The second of a two-book course in drafting, this manual consists of 12 topics in the following units: sketching techniques, geometric constructions, orthographic views, dimensioning procedures, basic tolerancing, auxiliary views, sectional views, inking tools and techniques, axonometrics, oblique, perspective, and computer-aided drafting. Included in the individual instructional units are some or all of the following: performance objectives, suggested activities for teachers, information sheets, assignment sheets, job sheets, visual aids, tests, and test answers. Instructional materials in the publication are written in terms of student performance using measurable objectives and include the content necessary for employment in an entry-level drafting occupation. (MN)
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FOREWORD

Basic Drafting: Book Two is the second volume of a series of drafting materials being produced by the Mid-America Vocational Curriculum Consortium. This book and Basic Drafting: Book One comprise the basics necessary to be employed in a drafting occupation. Areas of specialization such as Mechanical Drafting and Architectural Drafting are being written as supplements to be used with this book.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writers have numerous years of industry as well as teaching, and writing experience. Assisting them in their 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.

This publication is designed to assist teachers in improving instruction. As this publication is used, it is hoped that the student performance will improve and that 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.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accents 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
Basic Drafting: Book Two is the second of two publications designed to include the content necessary for employment in an entry level drafting occupation. Originally intended as only one volume, the separation of Basic Drafting into two books was done in order to reduce the size of the materials. The result is two books that are shorter, more handy to carry, and much more convenient to work with.

In a time when educational costs continue to rise, a lower priced text will be welcomed by teachers and students alike. But more than that, curriculum materials presented in such a comprehensive size will be easier to adapt to speciality programs with industry and adult education.

There has never been a MAVCC publication in which we failed to request that teachers and educators let us know how the curriculum is working out in the classroom. Teacher response to date has helped make the MAVCC format the most solid in vocational-technical education, and this new, comprehensive publication of Basic Drafting should prove once more that as MAVCC continues to publish, we also continue to listen—and respond.

Ann Benson
Executive Director
Mid-America Vocational Curriculum Consortium
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Appreciation is extended to those individuals who contributed their time and talents in the development of Basic Drafting: Book Two.

The contents of this publication were planned and review 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

*Basic Drafting: Book Two* includes twelve 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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<tr>
<th>Name</th>
<th>Identify</th>
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<tr>
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<td>Select</td>
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<td>List in writing</td>
<td>Mark</td>
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<td>Give</td>
<td>Label</td>
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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.
INSTRUCTIONAL/TASK ANALYSIS

UNIT I: SKETCHING TECHNIQUES

1. Terms
2. Purposes of sketching
3. Rules in sketching
4. Types of sketch views
5. Proportioning a sketch
6. Meaning of lines
7. Sketch straight lines
8. Sketch arcs
9. Sketch circles
10. Sketch an object using arcs and circles
11. Sketch an ellipse

UNIT II: GEOMETRIC CONSTRUCTIONS

1. Terms
2. Types of angles
3. Circular shapes
4. Polygons and diagonals
5. Basic geometric shapes
6. Interpreting degrees in a circle
7. Bisect a line and an arc
8. Bisect an angle
UNIT III: ORTHOGRAPHIC VIEWS

1. Terms
2. Types of projection systems
3. Projection symbols
JOB TRAINING: What the Worker Should Be Able to Do

RELATED INFORMATION: What the Worker Should Know

4. Views in orthographic projection
5. Types of planes
6. Line precedence

7. Identify types of planes in orthographic views
8. Identify projection lines in orthographic views
9. Construct a top view
10. Construct a front view
11. Construct a right side view
12. Construct missing hidden lines
13. Construct missing visible and hidden lines
14. Construct circles and arcs using a template
15. Make a two-view sketch
16. Make a three-view sketch
17. Construct a one-view drawing
18. Construct a two-view drawing
19. Construct a three-view drawing
20. Construct a runout
21. Construct a point in an orthographic view
22. Construct a line in an orthographic view
23. Construct a plane in an orthographic view

UNIT IV: DIMENSIONING PROCEDURES

1. Terms
2. Size and shape descriptions
3. Types of dimensions
4. Types of lines
Job Training: What the Worker Should Be Able to Do

Related Information: What the Worker Should Know

1. Rules for lines
2. Dual dimensioning
3. Placement of dimensions
4. Finish marks
5. Notes
6. Superfluous dimensions
7. Standard machine manufactured features

8. Construct arrowheads
9. Dimension arcs
10. Dimension angles
11. Dimension curves
12. Dimension rounded end shapes
13. Dimension spherical objects
14. Dimension cylindrical objects
15. Dimension cones, pyramids, and prisms
16. Dimension features on a circular center line
17. Dimension a theoretical point of intersection
18. Dimension an object using a rectangular coordinate system
19. Dimension an object using a polar coordinate system
20. Dimension an object using a tabular coordinate system
21. Dimension an object using an ordinate dimensioning system
22. Dimension an object using proper dimensioning rules and correct techniques to completely describe the object
UNIT V: BASIC TOLERANCING

1. Terms
2. Type of fits
3. Limit dimensions
4. Types of dimensioning systems
5. Interpret decimal tolerance dimensions
6. Calculate and dimension clearance fit tolerances of mating parts
7. Calculate and dimension interference fit tolerances of mating parts
8. Calculate and assign tolerances to mating parts using standard fit tables
9. Construct a drawing using datum dimensioning

UNIT VI: AUXILIARY VIEWS

1. Terms
2. Views
3. Projection of measurements
4. Locations of reference line
5. Label points and planes of a three view object
6. Construct a primary auxiliary of an inclined plane
7. Construct a true size auxiliary of a curved surface
8. Construct true length of an oblique line
9. Determine the true angle and slope of a line
10. Determine the true angle between two planes
11. Determine visibility of crossing skew lines in space
JOB TRAINING: What the Worker Should Be Able to Do

12. Determine the visibility of a line and a plane that cross in space

13. Locate piercing point of a line and a plane

14. Construct a secondary auxiliary view of an object

15. Construct point view of a line

16. Determine true angle between two planes in a secondary auxiliary

17. Construct a true size auxiliary of an oblique plane

18. Determine shortest distance between a point and a line

19. Determine shortest distance between two skew lines

UNIT VII: SECTIONAL VIEWS

1. Terms

2. Types of sectional views

3. Material symbols

4. Rules in sectioning

5. Conventional breaks

6. Construct various material symbols in section

7. Construct a full section of an object

8. Construct a half section of an object

9. Construct an offset section of an object

10. Construct a broken-out section of an object

11. Construct a removed section of an object

12. Construct a revolved section of an object

13. Construct a rib section of an object

14. Construct an aligned section of an object with holes, ribs, or spokes

15. Construct adjacent parts in assembly section
UNIT VIII: INKING TOOLS AND TECHNIQUES

1. Terms
2. Types of drawing inks
3. Use and care of technical pens
4. Precautions when using ink
5. Tips for working with ink
6. Alphabet of ink lines

7. Draw and erase ink lines on vellum or tracing cloth
8. Draw and erase ink lines on polyester film
9. Complete steps in inking a drawing or a tracing
10. Fill clean technical and pocket model pens
11. Refill a technical pen
12. Clean technical and pocket model pens using the standard cleaning method
13. Clean a technical pen with an ultrasonic cleaner

UNIT IX: AXONOMETRICS

1. Terms
2. Types of axonometrics
3. Positions
4. Plane surfaces
5. Rules in constructing isometrics
6. Rules in dimensioning isometrics

7. Sketch an isometric drawing
8. Sketch isometric circles
JOB TRAINING: What the Worker Should Be Able to Do

9. Construct an axonometric drawing by box method

10. Construct angles on an isometric

11. Construct isometric circles and arcs

12. Construct isometric curves by coordinates

13. Measure in isometric by offsets

14. Construct an isometric in the center of a drawing media

UNIT X: OBLIQUE

1. Terms

2. Types of oblique drawings

3. Positions

4. Rules in constructing oblique drawings

5. Rules in dimensioning oblique drawings

6. Sketch an oblique

7. Construct an oblique drawing by box method

8. Measure in oblique

9. Construct angles on an oblique object

10. Construct oblique circles

11. Construct oblique circles in depth plane

12. Construct an oblique drawing in the center of a drawing space

UNIT XI: PERSPECTIVE

1. Terms

2. Types of perspectives

3. Types of perspective views

4. Perspective equipment

5. Lines and points
TOOLS, MATERIALS, AND EQUIPMENT LIST

Standard triangles
Compass
Divider
Protractor
Irregular curve
Drafting machine or parallel bar
Adjustable triangle
V-track drafting machine
Elbow drafting machine
Sheet of vellum without a watermark
Nonabrasive hand eraser
Drawing pencil with soft lead
Lead holder or pencils
Lead pointer
Drawing paper or media
Pencil pointer
Paper towel or cleaning cloth
Braddock Rowe triangle
Drawing surface or table
Ames type lettering guide
Drafting tape
Horizontal machine scale
Vertical machine scale
Scale wrench
Hex wrench
Architect scale
Metric scale
Technical pen
Ink
Standard fit tables
Lead
Triangles 45°, 30° 60°
Cleaning solution
Lint-free cloth or tissue
Ultrasonic cleaner
Ultrasonic cleaning fluid
REFERENCES


**ADDITIONAL MATERIALS**

A. Filmstrip/cassette--"Drafting-Series I and II." Doubleday Multimedia; 1371 Reynolds Avenue; Santa Ana, CA 92705

B. Filmstrip/cassette--"Drafting/Mechanical Drawing." Prentice Hall Media; Serv Code VD354; 150 White Plains Road; Tarrytown, NY 10591.

C. Transparencies--"The ABC's of Drafting." DCA Educational Products: DCA Incorporated, Warrington, PA 18976.
SKETCHING TECHNIQUES
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to state the purpose and procedures for various types of sketching. The student should also be able to sketch straight lines, arcs, circles, and ellipses. 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 sketching techniques with their correct definitions.
2. State purposes of sketching.
3. Select true statements concerning rules in sketching.
4. Arrange in order the steps in completing a drawing.
5. List two types of sketch views.
6. Select true statements concerning guidelines for sketching straight lines.
7. Arrange in order the steps for sketching arcs.
8. Arrange in order the steps for sketching circles.
9. Match methods for sketching ellipses with their procedures.
10. Arrange in order the steps for blocking in a view.
11. Select true statements concerning factors in center line usage.
12. Define two methods for proportioning a sketch.
13. List three ways to interpret the meaning of lines.
14. Demonstrate the ability to:
   a. Sketch straight lines.
   b. Sketch arcs.
   c. Sketch circles.
   d. Sketch an object using arcs and circles.
   e. Sketch an ellipse.
SKETCHING TECHNIQUES
UNIT I

SUGGESTED ACTIVITIES

1. Provide student with objective sheet.
2. Provide student with information and assignment sheets.
3. Make transparencies.
4. Discuss unit and specific objectives.
5. Discuss information and assignment sheets.
6. Discuss advantages and disadvantages of sketching.
7. Demonstrate to the class the techniques used in making a field sketch.
8. Practice sketching techniques.

INSTRUCTIONAL MATERIALS

1. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Straight Line Sketches
      2. TM 2--Sketching Arcs, Circles, and Ellipses
      3. TM 3--Steps in Blocking in a View
      4. TM 4--Proportion in Sketching
      5. TM 5--Meaning of Lines
   D. Assignment sheets
      1. Assignment Sheet #1--Sketch Straight Lines
      2. Assignment Sheet #2--Sketch Arcs
      3. Assignment Sheet #3--Sketch Circles
      4. Assignment Sheet #4--Sketch an Object Using Arcs and Circles
      5. Assignment Sheet #5--Sketch an Ellipse
II. References:


SKETCHING TECHNIQUES
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. A picture is worth a thousand words-A concept used by drafters, architects, and engineers to express an idea on paper so that it can be understood by other people involved

B. Freehand technical sketching-Making a drawing without the use of instruments, yet with care taken to obtain the correct line widths

(Note: The drawing must not be crude or sloppy.)

C. Radius-The distance from the center point of a circle to the outside circumference

D. Diameter-The distance across a circle passing through its center point

E. Arc-Any portion of the circumference of a circle

F. Ellipse-A foreshortened circle having a major axis and a minor axis

G. Sketch lines-Freehand connections between two or more points

H. Focus (foci)-A point(s) at which lines come toward each other or move away from each other

I. Major axis-The axis passing through the foci of an ellipse

J. Minor axis-The chord of an ellipse passing through the center and perpendicular to the major axis

II. Purposes of sketching

A. Preliminary approach to a problem before going to the expense of making an instrument drawing

B. To give the drafter a better picture of the object to be drawn

C. For recording notes and technical information in the shop or field for future use in the drafting department

D. As an aid to "think through" the solution to an engineering type problem
INFORMATION SHEET

III. Rules in sketching
A. A scale is not required
B. Small objects are sketched larger than their normal size
C. Freehand lines are rough, not rigid
D. Sketches are drawn in proportion
E. Line contrast should be used
F. A soft pencil should be used
G. Finished linework should be dark and conform to line alphabet standards
H. Sketches are dimensioned the same as machine drawings

IV. Steps in completing a drawing
A. Select necessary views
B. Block in lightly the shape of the object
C. Block in details in each view
D. Erase unwanted construction lines
E. Darken lines

V. Types of sketch views
A. Pictorial
B. Multiview

VI. Guidelines for sketching straight lines (Transparency 1)
A. Properly locate end points of line
B. By trial movement from left point to right point, position arm without marking on the paper
C. Keep your eye on the point where the line will end and sketch short, light lines between points
   (NOTE: Do not permit your eye to follow the pencil.)
D. Erase unneeded lines with a soft eraser and darken the remaining line to form one uniformly wide, continuous line
   (NOTE: At this stage, your eye needs to lead the pencil along the light sketch line.)
E. Draw straight lines that are parallel to the drafting table edge (border lines) by aligning the paper on the drafting board edge and letting the third and fourth fingers of the drawing hand act as a guide by sliding them along the edge of the board while drawing the line

(CAUTION: This should be done only on tables with proper edging material.)

F. Rotate the paper for inclined straight lines to a position that would make them straight lines

G. Estimate angles by sketching a right angle and a 45° angle; subdivide into 15° angles, and then obtain the required angle

H. Erase all unneeded construction lines

VII. Steps for sketching arcs (Transparency 2)

A. Sketch right angle at the proper length

B. Sketch into form a square and mark proper diagonal

C. Mark off proper length on diagonal

D. Darken in arc

VIII. Steps for sketching circles (Transparency 2)

A. Sketch in box to proper scale and mark midpoint of each line of square

B. Sketch in diagonals in square and mark off proper length on diagonals

C. Darken in circle

IX. Methods for sketching ellipses and procedures (Transparency 2)

A. Method 1

1. Sketch in a rectangle the length of the major axis and minor axis and mark midpoint of each line of rectangle

2. Sketch a circular arc on each line of the rectangle

3. Darken in ellipse

B. Method 2

1. Sketch in major axis and minor axis

2. Sketch a circular arc on each end of an axis line

3. Darken in ellipse
INFORMATION SHEET

X. Steps for blocking in a view (Transparency 3)
   A. Block in main shapes of object
   B. Sketch in arcs and circles
   C. Darken final lines
   D. Erase construction lines

XI. Factors in center line usage
   A. Used to show axis of symmetry
      (NOTE: Center lines are sometimes called symmetry lines.)
   B. Symbol for center line is \( \square \)
   C. Used to show the center line of both circles and paths of motion
   D. The center line should extend past the visible line 1/4" if not being used as an extension line
   E. Long dashes should begin and terminate center lines
      (NOTE: Center lines for small holes can be a thin solid line.)
   F. A gap must be present when a center line is a continuation of a visible or hidden line
      (NOTE: Center lines need not be shown on filleted corners because they are self-locating.)

XII. Methods for proportioning a sketch (Transparency 4)
   A. Method 1--Use a piece of cardboard to mark off some unit of measurement (such as a 1/4" to form some scale); then, measure the actual object
      (NOTE: When sketching, it is important to keep the sketch in proportion.)
   B. Method 2--First, determine the overall width and height of the object; then, sketch in the medium areas (by use of diagonals if necessary); finally, sketch in the small details
      (NOTE: When the item has numerous curves, it is best to use graph paper.)

XIII. Ways to interpret the meaning of lines (Transparency 5)
   A. A visible or hidden line can mean (indicate) the intersection of two surfaces
INFORMATION SHEET

B. A visible or hidden line can mean (indicate) an edge view of a surface.

C. A visible or hidden line can mean (indicate) a contour view of a curved surface.

(NOTE: It is necessary to examine all views carefully to determine their meaning since no shading is used on working drawings.)
Straight Line Sketches

Keep eye on end point
Sketching Arcs, Circles, and Ellipses

Method 1

Method 2

Major Axis
Minor Axis
Steps in Blocking in a View

1. OBJECT
   Block in Main Shapes
2. Sketch Arcs and Circles
3. Darken Final Lines
Proportion in Sketching

(A) UNIT (full size or larger or smaller)

1 2 3 4 5 6 7 8

1 2 3

Difference between height and width

WIDTH

(A)
Meaning of Lines

- Contour
- Edge View of Surface
- Intersection of Surfaces
- Edge View of Surface
SKETCHING TECHNIQUES
UNIT I

ASSIGNMENT SHEET #1--SKETCH STRAIGHT LINES

Premise: Straight lines can be sketched by using the procedure in the following example.

Example:

1. Draw two points
2. Draw dash lines connecting the two points
3. Darken and fill in dash lines

(NOTE: The same procedure is used for vertical and inclined lines.)

Directions: Sketch the following lines by connecting point A to point B.

Problem A: Vertical lines

Problem B: Horizontal lines
Problem C: Inclined lines
SKETCHING TECHNIQUES
UNIT I

ASSIGNMENT SHEET #2-SKETCH ARCS

Premise: Arcs can be sketched by using the procedure in the following example.

Example:
1. Sketch a box corner

2. Mark off radius distance from corner point

3. Swing a rough arc from center point

4. Darken arc

Directions: Sketch arcs in the following corners.

Problem:
SKETCHING TECHNIQUES
UNIT 1

ASSIGNMENT SHEET #3: SKETCH CIRCLES

Premise: Circles can be sketched by using the procedure in the following example.

Example:

1. Sketch in center lines

2. Box in circle at diameter required

3. Puf in diagonal lines and mark radius points from center

4. Rotate wrist in a circular motion and connect circle points

Directions. Sketch three circles below using 1/2" approximate radius.
ASSIGNMENT SHEET #4 - SKETCH AN OBJECT USING ARCS AND CIRCLES

Premise: An object using arcs and circles can be sketched by using the procedure in the following example.

Example:
1. Decide which view of object is to be drawn

   Object

2. Box in overall shape of object

3. Sketch in arcs and circles

4. Erase construction lines and darken object
ASSIGNMENT SHEET #4

Directions Sketch the front view of this object.

Problem

[Diagram of an object with a front view indication]
SKETCHING TECHNIQUES
UNIT I

ASSIGNMENT SHEET #5--SKETCH AN ELLIPSE

Premise: An ellipse can be sketched by using the procedure in the following example.

Example:

1. Mark off major and minor axes on center lines

2. Box in outlines of the ellipse

3. Sketch in major and minor arcs of ellipse

4. Erase construction lines and darken ellipse outline

Directions: Sketch three ellipses using an approximate 3/4" major diameter and an approximate 1/2" minor diameter.
SKETCHING TECHNIQUES
UNIT I

NAME ____________________________

TEST

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

   a. A concept used by drafters, architects, and engineers to express an idea on paper so that it can be understood by other people involved

   b. Making a drawing without the use of instruments, yet with care taken to obtain the correct line widths

   c. The distance from the center point of a circle to the outside circumference

   d. The distance across a circle passing through its center point

   e. Any portion of the circumference of a circle

   f. A foreshortened circle having a major axis and a minor axis

   g. Freehand connections between two or more points

   h. A point at which lines come toward each other or move away from each other

   i. The axis passing through the foci of an ellipse

   j. The chord of an ellipse passing through the center and perpendicular to the major axis

   1. Major axis

   2. Diameter

   3. Arc

   4. Freehand technical sketching

   5. Minor axis

   6. A picture is worth a thousand words

   7. Sketch lines

   8. Radius

   9. Ellipse

   10. Focus

2. State three purposes of sketching.

   a. __________________________________________________________

   b. __________________________________________________________

   c. __________________________________________________________
3. Select true statements concerning rules in sketching by placing an "X" in the appropriate blanks.

   a. An architect scale must be used in sketching
   b. Small objects are sketched larger than their normal size
   c. Freehand lines are finished and rigid
   d. Sketches do not need to be drawn in proportion
   e. Line contrast should be used
   f. A hard pencil should be used
   g. Finished linework should be dark and conform to line alphabet standards
   h. Sketches are never dimensioned

4. Arrange in order the steps in completing a drawing by placing the correct sequence numbers in the appropriate blanks.

   a. Erase unwanted construction lines
   b. Select necessary views
   c. Block in lightly the shape of the object
   d. Darken lines
   e. Block in details in each view

5. List two types of sketch views.

   a. ____________________________
   b. ____________________________

6. Select true statements concerning guidelines for sketching straight lines by placing an "X" in the appropriate blanks.

   a. Properly locate end points of line
   b. Position arm by marking heavily on the paper while moving from left point to right point
   c. Keep your eye on the pencil and sketch short, heavy lines between points
   d. Erase unneeded lines with a soft eraser and darken the remaining line to form one uniformly wide, continuous line
e. Draw straight lines that are parallel to the drafting table edge by aligning the paper on the drafting board edge and letting the third and fourth fingers of the drawing hand act as a guide by sliding them along the edge of the board while drawing the line.

f. Do not rotate the paper to sketch inclined straight lines.

g. Estimate angles by sketching a right angle and then a $45^\circ$ angle; subdivide into $15^\circ$ angles, and then obtain the required angle.

