in gear—N
3. Diametral pitch—P
4. Pressure angle and form—Basic is 20° =
   (NOTE: 14 1/2° pressure angle can be used, but certain combinations of teeth must
   be used to avoid undercutting.)
5. Addendum for gear = \( \frac{1}{\text{Diametral pitch}} \) or select from table
   (NOTE: Use Machinery's Handbook for table.)
6. Addendum for pinion = Working depth • Addendum for gear
7. Addendum for pinion = \( \frac{1}{\text{Diametral pitch}} \)
8. Root angle—R = Pitch angle • Dedendum angle
9. Face angle—F = Pitch angle • Addendum angle
10. Whole depth—W = Addendum + Dedendum
   (NOTE: This is the same for pinion and gear.)
11. Chordal Addendum for Pinion—\( C_p = \text{Addendum for pinion} + \)
    Circular thickness for pinion • Cosine of pitch angle of pinion
    4 • Pitch diameter of pinion
12. Chordal Addendum for Gear—\( C_g = \text{Addendum for gear} + \)
    Circular thickness for gear • Cosine of pitch angle of pinion
    4 • Pitch diameter of gear
13. Chordal Thickness—\( C_T = \text{Circular thickness of pinion} - \)
    \( \frac{(\text{Circular thickness of pinion})^3}{6(\text{Pitch diameter of pinion})^2} \) • Select from Table
ASSIGNMENT SHEET #2

Example

CUTTING DATA

<table>
<thead>
<tr>
<th>Gear/Pinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Teeth</td>
</tr>
<tr>
<td>DIA Pitch</td>
</tr>
<tr>
<td>Tooth Form</td>
</tr>
<tr>
<td>Addendum</td>
</tr>
<tr>
<td>Root Angle</td>
</tr>
<tr>
<td>Whole Depth</td>
</tr>
<tr>
<td>Chordal Add</td>
</tr>
<tr>
<td>Chordal Thick</td>
</tr>
</tbody>
</table>

5.375

56° 19'

33° 41'

52° 48'

Problems:

(A Note: Your instructor may wish to assign an alternate problem.)

A. Bevel gear—Draw gear only

1. Number of teeth - 20
2. Diametral pitch - 5
3. Pressure angle - 14 1/2° INV
4. Addendum - 0.20
5. Root angle - 40° 25'
6. Whole depth - 0.431
7. Chordal addendum - 0.204
8. Outside diameter - 4.282
9. Pitch angle - 48°
10. Pitch diameter - 4"
11. Chordal thickness - 0.314
12. Backing - 0.707
13. Back angle - 42°
14. Face - 0.9375
15. Face angle - 53° 03'
17. Mounting distance - 2.563
18. Hole size - 0.875 DIA
19. Hub size - 1.5 DIA
20. Web thickness - 0.5625
21. Hub projection - 0.1875
22. Material - Cast Iron
Complete the following cutting data table using the given information.

<table>
<thead>
<tr>
<th>CUTTING DATA</th>
<th>Gear</th>
<th>Pinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Teeth</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Diametral Pitch</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Pressure Angle</td>
<td>14 1/2°</td>
<td></td>
</tr>
<tr>
<td>Whole depth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root angle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face angle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chordal Thickness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Addendum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
POWER-TRANSMISSION  
UNIT XI  

ASSIGNMENT SHEET #3—CONSTRUCT A WORM AND WORM GEAR

Directions: On "B" size vellum or other media assigned by instructor, construct a worm gear. Include cutting data table and dimensions. On a second sheet of media, construct a worm. Use the following formulas to solve the incomplete cutting data in the problems.

A. Cutting data for worm

1. Number of threads—n
2. Pitch—P
3. Pitch diameter—\( D = (2.4 \times \text{Pitch}) + 1.1 \)
   (NOTE: This is a recommended value.)
4. Lead and direction—Distance thread moves in one revolution; RH or LH
   (NOTE: In a single thread, lead = pitch, in a double thread, lead = 2 pitch.)
5. Lead angle—\( \tan \theta = \frac{\text{Lead}}{n(\text{Pitch diameter})} \)
6. Pressure angle—20° or 14 1/2°
7. Whole depth—\( W = .686 \times \text{Pitch} \)
8. Outside diameter—\( OD = \text{Pitch diameter} + .636 \times \text{Pitch} \)
9. Face length—\( F = \text{Pitch} \left(4.5 + \frac{\text{Number of teeth on gear}}{50}\right) \)

B. Cutting data for worm wheel (gear)

1. Number of teeth = n
2. Pitch—P
3. Pitch diameter—\( D = \text{Pitch} \left(\frac{\text{number of teeth}}{\text{number of teeth}}\right) \)
4. Addendum—\( a = 3.183 \times \text{Pitch} \)
5. Whole depth—\( W = .686 \times \text{Pitch} \)
6. Number of threads = t
7. Lead and direction—Distance thread moves in one turn; RH or LH
8. Lead angle—\( \tan \theta = \frac{\text{Lead}}{m(\text{Pitch diameter})} \)
ASSIGNMENT SHEET #3

9. Pressure angle--20° or 14 1/2°
10. Throat diameter--TD = Pitch diameter + .636 x Pitch
11. Outside diameter--OD = Throat diameter + .4775 x Pitch
12. Face radius--RF = 1/2 Pitch diameter of worm - .318 x Pitch
13. Rim radius--Rr = 1/2 Pitch diameter of worm + Pitch
14. Face width--F = 2.38 x Pitch + .25
15. Center distance--C = 1/2(Pitch diameter of wheel + Pitch diameter of worm)

Problems:

(NOTE: Your instructor may wish to assign an alternate problem.)