7. Arrange in order the steps for sketching arcs by placing the correct sequence numbers in the appropriate blanks.

   a. Mark off proper length on diagonal
   b. Sketch right angle at the proper length
   c. Darken in arc
   d. Box in to form a square and mark proper diagonal

8. Arrange in order the steps for sketching circles by placing the correct sequence numbers in the appropriate blanks.

   a. Sketch in diagonals in square and mark off proper length on diagonals
   b. Darken in circle
   c. Sketch in box to proper scale and mark midpoint of each line of square

9. Match methods for sketching ellipses on the right with their procedures.

   a. Sketch a circular arc on each end of an axis line
   b. Sketch in a rectangle the length of the major axis and minor axis and mark midpoint of each line of rectangle
   c. Sketch a circular arc on each line of the rectangle
   d. Sketch in major axis and minor axis

10. Arrange in order the steps for blocking in a view by placing the correct sequence numbers in the appropriate blanks

   a. Darken final lines
   b. Block in main shapes of object
   c. Erase construction lines
   d. Sketch in arcs and circles
11. Select true statements concerning factors in center line usage by placing an "X" in the appropriate blanks.

____ a. Does not show axis of symmetry

____ b. Symbol for center line is \( \circ \)

____ c. Used to show center line of squares

____ d. Long dashes should begin and terminate center lines

____ e. A gap must be present when a center line is a continuation of a visible or hidden line

12. Define two methods for proportioning a sketch.

Method 1: _______________________________________________________________

______________________________________________________________

Method 2: ______________________________________________________________

______________________________________________________________

13. List three ways to interpret the meaning of lines.

a. _________________________________________________________________

b. _________________________________________________________________

c. _________________________________________________________________

14. Demonstrate the ability to:

a. Sketch straight lines.

b. Sketch arcs.

c. Sketch circles.

d. Sketch an object using arcs and circles.

e. Sketch an ellipse.

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

## ANSWERS TO TEST

1. a. 6  
   b. 4  
   c. 8  
   d. 2  
   e. 3
   f. 9  
   g. 7  
   h. 10 
   i. 1  
   j. 5

2. Any three of the following:
   a. Preliminary approach to a problem before going to the expense of making an instrument drawing
   b. To give the drafter a better picture of the object to be drawn
   c. For recording notes and technical information in the shop or field for future use in the drafting department
   d. As an aid to "think through" the solution to an engineering-type problem

3. b, e, g,

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

5. a. Pictorial
   b. Multiview

6. a, d, e, g

7. a. 3  
   b. 1  
   c. 4  
   d. 2

8. a. 2  
   b. 3  
   c. 1

9. a. 2  
   b. 1  
   c. 1  
   d. 2

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

12. Method 1 - Use a piece of cardboard to mark off some unit of measurement; then, measure the actual object

Method 2 - First, determine the overall width and height of the object; then, sketch in the medium areas; finally, sketch in the small details

13. a. A visible or hidden line can mean the intersection of two surfaces
   b. A visible or hidden line can mean an edge view of a surface
   c. A visible or hidden line can mean a contour view of a curved surface

14. Evaluated to the satisfaction of the instructor
UNIT OBJECTIVE

After completion of this unit, the student should be able to match basic geometric terminology with correct definitions, match basic geometric shapes with their descriptions, and identify basic geometric shapes. The student should also be able to measure a circle and interpret the degrees in it, and construct basic geometric forms. 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 basic geometric terms with their correct definitions.
2. Match types of angles with their correct descriptions.
3. Match types of triangles with their correct descriptions.
4. Match circular shapes with their correct descriptions.
5. Match four-sided shapes, cones, and special figures with their correct descriptions.
6. Match polygons and diagonals with their correct descriptions.
7. Identify basic geometric shapes.
8. Match geometric terms with their correct symbols.
9. List three elements needed for measuring parts of a circle.
10. List three elements needed for interpreting degrees in a circle.
11. Demonstrate the ability to:
   a. Bisect a line and an arc.
   b. Bisect an angle.
   c. Draw parallel lines.
   d. Construct a perpendicular line to a line from a point.
e. Divide a line into equal parts.
f. Draw a line perpendicular through a point on a line.
g. Draw an arc tangent to a straight line and an arc.
h. Draw an arc tangent to two arcs.
i. Construct a triangle with sides given.
j. Construct a right triangle.
k. Construct an equilateral triangle with one side given.
l. Inscribe a hexagon inside a circle.
m. Construct a hexagon with the distance across the flat sides given.
n. Construct a circle through three given points.
o. Construct a pentagon by inscribing.
p. Draw an arc tangent to an acute angle and an obtuse angle.
q. Draw an arc tangent to a right angle.
r. Draw an involute of a circle.
s. Draw an ellipse using the approximate ellipse with compass method.
t. Draw a parabola.
u. Join two points with a parabolic curve.
GEOMETRIC CONSTRUCTIONS
UNIT II

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. Have students make models of some geometric shapes.
VII. Since this unit is very long, items 1-10 can be given as one test and item 11 as a separate test.
VIII. Select title block you want to be used in Assignment Sheet #8.
IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheets
   C. Transparency masters
      1. TM 1 - Basic Geometric Shapes and Terms
      2. TM 2 - Basic Geometric Shapes and Terms (Continued)
      3. TM 3 - Types of Angles
      4. TM 4 - Types of Triangles
      5. TM 5 - Circular Shapes
      6. TM 6 - Circular Shapes (Continued)
      7. TM 7 - Circular Shapes (Continued)
      8. TM 8 - Four-sided Shapes, Cones, and Special Figures
9. TM 9--Special Figures
10. TM 10--Quadrilaterals
11. TM 11--Solids
12. TM 12--Involutes
13. TM 13--Involutes of a Circle
14. TM 14--Polygons and Diagonals
15. TM 15--Polygons

D. Assignment sheets

1. Assignment Sheet #1--Bisect a Line and an Arc
2. Assignment Sheet #2--Bisect an Angle
3. Assignment Sheet #3--Draw Parallel Lines
4. Assignment Sheet #4--Construct a Perpendicular Line to a Line From a Point
5. Assignment Sheet #5--Divide a Line Into Equal Parts
6. Assignment Sheet #6--Draw a Line Perpendicular Through a Point on a Line
7. Assignment Sheet #7--Draw an Arc Tangent to a Straight Line and an Arc
8. Assignment Sheet #8--Draw an Arc Tangent to Two Arcs
9. Assignment Sheet #9--Construct a Triangle with Sides Given
10. Assignment Sheet #10--Construct a Right Triangle
11. Assignment Sheet #11--Construct an Equilateral Triangle with One Side Given
12. Assignment Sheet #12--Inscribe a Hexagon Inside a Circle
13. Assignment Sheet #13--Construct a Hexagon With the Distance Across the Flat Sides Given
14. Assignment Sheet #14--Construct a Circle Through Three Given Points
15. Assignment Sheet #15--Construct a Pentagon by Inscribing
16. Assignment Sheet #16--Draw an Arc Tangent to an Acute Angle and an Obtuse Angle
17. Assignment Sheet #17--Draw an Arc Tangent to a Right Angle
18. Assignment Sheet #18--Draw an Involute of a Circle
19. Assignment Sheet #19-Draw an Ellipse Using the Approximate Ellipse with Compass Method

20. Assignment Sheet #20-Draw a Parabola

21. Assignment Sheet #21-Join Two Points with a Parabolic Curve

E. Test

F. Answers to test

II. References:


GEOMETRIC CONSTRUCTIONS
UNIT II

INFORMATION SHEET

I. Basic geometric terms and definitions

A. Point—A small dot or small cross on a drawing or in space that does not have length, height, depth, or width (Transparency 1)

B. Line—A connection between two or more points (Transparency 1)

C. Straight line—The shortest distance between two points (Transparency 1)

D. Curved line—A line in which no segment is straight (Transparency 1)

E. Line segment—Any part of a line (Transparency 1)

F. Plane figure—A flat, level, even surface such as a piece of paper lying flat on a table (Transparency 1)

(NOTE: This is sometimes referred to simply as a plane.)

G. Intersect—To cut across each other (Transparency 1)

H. Vertex—The common point where lines or surfaces intersect (Transparency 1)

I. Perpendicular—At 90° angles to a given plane or line (Transparency 1)

J. Parallel—Straight lines that do not meet or intersect and are an equal distance apart at all points (Transparency 1)

K. Projection line—Line used to extend from one view to another view (Transparency 1)

L. Skew (oblique) lines—Straight lines that do not intersect and are not parallel or in the same plane (Transparency 2)

M. Bisect—To divide into two equal parts (Transparency 2)

N. Vertical—A line straight up and down perpendicular to the horizontal plane (Transparency 2)

O. Horizontal—Parallel to the plane of the horizon (Transparency 2)

P. Edge—What appears as a line when a plane surface is perpendicular to a plane of projection (Transparency 2)

Q. Equilateral—All sides are equal
INFORMATION SHEET

II. Types of angles and descriptions (Transparency 3)
   A. Angle—Figure formed by two intersecting lines
   B. Right angle—A 90° angle
   C. Acute angle—An angle less than 90°
   D. Obtuse angle—An angle greater than 90°
   E. Complementary angles—Two angles whose sum is 90°
   F. Supplementary angles—Two angles whose sum is 180°

III. Types of triangles and descriptions (Transparency 4)
   A. Triangle—A plane figure bound by three straight sides, and three interior angles which equal 180°
   B. Equilateral triangle—A triangle with three equal sides and three equal angles
   C. Isosceles triangle—A triangle with two equal sides and two equal angles
   D. Scalene triangle—A triangle with no angles or sides equal
   E. Right triangle—A triangle with one 90° angle
      (NOTE: The side opposite the 90° angle of a right triangle is the hypotenuse.)

IV. Circular shapes and descriptions
   A. Circumference—The distance around a circle (Transparency 5)
   B. Radius—The distance from the center point of a circle to the outside circumference (Transparency 5)
   C. Diameter—The distance across a circle passing through its center point (Transparency 5)
   D. Circle—A closed curve all points of which are an equal distance from the center (Transparency 5)
   E. Arc—Any portion of the circumference of a circle (Transparency 5)
   F. Sphere—A round body such as a ball which has all points of its circumference an equal distance from its center (Transparency 5)
   G. Concentric circles—Having the same point as center (Transparency 5)
   H. Eccentric circles—Having different points as center, one within the other (Transparency 5)
   I. Symmetrical—The same on both sides of a center line (Transparency 6)
INFORMATION SHEET

J. Intersected - A figure drawn within another figure so as to touch in as many places as possible (Transparency 6)

K. Circumscribed - A figure encircled so as to touch in as many places as possible (Transparency 6)

L. Axis - A straight line passing through the center of a geometric body upon which the geometric body rotates (Transparency 6)

M. Torus - A solid figure generated by a circle which is revolving on an axis which is eccentric to the circle (Transparency 6)

N. Ellipse - A foreshortened circle having a major diameter and a minor diameter (Transparency 6)

O. Cylinder - A solid figure obtained by taking a rectangle by its edge and rotating it around to its parallel edge, making the ends parallel, and the circles equal (Transparency 6)

P. Tangent - Meeting a curved line or surface, touching at one and only one point, but most definitely not intersecting (Transparency 7)

(Note: To make better tangencies, draw the circular object first, when possible; then draw the straight line from it.)

Q. Chord - Any straight line across a circle that does not pass through the center

R. Semicircle - One half of a circle

S. Circular segment - Less than a semicircle

T. Quadrant - One fourth of a circle

U. Sector - Less than a quadrant

V. Four sided shapes, cones, and special figures and descriptions

A. Square - A plane figure bound by four equal sides, and having four 90° angles (Equilateral parallelogram) (Transparency 8)

B. Rectangle - A plane figure bound by parallel sides of different lengths to form opposite sides that are equal, and having four 90° angles (Transparency 8)

C. Cone - A solid figure with a circle as its base, and a curved surface tapering evenly to the vertex, so that any point on the surface is in a straight line between the circumference of the base and the vertex (Transparency 8)

D. Conic sections - Curves produced by a plane when it intersects a right circular cone (Transparency 8)

(Note: Types of curves produced are the circle, ellipse, hyperbola, and parabola.)
INFORMATION SHEET

E. **Parabola**--A curve generated by a point moving so that its distance from a fixed point is equal to its distance from a fixed line (Transparency 8)

F. **Helix**--Generated by a point moving along and around the surface of a cone or cylinder with a uniform angular velocity about the axis, and with a uniform linear velocity in the direction of the axis (Transparency 9)

G. **Cycloid**--A curve generated by a point located on the circumference of a circle as the circle rolls along a straight line (Transparency 9)

H. **Quadrilateral**--A plane figure bound by four straight sides (Transparency 10)

I. **Parallelogram**--A plane figure bound by four straight sides with the opposite sides parallel (Transparency 10)

J. **Prism**--A solid figure whose plane bases are parallel equal polygons and whose faces are parallelograms (Transparency 11)

K. **Pyramid**--A solid figure with a polygon for a base, with triangular lateral faces that intersect at a common point called a vertex (Transparency 11)

L. **Involute**--A curve traced by a point on a thread or string, as the thread or string unwinds from a line (Transparencies 12 and 13)

VI. Polygons and diagonals and descriptions (Transparencies 14 and 15)

A. **Polygon**--A plane figure with more than three straight sides

B. **Diagonals**--Lines connecting opposite nonsymmetrical corners of a polygon

C. **Regular polygon**--A plane figure with equal straight sides and equal angles; it can be circumscribed around, or inscribed in a circle

D. **Pentagon**--A polygon that has five equal sides and five equal angles

E. **Hexagon**--A polygon that has six equal sides and six equal angles

F. **Octagon**--A polygon that has eight equal sides and eight equal angles

VII Basic geometric shapes

A. **Straight angle**--
INFORMATION SHEET

B. Acute angle

C. Obtuse angle

D. Isosceles triangle

E. Scalene triangle

F. Right triangle

G. Equilateral triangle
INFORMATION SHEET

H. Circle

I. Sphere

J. Pentagon

K. Hexagon
L. Octagon

M. Quadrilaterals

1. Trapezium

2. Trapezoid

3. Rectangle
4. Square:

N. Parallelograms
1. Equilateral
   a. Square:
   b. Rhombus
INFORMATION SHEET

2. Rhomboid--

3. Rectangle--

O. Prism--

P. Torus--
INFORMATION SHEET

Q. Pyramids
   1. Right triangular-

   2. Right square-

   3. Pentagonal-

R. Ellipse
S. Cylinder

T. Cone

U. Parabola
V. Helix

W. Involute of a line
INFORMATION SHEET

X. Involute of a square.

Y. Involute of a triangle.
INFORMATION SHEET

Z Involute of a circle

AA Cycloid
INFORMATION SHEET

VIII. Geometric terms and symbols

A. Perpendicular - \( \perp \)
B. Parallel - \( \parallel \)
C. Angle (singular) - \( \angle \)
D. Angles (plural) - \( \angle S \)
E. Less than - \(<\)
F. Greater than - \(>\)
G. Diameter - \( \Phi \)
H. Radius - \( R \)

IX. Three elements needed for measuring parts of a circle

A. Diameter is measured on a straight line passing through the center point of the circle and extending to the circumference
B. Radius is measured on a straight line from the center of the circle to any point on the circumference; equals one half the diameter
C. Circumference is measured by multiplying the diameter of the circle by \( \pi \) (3.1415926 or 3.14)

X. Three elements needed for interpreting degrees in a circle

A. A full circle has 360 degrees, written as 360°
B. Each degree is divided into 60 minutes, written as 60'
C. Each minute is divided into 60 seconds, written as 60"

Example: 52° 14' 5" would be read as fifty two degrees, 14 minutes, 5 seconds
Basic Geometric Shapes and Terms

Point

Lines

Plane Figure

Straight Line

Curved Line

Line Segments

Intersect

Vertex

Parallel

Perpendicular

Projection Lines
Basic Geometric Shapes & Terms
(Continued)

Bisected Angle

Vertical

Bisected Line

Horizontal

Bisected Arc

Skew

Edge
Types of Angles

- Angle
- Right Angle
- Acute Angle
- Obtuse Angle
- Complementary Angles
- Supplementary Angles
Types of Triangles

Equilateral Triangle

Isosceles Triangle

Scalene Triangle

Right Triangle

Hypotenuse
Circular Shapes

Circumference

Radius

Diameter

Circle

Arc

Sphere

Concentric Circles

Eccentric Circles
Circular Shapes (Continued)

- Inscribed Circle
- Circumscribed Circle
- Symmetrical
- Axis
- Cylinder
- Torus
- Ellipse
Circular Shapes
(Continued)

Tangent

Not Tangent
Four-Sided Shapes, Cones, and Special Figures

Square

Rectangle

Cone

Conic Sections

Circle

Ellipse

Parabola

Hyperbola

Parabola
Special Figures

Helix

Cycloid
Quadrilaterals

(TWO SIDES PARALLEL)

Trapezoid

(NO SIDES PARALLEL)

Trapezium

Parallelograms

Equilateral Parallelograms

Square

Rhombus

Rectangle

Rhomboid
Solids

Prism

Pyramids

Right Triangular Pyramid

Pentagonal Pyramid

Right Square Pyramid
Involutes

Involute of a Line

Involute of a Triangle

Involute of a Square
Involute of a Circle
Polygons and Diagonals

Rectangle

Diagonals

Rectangle

Diagonals

Pentagon

Octagon
Polygons

- Regular Polygon
- Pentagon
- Hexagon
- Octagon
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #1-BISECT A LINE AND AN ARC

Premise: A line and an arc can be bisected with a triangle and compass by using the procedure in the following example.

Example:

1. Use given line AB

2. From A and B use compass to draw equal arcs with radius greater than half

3. Join points D and E with triangle

4. Mark point at C
Directions: Bisect the line AB and arc AB below. Leave all construction lines.

Problem A
ASSIGNMENT SHEET #1

Directions: Draw construction lines lightly and do not erase them.

Problem B:

DRAW \( \frac{1}{2} \)" DIA HOLE AT INTERSECTION OF PERPENDICULAR BISECTORS OF LINES AB AND CD

NOTE: DRAW HORIZONTAL AND VERTICAL CENTER LINES ONLY THROUGH THE HOLE

GRINDER ADJUSTING ARM
Assignment Sheet #2: Bisect an Angle

Premise: An angle can be bisected with a triangle and compass by using the procedure in the following example.

Example:

1. Use given angle BAC

2. Strike a radius using a compass at any radius with point A as vertex

3. Strike equal arcs r with radius larger than half the distance from E to F

4. Draw a line from arc intersection D to vertex A
ASSIGNMENT SHEET #2

Directions. Bisect the angles below. Leave all construction lines.

Problem
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #3--DRAW PARALLEL LINES

Premise: Parallel lines can be drawn with a triangle, compass, and scale by using the procedure in the following example.

Example:

1. Use given line AB

2. Set compass any desired radius CD and swing two arcs anywhere along AB

3. Construct line GH tangent to arcs CD (radius CD required distance between parallel lines)

Directions: Construct a line parallel to line AB 1" below line AB. Leave all construction lines.

Problem:
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #4--CONSTRUCT A PERPENDICULAR LINE
TO A LINE FROM A POINT

Premise: A perpendicular line can be constructed to a line from a point with a triangle and compass by using the procedure in the following example.

Example:

1. Use given line AB and point C

2. Swing any radius from point C as long as it touches two points on line AB

3. Swing radius DF and radius EF equal to radius DC

4. Connect point C with point F

(NOTE: Line CF is 90° to A-B.)

Direction. Construct a line perpendicular from point C to line AB. Leave all construction lines.

Problem.
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #5 DIVIDE A LINE INTO EQUAL PARTS

Premise: A line can be divided into equal parts with a 45° and 30° 60° triangle and a scale by using the procedure in the following example.