A. Worm data--Complete data and draw
   1. Number of threads per inch - 2
   2. Pitch - .500
   3. Pressure angle - 14 1/2°
   4. Lead angle - 7° 53'
   5. Right hand lead - 1
   6. Whole depth
   7. Addendum - .159
   8. OD - 2.618
   9. Pitch diameter - 2.3
   10. Face length

   (NOTE: Gear has 36 teeth.)

B. Worm wheel data--Complete data and draw
   1. Number of teeth - 36
   2. Addendum - .159
   3. Whole depth - .343
   4. Number of threads - 2
   5. Pitch - .500
ASSIGNMENT SHEET #3

6. Pressure angle - 14 1/2°
7. Lead angle - 7° 53'
8. Right hand lead - 1
9. OD - 6.287
10. Throat diameter -
11. Pitch diameter -
12. Face radius - .99 R
13. Rim radius -
14. Hub width - 2"
15. Hub diameter - 2.125
16. Hole in hub -
   1.004
   1.000
17. Keyway - 1 1/4 x 1/8
18. Web thickness - .5
ASSIGNMENT SHEET #4–CALCULATE GEAR RATIOS

Directions: Using the information sheet, calculate the gear ratio of the gears below and write the correct answers in blanks provided.

Problems:

A. Calculate gear ratio from information given

1. Driven gear has 9 teeth
   Driving gear has 36 teeth
   What is the gear ratio?

2. Driven gear has 36 teeth
   Driving gear has 48 teeth
   What is the gear ratio?

3. Driven gear has 36 teeth
   Driving gear has 12 teeth
   What is the gear ratio?

4. Driven gear has 50 teeth
   Driving gear has 50 teeth
   What is the gear ratio?

B. Calculate gear ratio from illustrations below

1. [Diagram of gears with teeth counts]

2. [Diagram of gears with teeth counts]
POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #5: DETERMINE GEAR ROTATION

Directions: Calculate gear rotation by indicating with an arrow the direction in which the driven gears are turning.

Problems:
A. 

B. 

Driving Gear

Driving Gear
ASSIGNMENT SHEET #5

C.

Drive Gear

---
POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #6--CALCULATE GEAR SPEEDS

Directions: Calculate the direction of rotation, the gear ratio, and the RPM of each driven gear. Write answers in the blanks provided. For rotation, use C for clockwise and CC for counterclockwise.

Problems:

<table>
<thead>
<tr>
<th></th>
<th>Rotation</th>
<th>Ratio</th>
<th>R.P.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Gear A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Gear B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Gear C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Gear D</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C Gear
48 Teeth

A Gear
60 Teeth

B Gear
20 Teeth

D Gear
40 Teeth

Driving Gear
3600 R.P.M.

30 Teeth
ASSIGNMENT SHEET #6

<table>
<thead>
<tr>
<th></th>
<th>Rotation</th>
<th>Ratio</th>
<th>R.P.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.</td>
<td>Gear E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F.</td>
<td>Gear F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.</td>
<td>Gear G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H.</td>
<td>Gear H</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Gear F: 24 Teeth
- Gear G: 20 Teeth
- Gear H: 30 Teeth
- Gear E: 10 Teeth
- Driving 1200 RPM
POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #7--CONSTRUCT A CAM DRAWING

Directions: On "B" size vellum or other media assigned by instructor, construct a cam drawing profile and displacement diagram for one of the following problems.

Problems:

(NOTE: Your instructor may wish to assign a different problem.)

A. Cam

1. Harmonic rise 0° through 90° to .75"
2. Dwell 90° through 180° through 360°
3. Harmonic drop 180° through 360°
4. Follower displacement 1.5"
5. Roller follower diameter .5"
6. Ream .875" .3/16 x 3/32 keyway
7. Thickness .50"

B. Cam

1. Parabolic rise 0° through 60° to 1.25"
2. Dwell 60° through 90°
3. Parabolic rise 90° through 150° to 2.00"
4. Harmonic drop 150° through 260° to 1.00"
5. Modified uniform motion 260° to 360°
6. Direction of rotation--Clockwise
7. Ream .625" 1/2 x 1/4 keyway
8. Thickness .50"
Directions: In order to select a chain drive, you will need the charts which are included at the end of this assignment sheet. Use the following example as a guideline for solving the problems.

Example problem: Select a roller chain drive to transmit 5 HP from a countershaft to the main shaft of a barking drum of a paper mill. The input is on an electric motor operating to a countershaft at 1200 RPM. Both shafts are 1.5" in diameter to be located approximately 22 1/2" from center to center. The barking drum puts uneven demands on the output shaft. A design of 378 to 382 RPM on the output is needed.

Example solution:

1. Determine load classification
   a. Go to load classification chart (Table 1)
   b. Locate paper mills
   c. Under paper mills, locate barking drum
   d. Read to the right under the load classification column to find "heavy shock"
      (NOTE: Uneven demands on the output shaft help to classify it as heavy shock.)

2. Determine service factor
   a. Go to service factor chart (Table 2)
   b. Under load classification, find heavy shock
   c. Read to the left under electric motor for the service factor of 1.5

3. Determine design HP
   a. Multiply the application of horsepower by the service factor to obtain equivalent design HP
   b. \( 5 \times 1.5 = 7.5 \text{ HP} \)
      (NOTE: For stainless steel chains, multiply the design HP by a factor from the application condition table, Table 3.)