Example:

1. Use given line AB to divide into five equal parts.

2. Draw a line at any angle and any length and label point C.

3. Use scale to lay off five equal divisions on line AC, label the last division D.

4. Set triangle to project division back to line AB from point D.

5. Set triangles to be parallel to line BD, mark divisions on line AB parallel to line BD.
ASSIGNMENT SHEET #5

Directions: Divide line \( AB \) into seven equal divisions. Leave all construction lines.

Problem A

---

Directions: Divide horizontal line into five equal parts per inch starting at point A. Draw 60° V's as shown in the following threaded rod. Draw construction lines lightly and do not erase them. Complete section lines.

THREADED ROD

5 THREADS PER INCH

Problem B
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #6—DRAW A LINE PERPENDICULAR THROUGH A POINT ON A LINE

Premise: A line can be drawn perpendicularly through a point on a line with a triangle, compass, and scale by using the procedure in the following example.

Example:

1. **Use** given line AB with point C located on line AB

2. Set compass at any radius r and swing arc through line AB from point C

3. Set compass at distance greater than DC and swing arcs from D and E to form points F and G

4. Connect points F and G through C

Directions: Draw a line perpendicular through point C on line AB. Leave all construction lines.

Problem:
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #7 DRAW AN ARC TANGENT TO A STRAIGHT LINE AND AN ARC

Premise: An arc tangent can be drawn to a straight line and an arc with a triangle, compass, and scale by using the procedure in the following example.

Example:
1. Use given arc with radius G and straight line AB.

2. Swing given arc r from point B and draw a parallel line tangent to arc r.

3. Add radius G to radius r and swing arc G+r to point C from point G.

4. Draw line from the center point of radius G and G+r to point C to obtain tangency point.

5. With center C and given radius r, draw required tangent arc between the line AB and arc.
ASSIGNMENT SHEET #7

Directions: Connect line AB to arc OG with 1" R arc. Leave all construction lines

Problem A

Directions: Complete the drawing of a wing nut and mark all points of tangency. Draw construction lines lightly and do not erase them.

Problem B

There are ___ points of tangency of this wing nut.
ASSIGNMENT SHEET #7

Directions: Draw arc tangent to line AB at B, and through point C, as shown in the following bracket. Draw construction lines lightly and do not erase them.

Problem C:
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #8 DRAW AN ARC TANGENT TO TWO ARCS

Premise. An arc tangent can be drawn to two arcs with a triangle, compass, and scale by using the procedure in the following example.

Example:

1. Use given arcs with centers A and B, and required radius r.

   a. Swing arcs r using any point on circles as center point.
   b. Swing arc AC and arc BC tangent to given r arcs.

2. Draw lines of centers AC and BC to locate points of tangency T, and draw required tangent arc between the points of tangency, as shown from center C.
Assignment Sheet #8

Directions. Connect the two circles with 1/2" diameter circle. Leave all construction lines.

Problem A.

\[ \begin{align*}
&175 \text{ DIA} \\
&75 \text{ DIA} \\
&5 \text{ R} \\
&3.5 \text{ R} \\
&1.12 \text{ DIA} \\
&2.5 \text{ DIA}
\end{align*} \]

Scale: Full size on vellum

Problem B:

There are ___ tangency points on this view.
ASSIGNMENT SHEET #8

Directions: Complete the drawing of an operating arm as shown in the following drawing. Draw on size "A" vellum with title block determined by the instructor. Mark points of tangency. Draw construction lines lightly and do not erase them.

Scale: Full size on vellum

Problem C:

There are ___ tangency points on this view.
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #9—CONSTRUCT A TRIANGLE WITH SIDES GIVEN

Premise: A triangle can be constructed with sides given with a triangle and compass by using the procedure in the following example.

Example:
1. Use given sides A, B, and C

2. Draw one side, the length of C, in desired position, and strike arc with radius equal to given side A

3. Strike arc with radius equal to given side B

4. Draw sides A and B from intersection of arcs, as shown

Directions: Construct a triangle using the three lines given below. Leave all construction lines.

Problem: 

________

________

________
ASSIGNMENT SHEET #10 CONSTRUCT A RIGHT TRIANGLE

Premise: A right triangle can be constructed with a triangle and compass by using the procedure in the following example.

Example:

1. Use given sides R and S

2. Draw in line S with triangle

3. Swing arc with radius length as R

4. Find the middle of line S and use that point with radius 1/2 length of S to swing arc

5. At point of arc intersection connect to end points of line S as shown

\[ 30^\circ \text{ Angle} \]
ASSIGNMENT SHEET #10

Directions: Construct a right triangle using the two lines given below. Leave all construction lines.

Problem:

R

S
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #12 - INSCRIBE A HEXAGON INSIDE A CIRCLE

Premise: A hexagon can be inscribed inside a circle with a 30° 60° triangle by using the procedure in the following example.

Example:
1. Use given circle diameter equal to required distance across corners of hexagon

2. Draw vertical and horizontal center lines through circle

3. Use 30° triangle to construct diagonals AB and CD at 30° with horizontal through center point

4. Use 30° triangle to construct sides

Directions: Draw a hexagon in the circle below. Leave all construction lines.

Problem:
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #13-CONSTRUCT A HEXAGON WITH THE DISTANCE ACROSS THE FLAT SIDES GIVEN

Premise: A hexagon with the distance across the flat sides given can be constructed with a 30° 60° triangle, compass, and parallel bar or drafting machine by using the procedure in the following example.

Example:

1. Use given circle diameter or distance across hexagon flats (1 3/16")

2. Put in vertical and horizontal center lines

3. With the 30° 60° triangle and parallel bar or drafting machine, draw the six sides tangent to the circle; flats can be on sides or on top and bottom.

Flats on top and bottom

Flats on sides
Directions: Construct a hexagon using this circle as the distance across flats. Leave all construction lines.

Problem A: Put flats on top and bottom

Problem B: Put flats on sides
ASSIGNMENT SHEET #13

Directions: Draw hexagons and omit holes for the following hex turret. Scale is 1/8 size (1 1/2" = 1'0"). Have 16" across external flats and 13" across internal flats. Draw construction lines lightly and do not erase them.
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #14-CONSTRUCT A CIRCLE THROUGH THREE GIVEN POINTS

Premise: A circle can be constructed through three given points with a triangle and compass by using the procedure in the following example.

Example:

1. Use given points A, B, and C which are not in a straight line

2. Connect lines AB and BC

3. Find perpendicular bisectors of lines AB and BC; swing arcs as shown

4. Extend bisector lines until they intersect; this will be center point of circle

5. Use this point as center of circle radius
ASSIGNMENT SHEET #14

Directions: Construct a circle below that will pass through the three points given. Leave all construction lines.

Problem A

\[ A + B + C \]
ASSIGNMENT SHEET #14

Directions: Complete the view of the bracket by finding the center of the circle through the three points given. Draw all center lines in pictorial. Scale is 1/2 size. Draw construction lines lightly and do not erase them.

Problem B:

1" REAM

$\frac{1}{4}$" APPROX.

$3\frac{1}{2}$"

$\frac{3}{8}$ DRILL 3 HOLES EQUALLY SPACED
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #15—CONSTRUCT A PENTAGON BY INSCRIBING

Premise: A pentagon can be constructed with a triangle and compass by using the inscribing procedure in the following example.

Example:

1. Use given circle

2. Bisect radius OD at C

3. With C as center and CA as radius, strike arc AE

4. With A as center and AE as radius, strike arc EB

5. Draw line AB; then set off distances AB around the circumference of the circle using compass and draw the sides through these points
ASSIGNMENT SHEET #15

Directions: Inscribe a pentagon in the circles below. Leave all construction lines.

Problem A:

Problem B:

Directions: Inscribe a pentagon in a 2" circle (within hexagon) as used in the following drawing. Draw construction lines lightly and do not erase them.
GEOMETRIC CONSTRUCTIONS
UNTII

ASSIGNMENT SHEET #16—DRAW AN ARC TANGENT TO AN ACUTE ANGLE AND AN OBTUSE ANGLE

Premise: An arc tangent can be drawn to an acute angle and an obtuse angle with a triangle, compass, and parallel bar or drafting machine by using the procedure in the following example.

Example:

1. Use given acute angle and obtuse angle
   (NOTE: In this example every step will be performed on the acute angle on the left and on the obtuse angle on the right.)

2. Draw lines parallel to given lines at distance R from them, to intersect at C, the required center

3. From C drop perpendiculars to the given lines respectively to locate points of tangency T

4. With C as center and with given radius R, draw required tangent arc between the points of tangency
Directions: Connect the sides of the angles below with a 1/2" radius arc. Leave all construction lines.

Problem
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #17--DRAW AN ARC TANGENT TO A RIGHT ANGLE

Premise: An arc tangent can be drawn to a right angle with a triangle and scale by using the procedure in the following example.

Example:

1. Use given lines at right angles to each other, any radius required

2. With given radius R, strike arc intersecting given lines at tangent points T

3. With given radius R again, and with points T as centers, strike arcs intersecting at C

4. With C as center and given radius R, draw required tangent arc

Directions: Draw a 3/4" R arc in the right angles below. Leave all construction lines.

Problem A:
ASSIGNMENT SHEET #17

Directions: Draw arc tangents to complete the drawing as shown in the following bracket. Mark points of tangency. Draw construction lines lightly and do not erase them.

Problem B:

There are ___ points of tangency on this view.
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #18-DRAW AN INVOLUTE OF A CIRCLE

Premise: An involute of a circle can be drawn with a triangle, compass, and irregular curve by using the procedure in the following example.

Example:
1. Use given circle diameter

2. Divide circle into a given number of equal parts; in this case six equal parts

3. At each of these divisions, put in lines tangent to circle and perpendicular to radius lines
4. Lay off the length of the arc from point 1 to point 2; using 2 as center point, swing arc from 2 to 2', lay off the length of the arc from 2' to 3 and swing arc 3-3'

5. Continue in like manner for each point; sketch a light line through the points and darken the curve, using an irregular curve

Directions: Construct an involute of the following circle. Leave all constructions lines.

Problem:
ASSIGNMENT SHEET #19--DRAW AN ELLIPSE USING THE APPROXIMATE ELLIPSE WITH COMPASS METHOD

Premise: An ellipse can be drawn by the compass method with a triangle, compass, and parallel bar or drafting machine by using the procedure in the following example.

Example:

1. Use given axis AB and axis JD

2. Draw line AC

3. With O as center and OA as radius, strike arc AE

4. With C as center and CE as radius, strike the arc EF

5. Draw perpendicular bisector of the line AF; the points T, K, and J where it intersects the axes, are centers of the required arcs

(NOTE: If needed, refer to Assignment Sheet #1 for drawing a perpendicular bisector of a line.)
ASSIGNMENT SHEET #19

6. Find center M by measuring OJ with compass

7. Set compass point at O and strike point M

8. Find center L by measuring OK with compass

9. Set compass point at O and strike point L

10. Draw line M through point K to form point U

11. Draw line M through point L to form point V

12. Draw line J through point L to form point W

13. Keep arcs tangent as shown

14. Using K as the center point, swing arc KA from point U to point T

15. Using L as the center point, swing arc LB from point W to point V

16. Using J as the center point, swing arc JC from point T to point W

17. Using M as the center point, swing arc MD from point V to point U

Directions: Construct an approximate ellipse of the axis lines AB and CD. Leave all construction lines.

Problem A:
ASSIGNMENT SHEET #19

Directions: Draw an approximate ellipse 1 1/4" x 2 1/8" as shown in the following bracket. Draw construction lines lightly and do not erase them.

Problem B:

Directions: Draw an approximate ellipse as shown in the following cam. Draw construction lines lightly and do not erase them.

Problem C:
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #20-DRAW A PARABOLA

Premise: A parabola can be drawn with a triangle, compass, irregular curve, and parallel bar or drafting machine by using the procedure in the following example.

Example:

1. Use given lines ABCD

2. Divide line AD into some number of equal parts

3. Divide line AB into an equal number of parts amounting to the square of that number

Example: If A-D is divided into 4 equal spaces, then AB will be divided into 16 equal spaces
4. From line AD, every point on the parabola is determined by the number of spacing units equal to the square of the number on AD starting from point D which is also 0.

Example: \(1^2=1, 2^2=4, 3^2=9, 4^2=16\)

5. Sketch a light line through the points and darken the curve, using an irregular curve.

Directions: Construct a parabola in the given area. Leave all construction lines.

Problem:
GEOMETRIC CONSTRUCTIONS
UNIT II

ASSIGNMENT SHEET #21--JOIN TWO POINTS WITH A PARABOLIC CURVE

Premise: Two points can be joined in a parabolic curve with a triangle, scale, irregular curve, and parallel bar or drafting machine by using the procedure in the following example.

Example:
1. Use given lines ABCD

2. Divide line AD into an equal number of spaces

3. Divide line DC into the same number of equal spaces

4. Number the points on AD starting at A as 0 and number the points on DC starting at D as 0

5. Draw a straight line from point 1 on line AD to point 1 on line DC

6. Then do this for each point

7. Darken the curve, using an irregular curve
ASSIGNMENT SHEET #21

Directions: Construct a parabolic curve from point B to point D. Leave all construction lines.

Problem:
1. Match the terms on the right with their correct definitions.

a. A small dot or small cross on a drawing or in space that does not have length, height, depth, or width
b. A connection between two or more points
c. The shortest distance between two points
d. A line in which no segment is straight
e. Any part of a line
f. A flat, level, even surface such as a piece of paper lying flat on a table
g. To cut across each other
h. The common point where lines or surfaces intersect
i. At 90° angles to a given plane or line
j. Straight lines that do not meet or intersect and are an equal distance apart at all points
k. Line used to extend from one view to another view
l. Straight lines that do not intersect and are not parallel or in the same plane
m. To divide into two equal parts
n. A line straight up and down perpendicular to the horizontal plane
o. Parallel to the plane of the horizon
p. What appears as a line when a plane surface is perpendicular to a plane of projection
q. All sides are equal

1. Intersect
2. Skew lines
3. Edge
4. Bisect
5. Point
6. Vertex
7. Line
8. Projection line
9. Perpendicular
10. Horizontal
11. Curved line
12. Plane figure
13. Vertical
14. Equilateral
15. Straight line
16. Parallel
17. Line segment
2. Match types of angles on the right with their correct descriptions.

_____ a. Figure formed by two intersecting lines 1. Obtuse angle
_____ b. A 90° angle 2. Right angle
_____ c. An angle less than 90° 3. Supplementary angles
_____ d. An angle greater than 90° 4. Angle
_____ e. Two angles whose sum is 90° 5. Complementary angles
_____ f. Two angles whose sum is 180° 6. Acute angle

3. Match types of triangles on the right with their correct descriptions.

_____ a. A plane figure bound by three straight sides, and three interior angles which equal 180°
1. Triangle
_____ b. A triangle with three equal sides and three equal angles 2. Right triangle
_____ c. A triangle with two equal sides and two equal angles 3. Scalene triangle
_____ d. A triangle with no angles or sides equal 4. Equilateral triangle
_____ e. A triangle with one 90° angle 5. Isosceles triangle

4. Match circular shapes on the right with their correct descriptions.

_____ a. The distance around a circle 1. Tangent
_____ b. The distance from the center point of a circle to the outside circumference 2. Chord
_____ c. The distance across a circle passing through its center point 3. Sector
_____ d. A closed curve all points of which are an equal distance from the center 4. Circumference
_____ e. Any portion of the circumference of a circle 5. Arc
_____ f. A round body such as a ball which has all points of its circumference an equal distance from its center 6. Quadrant
_____ g. Having the same point as center 7. Symmetrical
_____ h. Having different points as center, one within the other
_____ i. The same on both sides of a center line
i. A figure drawn within another figure so as to touch in as many places as possible

k. A figure encircled so as to touch in as many places as possible

l. A straight line passing through the center of a geometric body upon which the geometric body rotates

m. Meeting a curved line or surface, touching at one and only one point, but most definitely not intersecting

n. A solid figure generated by a circle which is revolving on an axis which is eccentric to the circle

o. A foreshortened circle having a major diameter and a minor diameter

p. A solid figure obtained by taking a rectangle by its edge and rotating it around to its parallel edge, making the ends parallel, and the circles equal

q. Any straight line across a circle that does not pass through the center

r. One-half of a circle

s. Less than a semicircle

t. One-fourth of a circle

u. Less than a quadrant

5. Match four-sided shapes, cones, and special figures on the right with their correct descriptions.

a. A plane figure bound by four equal sides, and having four 90° angles

b. A plane figure bound by parallel sides of different lengths to form opposite sides that are equal, and having four 90° angles

c. A solid figure with a circle as its base, and a curved surface tapering evenly to the vertex, so that any point on the surface is in a straight line between the circumference of the base and the vertex

d. Curves produced by a plane when it intersects a right circular cone

1. Helix

2. Cycloid
e. A curve generated by a point moving so that its distance from a fixed point is equal to its distance from a fixed line.

f. Generated by a point moving along and around the surface of a cone or cylinder with a uniform angular velocity about the axis, and with a uniform linear velocity in the direction of the axis.

g. A curve generated by a point located on the circumference of a circle as the circle rolls along a straight line.

h. A plane figure bound by four straight sides.

i. A plane figure bound by four straight sides with the opposite sides parallel.

j. A solid figure whose plane bases are parallel equal polygons and whose faces are parallelograms.

k. A solid figure with a polygon for a base, with triangular lateral faces that intersect at a common point called a vertex.

l. A curve traced by a point on a thread or string, as the thread or string unwinds from a line.

Match polygons and diagonals on the right with their correct descriptions.

a. A plane figure with more than three straight sides.

b. Lines connecting opposite nonsymmetrical corners of a polygon.

c. A plane figure with equal straight sides and equal angles; it can be circumscribed around, or inscribed in a circle.

d. A polygon that has five equal sides and five equal angles.

e. A polygon that has six equal sides and six equal angles.

f. A polygon that has eight equal sides and eight equal angles.
7. Identify the following basic geometric shapes.

a. 

b. 

c. 

d. 

e. 

f. 

g. 

h. 

i. 

j. 


k. m. Quadrilaterals

l. n. Parallelograms

1) Equilateral

2) Parallellogram

3) Parallellogram

4) Parallellogram
o. 

q. Pyramids

1) 

p. 

2) 

3) 

r. 

s. 

t.
8. Match geometric terms on the right with their correct symbols.

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   1. Perpendicular
   2. Parallel
   3. Angle
   4. Angles
   5. Less than
   6. Greater than
   7. Diameter
   8. Radius

9. List three elements needed for measuring parts of a circle.
   a. 
   b. 
   c. 

10. List three elements needed for interpreting degrees in a circle.
    a. 
    b. 
    c. 

11. Demonstrate the ability to:
    a. Bisect a line and an arc.
    b. Bisect an angle.
    c. Draw parallel lines.
    d. Construct a perpendicular line to a line from a point.
    e. Divide a line into equal parts.
    f. Draw a line perpendicular through a point on a line.
    g. Draw an arc tangent to a straight line and an arc.
    h. Draw an arc tangent to two arcs.
    i. Construct a triangle with sides given.
j. Construct a right triangle.

k. Construct an equilateral triangle with one side given.

l. Inscribe a hexagon inside a circle.

m. Construct a hexagon with the distance across the flat sides given.

n. Construct a circle through three given points.

o. Construct a pentagon by inscribing.

p. Draw an arc tangent to an acute angle and an obtuse angle.

q. Draw an arc tangent to a right angle.

r. Draw an involute of a circle.

s. Draw an ellipse using the approximate ellipse with compass method.

t. Draw a parabola.

u. Join two points with a parabolic curve.

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

ANSWERS TO TEST

1. a. 5 b. 7 c. 15 d. 11 e. 17 f. 12 g. 1 h. 6 i. 9 j. 16 k. 8 l. 2 m. 4 n. 13 o. 10 p. 3

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

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

4. a. 4 b. 10 c. 16 d. 15 e. 5 f. 3 g. 20 h. 13 i. 7 j. 18 k. 19 l. 11 m. 1 n. 8 o. 12 p. 17 q. 2 r. 9 s. 21 t. 6 u. 3

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

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

n. Parallelograms
   1.) Equilateral
      a.) Square
      b.) Rhombus
   2.) Rhomboid
   3.) Rectangle

o. Prism

p. Torus

q. Pyramids
   1.) Right triangular
   2.) Right square
   3.) Pentagonal

r. Ellipse

s. Cylinder

t. Cone

u. Parabola

v. Helix

w. Involute of a line

x. Involute of a square

y. Involute of a triangle

z. Involute of a circle

aa. Cycloid

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

9. a. Diameter is measured on a straight line passing through the center point of the circle and extending to the circumference

   b. Radius is measured on a straight line from the center of the circle to any point on the circumference; equals one half the diameter

   c. Circumference is measured by multiplying the diameter of the circle by π

10. a. A full circle has 360 degrees, written as 360°
   
   b. Each degree is divided into 60 minutes, written as 60'

   c. Each minute is divided into 60 seconds, written as 60"

11. Evaluated to the satisfaction of the instructor
ORTHOGRAHIC VIEWS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify planes and lines, and construct missing hidden and visible lines, various views, and points, planes, and lines in orthographic views. 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 orthographic views with their correct definitions.
2. Distinguish between the types of projection systems.
3. Identify the ISO projection symbols.
4. Arrange in order the steps in visualizing an orthographic projection.
5. List the six views possible in orthographic projection.
6. List the three most commonly used views in orthographic projection.
7. Select true statements concerning the steps in selecting correct views of an object.
8. List the basic dimensions of an object.
9. List the most common methods of transferring dimensions.
10. Select the projection of lines in orthographic views.
11. Identify types of planes.
12. Select the correct usage of hidden lines.
13. Select correct line precedence in an orthographic drawing.
14. Identify line thicknesses used in orthographic drawings.
15. State the purpose of runouts.
16. Demonstrate the ability to:
   a. Identify types of planes in orthographic views.
   b. Identify projection of lines in orthographic views.
c. Construct a top view.
d. Construct a front view.
e. Construct a right side view.
f. Construct missing hidden lines.
g. Construct missing visible and hidden lines.
h. Construct circles and arcs using a template.
i. Make a two-view sketch.
j. Make a three-view sketch.
k. Construct a one-view drawing.
l. Construct a two-view drawing.
m. Construct a three-view drawing.
n. Construct a runout.
o. Construct a point in an orthographic view.
p. Construct a line in an orthographic view.
q. Construct a plane in an orthographic view.

17. Construct various orthographic drawings.
ORTHOGONIC VIEWS
UNIT III

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. Construct a model in a "Glass box" and discuss orthographic projection.
VII. Use blocks to show various angles and use blocks for sketching.
VIII. Construct blocks, if necessary.
IX. Assignment sheets suggest the use of vellum. Other media may be substituted.
X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Comparison Between First and Third Angle Projection
      2. TM 2--Orthographic Projection
      3. TM 3--Orthographic Projection (Continued)
      4. TM 4--Orthographic Projection (Continued)
      5. TM 5--Orthographic Projection (Continued)
      6. TM 6--Principal Views in Orthographic Projection
      7. TM 7--One-View Drawings
      8. TM 8--Two-View Drawings
      9. TM 9--Three-View Drawings
10. TM 10--Positioning of Views
11. TM 11--Position of Side View
12. TM 12--Methods of Transferring Dimensions
13. TM 13--Visualization of Lines
14. TM 14--Projection of Lines in Orthographics
15. TM 15--Visualization of Planes
16. TM 16--Planes in Orthographic Projection
17. TM 17--Visualization of a Point
18. TM 18--Usage of Hidden Lines
19. TM 19--Line Precedence
20. TM 20--Line Thickness in Orthographic Drawing
21. TM 21--Fillets, Rounds, and Runouts
22. TM 22--Projection of Fillet and Round Edges

Assignment sheets
1. Assignment Sheet #1--Identify Types of Planes in Orthographic Views
2. Assignment Sheet #2--Identify Projection of Lines in Orthographic Views
3. Assignment Sheet #3--Construct a Top View
4. Assignment Sheet #4--Construct a Front View
5. Assignment Sheet #5--Construct a Right Side View
6. Assignment Sheet #6--Construct Missing Hidden Lines
7. Assignment Sheet #7--Construct Missing Visible and Hidden Lines
8. Assignment Sheet #8--Construct Circles and Arcs Using a Template
9. Assignment Sheet #9--Make a Two-View Sketch
10. Assignment Sheet #10--Make a Three-View Sketch
11. Assignment Sheet #11--Construct a One-View Drawing
12. Assignment Sheet #12--Construct a Two-View Drawing
13. Assignment Sheet #13--Construct a Three-View Drawing
14. Assignment Sheet #14--Construct a Runout

15. Assignment Sheet #15--Construct a Point in an Orthographic View

16. Assignment Sheet #16--Construct a Line in an Orthographic View

17. Assignment Sheet #17--Construct a Plane in an Orthographic View

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:


ORTHOGRAPHIC VIEWS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Orthographic projection--Method of representing the exact shape of an object in two or more views on planes at right angles to each other

B. First-angle projection--All views are projected onto planes located behind the object

C. Third-angle projection--All views are projected onto planes lying between the object and viewer

D. Projection lines--Lines used to extend from one view to the next view

E. Height--Distance from bottom to top plane

F. Length--Distance from left side to right side plane

G. Depth--Distance from front to back plane

H. Normal plane--True size plane that is parallel to one principal viewing plane and edge view in other two principal planes

I. Foreshortened--To appear shorter to the eye than it actually is

J. Inclined plane--A plane that is foreshortened in two principal viewing planes and edge view in one other principal viewing plane

K. Oblique plane--A plane that is foreshortened in all three principal viewing planes

L. Visualize--To form a mental picture or image

M. Frontal view--Front view

N. Profile view--Left side or right side view

O. Horizontal view--Top view

P. True size--A surface or line that is shown in its actual size

Q. Fold line--A theoretical line between two views where viewing planes fold (NOTE: This is used as a reference line on drawings.)

R. Line of sight--Direction from which an object is being viewed
INFORMATION SHEET

S. Transfer--Take from one point of view and put in another view

T. Coincide--To match up identically

U. Line precedence--Lines that are more important to show than others

V. Skew (oblique) lines--Nonintersecting lines, not parallel to each other or to the principal views

W. Runout--Intersection of a fillet or round with another surface

X. Fillet--Small rounded inside corner of an object

Y. Round--Small rounded outside corner of an object

(NOTE: Fillets and rounds are normally 1/4" radius or less.)

Z. Line--Straight element that is generated by a moving point and has extension only along the path of the point

II. Types of projection systems (Transparency 1)

A. First-angle--Used in European and Asian countries

B. Third-angle--Used in the United States, Canada, and other countries

III. ISO (International Standards Organization) projection symbols (Transparency 1)

A. First-angle

B. Third angle

(NOTE: Location of symbol is in lower right hand corner of drawing and adjacent to title block.)
IV. Steps in visualizing an orthographic projection (Transparencies 2, 3, 4, 5, and 6)
   A. Visualize by looking at the actual object or picture of the object
   B. To obtain views, project the lines of sight to each plane of projection from all points on the object
   C. Rotate all planes until they align with front plane of projection
   D. Visualize the six possible views of the object that are revolved into the same plane as on a drawing surface
   E. Inspect views and determine those needed to adequately represent the object

V. Views possible in orthographic projection (Transparency 4)
   A. Top
   B. Front
   C. Right side
   D. Left side
   E. Bottom
   F. Rear

VI. Most commonly used views in orthographic projection (Transparency 5)
   A. Top
   B. Front
   C. Right side

VII. Steps in selecting correct views of an object (Transparencies 6, 7, 8, 9, 10, and 11)
    A. Select view necessary to best describe contour shape in front view
    B. Select the view that contains the least number of hidden lines
    C. Select alternate position for right side view if drawing area is crowded
    D. Select only needed views necessary to present an understanding of an object
E. If there is no other option, select the view that best describes the object
F. Select view positions to avoid crowding of dimensions and notes

VIII. Basic dimensions of an object (Transparencies 2 and 6)
A. Length
B. Height
C. Depth

IX. Most common methods of transferring dimensions (Transparency 12)
A. 45° mitre line
   (NOTE: This is used for projecting depth dimensions.)
B. Dividers
C. Scale

X. Projection of lines in orthographic views (Transparencies 13 and 14)
A. Point
B. True length
C. Foreshortened

XI. Types of planes (Transparencies 15 and 16)
A. Normal
B. Inclined
   (NOTE: True size is determined by auxiliary views.)
C. Oblique
   (NOTE: True size is determined by auxiliary views.)
XII. Usage of hidden lines (Transparency 18)

A. Correct

B. Incorrect

C. Correct

D. Incorrect

XIII. Line precedence in an orthographic drawing (Transparency 19)

A. Visible line

B. Hidden line

C. Cutting plane line

D. Center line

XIV. Line thicknesses used in orthographic drawings (Transparency 20)

A. Visible line-- (thick)

B. Hidden line-- (thin)

C. Center line-- (thin)

D. Phantom line-- (thin)

XV. Purpose of runouts: Intersection of fillets and rounds are used to eliminate problems in castings (Transparencies 21 and 22)
Comparison Between First and Third Angle Projection

Object Between Plane and Viewer

First Angle

Symbol

Viewing Plane Between Object and Viewer

Third Angle

Symbol
Orthographic Projection

Projectors perpendicular to planes of projection.

Line of Sight

Top View

Front View

R. Side View

Length

Height

Depth

Line of Sight
Front Plane of Projection

All planes revolve until they align with front plane of projection.
The six planes are laid on a flat plane as on a drawing surface.
Orthographic Projection Continued

Draftsman should be able to rotate views in his mind as pictured below.
Principal Views in Orthographic Projection

Eliminate Views Not Needed

Right angled notch shown in front view and side view.

Rear
L. Side

Front
R. Side

Bottom
One-View Drawings

Objects with very little thickness require only one view.
Two-View Drawings

Some objects require only two views.
Some objects require three views to describe their shape.
Positioning of Views

Top

Front

R. Side

INCORRECT

Correct

INCORRECT

Correct

Top Should Be Above Front

Top

R. Side

Views Not Lined Up

Front

R. Side
Position of Side View

- Shape of object determines best location for side view.
- R. Side view can be projected off the front view or the top view.
- Space limitation requires alternate location.
Methods of Transferring Dimensions

45° Mitre Line

Dividers

Scale
Visualization of Lines

Normal Line

Inclined Line

Oblique Line

All Three Views Fore-shortened
Projection of Lines in Orthographics

Point

True Length Line

Foreshortened

Foreshortened
Visualization of Planes

Normal plane

Inclined Plane

Oblique Plane

All Three Views Fore-shortened
Planes in Orthographic Projection

Normal

Inclined

Oblique
Visualization of a Point

Space Picture

Orthographic View
Usage of Hidden Lines

Correct Incorrect

Correct Incorrect

Correct Incorrect

Correct Incorrect

Correct Incorrect

Correct Incorrect

Correct Incorrect

Correct Incorrect

Correct Incorrect
Line Precedence

Visible line precedes hidden line

Visible line precedes center line

Hidden line precedes center line

Cutting plane line precedes center line
Line Thickness in Orthographic Drawing

Thick Solid Lines Used to Indicate Visible Lines

Approx. 1/4" Min.

Center Line Should not be Broken When it Extends Beyond Visible Line

Thin Dash Lines Used to Indicate Hidden Edges

Phantom Lines Used to Indicate Alternate Position
Fillets, Rounds, and Runouts

- Fillet
- Casting Surface Rough
- Round
- Finish Surface Smooth

Rounded Corners
Round

Runout Intersection Between a Cylinder and an Elliptical Part

Point of Tangency
Rounded Corners

Runout Intersection Between a Cylinder and Rounded Part
Projection of Fillet and Round Edges

Incorrect

Correct

Incorrect

Correct

Incorrect
**ORTHOGRAFIC VIEWS**
**UNIT III**

**ASSIGNMENT SHEET #1--IDENTIFY TYPES OF PLANES IN ORTHOGRAPHIC VIEWS**

Directions: Identify the types of planes in the drawings by writing normal, inclined, or oblique in the chart provided.

<table>
<thead>
<tr>
<th>PLANE</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>B</td>
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<td>E</td>
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<tr>
<td>F</td>
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<tr>
<td>G</td>
<td></td>
</tr>
</tbody>
</table>

**Problem A**

![Diagram of Problem A]

**Problem B**

![Diagram of Problem B]
ORTHOGONAL VIEWS
UNIT III

ASSIGNMENT SHEET #2: IDENTIFY PROJECTION OF LINES IN ORTHOGRAPHIC VIEWS

Directions: Identify correct projection of lines in the drawings by writing point, true length, or foreshortened in the chart provided.

<table>
<thead>
<tr>
<th>LINE</th>
<th>TOP</th>
<th>FRONT</th>
<th>R SIDE</th>
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Problem B:

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</table>
ORTHOGRAPHIC VIEWS
UNIT III

ASSIGNMENT SHEET #3 - CONSTRUCT A TOP VIEW

Premise The top view is first viewed on an imaginary plane, and then drawn in its correct position using mitre method of transferring dimensions.

Example

Directions Align views with drafting machine and tape down. Construct top views of the following objects. Do not show hidden lines.

Problem A.

Top Here
ORTHOGRAPHIC VIEWS
UNIT III

ASSIGNMENT SHEET #4—CONSTRUCT A FRONT VIEW

Premise: The front view is first viewed on an imaginary plane, and then drawn in its correct position.

Example:

Directions: Construct the front views of the following objects. Align, tape down, and do not show hidden lines.

Problem A:
Problem B

Problem C:

Problem D.
ORTHOGRAPHIC VIEWS
UNIT III

ASSIGNMENT SHEET #5: CONSTRUCT A RIGHT SIDE VIEW

Premise: The end view is first viewed on an imaginary plane, and then drawn in its correct position (right or left).

Example:

Directions: Align views with drafting machine and tape down Construct the right side view in the space provided.

Problem A:
Problem B:

Problem C:

Problem D
Example:

Directions: Construct the missing hidden lines in the views below. Align and tape down.

Problem A:

Problem B:
ASSIGNMENT SHEET #6

Problem C:

Problem D:
ASSIGNMENT SHEET #7: CONSTRUCT MISSING VISIBLE AND HIDDEN LINES

Directions: Study the views below and construct the missing visible and hidden lines. Align and tape down.

Problem A:

Problem B:

Problem C:

Problem D:
ORTHOGRAPHIC VIEWS
UNIT III

ASSIGNMENT SHEET #8-CONSTRUCT CIRCLES AND ARCS USING A TEMPLATE

Premise: Using circle templates in constructing small circles and arcs will save time. The templates have four alignment marks that will coincide with the center lines. The template hole openings will allow for width of lead. A 3/4" hole will actually measure about 13/16". Make sure pencil is perpendicular with template. Use the procedure in the following example for circles and arcs.

Example:

1. Block in object with light construction lines

2. Locate and construct light center lines for circles and arcs

3. Select correct hole diameter on circle template
4. Align marks on template with center lines, and construct the required circle lightly

(NOTE: Alignment marks on some templates are not printed accurately.)

5. Select correct hole on circle template for arc radius

(NOTE: Radius is equal to \( r/2 \) diameter.)

6. Align marks on template with center lines, and construct the required arc lightly

7. Erase all construction lines not needed

8. Darken in circles and arcs first, then straight lines

(NOTE: Arcs tangent to straight lines should meet and align smoothly.)

TANGENT
Directions: Align bottom of paper with drafting machine and tape down. Construct a one-view drawing of the gasket in the space below using a circle template. Erase construction lines and darken in visible and center lines. Do not dimension.

Problem A.

Premise: The intersection of a hole or cylinder with an inclined plane will be shown as an ellipse or elliptical curve. Ellipses can be constructed with templates or by hand. Ellipse templates are available in ellipse angles at 5° intervals, such as 15°, 20°, 25°. If an ellipse template is not available, use the procedure in the following example:

Example:

1. Construct the three views showing circle or curve and angle of inclined plane

2. Divide the curve into an equal or random number of points

   (NOTE: Several points are needed for a smooth curve.)
3. Project point marked No. 4 on curve to other views to intersect in top view.

4. Project the other marked points to intersect, representing inclined edge.

5. Sketch a light curved line through the intersection of points.

6. Erase construction lines and darken in curve line with the aid of an irregular curve.
ASSIGNMENT SHEET #8

Directions: Construct three views of the following object full size on available media. Leave construction lines. Do not dimension. Leave 1" of space between views.

Problem B:

Directions: Construct three views of the following object full size on available media. Leave construction lines. Do not dimension. Leave 1" of space between views.

Problem C:

Directions: Construct three views of the following object full size on available media. Leave construction lines. Do not dimension. Leave 1" of space between views.
ASSIGNMENT SHEET #8

Directions. Construct three views of the object below full size on available media. If ellipse template is not available, use 45° inclined plane angle. Erase construction lines. Do not dimension.

Problem D

--- Diagram ---

FRONT

MATL \( \frac{3}{8} \) THICK

DRILL \( \frac{5}{8} \) 2 HOLES

--- Measurements ---

2 holes

40°

MATL \( \frac{3}{8} \) THICK

FRONT
ORTHOGRAPHIC VIEWS
UNIT III

ASSIGNMENT SHEET #9: MAKE A TWO-VIEW SKETCH

Premise: A two-view sketch can be made by using the procedure in the following example.

Example:

1. Sketch the horizontal lines to locate the height of the object
   (NOTE: The distance at the top and bottom of the paper should be the same.)

2. Sketch the vertical lines to locate the width and depth of the object
   (NOTE: The distance at the left side and right side of the paper should be the same. The distance between the views can be the same as that on the left side and right side or slightly less than that space.)

3. Block in details using diagonals to locate centers, and lightly sketch the circles and arcs

4. Use an art gum eraser to dim construction lines and darken in visible lines

Directions: Make a two-view sketch of the following object.

Problem
ORTHOGRAPHIC VIEWS
UNIT III

ASSIGNMENT SHEET #10—MAKE A THREE-VIEW SKETCH

Example:

1. Sketch the horizontal lines to locate the height of the object
   (NOTE: The distance at the top and bottom of the paper should be the same. The distance between the top and front views can be the same as that on the top and bottom or slightly less than that space.)

2. Sketch the vertical lines to locate the width and depth of the object
   (NOTE: The distance at the left side and right side of the paper should be the same. The distance between the views can be the same as that on the left side and right side or slightly less than that space. In the top and side views, the depth must be equal; this can be done by marking a piece of paper with depth.)

3. Block in details using diagonals to locate centers, if necessary, and lightly sketch the circles and arcs

4. Add line features to the views of the object

5. Use an artgum eraser to dim construction lines and darken in visible lines
ASSIGNMENT SHEET #10

Directions: Sketch three views of the object using grids for measurements.

Problem.
ORTHOGRAFIC VIEWS
UNIT III

ASSIGNMENT SHEET #11--CONSTRUCT A ONE VIEW DRAWING

Premise: It is important for good appearance that views be well balanced on drawing media, whether the drawing shows one, two, three views, or more. Use the procedure in the following example for spacing a one-view drawing.

Example:

1. Locate the center of the working space by constructing diagonals (Figure 1)

2. Block in lightly horizontal construction lines by measuring the distances (Figure 2)

3. Block in lightly vertical construction lines by measuring the distances (Figure 3)
ASSIGNMENT SHEET #11

4 Construct the necessary light center lines, circles, arcs and then straight lines (Figure 4).

5 Erase construction lines not needed (Figure 5).

6 Darken circles and arcs first, then straight lines (Figure 5).

7 Fill in title block.

Directions: Center and construct the gasket full size on A size vellum. Use standard title block. Do not dimension.

Problem:
ORTHOGRAHIC VIEWS
UNIT III

ASSIGNMENT SHEET #12--CONSTRUCT A TWO-VIEW DRAWING

Premise: It is important for good appearance that views be well balanced on drawing media. The drafter must determine the size of the object to be drawn, number of views, scale used, and space between views. Space between views should be allotted for notes and dimensions. Use the procedure in the following example for allotted space for a two-view drawing.

Example:

1. Calculate the spacing of views for object shown in Figure 1 (Figure 2)
   (NOTE: Spacing is assumed between views when drawing is dimensioned.)

2. Block in views, with light horizontal and vertical construction lines through spacing marks (Figure 2)

3. Locate center lines, and then construct light arcs and circles (Figures 2 and 3)

4. Add light visible and hidden lines (Figure 3)
   (NOTE: Do not complete one view before starting on another.)
5. Erase unnecessary construction lines, and then darken in circles, hidden lines, and visible lines (Figure 4)

(NOTE: Hidden and center lines should be thin in contrast to the visible lines, but should be dark enough to reproduce well.)

6. Letter in title block

Directions: Construct two views full size on A size vellum. Use standard border and title block. Do not dimension.

Problem:
ORTHOGRAPHIC VIEWS
UNIT III

ASSIGNMENT SHEET #13--CONSTRUCT A THREE-VIEW DRAWING

Premise: A drafter should space views so that they will give the drawing a balanced appearance. Before drawing an object, the number of views needed must be decided and a three-view drawing is sometimes required. To construct a three-view drawing use the procedure in the following example.

Example:

1. Select the proper surface to represent the front view for object shown in Figure 1

2. Construct a three-view sketch to determine dimension for blocking in and to clear up any uncertain details

3. Select a sheet size and scale that will avoid crowding of views, dimensions, and notes

   (NOTE: For this procedure the scale, dimensions, notes, and title block are omitted.)