4. Determine chain size
   a. Go to chain selection table (Table 4)
ASSIGNMENT SHEET #8

b. Find the intersection of the columns of design horsepower at 7 1/2 and RPM of smaller sprocket at 1200
   (NOTE: 1200 RPM falls into the category of 1150-1399 RPM.)

c. Chain size is #40

5. Determine minimum size sprocket
   a. Go to HP ratings for ANSI roller chains table (Table 5)
   b. Using chart for No. 40 and 1/2" pitch, read down 1200 RPM column to 7.27
      (NOTE: This is as close to your design HP of 7.5 as there is.)
   c. Read left on 7.27, column to 19 teeth
      (NOTE: Check the maximum bore to accommodate the 1 1/2" shafts.)

6. Calculate speed ratio
   a. Maximum input RPM = 1200 RPM
   b. Maximum output RPM = 382 RPM
   c. Speed ratio is 3.12 RPM minimum

7. Find center-distance and length
   a. Using Speed ratio chart (Table 6), read down teeth on driver sprocket column to 19
   b. Read across ratio on 19 to a number close to your ratio of 3.12; this is 3.16 on the chart
   c. Read up from 3.12 to see that there are 60 teeth on the driven sprocket
   d. Center distance (CD) in same box with 3.12 is 23.332
   e. Length in same box with 3.12 is 88
      (NOTE: Center distance and length are expressed in pitches in this chart. You will need to convert these to feet or inches.)

8. Convert pitches to inches
   a. Length x pitch = 88 x 1/2
   b. Chain length in inches = 44"
   c. Center distance x pitch = 23.332 x 1/2
   d. Center distance in inches = 11.67"
      (NOTE: Stop here if center to center distance is not important.)
ASSIGNMENT SHEET #8

9. Calculate chain length for center to center distance
   a. Since a set center distance has been established of 22 1/2" in this problem, the following calculations must be made to determine the chain length
   b. Chain length in pitches = \( \frac{2 \times \text{set center distance}}{\text{Pitch}} \)
      
      \[ \text{Total number teeth on both sprockets + constant} \times \frac{2}{2} \]

   *Constant
   If ratio is up to 4:1, use 2
   4 to 6:1, use 4
   6 to 8:1, use 6
   (NOTE: Ratio in this example is 3.12 which is up to 4:1, so use 2.)

   c. Chain length in pitches = \( \frac{2 \times (22.5)}{.5} + \frac{19 + 60}{2} + 2 \times \frac{1}{2} \)
      
      = \( \frac{45.0}{.5} + \frac{79}{2} + 2 \times \frac{1}{2} \)

      = 90 + 39.5 + 2 = 131.5
      (NOTE: Round to 132 pitches since 22 1/2" center distance is not absolutely critical.)

   d. Chain length in inches = Chain length in pitches x pitch
      
      = 132 \times (.5) \times 2

      = 66" chain length at 22.5" approximate center distance
      (NOTE: It must be remembered that more than one combination of sockets and chain will give acceptable results.)

Problems:

A. A conveyor belt, uniformly loaded is to be driven at approximately 40 RPM by a speed reducer powered by a 5 HP electric motor. The output shaft is 1 5/8" diameter reduced to 100 RPM by a speed reducer. The shaft diameter of the conveyor belt is 1 7/8". Select a center distance of not greater than 27". Select a chain length and center distance.

B. A rotary gear type of lubrication pump in a hydraulic press is driven from a 1 3/8" diameter shaft at 750 RPM. The driver rated at 3 HP has a shaft diameter of 1 1/4", operating at 1200 RPM, center distance must not be less than 12". Select a center distance and belt length.
# ASSIGNMENT SHEET #8

## Table 1

### Load Classification Chart

<table>
<thead>
<tr>
<th>Type of Machine to be Driven</th>
<th>Table 1</th>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load Classification</td>
<td>Class of Service Number</td>
</tr>
<tr>
<td></td>
<td>(For Horizontal &amp; Radial &amp; Reversing Reductions)</td>
<td>3 to 10 Hours Day Service</td>
</tr>
<tr>
<td>Actuation</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Lash</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Spindle</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Elevator</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Gearbox</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Geared Units</td>
<td>s or h</td>
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<tr>
<td>Open Driving</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Closed Driving</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Universal Couplings</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Coupling Units</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Coupling Units</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Geared Units</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Open Driving</td>
<td>s or h</td>
<td>s or h</td>
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<tr>
<td>Closed Driving</td>
<td>s or h</td>
<td>s or h</td>
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<td>Universal Couplings</td>
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<td>Coupling Units</td>
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<tr>
<td>Coupling Units</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Geared Units</td>
<td>s or h</td>
<td>s or h</td>
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<tr>
<td>Open Driving</td>
<td>s or h</td>
<td>s or h</td>
</tr>
<tr>
<td>Closed Driving</td>
<td>s or h</td>
<td>s or h</td>
</tr>
</tbody>
</table>

Courtesy of Boston Gear/Incom International Inc.
ASSIGNMENT SHEET #8

Table 1 (Continued)