4. Calculate the spacing of the views for a standard drawing sheet (Figure 2)

5. Block in views with light horizontal and vertical construction lines through spacing marks (Figure 3)

   (NOTE: Check measurements carefully when blocking in views.)
6. Construct mitre line for transferring of measurements in top and right side view (Figure 3)

7. Locate center lines and construct light arcs and circles, straight visible lines, and hidden lines (Figure 4)

   (NOTE: Check layout carefully for missing lines, notes, or special shapes required.)

8. Erase unnecessary construction lines and give drawing a good cleaning (Figure 5)

9. Darken in arcs and circles, and then center lines, hidden lines, and visible lines (Figure 5)

10. Letter notes and title block

11. Check finished drawing carefully for spelling, lineweight, and general appearance
ASSIGNMENT SHEET #13

Directions: Construct three views of objects shown full size on B size vellum. Do not dimension.

Problem A: Normal surfaces

Problem B: Oblique surfaces
Premise: The arc of the runout is the same radius as the fillet or round. It may be drawn freehand, with irregular curve, or with a circle template. The circle template procedure is used in the following example.

Example:

1. Project point of tangency from top to front view (Figure 1)

2. Construct 45° line through fillet’s center to locate point A, and then project to point A' (Figure 2)

3. Center B is found by projecting from A' to 45° to the horizontal projection through B' (Figure 3)

4. Use circle template to construct runout arc from A' using center B (Figure 4)
Directions: Align the horizontal center line of the object below with drafting machine. Tape down. Construct the runouts. Do not erase construction lines.

Problem:
ORTHOGONAL VIEWS
UNIT III

ASSIGNMENT SHEET #15--CONSTRUCT A POINT IN AN ORTHOGRAPHIC VIEW

Premise: A point in space has position but no extension such as the intersections of two lines. Three dimensions are necessary to fix its position in space. The procedure for the orthographic projection of one point will be used in the following example.

Example:

1. Use given point A in two views (Figure 1)

2. Project perpendicular lines from point A to reference lines RL1 and RL2 (Figure 1)

   (NOTE: Light projected lines perpendicular to reference lines should be used to align the projections.)

3. Construct mitre line to project depth dimension from top to right side or right side to top (Figure 1)

   (NOTE: This is needed only to establish position in top view or right side view.)

4. Project point SAT and AF to intersect in right side view to establish point in third view (Figure 2)
ASSIGNMENT SHEET #15

Directions: Align drafting machine with reference line and tape down for the following problems. Leave construction lines. Construct the points in the third view. Label points in third view.

Problem A:

Problem B:
ORTHOGRAPHIC VIEWS
UNIT III

ASSIGNMENT SHEET #16--CONSTRUCT A LINE IN AN ORTHOGRAPHIC VIEW

Premise: Lines are grouped into types as normal, inclined, or oblique, depending on how they are positioned with relationship to the reference lines. The procedure in the following example for oblique lines can be used for inclined or normal lines.

Example:

1. Use given line AB in two views (Figure 1)

2. Project perpendicular lines from points A and B to reference lines RL1 and RL2 (Figure 2)

3. Construct mitre line to project depth dimensions from top to right side or right side to top view (Figure 2)

4. Project points AT, BT and AF, BF to right side view, locating points ARS, BRS (Figure 3)
ASSIGNMENT SHEET #16

5. Connect points \(A_{RS}, B_{RS}\) with a line (Figure 4)

Directions: Align drafting machine with reference line and tape sheet down. Construct the third view of the line or lines given in the space provided.

Problem A:
ASSIGNMENT SHEET #16

Problem B:

\[ C_T \quad D_T \]
\[ \quad T \quad RS \]
\[ F \]
\[ C_F \quad D_F \]

Problem C:

\[ A_T \]
\[ B_T \]
\[ C_T \quad D_T \]
\[ T \quad RS \]
\[ F \]
\[ A_F \quad D_F \]
\[ C_F \quad B_F \]
Problem D.
ORTHOGONIC VIEWS
UNIT II

ASSIGNMENT SHEET #17-CONSTRUCT A PLANE IN AN ORTHOGRAPHIC VIEW

Premise: Planes are without thickness. A plane may be constructed by intersecting lines, two parallel lines, a line and a point, three points, or a triangle. The procedure in the following example is for constructing the third view when two views are given.

Example:

1. Use given plane ABC in two views (Figure 1)

2. Project perpendicular lines from points A, B, and C, to reference lines RL1 and RL2 (Figure 2)

3. Construct mitre line to project depth dimension from top to right side or right side to top view (Figure 2)

4. Project points AT, BT, CT, and AF, B F, CT, to right side view, locating points ARS, BRS, CRS (Figure 3)
5. Connect points $A_{RS}$, $B_{RS}$, $C_{RS}$ with lines to form plane (Figure 4)

Directions: Align drafting machine with reference line and tape sheet down. Construct the third view of the plane given in the space provided.

Problem A:
Problem B:

Problem C:
Problem D.
ORTHOGRAPHIC VIEWS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

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<thead>
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Assignment Sheet #2

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Assignment Sheet #7

E. 

F. 

G. 

H. 

I. 

J. 

K. 

L. 

M. 

N. 

O. 

P.
Assignment Sheet #8

A. Evaluated to satisfaction of the instructor

B.

C.

D.
Assignment Sheet #17

A. 

B. 

C. 

D. 

E. 

F. 

G. 

H. 

I. 

J.
ORTHOGRAPHIC VIEWS
UNIT III

NAME _________________________

TEST

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

   a. Method of representing the exact shape of an object in two or more views on planes at right angles to each other

   b. All views are projected onto planes located behind the object

   c. All views are projected onto planes lying between the object and viewer

   d. Lines used to extend from one view to the next view

   e. Distance from bottom to top plane

   f. Distance from left side to right side plane

   g. Distance from front to back plane

   h. True size plane that is parallel to one principal viewing plane and edge view in other two principal planes

   i. A plane that is foreshortened in two principal viewing planes and edge view in one other principal viewing plane

   j. A plane that is foreshortened in all three principal viewing planes

   k. To appear shorter to the eye than it actually is

   l. To form a mental picture or image

   m. Front view

   n. Left side or right side view

   o. Top view

   p. A surface or line that is shown in its actual size

   q. A theoretical line between two views where viewing planes fold

   1. Skew lines

   2. Fold line

   3. Horizontal view

   4. Frontal view

   5. Oblique plane

   6. Line

   7. Round

   8. Profile view

   9. Fillet

   10. Length

   11. First-angle projection

   12. Coincide

   13. Visualize

   14. Projection lines

   15. Runout

   16. Height

   17. Line precedence
r. Direction from which an object is being viewed
s. Take from one point of view and put in another view
t. To match up identically
u. Lines that are more important to show than others
v. Nonintersecting lines, not parallel to each other or to the principal views
w. Intersection of a fillet or round with another surface
x. Small rounded inside corner of an object
y. Small rounded outside corner of an object
z. Straight element that is generated by a moving point and has extension only along the path of the point

2. Distinguish between the types of projection systems by placing an "X" next to the type used in the United States.
   a. First-angle
   b. Third-angle

3. Identify the ISO projection symbols.

   a. 
   b. 

18. Foreshortened
19. Orthographic projection
20. Inclined plane
21. True size
22. Third-angle projection
23. Depth
24. Normal plane
25. Line of sight
26. Transfer
4. Arrange in order the steps in visualizing an orthographic projection by placing the correct sequence numbers in the appropriate blanks.

   a. To obtain views, project the lines of sight to each plane of projection from all points on the object
   b. Inspect views and determine those needed to adequately represent the object
   c. Visualize by looking at the actual object or picture of the object
   d. Rotate all planes until they align with front plane of projection
   e. Visualize the six possible views of the object that are revolved into the same plane as on a drawing surface

5. List the six views possible in orthographic projection.

   a. ____________________________  d. ____________________________
   b. ____________________________  e. ____________________________
   c. ____________________________  f. ____________________________

6. List the three most commonly used views in orthographic projection.

   a. ____________________________
   b. ____________________________
   c. ____________________________

7. Select true statements concerning the steps in selecting correct views of an object by placing an "X" in the appropriate blanks.

   a. Select view necessary to best describe contour shape in right side view
   b. Select the view that contains the greatest number of hidden lines
   c. Select only needed views necessary to present an understanding of an object
   d. If there is no other option, select the view that best describes the object
   e. Select view positions to avoid crowding of dimensions and notes
8. List the basic dimensions of an object:
   a. 
   b. 
   c. 

9. List the most common methods of transferring dimensions:
   a. 
   b. 
   c. 

10. Select the projection of lines in orthographic views by placing an "X" in the appropriate blanks:
    a. For short
    b. Skew
    c. Point
    d. True length

11. Identify types of planes:
    a. A planes
    b. B planes
    c. C planes
12. Select the correct usage of hidden lines by placing an "X" in the appropriate blanks.

```plaintext
a.     b.     c.     d.     e.  
      - - -

f.     g.     h.     i.     j.  

k.     l.     m.     n.     o.  
```

13. Select correct line precedence in an orthographic drawing by placing an "X" in the appropriate blanks.

```plaintext
_____ c. cutting plane line  
_____ d. center line  
_____ e. visible line  
_____ f. hidden line  

_____ a. center line  
_____ b. visible line  
```

```plaintext
_____ g. center line  
_____ h. hidden line  
```
14 Identify line thicknesses used in orthographic drawings.

a

b

c

d

15 State the purpose of runouts.

16 Demonstrate the ability to

a Identify types of planes in orthographic views
b Identify projection of lines in orthographic views
c Construct a top view
d Construct a front view.
e Construct a right side view
t Construct missing hidden lines
g Construct missing visible and hidden lines
h Construct circles and arcs using a template
Make a two-view sketch.
i Make a three view sketch
k Construct a one view drawing
l Construct a two view drawing
m Construct a three view drawing
n Construct a runout
o Construct a point in an orthographic view
p Construct a line in an orthographic view
q Construct a plane in an orthographic view

(Note: If these activities have not been assigned, the days and instructors when they should be completed.)
17. Construct various orthographic drawings.

   a. Complete the missing lines and views.

      1)      2)      3)      4)      5)      6)

   b. Construct three views of the object full size shown in pictorial. Begin the views using the corners given. Each mark is equal to 1/4".
c. Construct three views of the object full size shown in pictorial. Each mark is equal to 1/4".

d. Construct a runout. Leave construction lines.

e. Construct points A and B in right side view.

f. Construct plane ABC in right side view.
ORTHOGRAPHIC VIEWS
UNIT III

ANSWERS TO TEST

<table>
<thead>
<tr>
<th>1. a.</th>
<th>19</th>
<th>m.</th>
<th>4</th>
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<tbody>
<tr>
<td>b.</td>
<td>11</td>
<td>n.</td>
<td>8</td>
</tr>
<tr>
<td>c.</td>
<td>22</td>
<td>o.</td>
<td>3</td>
</tr>
<tr>
<td>d.</td>
<td>14</td>
<td>p.</td>
<td>21</td>
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<tr>
<td>e.</td>
<td>16</td>
<td>q.</td>
<td>2</td>
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<tr>
<td>f.</td>
<td>10</td>
<td>r.</td>
<td>25</td>
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<tr>
<td>g.</td>
<td>23</td>
<td>s.</td>
<td>26</td>
</tr>
<tr>
<td>h.</td>
<td>24</td>
<td>t.</td>
<td>12</td>
</tr>
<tr>
<td>i.</td>
<td>20</td>
<td>u.</td>
<td>17</td>
</tr>
<tr>
<td>j.</td>
<td>5</td>
<td>v.</td>
<td>1</td>
</tr>
<tr>
<td>k.</td>
<td>18</td>
<td>w.</td>
<td>15</td>
</tr>
<tr>
<td>l.</td>
<td>13</td>
<td>x.</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>y.</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>z.</td>
<td>6</td>
</tr>
</tbody>
</table>

2. b

3. a  Third angle
     b  First angle

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

5. a  Top  d  Left side
     b  Front e  Bottom
     c  Right side f  Rear

6. a  Top
     b  Front
     c  Right side

7  c, d, e

8. a  Length
     b  Height
     c  Depth

9. a  45° mitre line
     b  Dividers
     c  Scale

10. a, c, d

11. a  Oblique
     b  Inclined
     c  Normal
12.  a, d, f, i, k, m, n
13.  b, c, e, h
14.  a.  Phantom line (thin)  c.  Center line (thin)
b.  Visible line (thick)  d.  Hidden line (thin)
15.  Intersection of fillets and rounds are used to eliminate problems in castings
16.  Evaluated to the satisfaction of the instructor
17.  a.
DIMENSIONING PROCEDURES
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to relate dimensioning to correct size, shape, and location and be able to identify lines and correct line placement. The student should also be able to relate arrowheads, dual dimensions, finish marks, and mating dimensions to their purposes, and draw various illustrations that show how to properly apply the rules of dimensioning. 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 dimensioning procedures with their correct definitions.
2. Distinguish between size description and shape description.
3. Differentiate between the types of dimensions.
4. Match the systems of placing dimensions with their correct definitions.
5. Match common abbreviations with their correct meanings.
6. Name and define three systems of writing dimensional values.
7. Identify four basic types of lines used in dimensioning.
8. Select true statements concerning rules for lines used in dimensioning.
9. Differentiate between correct and incorrect placement of leader lines.
10. State how to draw arrowheads.
11. List two rules concerning arrowheads.
12. Select true statements concerning rules for dimensional figures.
13. State the purpose for using dual dimensioning.
14. Match the methods of dual dimensioning with their correct definitions.
15. Select true statements concerning rules for placement of dimensions.
16. Arrange in order the steps in applying dimensions to an object.
17. State the purpose of finish marks.
18. Draw four types of finish marks.
19. Select true statements concerning rules for finish marks.

20. State the purpose for a notation on a drawing.

21. Select true statements concerning rules for notations.

22. Name and define the two types of notes used on a drawing.

23. Select true statements concerning rules for dimensioning common machine manufactured features.

24. Select true statements concerning methods of dimensioning arcs in available spaces.

25. Draw an illustration that shows how to correctly dimension angles.

26. Draw an illustration that shows how to correctly dimension curves.

27. Draw an illustration that shows how to correctly dimension rounded end shapes.

28. Draw an illustration that shows how to correctly dimension a spherical object.

29. Draw an illustration that shows how to correctly dimension cylindrical objects.

30. Draw illustrations that show how to correctly dimension cones, pyramids, and prisms.

31. Draw an illustration that shows how to correctly dimension features on a circular center line.

32. Draw an illustration that shows how to correctly dimension a theoretical point of intersection.

33. State two reasons for avoiding superfluous dimensions.

34. List ways to avoid superfluous dimensions.

35. List two factors concerning mating dimensions.

36. Draw an illustration that shows how to dimension an object using a selected coordinate system.

37. Identify various standard machine manufactured features.

38. Write proper dimension notes for standard machine manufactured features.

39. Demonstrate the ability to:
   a. Construct arrowheads.
   b. Dimension arcs.
   c. Dimension angles.
   d. Dimension curves.
e. **Dimension rounded end shapes.**

f. **Dimension spherical objects.**

g. **Dimension cylindrical objects.**

h. **Dimension cones, pyramids, and prisms.**

i. **Dimension features on a circular center line.**

j. **Dimension a theoretical point of intersection.**

k. **Dimension an object using a rectangular coordinate system.**

l. **Dimension an object using a polar coordinate system.**

m. **Dimension an object using a tabular coordinate system.**

n. **Dimension an object using an ordinate dimensioning system.**

o. **Dimension an object using proper dimensioning rules and correct techniques to completely describe the object.**
DIMENSIONING PROCEDURES
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. Arrange for the test to be presented one half at a time to facilitate its length.
VII. Have file drawings or working drawings available to demonstrate dimensioning to the class.
VIII. Give test.

INSTRUCTIONAL MATERIALS

Included in this unit:
A. Objective sheet
B. Information sheet
C. Transparency masters
   1. TM 1 - Descriptions and Dimensions
   2. TM 2 - Aligned System
   3. TM 3 - Unidirectional System
   4. TM 4 - Types of Lines
   5. TM 5 - Rules for Lines
   6. TM 6 - Arrowheads
   7. TM 7 - Rules for Figures
   8. TM 8 - Staggered Numerals
   9. TM 9 - Dual Dimensioning Methods
  10. TM 10 - Placement of Dimensions
11. TM 11-Steps in Applying Dimensions
   11A-Overlay
   11B-Overlay
   11C-Overlay
   11D-Overlay

12. TM 12-Rules Pertaining to Dimensioning Common Features

13. TM 13-Dimensioning Arcs

14. TM 14-Dimensioning Angles

15. TM 15-Dimensioning Curves

16. TM 16-Dimensioning Rounded End Shapes

17. TM 17-Dimensioning Spherical Objects

18. TM 18-Dimensioning Cylindrical Objects

19. TM 19-Dimensioning Cones, Pyramids, and Prisms

20. TM 20-Dimensioning Features on a Circular Center Line

21. TM 21-Superfluous Dimensions

22. TM 22-Superfluous Dimensions (Continued)

23. TM 23-Superfluous Dimensions (Continued)

24. TM 24-Mating Dimensions

25. TM 25-Hole Operations

D Handout 1-Abbreviations

E Assignment sheets

1. Assignment Sheet #1-Write Proper Dimension Notes for Standard Machine Manufactured Features

2. Assignment Sheet #2-Construct Arrowheads

3. Assignment Sheet #3-Dimension Arcs

4. Assignment Sheet #4-Dimension Angles

5. Assignment Sheet #5-Dimension Curves

6. Assignment Sheet #6-Dimension Rounded End Shapes

7. Assignment Sheet #7-Dimension Spherical Objects
8. Assignment Sheet #8- Dimension Cylindrical Objects
9. Assignment Sheet #9- Dimension Cones, Pyramids, and Prisms
10. Assignment Sheet #10- Dimension Features on a Circular Center Line
11. Assignment Sheet #11- Dimension a Theoretical Point of Intersection
12. Assignment Sheet #12- Dimension an Object Using a Rectangular Coordinate System
13. Assignment Sheet #13- Dimension an Object Using a Polar Coordinate System
14. Assignment Sheet #14- Dimension an Object Using a Tabular Coordinate System
15. Assignment Sheet #15- Dimension an Object Using an Ordinate Dimensioning System
16. Assignment Sheet #16- Dimension an Object Using Proper Dimensioning Rules and Correct Techniques to Completely Describe the Object

F. Test
G. Answers to test

II. References:


DIMENSIONING PROCEDURES
UNIT IV
INFORMATION SHEET

I. Terms and definitions
A. Superfluous--Exceeding what is sufficient or necessary
B. Datum--Points, lines, or other geometric shapes assumed to be exact from which the location or geometric features of a part may be established
C. Tabular--Set up in rows and columns, by means of a table
D. Reference dimension--A dimension used for information purposes only; it does not govern production or inspection operations
E. Actual size--Measured size of a complete object
F. Finish mark--A symbol used to indicate a surface to be machined
G. Taper--A gradual decrease or change of diameter from one end to the other
H. Bevel--A slanted flat surface not at 90° to another surface
I. Chamfer--A slight bevel removed from an edge
J. Drill--A tool with a pointed cutting edge used to make a hole in hard surfaces
K. Bore--To enlarge a hole with a boring bar or tool in a lathe, drill press, or boring mill
L. Ream--To enlarge a finished hole slightly to a very precise diameter with a reamer
M. Counterdrill--A second, larger drill along the same center line as a first drill, but not as deep
N. Countersink--A funnel-like bevel at the surface end of a drilled hole; standard included angle is 82°
O. Counterbore--An enlargement of the end of a hole to a specified diameter and depth
P. Spot face--A machined circular spot on the surface of a part to provide a flat bearing surface for a bolt head
Q. Knurl--The process of rolling depressions in the surface of an object
R. Relief groove--A shallow groove that allows for a thread relief
S. Blind hole--A hole not drilled all the way through
INFORMATION SHEET

T. Tap-A tool used to cut internal threads
U. Die-A tool used to cut external threads
V. Boss-A raised flat, cylindrical surface providing a flat surface for bolts
W. Radial-Moving along a radius
X. Nominal-Designated or theoretical size that may vary from the actual

II Size and shape description (Transparency 1)
A. Size description-The notes and dimensions that tell the size of an object
B. Shape description-The views that illustrate the shape of an object

III Types of dimensions (Transparency 1)
A. Size dimension-Any type of dimension that tells how large or small an object is
B. Location dimension-Any type of dimension that locates a feature on an object

Example:

--- SIZE --- --- SIZE ---
--- LOCATION --- LOCATION --- LOCATION

IV Systems of placing dimensions and definitions
A. Aligned system-All dimension figures are aligned with the dimension lines so that they may be read from the bottom or from the right side of the sheet (Transparency 2)

(NOTE: Dimensions and notes shown with leader lines are aligned with the bottom of the page.)
INFORMATION SHEET

B. Unidirectional system. All dimension figures and notes are lettered horizontally on the sheet and read from the bottom of the drawing (Transparency 3).