<table>
<thead>
<tr>
<th>Table #1 Load Classification</th>
<th>Table #2 Class of service number</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Helical Base-Mounted Reducers, Worm Gear Reducers &amp; Ratemotors and Roller, Chain-Drive</td>
<td>For Helical Shaft-Mounted Reducers &amp; Ratemotors and Base-Mounted Ratemotors</td>
</tr>
<tr>
<td>Type of Machine to Be Driven</td>
<td>3 to 10 hours-day service</td>
</tr>
<tr>
<td><strong>Helical Reducers</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Reversing</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Screw</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Gearboxes</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Central Casters</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Drum-Mounted</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Conveyor</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Hammer Mills</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Bolts</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Machines, Drums, and Drives</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Nuts</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Pipe Plungers</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Other Machine Tools</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Machine Tools</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Plunging Machines</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>For Helical Shaft-Mounted Reducers &amp; Ratemotors and Base-Mounted Ratemotors</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Medium Loads</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Universal Load</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Overhead Cranes</strong></td>
<td>Moderate Shock</td>
</tr>
<tr>
<td><strong>Metal Mills</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Draw Bench, Carriage and Stand</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>Wiring</strong></td>
<td>Heavy Shock</td>
</tr>
<tr>
<td><strong>1900 Cylinders</strong></td>
<td>Heavy Shock</td>
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<tr>
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<td><strong>Wire Drawing and Braiding Machines</strong></td>
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<td><strong>Wire Welding Machines</strong></td>
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<tr>
<td><strong>Casters, Casters, and Casters</strong></td>
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<td><strong>Pumps</strong></td>
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<tr>
<td><strong>Mils</strong></td>
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<td><strong>Intermittent Dams</strong></td>
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<td><strong>Variable Decks</strong></td>
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<td><strong>Paper Mills</strong></td>
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<td><strong>Hydrostatics - Axles</strong></td>
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<tr>
<td><strong>Bolts, Mains, and Dams</strong></td>
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<td><strong>Rack and Pinion</strong></td>
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<td><strong>Covering Machines</strong></td>
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<td><strong>For End Cams, Plungers</strong></td>
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<td><strong>Conveyors</strong></td>
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<td><strong>Drawers</strong></td>
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Courtesy of Boston Gear/Incom International Inc.
## ASSIGNMENT SHEET #8

### Table 1 (Continued)

#### Load Classification Chart

<table>
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<tr>
<th>Type of Machine to Be Driven</th>
<th>Table 1 Load Classification</th>
<th>Table 2 Class of Service Number</th>
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<td></td>
<td>For Helical Base-Mounted Reducers, Worm Gear Reducers &amp; Ratiometers and Roller Chain-Drive</td>
<td>For Helical Shaft-Mounted Reducers &amp; Ratiometers and Base-Mounted Ratiometers</td>
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<td>3 to 10 hours/day service</td>
<td>Over 10 hours/day service</td>
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<td>Cutting Planes</td>
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<td>Grinding Mills</td>
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<tr>
<td>Milling Machines</td>
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<td>III</td>
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<tr>
<td>Drill Machines</td>
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<td>Sand Blast</td>
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<td>Presses</td>
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<td>Sheet Metal</td>
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<tr>
<td>Machine Tools</td>
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<td>Printing Presses</td>
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<td>Door and Window</td>
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<td>Sewage Disposal Equipment</td>
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<td>Winding</td>
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| Table 2 Service Factor Table

### Table 2

#### Type of Input Power

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<th>Load Classification</th>
<th>Internal Combustion Engine With Hydrostatic Drive</th>
<th>Electric Motor With Mechanical Drive</th>
<th>Internal Combustion Engine With Mechanical Drive</th>
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Courtesy of Boston Gear/Incom International Inc.
### Table 3
Application Conditions Table for Stainless Steel Chains

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</tbody>
</table>

Courtesy of Boston Gear/Incom International Inc.
# Assignment Sheet #8

## Table 5

HP Ratings for ANSI Roller Chains Table

### HP Ratings - Standard Single Strand Rollerless Chain - No 25 - 1/4" Pitch

<table>
<thead>
<tr>
<th>Small Sprocket</th>
<th>HP Ratings - STANDARD SINGLE* STRAND ROLLERLESS CHAIN - NO 25 - 1/4&quot; PITCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPM</td>
<td>10</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>12</td>
<td>0.62</td>
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<tr>
<td>15</td>
<td>0.59</td>
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<tr>
<td>18</td>
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<tr>
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### HP Ratings - Standard Single Strand Rollerless Chain - No 25 - 3/8" Pitch

<table>
<thead>
<tr>
<th>Small Sprocket</th>
<th>HP Ratings - STANDARD SINGLE* STRAND ROLLERLESS CHAIN - NO 25 - 3/8&quot; PITCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPM</td>
<td>10</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------------------------------------------------------------</td>
</tr>
<tr>
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</tbody>
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**Ratings for Intermediate Numbers of Teeth or RPM May Be Obtained by Interpolation**

Courtesy of Boston Gear/Incom International Inc.
ASSIGNMENT SHEET #8

Table 5 (continued)

<table>
<thead>
<tr>
<th>RPM</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
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RATINGS FOR INTERMEDIATE NUMBERS OF TEETH OR RPM MAY BE OBTAINED BY INTERPOLATION

Courtesy of Boston Gear/Incom International Inc.
**ASSIGNMENT SHEET #8**

Table 5 (continued)

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<th>Small Sprocket</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
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RATINGS FOR INTERMEDIATE NUMBERS OF TEETH OR RPM MAY BE OBTAINED BY INTERPOLATION

Courtesy of Boston Gear/Incom International Inc.
### Table 6 - Speed Ratio Chart

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<th>Teeth on Input Sprocket</th>
<th>Teeth on Output Sprocket</th>
<th>SPEED RATIOS</th>
<th>CENTER DISTANCES</th>
<th>CHAIN LENGTHS</th>
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 Courtesy of Boston Gear/Incom International Inc.
### SPEED RATIOS - CENTER DISTANCES - CHAIN LENGTHS

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*Courtesy of Boston Gear/Incom International Inc.*
Directions: Using the tables included in Transparencies 1, 2, and 3, select V-belt drives for the problems which follow. An example is included to be used as a guideline for solving the problems.

Example problem: 1/3 HP, 1750 RPM motor for a drill press having a spindle speed of 1000 RPM. Center to center distance 20". Type belt needed is V-belt.