(NOTE: Never letter dimensions or notes in either system to read from the left of the sheet.)

Common abbreviations and meanings (Handout 1)

A. ANSI- American National Standards Institute
B. ASSY- Assembly
C. BEV- Bevel
D. B/M Bill of materials
E. BC- Bolt circle
F. CI- Cast iron
G. CS- Cast steel
H. CL- Center line
I. C to C- Center to center
J. CHAM- Chamfer
K. CRS- Cold rolled steel
L. CBORE- Counterbore
M. CDRILL- Counterdrill
N. CSK- Countersink
O. DEG- Degree
P. DIA- Diameter
Q. DIM. Dimension
R. DWG- Drawing
S. FAO- Finish all over
T. ID- Inside diameter
U. KST- Keyseat
V. KWY- Keyway
W. LH- Left hand
INFORMATION SHEET

X. MATL.-Material
Y. MIL-STD.-Military standard
Z. OD.-Outside diameter
AA. R.-Radius
BB. SAE.-Society of Automotive Engineers
CC. SF.-Spot faced
DD. THD.-Thread
EE. TOL.-Tolerance

(NOTE: Refer to Handout 1 or ANSI Y1.1-1972 for other standard abbreviations.)

VI Systems of writing dimensional values and their definitions

A. Fractional.-System of units and common fractions used primarily in structural work

B. Decimal.-System of units and decimals used in machine drawing where extreme accuracy is required

(NOTE: The decimal system is compatible with the calibrations of machine tool controls and numerically controlled machine tools.)

C. Metric.-System of units and decimals based on "The International System of Units", where the millimeter is the linear unit of measure

(NOTE: Industry is moving rather rapidly to conform with this universal system. Many companies are requiring drawings to be dual dimensioned in millimeters and decimal inches.)

VII Basic types of lines used in dimensioning (Transparency 4)

A. Dimension line.-A line, with arrowheads, that shows the direction and length of what is being measured

Example:

B. Extension line.-A line used to indicate the extension of a surface or a point to a location outside the part outline

Example:
INFORMATION SHEET

C. Center line-A line used to indicate the center of a cylindrical feature

Example:

[Diagram of a center line symbol]

D. Leader line-A thin solid line that "leads" from a note or dimension and is terminated by an arrowhead touching the part to which attention is directed

Example:

[Diagram of a leader line]

VIII. Rules for lines used in dimensioning (Transparency 5)

A. Extension lines show what is to be measured.

B. Extension lines show the location of other details.

C. Extension lines start or stop 1/16" away from visible lines and are extended approximately 1/8" beyond dimension lines.

D. Extension lines may cross each other or visible lines without a break.

E. Extension lines are classified as thin lines.

F. Extension lines may cross each other but they can never cross dimension lines.

G. Center lines may be used as extension lines but never as dimension lines.

H. Dimension lines should not be less than 40" away from visible lines or 24" away from each other.

(NOTE: Refer to ANSI Y14.5 1973)

I. Dimension lines are classified as thin lines.

J. Dimension lines are broken to allow space for the dimension.

K. Keep dimensions in line.

L. Dimension lines are drawn as arcs to show angular measurement.
M. Leaders are usually drawn at a 45°, 30°, or 60° angle to the horizontal, but never vertical or horizontal.

N. The leader arrowhead touches the arc and points toward the center point.

O. The leader arrow is placed on the outside of small arcs and on the inside of larger arcs.

P. A horizontal "shoulder" approximately 1/8" long should extend from end of leader.

Q. Leaders should extend past the visible lines to keep the dimensions of notes off the object; leaders and notes should be added last so that a neat drawing will result.

R. A leader always points toward the center of a circle, but it stops at the circumference of the circle.

S. A leader should always point to the beginning or the end of a note.

T. Normally, a leader terminates in an arrowhead; however, where it is intended for a leader to make reference to a surface by ending within the outline of that surface, the leader should terminate in a dot.

IX Correct and incorrect placement of leader lines

A. Dimensions are specified individually to avoid complicated leaders.

Example:

![Recommended Leader Example](image1)

![Not Recommended Leader Example](image2)

B. If too many leaders would impair the legibility of the drawing, letter symbols should be used to identify features.

Example:

![Recommended Letter Symbol Example](image3)

![Not Recommended Letter Symbol Example](image4)
INFORMATION SHEET

C. Where a leader is directed to a circle or arc, its direction should be toward the center.

Example.

- Recommended
- Not recommended

D. Avoid small angles between leaders and the lines where they terminate.

Example.

- Recommended
- Not recommended

X. How to draw arrowheads: Arrowheads are drawn with two sharp strokes toward or away from the point; length will vary depending on size of drawing, but width should always be 1/3 of the length (Transparency 6).

Example.

- Average (3 mm)

XI. Rules concerning arrowheads (Transparency 6):

A. Arrowheads always touch extension lines.

B. Arrowheads are reversed when space for the dimension is too small.

XII. Rules for dimensional figures (Transparency 7):

A. All lettering, letters, and numerals must be perfectly legible.

B. Numerals should be large enough to be easily read; standard height is 1/8".

C. Fractions are two times the height of whole numbers.
INFORMATION SHEET

D. Inch marks ("") are omitted unless a dimension may be misunderstood; thus, 1" DRILL should be written 1 DRILL.

E. The fraction bar is always in line with the dimension line; the fraction bar is never drawn at an angle.

(NOTE: An exception to this may be made in crowded places, such as parts lists, but never in dimensioning on a view.)

F. The numerator and denominator of a fraction should never touch the fraction bar.

G. Never letter a dimension figure over any line on the drawing; break the line if necessary.

H. Make all decimal points bold.

I. In a group of parallel dimension lines, the numerals should be staggered, not stacked one above the other (Transparency 8).

XIII. Purpose for using dual dimensioning—To show dimensions in millimeters and inches; it is especially applicable to the manufacture of interchangeable parts on an international basis.

XIV. Three methods of dual dimensioning (Transparency 9).

A. Position method—The millimeter value is placed above the inch dimension and separated by a dimension line (A), or an alternative arrangement is to place the millimeter dimension to the left of the inch dimension separated by a slash (B).

Examples:

(a) \[
\begin{array}{c}
68.134 \pm 0.076 \\
2.681 \pm 0.003
\end{array}
\]

(b) \[
\begin{array}{c}
68.134 \pm 0.076 / 2.681 \pm 0.003
\end{array}
\]

(NOTE: Placement of the inch dimension above or to the left of the millimeter is not acceptable.)
INFORMATION SHEET

B. Bracket method--The millimeter dimension is enclosed in square brackets, and the location of this dimension is optional, but should be uniform on any drawing.

Examples:

\[ [68.134 \pm 0.076] \]
\[
\begin{array}{c}
2.681\\ 2.678
\end{array}
\]

\[ [68.210] [68.058] \]
\[
\begin{array}{c}
2.684\\ 2.678
\end{array}
\]

(Note: Drawing should include a note to identify the dimension value in the brackets.)

Example: NOTE: All dimensions in [ ] are millimeters.

C. Chart method--One dimension value is given for each dimension on the drawing, and elsewhere on the drawing a conversion table lists in two columns the millimeter values and the inch equivalents.

<table>
<thead>
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<th>mm (inch)</th>
<th>mm (inch)</th>
<th>mm (inch)</th>
<th>mm (inch)</th>
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<td>43.2 1.70</td>
<td>101.6 4.00</td>
</tr>
</tbody>
</table>

XV. Rules for placement of dimensions (Transparency 10)

A. Each dimension should be given clearly so that it can be interpreted in only one way.

B. Dimensions should not be duplicated or the same information be given in two different ways, dual dimensioning excluded, and no dimensions should be given except those needed to produce or inspect the part.

C. Dimensions should be given between points or surfaces that have a functional relation to each other or that control the location of mating parts.

D. Dimensions should be given to finished surfaces or important center lines in preference to rough surfaces wherever possible.
E. Dimensions should be so given that it will not be necessary for the machinist to calculate, scale, or assume any dimension.

F. Dimensions should be attached to the view where the shape is best shown (contour rule).

G. Dimensions should be placed in the views where the features dimensioned are shown true shape.

H. Avoid dimensioning to hidden lines wherever possible.

I. Dimensions should not be placed upon a view unless clearness is promoted and long extension lines are avoided.

J. Dimensions applying to two adjacent views should be placed between views unless clearness is promoted by placing some of them outside.

K. The longer dimensions should be placed outside all intermediate dimensions so that dimension lines will not cross extension lines.

L. Do not expect the worker to assume that a feature is centered (as a hole on a plate), but give a location dimension from one side.

M. Horizontal and vertical center lines may be used as reference (base) lines for dimensions.

XVI. Steps in applying dimensions to an object (Transparency 11)

A. Draw extension lines and extend the center lines of the hole to be used in the same manner as extension lines (Overlay 11A).

B. Use scale to measure dimension line locations with adequate space between each and gaps for dimension figures (Overlay 11B).

C. Draw in arrowheads (Overlay 11C).

D. Draw in guidelines for figures.

E. Letter in dimensions (Overlay 11D).

XVII. Purpose of finish marks—To indicate a surface on an object that is to be finished or machined.
INFORMATION SHEET

XVIII. Four types of finish marks
A. [Diagram A]
B. [Diagram B]
C. [Diagram C]
D. [Diagram D]

Examples:

XIX. Rules for finish marks
A. Finish marks should be placed on the edge views of all finished surfaces, including hidden edges and the contour and circular views of cylindrical surfaces.
B. Finish marks should be omitted on holes or other features where a note specifies a machining operation.
C. Finish marks should be omitted on parts made from rolled stock.
D. If a part is finished all over, omit all finish marks, and use the following general note: FINISH ALL OVER, or FAO.

XX. Purpose for a notation on a drawing: To provide in concisely worded statements information that cannot be given by standard dimensions.

XXI. Rules for notations
A. Notes are always placed parallel to the bottom of the drawing.
B. Notes should be brief and clear and contain only pertinent data.
C. Notes should be spaced far enough from the views not to crowd, but still close enough to eliminate the need for a long leader.
D. Notes should always be composed so that the various shop operations are listed in the order in which they should be performed.
INFORMATION SHEET

E. Use upper case letters for all notes on machine drawings

XXII. Two types of notes used on a drawing and their definitions

A. General note—Consists of information which applies to the entire drawing
   Example: All fillets and rounds 1/8 R unless otherwise specified

B. Local (specific) note—Refers to one particular feature and requires the use of a leader
   Example:

   "7 (.201) DRILL, \( \frac{1}{4} \) - 20 UNC - 2B TAP"

XXIII. Rules for dimensioning common machine manufactured features (Transparency 12)

A. "R" follows all radii dimensions; the center is shown by a cross and only one arrowhead is used; available space determines whether the dimension figure goes inside or outside the arc

B. In general, a circle is dimensioned by its diameter, an arc by its radius

C. Avoid diagonal diameters, except for very large holes and for circles of centers; they may be used on positive cylinders when clearness is gained thereby

D. A metric diameter dimension value should be preceded by the symbol \( \Phi \) and the diameter dimension value in inches should be followed by DIA except when either dimension is obviously a diameter

E. The letter R should always follow a radius dimension figure; the radial dimension line should have only one arrowhead, and it should pass through or point through the arc center and touch the arc

F. Cylinders should be located by their center lines

G. Drill sizes are preferably expressed in decimals; for drills designated by number or letter, the decimal size must also be given
INFORMATION SHEET

H. Cylinders should be located in the circular views, if possible

I. Cylinders should be located by coordinate dimensions in preference to angular dimensions where accuracy is important

J. When there are several rough noncritical features obviously the same size such as fillets or rounds, it is necessary to give only typical dimensions, or to use a note

K. When a dimension is not to scale, it should be underscored with a wavy line or marked NTS or NOT TO SCALE

Example:

L. Mating dimensions should be given correspondingly on drawings of mating parts

M. Pattern dimensions should be given in two place decimals or in common whole numbers and fractions to the nearest 1/16"

N. Decimal dimensions should be used when accuracy greater than 1/64" is required on a machine dimension

XXIV Methods of dimensioning arcs in available spaces (Transparency 13)

A. An arc is dimensioned in the view in which its true shape is shown

B. The center should be indicated by a small cross to locate exact center point

   (NOTE Center cross should be omitted for small or unimportant radii.)

C. In least limited space, keep figure and arrowhead inside
INFORMATION SHEET

D. In limited space, move figure outside

E. In most limited space, move figure and arrowhead outside

Example:

XXV. How to correctly dimension angles (Transparency 14)

A. By means of coordinate dimensions of the two legs of a right triangle

(Note: Coordinate dimensions are preferred when a high degree of accuracy is required.)

Example:

B. By means of a linear dimension and an angle in degrees

Example:
INFORMATION SHEET

C. Variations of degrees and arrowhead placement should be as follows.

Example:

\[ \begin{align*}
\text{30°} & \quad \text{15°} \\
\text{5°} & \quad \text{5°} \\
\text{120°} & \\
\end{align*} \]

(NOTE: The circular dimension lines are always drawn with the compass center at the vertex of the angle.)

D. For a long radius with center point outside available space, the dimension leader is drawn toward the actual center, but a false center is indicated and the dimension line is jogged to it.

XXVI. How to correctly dimension curves (Transparency 15)

A. Continuous curves made up of a series of circular arcs with known center points

1. Dimension all arcs with leader lines

2. Locate all center points from each other and from some common datum point

Example:

(NOTE: For extremely large radii, such as the 12 1/2" radius in the example above. The center may be drawn closer to the arc than actual size, the actual location dimension is still given even though it is not to scale.)
INFORMATION SHEET

B. Irregular curves with unknown center points can be dimensioned by means of coordinate dimensions or from two datum base lines, a method which will provide a series of points which can be connected with an irregular curve.

Example:

(NOTE: Values in upper line in example are not accumulative, yet they are all in one line.)

XXVII How to correctly dimension rounded end shapes (Transparency 16)

A. By giving C to C dimension and radius of rounded end

(NOTE: This method is used when precision is not necessary.)

Example:

B. By giving overall dimension and diameter of feature

(NOTE: This method is used when precision is required.)

XXVIII How to correctly dimension a spherical object (Transparency 17)

A. A spherical end is dimensioned by a radius, followed by "SPHER R" (example a)
INFORMATION SHEET

B. A sphere is dimensioned by giving its diameter. (example b)

Examples.

(a)  

(b)  

XXIX. How to correctly dimension cylindrical objects: give both the diameter and the length in the rectangular view (Transparency 18)

(NOTE: The radius of a cylinder should never be given.)

Example:

XXX. How to correctly dimension cones, pyramids, and prisms (Transparency 19)

A Cones

1. Diameter and height in the triangular view (example a)

2. Diameter and the angle (example b)

3. Give two diameters and the height (example c)

4. Diameter of the end, and the height and the taper (example d)

Examples.

(a)  

(b)  

(c)  

(TAPER 3 PER FT)

(NOTE: The appropriate method to use depends on the cone, length required and the process that will be used to make the cone.)
B. Pyramids

1. Give dimensions of base in rectangular view and the height in the other view (example a)

2. Give dimensions of base and locate center point in rectangular view and give height in the other view (example b)

Examples:

```
(a)  (b)  (c)  (d)
```

C. Prisms

1. Give the height, width, and depth

2. Two of the dimensions will be in one view and the third dimension will always be in the next view

Examples:

```
(a)  (b)
```

XXXI How to correctly dimension features on a circular center line (Transparency 20)

A. Holes equally spaced are dimensioned by giving the diameter of the center line or bolt circle and specifying "equally spaced" in a note (example a)
INFORMATION SHEET

B. Holes unequally spaced are dimensioned by giving the diameter of the center line plus angular measurements with reference to one of the center lines (example b)

C. When precise accuracy is required, coordinate dimensions should be given using the center lines as datum lines (example c)

(NOTE: Circular center line will be marked "REF" to indicate that it is to be used only as a reference line.)

Examples:

XXXII How to correctly dimension a theoretical point of intersection - Project extension lines until they cross, forming a point that can be dimensioned
INFORMATION SHEET

XXXIII. Reasons for avoiding superfluous dimensions

A. Duplication of effort (wasted time)
B. Increased chance of error for drafter and workers

XXXIV. How to avoid superfluous dimensions (Transparencies 21, 22, and 23)

A. Give dimensions in the most direct and simple way
B. Always dimension to shop operation requirements
C. Never give a dimension more than once in the same view or in different views
D. Remember that the worker should never have to do any calculations from a drawing to find a necessary dimension

XXXV. Factors concerning mating dimensions (Transparency 24)

A. On two mating parts certain dimensions must correspond to make the parts fit together; these are mating dimensions
B. While the base size will remain the same, the actual values of two corresponding mating dimensions may not be exactly the same because the difference will depend on the accuracy of fit required

XXXVI. How to dimension an object using coordinate dimension systems

A. Rectangular coordinate system
   1. All horizontal dimensions are from a common datum line
   2. All vertical dimensions are from a common datum line

Examples:

![Examples Diagram]

(Note: This method is used to draw parts that are to be numerically machined.)

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**INFORMATION SHEET**

**B. Polar coordinate system**

*(NOTE: This is used when holes or other features to be located lie in a circular or radial pattern.)*

1. Give a radial dimension from the center of the pattern in the form of a diameter.

2. Give angular dimensions from a datum.

Example:

![Polar coordinate diagram](image)

**C. Tabular coordinate system**

1. Dimension placement is the same as for rectangular coordinate dimensioning, using horizontal and vertical datum planes.

2. Dimension figures are not applied directly to the views but are placed in a table and the holes are labeled with a code letter.

Examples:

![Tabular coordinate diagram](image)
D. Ordinate dimensioning

(NOTE: Other names for this system are zero plane or arrowless.)

1. Dimension placement is the same as for rectangular coordinates in that it uses perpendicular datum planes.

2. The datum planes are indicated as zero coordinates.

3. Dimensions from these planes are shown on extension lines without the use of dimension lines or arrowheads.

XXXVII. Various standard machine manufactured features

A. Hole operations (Transparency 25)

1. Drill, bore, ream

2. Counterdrlill

3. Countersink
INFORMATION SHEET

4. Counterbore

5. Spot faced

(NOTE: Refer to terms and definitions for descriptions.)

Examples:

- **DRILL**
- **CBORE**
- **SF**
- **CSK**
- **CDRILL**

**SECTIONAL VIEW**

- **BLIND HOLE**
- **04**
- **120°**

**B Taper**

Examples:

- **TAPER 0.125 I ON**
  - **DIA FIT TO GAGE**
  - **0.62**
  - **30°00**

**METRIC**

- **TAPER 0.125 I ON**
  - **DIA FIT TO GAGE**
  - **31.75**
  - **75 00**
C. Knurl

1. Diamond pattern
   Example:

2. Straight line
   Example:

D. Chamfers:
   Examples.
E. Threads

1. Internal
2. External

Examples:

F. Keyways and keyseats

1. Square
2. Flat
3. Gib head
4. Pratt and Whitney
5. Woodruff

(1) SQUARE KEY  (2) FLAT KEY  (3) GIB HEAD KEY

(4) PRATT & WHITNEY KEY  (5) WOODRUFF
INFORMATION SHEET

G. Relief groove

Examples:

![Relief groove diagram](image)

USING A NOTE

USING DIMENSIONS

H. Neck

Examples:

![Neck diagram](image)

USING A NOTE

USING DIMENSIONS

XXXVIII Proper dimension notes for standard machine manufactured features

A. Hole operations: Holes are always dimensioned on the view in which they appear as a circle

1. Drill: Hole sizes are always specified by diameter, never by radius, the diameter is given in a common fraction or in decimal form and the word drill follows the size

(NOTE: For drills designated by number or letter, the decimal size must be given.)

Examples:

![Drill examples](image)

(NOTE: A drill that does not go all the way through is a blind drill and depth must be included.)
INFORMATION SHEET

2. Bore-Hole diameter is specified in decimal form and the word bore follows the size

Example:

![Diagram of bore-Hole diameter]

(Note: A bore is a more precise method of obtaining a diameter than a drill but not as precise as a ream.)

3. Ream-Predrill size is specified first, then the ream size in decimal form followed by the word ream is applied to view in form of a note

Example:

![Diagram of ream-Predrill size]

(Note: A ream is the most precise method of obtaining an accurate diameter.)

B. Counterdrill-Diameter of first drill is given first, then the diameter of the second drill by the depth

Example:

![Diagram of counterdrill]
INFORMATION SHEET

C. Counterbore Diameter of the drill is given first, then the diameter of the bore by the depth it is to be cut.

Example:

\[ \frac{3}{8} \text{ DRILL, } \frac{9}{16} \text{ C BORE} \times \frac{1}{2} \text{ DEEP} \]

D. Countersink Diameter of the drill is given first, then the diameter of the top of countersink by the included angle of the countersink.