Example solution:

1. Decide whether belt will be used on light, normal, or heavy duty equipment; a drill press for this example is normal duty so use normal duty tables

   (NOTE: If equipment is light duty, multiply horsepower rating by 1.20. If it is heavy duty, multiply by .85.)

2. Select outside diameter of small V-pulley

   a. Using table on Transparency 1, go across from 1750 RPM to the .38 column; the .38 is a conversion from 1/3 HP; that is, 1/3 = .33 and .38 is closest to .33
   b. Read up from .38 to the top of the column to get 2.50" outside diameter of the small V-pulley for the motor
   c. Since the background area is white, the belt cross section is "A", 1/2" wide by 5/16" thick

3. Select driven V-pulley diameter

   a. Using table on Transparency 2 under "Driven Speeds for 1750 RPM Motors", read across the top row until the 2.50" column is reached; the 2.50" is the outside diameter of the small V-pulley for the motor
   b. Read down the 2.50" column until you come to the nearest RPM of the desired speed of 1000 RPM; the nearest RPM to 1000 RPM is 1050 RPM
   c. Read in the row to the left of the 1050 RPM until you come to the first column entitled "Driven V-Pulley O.D. Inches"; your answer is 4.0"; the 4.0" is the outside diameter of the driven V-pulley

4. Determine belt length

   a. Add the diameters of the small pulley and the driven (larger) pulley
   
   
   
   2.5 + 4.0 = 6.5

   b. Using table on Transparency 3, select the number on the top row of the table closest to the sum of 6.5; your selection should be 6 1/2"
ASSIGNMENT SHEET #9

c. Read down the 6'1/2" column to the first number just below the shaded area; this number is the ideal center to center distance of 6.8"

d. Read across the row to the left of 6.8" to column "Belt Length" which gives you a 24" belt length; the 24" belt length would be the ideal belt length

e. Our problem has a center to center distance of 20"; proceed down the 6 1/2" column to the closest to 20", which is the 19.9"
f. Read across the top to the left of the 19.9" to find the belt length of 50"

Problems:

A. A one horsepower, 1160 RPM motor is to operate a generator. The generator is connected to a pulley by a V-belt. The generator pulley must rotate approximately 600 RPM. The center to center distance is to be 14". Calculate the size of the V-belt required.

B. A 1750 RPM, 3/4 horsepower motor is used to drive a 500 RPM flywheel connected to a punch press. Center to center distance is 17". The motor pulley is connected to a pulley on the flywheel shaft. Calculate the size of the V-belt required.
ASSIGNMENT SHEET #10: SELECT TYPES OF BEARINGS FROM HANDBOOKS

Directions: Select types of bearings for the following problems using available bearing handbooks and the table included at the end of this assignment sheet. An example is given to be used as a guideline for solving the problems. The following is a list of general considerations for selecting bearings.

1. Choose roller bearings for larger sizes and heavier loads because they are less expensive than ball bearings.
2. Choose ball bearings for smaller sizes and lighter loads because they are less expensive than roller bearings.
3. Under shock or impact loading, roller bearings are more satisfactory than ball bearings.
4. Use a self-aligning or spherical roller bearing when there is misalignment between housing and shaft.
5. Ball thrust bearings should be used for pure thrust loads only.
6. Use a deep groove or angular contact ball bearing for high speeds or pure thrust loads.
7. For long operating periods without attention, the deep-groove ball bearing is available with seals built into the bearings.

Example problem: Select a light inch ball bearing from a handbook that would satisfy the following design needs:

1. Maximum speed = 5800 RPM
2. Dynamic load rating = 3400 lbs.
3. Static load rating = 1800 lbs.

What is the bore size and outside diameter size?

(NOTE: Experience has shown that actual failure of ball bearings has been due to fatigue. Calculation of rating life, basic load rating, and other factors will be found in a machine design class.)

Example solution:

1. Locate light inch ball bearings from mechanical components handbook or Table 1
2. Read down the limiting speed column for 5800 RPM; notice it falls between 5600 and 6300
3. Choose 6300 RPM which is LS 13 1/2
ASSIGNMENT SHEET #10

4. Read down the dynamic load rating column for 3400 lbs.; notice it falls between 3350 and 4050 lbs.

5. Choose 4050 lbs. which is LS 12

6. Read down the static load rating column for 1800 lbs. which is LS 10

7. Decide which bearing will satisfy the extreme conditions and yet satisfy the other conditions
   a. Choose the largest load either dynamic or static as the controlling factor
   b. The LS 12 bearing number at 4050 lbs. dynamic load is chosen
   c. The 1800 lbs. static load is within the static load rating of 2750 lbs.
   d. The limiting speed of 8000 RPM covers the 5800 RPM expected speed

8. Bore size is 1 1/4"; outside diameter is 2 3/4"

Problems:

A. Select a light inch ball bearing from a handbook that would satisfy the following design needs:
   1. Maximum speed = 3400 RPM
   2. Dynamic load rating = 7500 lbs.
   3. Static load rating = 9150 lbs.

   What is the bore size and outside diameter size?

B. Select a light inch ball bearing from a handbook that would satisfy the following design needs:
   1. Maximum speed = 2200 RPM
   2. Dynamic load rating = 4800 lbs.
   3. Static load rating = 1375 lbs.

   What is the bore size and outside diameter size?
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*Courtesy of FAG Bearings Corporation*
POWER TRANSMISSION
UNIT XI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Drawing evaluated to the satisfaction of the instructor
   Chordal addendum = .575
B. Drawing evaluated to the satisfaction of the instructor
   Pitch diameter = 12
   Whole depth = .2697
   Chordal addendum = .2008

Assignment Sheet #2

A. Drawing evaluated to the satisfaction of the instructor
B. CUTTING DATA

<table>
<thead>
<tr>
<th></th>
<th>Gear</th>
<th>Pinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teeth</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Diametral Pitch</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Pressure angle</td>
<td>14 1/2°</td>
<td></td>
</tr>
<tr>
<td>Whole depth</td>
<td>.4314</td>
<td></td>
</tr>
<tr>
<td>Root angle</td>
<td>52.6°</td>
<td>30.4°</td>
</tr>
<tr>
<td>Face angle</td>
<td>59.5°</td>
<td>36.9°</td>
</tr>
<tr>
<td>Chordal Thickness</td>
<td>.314</td>
<td>.314</td>
</tr>
<tr>
<td>Addendum</td>
<td>.2</td>
<td></td>
</tr>
</tbody>
</table>

Assignment Sheet #3

A. Drawing evaluated to the satisfaction of the instructor
   Whole depth = .343
   Face length = 2.61
B. Drawing evaluated to the satisfaction of the instructor
   Throat diameter = 6.048
   Pitch diameter = 5.730
   Rim radius = 1.650 R

Assignment Sheet #4

A. 1. 25:1
   2. 75:1
   3. 3:1
   4. 5:1
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #5

A.

![Diagram of gear arrangement with driving gear labeled](image)

B.

![Diagram of gear arrangement with driving gear labeled](image)

C.

![Diagram of gear arrangement with drive gear labeled](image)

Assignment Sheet #6

<table>
<thead>
<tr>
<th>Gear</th>
<th>CC</th>
<th>Rotation</th>
<th>Ratio</th>
<th>R.P.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Gear A</td>
<td>C</td>
<td>2:1</td>
<td>1800</td>
</tr>
<tr>
<td>B.</td>
<td>Gear B</td>
<td>C</td>
<td>3:1</td>
<td>5400</td>
</tr>
<tr>
<td>C.</td>
<td>Gear C</td>
<td>C</td>
<td>8:1</td>
<td>2250</td>
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<tr>
<td>D.</td>
<td>Gear D</td>
<td>CC</td>
<td>83:1</td>
<td>2700</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gear</th>
<th>CC</th>
<th>Rotation</th>
<th>Ratio</th>
<th>R.P.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.</td>
<td>Gear E</td>
<td>CC</td>
<td>16:1</td>
<td>7200</td>
</tr>
<tr>
<td>F.</td>
<td>Gear F</td>
<td>CC</td>
<td>40:1</td>
<td>3000</td>
</tr>
<tr>
<td>G.</td>
<td>Gear G</td>
<td>C</td>
<td>83:1</td>
<td>3600</td>
</tr>
<tr>
<td>H.</td>
<td>Gear H</td>
<td>CC</td>
<td>50:1</td>
<td>2400</td>
</tr>
</tbody>
</table>
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #7--Evaluated to the satisfaction of the instructor

Assignment Sheet #8

A. 1. Load classification--uniform
   2. Service factor = 1
   3. Using 100 RPM and 5 HP, select chain #80 from Chain selection table
   4. On HP Rating table and using 100 RPM and interpolation, select 16 teeth. 5 HP is approximately halfway between 4.70 (15 teeth) and 5.38 (17 teeth)
   5. Speed ratio $\frac{100}{40} = 2.5$
   6. Larger sprocket $16 \times 2.5 = 40$ teeth or use Speed ratio table.
   7. Answer is 15.528 center distance in pitch
      60 chain length in pitches
   8. Convert to inches
      15.528 (1) = 15.528" center distance
      60 (1) = 60" chain length
   9. 15.528" center distance is within the 27" center distance limitation

B. 1. Load classification under pumps rotary gear type--uniform load
   2. Service factor = 1
   3. Chain selection table using 3 HP and 1200 RPM, select #35--3/8" pitch chain number
   4. Using 1200 RPM and 3 HP, select 19 teeth from HP ratings table
   5. Speed ratio $\frac{1200}{750} = 1.60$
   6. Larger sprocket $19 \times 1.60 = 30.4$ or use speed ratio table for similar results, and select 30 teeth
   7. Answer is 13.638 center distance in pitches
      52 chain length in pitches
   8. Convert to inches
      13.638 (3.75) = 5.115" center distance
      52 (3.75) = 19.5" chain length
   9. 19.5 center distance is not less than 12" center distance limitation

Assignment Sheet #9

A. 1. Classification: normal duty
   2. Using Transparency 1, go across from 1160 RPM of small pulley to .98 column; the .98 is a conversion from 1 HP; that is, 1 HP is closest to .98 HP
   3. Read up from .98 to the top; select 4.25" outside diameter of small pulley
   4. Since the background area is darker, use cross section B - 21 wide by 13 thick
   5. Using Transparency 2 under 1160 RPM motors, read across the top until 4.25 column is reached
   6. Read down 4.25 column to the nearest RPM of the desired speed of 600 RPM which is 599 RPM
   7. Read in the row to the left of the 599 RPM until you reach 8.0" O.D. of Drive N. V.Pulley
8. Add the diameters of the small pulley and the driven pulley: $4.25 + 8 = 25.25''$
9. Using table on Transparency 3, select the number on the top row of the table closest to the sum of 12.25; use 12
10. Read down the 12 1/2 column to the number closest to the center to center distance of 14''.
11. Using 13.9'', read to the left over to belt length column of 48''.

B. 1. Classification: heavy duty—multiply horsepower by .85, then use normal duty tables; .85 x .75 = .64 HP; the .75 HP is a conversion of 3/4 HP.