Example:

\[ \frac{3}{8} \text{ DRILL, } \frac{9}{16} \times 82^\circ \text{ C SK} \]

(NOTE The standard countersink for manufacturing is 82\(^\circ\).)

E. Spot faced Diameter of the drill is given first, then the diameter is given, the depth is not normally given for a spot face.

(NOTE Common practice is for a spot face to be cut 1/16" deep.)

Example:

\[ \frac{3}{8} \text{ DRILL, } \frac{5}{8} \text{ SF} \]
F. Tapers

(NOTE: There are three methods of dimensioning a taper; the accuracy required and the machine process available to cut the taper will determine the method to use.)

1. Standard machine tapers—The diameter, usually at the large end, and the length are applied to the view in the form of dimensions; the actual taper is given as a note such as "No. 4 AMER. NATL STD TAPER."

Example:

\[ \text{NO 4, AMER. NATL STD TAPER} \]

\[ \begin{align*}
&625 \\
&630 \\
&300
\end{align*} \]

2. Non-critical tapers—The diameter at the large end, the length, and the included angle are applied to the view in the form of dimensions.

Example:

\[ \begin{align*}
&75.005 \\
&2250 \\
&2246 \\
&20^\circ.0'
\end{align*} \]

\[ 0^\circ.15' \]
INFORMATION SHEET

3. Critical tapers: The diameter of the large end and the length are applied to the view as dimensions and the "taper per unit on diameter" is indicated in a note.

Example:

(NOTE: Taper on diameter means the difference in diameter per unit of length.)

Knurl

1. Diamond pattern
   a. Coarse knurl (33 pitch)
      (NOTE: Pitch is the distance between two points per inch.)
   b. Medium knurl (21 pitch)
   c. Fine knurl (14 pitch)

2. Straight pattern
   a. Coarse knurl (33 pitch)
   b. Medium knurl (21 pitch)
   c. Fine knurl (14 pitch)

3. The pitch, type of knurl, and the minimum diameter after knurling are applied to the view in the form of a note.

Example.

(NOTE: Taper on diameter means the difference in diameter per unit of length.)
H. Chamfer--The length of the offset and the angle are applied to the view in the form of a note

Example:

\[ \frac{3}{32} \times 45^\circ \text{ CHAMFER} \]

I. Threads

1. Internal thread

   a. Through-drill--The following items are applied to the view in the form of a note

      1) Tap drill size
      2) Nominal thread diameter
      3) Threads per inch
      4) Thread series type
      5) Class of thread fit
      6) LH (if it is left handed)

Example:

\[ \frac{13}{16} \text{ DRILL } \frac{7}{8} - 14 \text{ UNF - I} \]

(NOTE: Tap drill size is determined by referring to American National Standard Thread tables, *Machinery Handbook*, or various textbook appendixes.)
INFORMATION SHEET

b. Blind drill: The following items are applied to the view in the form of a note.

1) Tap drill size
2) Depth of tap drill
3) Nominal thread diameter
4) Threads per inch
5) Thread series type
6) Class of thread fit
7) LH (if it is left handed)
8) Depth of thread

Example:

\[ \begin{align*}
\text{#7 (201) DRILL, } & \quad \text{DEEP} \\
\frac{3}{4} \quad & \text{20 NC - 2 - LH, } \\
\text{DEEP} \end{align*} \]

External thread: The following items are added to the view in the form of a note.

a. Nominal thread diameter
b. Threads per inch
c. Thread series types
d. Class of thread fit
INFORMATION SHEET

e. LH (if it is left handed)

Example:

- [Diagram showing a keyway with dimensions and notes for LH keys]

J. Keysays—The size and number of the required key is given in the form of a note and the location on the shaft of the keyway is given in the form of dimensions on the two views showing the keyway.

Example:

- [Diagram showing dimensions for a keyway with notes]

(NOTE: Notice the use of a dimension to center the keyway in the shaft.)

K. Keyseats—The size and location of the slot is given in the form of dimensions applied to the view.

( NOTE: The proper clearance for various keys can be obtained from a machinists' handbook.)

Example:

- [Diagram showing a keyseat with notes and calculations]

(253)
INFORMATION SHEET

L. Relief groove. The width and depth of a relief can be given by placing dimensions on the view or in the form of a note.

Example:

![Diagram of relief groove using dimensions](image)

**USING DIMENSIONS**

![Diagram of relief groove using a note](image)

**USING A NOTE**

M. Neck. The width and depth of a neck is given in the form of a note.

Example:

![Diagram of neck using a note](image)

**USING A NOTE**
Descriptions and Dimensions

Size Dimension

1/4 Drill

Location Dimension

1 1/8

7

Size Description

3 1/8

5 16

7 16

1/16

3/16

1/8

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Aligned System
Unidirectional System
Types of Lines

Leader—Draw at any convenient radius angle usually 45°, 30°, or 60°

Size Dimension

Points to Center Point

.25 Drill

.06 Gap

Approx .13

Approximately .13

.40 Minimum Space

.25 Minimum Space

Location Dimension

Extension Line

Ok to Cross

Dimension Line

.25

.25

.13

1.13

24

1.13

.13

.13

3.13

.13

88

.63

4.2

1.13

25
Rules for Lines

Notes:
1. Material to be made of 3/16 carbon steel.
2. Six pieces required.
3. Heat treat after machining.
Arrowheads

Correct

Incorrect

Correct
(In Some Fields)

Incorrect
Rules For Figures
Staggered Numerals

Preferred (a)

Poor Practice (b)
Dual Dimensioning Methods

Position Method

Bracket Method

Conversion Chart

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Placement of Dimensions

Correct

Incorrect

Incorrect

Incorrect
Steps in Applying Dimensions

- Views of object completed
- Add extension and center lines
- Add dimension lines and leader lines
- Add arrowheads
Letter in dimensions
Rules Pertaining to Dimensioning Common Features

I.25

2500 ± 0005 TAPER ON DIA PER INCH OF LENGTH

126
125
124
125
938 REF

Ø .50 2 HOLES

3.0
1.5R
Dimensioning Arcs

- Keep figures inside if possible

- Move figure outside if necessary

- Move both arrow and figure outside if necessary
Dimensioning Angles

Angles May be Measures in
Degrees °
Minutes '
Seconds "

312

313
Dimensioning Curves

[Diagram showing dimensioning curves with DATUM BASELINE and dimensions marked.]

~ MEANS NOT TO SCALE
Dimensioning Rounded End Shapes

- Ø 50 2 HOLES
- 19 R
- 27 R
- 15 R
- 30

- 75 DIA - 2 HOLES
- 875
- 175
- 3 400
- 5 160

- 1125 ± 001 HOLE CTR
- 1125 ± 010 R CTR
- 4 50 ± 001 HOLE CTR
- 4 50 ± 008 R CTR
- 985 R

- 5 12 ± 002
- 2
- 4 125
- 0.875
Dimensioning Spherical Objects
Dimensioning Cylindrical Objects

Not recommended
Dimensioning Cones, Pyramids & Prisms

(a) 
(b) 
(c) 
(d) 

TAPER 3" PER FT
Dimension Features on a Circular Center Line

(a) Ø 12.50 - 5 HOLES EQUALLY SPACED

(b) Ø 12.50
4 HOLES

69°

45°

63.5

55°

35°

250 - 252 DIA
3 HOLES

(c) 153

168

132

METRIC
Superfluous Dimensions

\[ \frac{1}{2} \text{ DRILL} - \frac{3}{8} \text{ DEEP} \]

Either \( \frac{1}{2} \) is correct
But Don't use Both
Give drill depth in note

Omit one dimension in a chain
Superfluous Dimensions (Continued)

Omit one dimension of the four shown.

Omit dimensions and use note for hole.

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Superfluous Dimensions (Continued)

Omit width and overall length

Omit diagonal diameter
Mating Dimensions
Hole Operations

DRILL  BORING  CHUCKING  HAND  HAND  TAPER  COUNTER-  SPOTFACER  COUNTER-
BAR     REAMER     REAMER     REAMER     BORE       SINK
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DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #1--WRITE PROPER DIMENSION NOTES FOR
STANDARD MACHINE MANUFACTURED FEATURES

Premise: Proper dimension notes for standard machine manufactured features can be written by using the procedure in the following example.

Example:

1. Determine what information goes into the note
   
   (NOTE: This may require using reference tables for features such as tap drill sizes or key sizes.)

2. Determine in what order machining operations will be performed

3. Add leader lines to views

4. Add guidelines for lettering

5. Letter note

Directions: Dimension the following standard features correctly by adding all necessary notes and dimensions to the views. Dimensions can be taken directly from the views.

Problem A: Blind drill
ASSIGNMENT SHEET #1

Problem B: Chamfer

Problem C: Ream
ASSIGNMENT SHEET #1

Problem D: Counterdrill

Problem E: Counterbore

Problem F: Countersink
Problem G: Spot faced

Problem H: Non-critical taper
ASSIGNMENT SHEET #1

Problem 1: Knurl

Problem J: Thread

UNF

UNC
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #2--CONSTRUCT ARROWHEADS

Premise: Arrowheads add much to a drawing if constructed correctly. They must be uniform in size and shape and the drafter must be able to construct them with speed, neatness, and accuracy. Arrowheads can be constructed correctly by using either form in the following example.

Example:

1. Conventional
   
   
   1/8"

2. USA Standard
   
   
   1/8"

Directions: Place arrowheads at all intersecting lines below.

Problem:
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #3: DIMENSION ARCS

Premise: Arcs can be dimensioned by using the procedure in the following example.

Example:

1. Determine if there is room inside the arc for either the numeral or the arc or both
2. Determine best location for leader line
3. Draw in leader line and add arrowhead
4. Add guidelines for lettering
5. Letter dimension figures
6. Add arrowheads

Directions: Dimension the following arcs and radii using correct dimensioning procedures.

Problem A:

Problem B:
Problem H:
DIMENSIONING PROCEDURES
UNIT

ASSIGNMENT SHEET #4 - DIMENSION ANGLES

Premise: Angles can be dimensioned by using the procedure in the following example.

Example:

1. Decide which dimensioning method will be more appropriate to use
2. Add dimension and extension lines as needed
3. Add circular dimension lines if needed
   (NOTE: Use vertex of angle for compass center; circle template is not recommended for this purpose.)
4. Add guidelines for lettering
5. Letter dimension figures
6. Add arrowheads

Directions: Dimension the following objects using correct dimensioning procedures. Pay particular attention to dimensioning the angles.

Problem A:
ASSIGNMENT SHEET #4

Directions: Dimension the following objects using correct dimensioning procedures. Add ALL necessary dimensions to describe the object.

Problem B:

Top

Front

Side
ASSIGNMENT SHEET #4

Directions: Measure and dimension all inside angles in degrees and minutes.

Problem C Scale 1" = 100'
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #5: DIMENSION CURVES

Premise: Curves can be correctly dimensioned by using the procedure in the following example.

Example:

1. Determine if the curves have all center points given or if they can be located through geometric construction.
2. Decide which dimensioning has to be used.
   (NOTE: Refer to objective 26.)
3. Add dimension and extension lines as needed.
4. Add leaders as needed.
5. Add guidelines for lettering.
7. Add arrowheads.

Directions: Dimension the following objects using correct dimensioning procedures.

Problem A

Problem B
Problem C
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #6--DIMENSION ROUNDED END SHAPES

Premise: Rounded end shapes can be correctly dimensioned by using the procedure in the following example.

Example:

1. **Determine if the objects have all center points given or if they can be located through geometric construction**

2. **Decide what dimensions have to be added**
   
   (NOTE. Refer to objective 27.)

3. **Add dimension and extension lines as needed**

4. **Add leaders as needed**

5. **Add guidelines for lettering**

6. **Letter dimension figures**

7. **Add arrowheads**

Directions: Dimension the following objects using correct dimensioning procedures.

Problem A:
Problem B
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #7: DIMENSION SPHERICAL OBJECTS

Premise. Spherical objects can be correctly dimensioned by using the procedure in the following example.

Example:

1. Determine if the objects have all center points given or if they can be located through geometric construction.

2. Decide what dimensions have to be added.
   (NOTE: Refer to objective 28.)

3. Add dimension and extension lines as needed.

4. Add leaders as needed.

5. Add guidelines for lettering.


7. Add arrowheads.

Directions: Dimension the following objects using correct dimensioning procedures.

Problem A:

1.

2.

3.
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #8: DIMENSION CYLINDRICAL OBJECTS

Premise: Cylindrical objects can be correctly dimensioned by using the procedure in the following example.

Example:

1. Determine if the object has all center points given or if they can be located through geometric construction

2. Decide what dimensions have to be added
   (NOTE: Refer to objective 29.)

3. Add dimension and extension lines as needed

4. Add leaders as needed

5. Add guidelines for lettering

6. Letter dimension figures

7. Add arrowheads

Directions: Dimension the following object using correct dimensioning procedures.

Problem:
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #9-DIMENSION CONES, PYRAMIDS, AND PRISMS

Premise: Cones, pyramids, and prisms can be correctly dimensioned by using the procedure in the following example.

Example:

1. Determine if the objects have all center points given or if they can be located through geometric construction
2. Decide what dimensions have to be added
   (NOTE: Refer to objective 30.)
3. Add dimension and extension lines as needed
4. Add leaders as needed
5. Add guidelines for lettering
6. Letter dimension figures
7. Add arrowheads

Directions: Dimension the following objects using correct dimensioning procedures.

Problem A: Cones

1. Diameter and height
   ![Circle with diameter and height]

2. Diameter and angle
   ![Circle with angle]

3.
 ASSIGNMENT SHEET #9

3. Two diameters and height

4. Large end diameter, height, and taper

Problem B. Pyramids

1. Dimensions of base in rectangular view and height in the other view

2. Dimensions of base in square view and center point in rectangular view
Problem C. Height, width, and depth of prisms

1

2
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #10-DIMENSION FEATURES ON A CIRCULAR CENTER LINE

Premise: Features on a circular center line can be correctly dimensioned by using the procedure in the following example.

Example:

1. Determine if the objects have all center points given or if they can be located through geometric construction
2. Decide what dimensions have to be added
   (NOTE: Refer to objective 31.)
3. Add dimension and extension lines as needed
4. Add leaders as needed
5. Add guidelines for lettering
6. Letter dimension figures
7. Add arrowheads

Directions: Dimension the following objects using correct dimensioning procedures.

Problem A. Holes equally spaced

Problem B. Holes unequally spaced indicate angular measurements
ASSIGNMENT SHEET #10

Problem 2. Holes unequally spaced, use coordinate dimensions.
ASSIGNMENT SHEET #11 DIMENSION A THEORETICAL POINT OF INTERSECTION

Premise: A theoretical point of intersection can be correctly dimensioned by using the procedure in the following example.

Example:
1. Determine if the objects have all center points given or if they can be located through geometric construction.
2. Determine what dimensions have to be added.
   (NOTE: Refer to objective 32)
3. Add dimension and extension lines as needed.
4. Add leaders as needed.
5. Add guidelines for lettering.
7. Add arrowheads.

Directions: Dimension the following objects using correct dimensioning procedures.

Problem A

Problem B
Problem C.
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #12: DIMENSION AN OBJECT USING A RECTANGULAR COORDINATE SYSTEM

Premise. An object can be correctly dimensioned using a rectangular coordinate system by using the procedure in the following example.

Example:

1. Determine if the objects have all center points given or if they can be located through geometric construction
2. Decide what dimensions have to be added
   (NOTE: Refer to objective 36.)
3. Add dimension and extension lines as needed
4. Add leaders as needed
5. Add guidelines for lettering
6. Letter dimension figures
7. Add arrowheads

Directions. Dimension the following objects using correct dimensioning procedures.

Problem A

Problem B
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #13: DIMENSION AN OBJECT USING A POLAR COORDINATE SYSTEM

Premise: An object can be correctly dimensioned using a polar coordinate system by using the procedure in the following example.

Example.

1. Determine if the object has all center points given or if they can be located through geometric construction

2. Decide what dimensions have to be added

   (NOTE: Refer to objective 36.)

3. Add dimension and extension lines as needed

4. Add leaders as needed

5. Add guidelines for lettering

6. Letter dimension figures

7. Add arrowheads

Directions: Dimension the following object using correct dimensioning procedures.

Problem.
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #14: DIMENSION AN OBJECT USING A TABULAR COORDINATE SYSTEM

Premise: An object can be correctly dimensioned using a tabular coordinate system by using the procedure in the following example.

Example:

1. Determine if the object has all center points given or if they can be located through geometric construction
2. Decide which dimensioning has to be used
   (NOTE. Refer to objective 36.)
3. Add dimension and extension lines as needed
4. Add leaders as needed
5. Add guidelines for lettering
6. Letter dimension figures
7. Add arrowheads

Directions: Dimension the following object using correct dimensioning procedures and properly make a chart.

Problem:
DIMENSIONING PROCEDURES
UNIT IV

ASSIGNMENT SHEET #15—DIMENSION AN OBJECT USING AN ORDINATE DIMENSIONING SYSTEM

Premise: An object can be correctly dimensioned using an ordinate dimensioning system by using the procedure in the following example.

Example:

1. Determine if the object has all center points given or if they can be located through geometric construction.

2. Decide which dimensioning has to be used.

   (NOTE: Refer to objective 36.)

3. Add dimension and extension lines as needed.

4. Add leaders as needed.

5. Add guidelines for lettering.


7. Add arrowheads.

Directions: Dimension the following object using correct dimensioning procedures.

Problem:
ASSIGNMENT SHEET #16 DIMENSION AN OBJECT USING PROPER DIMENSIONING RULES AND CORRECT TECHNIQUES TO COMPLETELY DESCRIBE THE OBJECT

Premise: An object can be correctly dimensioned and completely described by using the procedure in the following example.

Example:

1. Determine if the objects have all center points given or if they can be located through geometric construction.
2. Decide which dimensioning has to be used
   (NOTE: Refer to objectives 37 and 38)
3. Add dimension and extension lines as needed
4. Add leaders as needed
5. Add guidelines for lettering
6. Letter dimension figures
7. Add arrowheads

Directions: Dimension the following objects using correct dimensioning procedures.

Problem A: Drill

1. Four methods of dimensioning an all the way through hole

   ![Diagram of all the way through hole dimensioning]

2. Four methods of dimensioning a blind hole

   ![Diagram of blind hole dimensioning]
Problem B: 1 1/2" diameter bore

Problem C: 1/2" diameter drill and 9/16" diameter ream

Problem D: Size of counterdrill

Problem E: Size of counterbore
ASSIGNMENT SHEET #16

Problem F. Size of countersink

Problem G. Size of spot face

Problem H. Tapers

1. Standard machine taper labeled with an American National Standard taper #4

2. Size of non critical taper
ASSIGNMENT SHEET #16

3. Size of critical taper

Problem I: Size and type of coarse knurl

Problem J: Size of metric chamfers

Problem K: Threads

1. Size of internal and external threads
ASSIGNMENT SHEET #16

2. Left handed thread

Problem 1. Types of keyways

1. 
2. 
3. 
4. 
5. 

Problem M. Size of keyseat
Problem 4. Sizes of relief grooves

Problem 5. Size of neck
1. Match the terms on the right with their correct definitions.

   a. Exceeding what is sufficient or necessary
   b. Points, lines, or other geometric shapes assumed to be exact from which the location or geometric features of a part may be established
   c. Set up in rows and columns, by means of a table
   d. A dimension used for information purposes only; it does not govern production or inspection operations
   e. Measured size of a complete object
   f. A symbol used to indicate a surface to be machined
   g. A gradual decrease or change of diameter from one end to the other
   h. A slanted flat surface not at 90° to another surface
   i. A slight bevel removed from an edge
   j. A tool with a pointed cutting edge used to make a hole in hard surfaces
   k. To enlarge a hole with a boring bar or tool in a lathe, drill press, or boring mill
   l. To enlarge a finished hole slightly to a very precise diameter with a reamer
   m. A second, larger drill along the same center line as a first drill, but not as deep
   n. A funnel-like bevel at the surface end of a drilled hole; standard included angle is 82°
   o. An enlargement of the end of a hole to a specified diameter and depth

1. Tap
2. Drill
3. Counterbore
4. Boss
5. Chamfer
6. Spot face
7. Finish mark
8. Tabular
9. Superfluous
10. Countersink
11. Counterdrill
12. Radial
13. Ream
14. Actual size
15. Datum
16. Bevel
17. Die
18. Nominal
19. Relief groove
20. Reference dimension
21. Blind hole
22. Taper
23. Bore
24. Knurl
p A machined circular spot on the surface of a part to provide a flat bearing surface for a bolt head

q The process of rolling depressions in the surface of an object

r A shallow groove that allows for a thread relief

s A hole not drilled all the way through

t A tool used to cut internal threads

u A tool used to cut external threads

v A raised flat, cylindrical surface providing a flat surface for bolts

w Rolling along a radius

x Designated or theoretical size that may vary from the actual

2 Distinguish between size description and shape description by placing an "X" next to the size description.

a The views that illustrate the shape of an object

b The notes and dimensions that tell the size of an object

3 Differentiate between the types of dimensions in the accompanying illustration by placing an "X" next to the location dimensions.

d Dimension A

e Dimension B

f Dimension C

g Dimension D

h Dimension E

i Dimension F

j Dimension G

k Dimension H

l Dimension I

m Dimension J

3'
4. Match the systems of placing dimensions on the right with their correct definitions.
   a. All dimension figures are aligned with the dimension lines so that they may be read from the bottom or from the right side of the sheet.
   b. All dimension figures and notes are lettered horizontally on the sheet and read from the bottom of the drawing.