2. Using Transparency 1 go across from 1750 RPM of small pulley to .63 HP; that is, .63 HP is closest to .64 HP.

3. Read up from .63 to the top and select 3.00'' outside diameter of small pulley.

4. Since the background area is white area, use cross section A - 1/2'' wide by 5/16'' thick.

5. Using Transparency 2 under 1750 RPM motors, read across the top until 3.00 column is reached.

6. Read down 3.00 column to the nearest RPM of the desired speed of 500 RPM which is 474 RPM.

7. Read in the row to the left of the 474 RPM until you reach 7.0 OD of Drive N V-Pulley.

8. Add the diameters of the small pulley and the driven pulley: $3.00 + 7.00 = 10.00$

9. Using table on Transparency 3, select the number on the top row of the table closest to the sum of 10.00; use 10

10. Read down the 10 column to the closest center to center distance of 17 inches; use 17.1

11. Using 17.1'', read to the left over to belt length column of 50''.

Assignment Sheet #10

A. 1. Limiting speed 3600 RPM

2. Dynamic load rating 7500 lbs.

3. Static load rating 9150 lbs.

4. Select 9150 lb. static load as controlling factor—LS16

5. The 11400 lb. dynamic limit will cover the 7500 lb. design load

6. The 4000 RPM will cover the 3600 RPM design load.

7. LS16 bore size = 2 3/4''; outside diameter = 5 1/4''

B. 1. Limiting speed 2200 RPM

2. Dynamic load rating 5500 lbs.

3. Static load rating 1800

4. Select the 5500 lbs. as controlling factor—LS13

5. The 3800 lb. static load will cover the 1800 lb. design load.

6. The 7100 RPM limiting speed will cover the 2200 RPM design load.

7. LS13 bore size = 1 1/2''; outside diameter = 3 1/4''
1. Match the terms on the right with the correct definitions.

   a. Machine parts used to lessen friction
   b. Devices for joining shafts together
   c. Compressed air used as power transmission
   d. Toothed wheel meshing with another toothed wheel
   e. Devices used to transmit power around corners and different angles when the driver and driven shafts are not lined up
   f. Endless flexible belt on pulleys
   g. Liquid is used as power transmission
   h. Devices for slowing or stopping power driven shafts
   i. Motion and function generators
   j. Endless chain on sprockets
   k. Devices for stopping or starting a machine without stopping the prime mover
   l. Machine elements designed to produce a specific motion
   m. Any device used to reduce the speed of the output device
   n. A second motion or intermediate shaft in a power transmission system
   o. As a gear it serves to fill up space and reverse direction; as a pulley it serves to take up slack
   p. A liner forced in a hole to provide a better wearing or bearing surface and to provide for easy renewal
   q. Parts used to protect ball or roller bearings from loss of lubricant and entrance of dust and dirt on bearings

1. Gear drive
2. Belt drive
3. Chain drive
4. Countershaft
5. Couplings
6. Clutches
7. Gear reduction
8. Brakes
9. Splines
10. Flexible shafts
11. Speed reducer
12. Seals
13. Bearings
14. Cams
15. Linkages
16. Power train
17. Hydraulics
18. Pneumatics
19. Idler
20. Bushing
21. Gear ratio
r. A combination of gears used to reduce the input speed to a lower output speed

s. The number of revolutions the drive gear must make to turn the driven gear one revolution

t. Revolving components involved in the transmission of power from the engine to the drive wheel

u. Multiple keys in the general form of internal and external gear teeth, used to prevent rotation of a shaft

2. Distinguish between advantages of chain drives and gear drives by placing an "X" next to the advantages of chain drives and an "O" next to the advantages of gear drives.

a. Better shock absorbing

b. Higher RPM can be obtained

c. Maximum speed ratio can be greater

d. Wear is reduced

e. Center to center distance is not restricted

f. Generally more practical at higher RPM and higher horsepower

g. Ease of changes in design

3. Distinguish between advantages of chain drives and belt drives by placing an "X" next to the advantages of chain drives and an "O" next to the advantages of belt drives.

a. Lower loads on bearings due to slack

b. Occupies less overall space

c. Does not deteriorate with age

d. Generally operates with less noise

e. Easier to install

4. Arrange in order the steps for selecting a V-belt drive by placing the correct sequence numbers in the appropriate blanks.

a. Select driven V-pulley diameter

b. Select outside diameter of small V-pulley

c. Decide whether belt will be used on light, normal, or heavy duty equipment

d. Determine belt length
5. Complete the following list of major types of power transmission chains.
   a. ____________________________
   b. Offset sidebar
   c. Double pitch
   d. ____________________________
   e. Detachable
   f. ____________________________
   g. Inverted tooth

6. Match the axes positions on the right with the correct types of gears.
   a. Worm and worm gear  1. Axes intersect
   b. Plain bevel gear  2. Axes are parallel
   c. Rack and pinion gear  3. Axes do not intersect
   d. Planetary gear
   e. Spur gear  4. Axes do not intersect and straight line motion converts to circular motion and vice versa
   f. Helical gear
7. Identify parts of gear teeth.

a. ___________________________ b. ___________________________

c. ___________________________ d. ___________________________

e. ___________________________ f. ___________________________

g. ___________________________

8. Identify parts of pinion and gear.

a. ___________________________ b. ___________________________

c. ___________________________ d. ___________________________

d. ___________________________
9. Name three types of cutting data needed for spur gear drawings.
   a. 
   b. 
   c. 

10. Identify parts of a bevel gear.
    ![Diagram of bevel gear parts]
    a. 
    b. 
    c. 
    d. 

11. Complete the following list of cutting data needed for bevel gears.
    a. Number of teeth in pinion
    b. 
    c. Diametral pitch
    d. Pressure angle
    e. 
    f. Root angle
    g. Face angle
12. Distinguish between cutting data needed for worm and cutting date needed for worm wheel by placing an "X" next to the cutting data needed for a worm and an "O" next to cutting data needed for a worm wheel.

   a. Number of teeth
   b. Rim radius
   c. Face length
   d. Throat diameter

13. Calculate the gear ratio of the gears below and write the correct answers in the blanks provided.

   a. Driven gear has 64 teeth
      Driving gear has 36 teeth

   b. __________________________
   c. __________________________
14. Determine gear rotation of the gears below by writing "C" for clockwise or "CC" for counterclockwise in the blanks provided.

   a. Gear A 
   b. Gear B 
   c. Gear C 
   d. Gear D 

15. Calculate gear speed and write the answers in the blanks provided.

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Ratio</th>
<th>RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Gear A</td>
<td>C</td>
<td>1.29:1</td>
</tr>
<tr>
<td>b. Gear B</td>
<td>CC</td>
<td>2:1</td>
</tr>
<tr>
<td>c. Gear C</td>
<td>C</td>
<td>.63:1</td>
</tr>
<tr>
<td>d. Gear D</td>
<td>C</td>
<td>.33:1</td>
</tr>
</tbody>
</table>
16. List two types of couplings.
   a. 
   b. 

17. Distinguish between types of bearings by placing an "X" next to the plain bearing, and an "O" next to the antifriction bearings.
   a. Ball
   b. Radial
   c. Thrust
   d. Roller
   e. Guide or slipper

18. Identify cam nomenclature.

[Diagram of cam nomenclature with labeled parts: Direction of Motion, Trace Point, Pitch Point, Tangent, Normal, Cam Profile, Pitch Circle]
19. Identify types of cam followers.

a. [Diagram]

b. [Diagram]

20. Select types of cam motions by placing an "X" in the appropriate blanks.

   a. Modified
   b. Readjusted
   c. Parabolic, construction method
   d. Simplified
   e. Uniform
   f. Harmonic

21. Match hydraulic nomenclature on the right with the correct definitions.

   a. Device to convert fluid energy into mechanical force
      1. Tank
   b. Instruments to measure pressure, temperature, or flow
      2. Pump
   c. Reservoir to hold fluid
      3. Valves
   d. Parts to control flow and pressure
      4. Cylinder or motor
   e. Device to force liquid through system
      5. Filters and strainers
   f. Parts to clean fluid
      6. Accumulator
   g. A cylinder in which fluid is stored under pressure and used to meet fluctuating demands
      7. Gages
22. Match basic pneumatic components on the right with the correct functions.

____ a. Compresses the air
____ b. Removes dirt and water
____ c. Lubricates the operating components of a system
____ d. Indicates pressure
____ e. Stores compressed air
____ f. Keeps air pressure within an acceptable range

1. Pressure gage
2. Filter
3. Regulator
4. Compressor
5. Receiving tank
6. Lubricator

23. Distinguish between air circuit components by placing an "X" next to the control elements and an "O" next to the power elements.

____ a. 3-position
____ b. Cylinders
____ c. Air motors
____ d. 2-way

4. Demonstrate the ability to:

a. Construct a spur gear drawing.
b. Construct a bevel gear.
c. Construct a worm and worm gear.
d. Calculate gear ratios.
e. Determine gear rotation.
f. Calculate gear speeds.
g. Construct a cam drawing.
h. Select a chain drive.
i. Select a V-belt drive.
j. Select types of bearings from handbooks.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
# Answers to Test

### 1.
1. a. 13  
   b. 5  
   c. 18  
   d. 1  
   e. 10  
   f. 2  
2. a. X  
   b. O  
   c. O  
   d. X  
3. a. X  
   b. X  
   c. X  

### 2.
4. a. 3  
   b. 2  
   c. 1  
   d. 4  

### 3.
5. a. Rolfer  
   d. Pintle  
   f. Bead  

### 4.
6. a. 3  
   b. 1  
   c. 4  
   d. 2  
   e. 2  
   f. 2 or 3  

### 5.
7. a. Outside diameter  
   b. Root diameter  
   c. Circular thickness  
   d. Circular pitch  
   e. Addendum  
   f. Dedendum  
   g. Whole depth  

### 6.
8. a. Line of action  
   b. Pressure angle  
   c. Clearance  
   d. Pitch circle  
   e. Center distance
9. Any three of the following:
   a. Number of teeth
   b. Pitch diameter
   c. Diametral pitch
   d. Pressure angle
   e. Whole depth
   f. Chordal addendum
   g. Chordal thickness

10. a. Pitch diameter
    b. Cone distance
    c. Back angle
    d. Backing

11. b. Number of teeth in gear
     e. Addendum
     i. Pinion
     j. Gear
     k. Thickness

12. a. 0
    b. O
    c. X
    d. O

13. a. 1.77:1
    b. 3.16:1
    c. .25:1

14. a. C
    b. CC
    c. CC
    d. C

15. a. 1250
    b. 625
    c. 1000
    d. 1875

16. a. Permanent
    b. Clutches

17. a. O
    b. X
    c. X or O
    d. O
    e. X

18. a. Pitch circle
    b. Base circle
    c. Follower
    d. Pressure angle
19. a. Roller
   b. Flat face

20. a, c, e, f

21. a. 4 e. 2
     b. 7 f. 5
     c. 1 g. 6
     d. 3

22. a. 4 d. 1
     b. 2 e. 5
     c. 6 f. 3

23. a. X
d. X

24. Evaluated to the satisfaction of the instructor