5. Match common abbreviations on the right with their correct meanings.
   a. American National Standards Institute
   b. Assembly
   c. Bevel
   d. Bill of materials
   e. Bolt circle
   f. Cast iron
   g. Cast steel
   h. Center line
   i. Center to center
   j. Chamfer
   k. Cold rolled steel
   l. Counterbore
   m. Counterdrill
   n. Countersink
   o. Degree
   p. Diameter
   q. Dimension
   r. Drawing
   s. Finish all over
   t. Inside diameter
   u. Keyseat

   1. Unidirectional system
   2. Aligned system
   3. ANSI
   4. THD
   5. MIL-STD
   6. ASSY
   7. CL
   8. DIA
   9. SF
   10. CRS
   11. DIM.
   12. B/M
   13. ID
   14. OD
   15. CRS
   16. CS
   17. SAE
v. Keyway
w. Left hand
x. Material
y. Military standard
z. Outside diameter
aa. Radius
bb. Society of Automotive Engineers
c. Spot faced
d. Thread
e. Tolerance

6. Name and define three systems of writing dimensional values.

7. Identify four basic types of lines used in dimensioning.
8. Select true statements concerning rules for lines used in dimensioning by placing an "X" in the appropriate blanks.

   a. Extension lines start or stop 1/16" away from visible lines and are extended approximately 1/8" beyond dimension lines
   b. Extension lines may never cross each other
   c. Extension lines are classified as thin lines
   d. Extension lines may cross dimension lines
   e. Center lines may be used as dimension lines
   f. Dimension lines are classified as thick lines
   g. Dimension lines are broken to allow space for the dimension
   h. Dimension lines are drawn as arcs to show angular measurement
   i. Leaders are usually drawn vertical or horizontal
   j. The leader arrowhead touches the arc and points toward the center point
   k. A leader should always point to the middle of a note

9. Differentiate between the correct and incorrect placement of leader lines by placing an "X" next to the leaders that are placed correctly.

   a. 
   b. 
   c. 
   d. 

10. State how to draw arrowheads.

11. List two rules concerning arrowheads.

   a. 
   b. 

12. Select true statements concerning rules for dimensional figures by placing an "X" in the appropriate blanks.

   a. All lettering, letters, and numerals must be perfectly legible
   b. Standard height of numerals is 1"
Fractions are four times the height of whole numbers.

Inch marks ("") should always be used.

The fraction bar is always drawn at an angle on a view.

The numerator and denominator of a fraction should touch the fraction bar.

Never letter a dimension figure over any line on the drawing, break the line if necessary.

Make all decimal points bold.

In a group of parallel dimension lines, the numerals should be stacked one above the other.

State the purpose for using dual dimensioning.

Match the methods of dual dimensioning on the right with their correct definitions.

a) The millimeter value is placed above the inch dimension and separated by a dimension line, or an alternative arrangement is to place the millimeter dimension to the left of the inch dimension separated by a slash.

b) The millimeter dimension is enclosed in square brackets, and the location of this dimension is optional, but should be uniform on any drawing.

One dimension value is given for each dimension on the drawing, and elsewhere on the drawing a conversion table lists in two columns the millimeter values and the inch equivalents.

Select true statements concerning rules for placement of dimensions by placing an "X" in the appropriate blanks.

a) Each dimension should be given clearly so that it can be interpreted in only one way.

b) Dimensions may be duplicated at any time.

c) Dimensions should be given between points or surfaces that have a functional relation to each other or that control the location of mating parts.
d. Dimensions should be given to finished surfaces or important center lines in preference to rough surfaces wherever possible

e. Dimensions do not need to be complete enough for a machinist

f. Dimensions should be drawn to hidden lines wherever possible

g. Dimensions applying to two adjacent views should be placed between views unless clearness is promoted by placing some of them outside

h. Do not expect the worker to assume that a feature is centered (as a hole on a plate), but give a location dimension from one side

i. Horizontal and vertical center lines should not be used as reference lines for dimensions

16. Arrange in order the steps in applying dimensions to an object by placing the correct sequence numbers in the appropriate blanks.

a. Draw in arrowheads

b. Draw extension lines and extend the center lines of the hole to be used in the same manner as extension lines

c. Draw in guidelines for figures

d. Letter in dimensions

e. Use scale to measure dimension line locations with adequate space between each and gaps for dimension figures

17. State the purpose of finish marks.

18. Draw four types of finish marks.

a. __________________________  b. __________________________

c. __________________________  d. __________________________

19. Select true statements concerning rules for finish marks by placing an "X" in the appropriate blanks.

a. Finish marks should be placed on the edge views of all finished surfaces, including hidden edges and the contour and circular views of cylindrical surfaces

b. Finish marks should be used on holes and other features where a note specifies a machining operation
Finish marks should always be used on parts made from rolled stock.

If a part is finished all over, omit all finish marks, and use the following general note: FINISH ALL OVER, or FAO.

20 State the purpose for a notation on a drawing.

21 Select true statements concerning rules for notations by placing an "X" in the appropriate blanks.

a. Notes are always placed parallel to the side of the drawing.

b. Notes should be brief and clear and contain only pertinent data.

c. Notes should be spaced far enough from the views not to crowd, but still close enough to eliminate the need for a long leader.

d. Notes should always be composed so that the various shop operations are listed in the order in which they should be performed.

e. Use lower case letters for all notes on machine drawings.

22 Name and define the two types of notes used on a drawing.

23 Select true statements concerning rules for dimensioning common machine manufactured features.

a. "R" follows all radius dimensions, the center is shown by a cross, and only one arrowhead is used; available space determines whether the dimension figure goes inside or outside the arc.

b. A circle is always dimensioned by its radius.

c. A metric diameter dimension value should be preceded by the symbol Φ and the diameter dimension value in inches should be followed by DIA except when either dimension is obviously a diameter.

d. Cylinders should be located by their radius.

Cylinders should be located in the circular views, if possible.
g. Cylinders should always be located by angular dimensions where accuracy is important

h. When a dimension is not to scale, it should be underscored with a bold straight line

i. Decimal dimensions should be used when accuracy greater than 1" is required on a machine dimension

24. Select true statements concerning methods of dimensioning arcs in available spaces by placing an "X" in the appropriate blanks.

   a. An arc is dimensioned in the view in which its true shape is shown

   b. A center cross can be omitted for all center points

   c. In least limited space, move figure and arrowhead outside

   d. In most limited space, move figure and arrowhead outside

25. Draw an illustration that shows how to correctly dimension angles.

26. Draw an illustration that shows how to correctly dimension curves.
Draw an illustration that shows how to correctly dimension rounded end shapes.

Draw an illustration that shows how to correctly dimension a spherical object.

Draw an illustration that shows how to correctly dimension cylindrical objects.

Draw three illustrations that show how to correctly dimension cones, pyramids, and cubes.
31. Draw an illustration that shows how to correctly dimension features on a circular center line.

32. Draw an illustration that shows how to correctly dimension a theoretical point of intersection.

33. State two reasons for avoiding superfluous dimensions.
   a. ________________________________
   b. ________________________________

34. List three ways to avoid superfluous dimensions.
   a. ________________________________
   b. ________________________________
   c. ________________________________

35. List two factors concerning mating dimensions.
   a. ________________________________
   b. ________________________________
A illustration that shows how to dimension an object using the rectangular coordinate system.

Identify various standard machine manufactured features.
38. Write proper dimension notes for standard machine manufactured features.

a. Ream--Drilled to .20, reamed to .2415

b. Counterdrill--Diameter of second drill, 3/4 and 7/16 deep; diameter of first drill, 1/2

c. Chamfer--Length of offset, 1/16; 45°

d. Internal thread, through-drill--
   1) 7/8-fractional size of tap drill
   2) 3/4 - Nominal thread diameter
   3) 1 - Class 1 thread fit
   4) UN - Unified thread fit
   5) 12 - Threads per inch
   6) F - Fine thread series

39. Demonstrate the ability to:

a. Construct arrowheads.

b. Dimension arcs.

c. Dimension angles.

d. Dimension curves.

e. Dimension rounded end shapes.

f. Dimension spherical objects.

g. Dimension cylindrical objects.

h. Dimension cones, pyramids, and prisms.

i. Dimension features on a circular center line.

j. Dimension a theoretical point of intersection.

k. Dimension an object using a rectangular coordinate system.
Dimension an object using a polar coordinate system.

Dimension an object using a tabular coordinate system.

Dimension an object using an ordinate dimensioning system.

Dimension an object using proper dimensioning rules and correct techniques to completely describe the object.

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

1. a. 9    h. 16    o. 3    u. 17
   b. 15    i. 5    p. 6    v. 4
   c. 8     j. 2    q. 24   w. 12
   d. 20    k. 23   r. 19   x. 18
   e. 14    l. 13   s. 21
   f. 7     m. 11   t. 1
   g. 22    n. 10

2. b

3. b, c, d, f

4. a. 2    b. 1

5. a. 11    h. 7     o. 31   v. 21   co. 10
   b. 6     i. 30    p. 9     w. 29 < dd. 2
   c. 14    j. 12    q. 18    x. 8    ee. 13
   d. 19    k. 17    r. 4     y. 8
   e. 28    l. 1     s. 27    z. 16
   f. 5     m. 20    t. 15    aa. 24
   g. 22    n. 25    u. 26    bb. 23

6. a. Fractional--System of units and common fractions used primarily in structural work
   b. Decimal--System of units and decimals used in machine drawing where extreme accuracy is required
   c. Metric--System of units and decimals based on "The International System of Units", where the millimeter is the linear unit of measure

7. a. Dimension line
     b. Extension line
     c. Center line
     d. Leader line

8. a, c, g, h, j

9. a, d

10. Arrowheads are drawn with two sharp strokes toward or away from the point; length will vary depending on size of drawing, but width should always be 1/3 of the length

11. a. Arrowheads always touch extension lines
     b. Arrowheads are reversed when space for the dimension is too small

12. a, g, h
13. To show dimensions in millimeters and inches; it is especially applicable to the manufacture of interchangeable parts on an international basis

14. a. 2
   b. 3
   c. 1

15. a, c, d, g, h

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

17. To indicate a surface on an object that is to be finished or machined

18. a. ✔
   b. ✔
   c. ✗
   d. ✗

19. a, d

20. To provide in concisely worded statements information that cannot be given by standard dimensions

21. b, c, d

22. a. General note--Consists of information which applies to the entire drawing
   b. Local (specific) note--Refers to one particular feature and requires the use of a leader

23. a, c, f

24. a, d

25-32. Evaluated to the satisfaction of the instructor

33. a. Duplication of effort
   b. Increased chance of error for drafter and workers

34. Any three of the following:
   a. Give dimensions in the most direct and simple way
   b. Always dimension to shop operation requirements
   c. Never give a dimension more than once in the same view or in different views
   d. Remember that the worker should never have to do any calculations from a drawing to find a necessary dimension
35. a. On two mating parts certain dimensions must correspond to make the parts fit together; these are mating dimensions

b. While the base size will remain the same, the actual values of two corresponding mating dimensions may not be exactly the same because the difference will depend on the accuracy of fit required

36. Evaluated to the satisfaction of the instructor

37. a. Taper
   b. Diamond pattern knurl
   c. Neck
   d. Woodruff key
   e. Chamfer
   f. Flat key

38. a. 
   ![Diagram](image1)

b. 
   ![Diagram](image2)

c. 
   ![Diagram](image3)

d. 
   ![Diagram](image4)

39. Evaluated to the satisfaction of the instructor
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to illustrate dimensioning tolerances on drawings. The student should also be able to determine clearance fits, interference fits, transition fits, and assign tolerances from standard fit tables to 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 basic tolerancing with their correct definitions.
2. Illustrate the systems of dimensioning tolerances on drawings.
3. List the general types of fits.
4. Complete a chart of standard fits.
5. Determine clearance fit tolerance of mating parts using standard fit tables.
6. Determine interference fit tolerance of mating parts using standard fit tables.
7. Determine the limit dimensions of mating parts using standard fit tables.
8. Distinguish between the types of dimensioning systems.
9. Demonstrate the ability to:
   a. Interpret decimal tolerance dimensions.
   b. Calculate and dimension clearance fit tolerances of mating parts.
   c. Calculate and dimension interference fit tolerances of mating parts.
   d. Calculate and assign tolerances to mating parts using standard fit tables.
   e. Construct a drawing using datum dimensioning.
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. Show available standard fit tables from Machinery's Handbook or textbook appendixes and discuss how to use the tables.

VII. Provide part drawings which include specified tolerances.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters
   1. TM 1--Types of Tolerances
   2. TM 2--Application of Dimensioning
   3. TM 3--Types of Fits
   4. TM 4--Types of Dimensioning Systems

D. Assignment sheets
   1. Assignment Sheet #1--Interpret Decimal Tolerance Dimensions
   2. Assignment Sheet #2--Calculate and Dimension Clearance Fit Tolerances of Mating Parts
   3. Assignment Sheet #3--Calculate and Dimension Interference Fit Tolerances of Mating Parts
   4. Assignment Sheet #4--Calculate and Assign Tolerances to Mating Parts Using Standard Fit Tables
   5. Assignment Sheet #5--Construct a Drawing Using Datum Dimensioning
E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:


I. Terms and definitions

A. Tolerancing--System designed to control dimensions to allow interchangeability in manufacturing

B. Interchangeability--The condition that refers to a part made to limit dimensions so that it will fit any part similarly manufactured

C. Basic dimension--A theoretically exact value used to describe the size, shape, or location of a feature

   (NOTE: Basic dimensions are indicated on the drawing by the word BASIC or the abbreviation BSC.)

D. Feature--A portion of a part, such as a diameter, hole, keyway, or flat surface

E. Reference dimension--Untoleranced dimensions placed on drawings for the convenience of engineering and manufacturing

   (NOTE: Reference dimensions are indicated by the abbreviation REF.)

F. 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

G. Nominal size--The classification size given to manufactured products such as pipe or lumber

   (NOTE: It may or may not indicate exact size of the product.)

H. Basic size--The size of a part determined by engineering and design requirements from which the limits of size are determined

I. Actual size--The measured size of an object

J. Allowance--The minimum intentional difference in the dimensions of mating parts to provide for different classes of fits

K. Fit--Degree of tightness or looseness between mating parts

L. Design size--The size of a feature after an allowance for clearance has been applied and tolerances have been assigned
INFORMATION SHEET

M. Limits--The extreme permissible dimensions of a part resulting from the application of a tolerance

N. Tolerance--The total amount of variation permitted in limit dimension of a part

O. Variation--The extent to which or the range in which a dimension or size varies

P. Unilateral tolerance--The variation is in only one direction from the specified dimensions

Q. Bilateral tolerance--The variations permitted are in both directions from the specified dimensions

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

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

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

U. Dimension--Measurements given on a drawing such as size and location

V. Limit dimensioning--Method of dimensioning where only the maximum and minimum dimensions are given

W. Chain dimensioning--Successive dimensions that extend from one feature to another, rather than each originating at a datum

(Note: Tolerances accumulate with chain dimensions unless the note, "Tolerances do not accumulate," is placed on the drawing.)

X. Datum dimensioning--Method where features are dimensioned individually from a datum

(Note: System does not accumulate tolerances or dimensions from feature to feature.)

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

Z. Basic hole system--The basic size of the hole is the design size and the allowance is applied to the shaft
II. Systems of dimensioning tolerances on drawings (Transparencies 1 and 2)

A. Limits

<table>
<thead>
<tr>
<th>ø</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.876</td>
</tr>
<tr>
<td>47.70</td>
</tr>
<tr>
<td>1.876 +0.002</td>
</tr>
</tbody>
</table>

B. Plus and minus

<table>
<thead>
<tr>
<th>ø</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.70+0.00</td>
</tr>
<tr>
<td>47+0.03</td>
</tr>
</tbody>
</table>

C. Notes

(NOTE: In cases where all tolerances are the same, it is more convenient to list the information in a note than to list the tolerances separately.)

Example: Note: Tolerances are ± .010 unless otherwise specified.

III. General types of fits (Transparency 3)

A. Clearance
B. Interference
C. Transition
### INFORMATION SHEET

#### IV. Chart of standard fits

<table>
<thead>
<tr>
<th>LETTER SYMBOL</th>
<th>CLASS NAME</th>
<th>DESIGNED USE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Running and Sliding Fits</strong></td>
<td></td>
</tr>
<tr>
<td>RC1</td>
<td>Close sliding fit</td>
<td>Parts that will assemble without play</td>
</tr>
<tr>
<td>RC2</td>
<td>Sliding fit</td>
<td>Greater clearance than RC1</td>
</tr>
<tr>
<td>RC3</td>
<td>Precision running fits</td>
<td>Close fits for slow speeds and light shaft pressure</td>
</tr>
<tr>
<td>RC4</td>
<td>Close running fits</td>
<td>Accurate machinery with moderate surface speeds</td>
</tr>
<tr>
<td>RC5 &amp; RC6</td>
<td>Medium running fit</td>
<td>High running speeds or heavy shaft pressures</td>
</tr>
<tr>
<td>RC7</td>
<td>Free running fit</td>
<td>Accuracy is not essential or where large temperature variations exist</td>
</tr>
<tr>
<td>RC8 &amp; RC9</td>
<td>Loose running fit</td>
<td>Wide commercial tolerances if needed</td>
</tr>
<tr>
<td></td>
<td><strong>Locational Fits</strong></td>
<td></td>
</tr>
<tr>
<td>LC1 thru LC11</td>
<td>Locational clearance fits</td>
<td>Parts which can be freely assembled or disassembled</td>
</tr>
<tr>
<td>LT1 thru LT6</td>
<td>Locational transition fits</td>
<td>Medium fit between clearance and interference fit</td>
</tr>
<tr>
<td>LN1 thru LN3</td>
<td>Locational interference fits</td>
<td>Provides accuracy of location for parts requiring rigidity and alignment</td>
</tr>
<tr>
<td></td>
<td><strong>Force Fits</strong></td>
<td></td>
</tr>
<tr>
<td>FN1</td>
<td>Light drive fits</td>
<td>Parts requiring light assembly pressures</td>
</tr>
<tr>
<td>FN2</td>
<td>Medium drive fits</td>
<td>For ordinary steel parts or shrink fits on light sections</td>
</tr>
<tr>
<td>FN3</td>
<td>Heavy drive fits</td>
<td>Heavier steel parts or shrink fits in medium sections</td>
</tr>
<tr>
<td>FN4 &amp; FN5</td>
<td>Force fits</td>
<td>Parts which can be highly stressed</td>
</tr>
</tbody>
</table>
How to determine the clearance fit tolerance of mating parts

A. Determine tolerance for shaft
B. Determine tolerance for hole
C. Determine allowance
D. Determine maximum clearance

Example:

- Tolerance for shaft = 1.248 - 1.247 = .001
- Tolerance for hole = 1.251 - 1.250 = .001
- Allowance = 1.250 smallest hole diameter limit - 1.248 largest shaft diameter limit = .002
- Maximum clearance = 1.251 largest hole diameter limit - 1.247 smallest shaft diameter limit = .004

(Note: Allowance is the minimum clearance of mating parts.)
VI. How to determine the interference fit tolerance of mating parts

A. Determine tolerance for shaft

B. Determine tolerance for hole

C. Determine interference

D. Determine maximum interference

Example:

<table>
<thead>
<tr>
<th></th>
<th>Tolerance for shaft</th>
<th>Tolerance for hole</th>
<th>Interference</th>
<th>Maximum interference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.2519 ( \cdot ) 1.2513 = .0006</td>
<td>1.2506 ( \cdot ) 1.2500 = .0006</td>
<td>1.2513 smallest shaft diameter limit</td>
<td>1.2506 largest hole diameter limit = .0007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.2519 largest shaft diameter limit</td>
<td>1.2500 smallest hole diameter limit = .0019</td>
</tr>
</tbody>
</table>
### VII. How to determine the limit dimensions of mating parts from standard fit tables

#### Running and sliding fits

<table>
<thead>
<tr>
<th>Nominal Size Range inches</th>
<th>Class RC 1</th>
<th></th>
<th>Class RC 2</th>
<th></th>
<th>Class RC 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Limits of Clearance</td>
<td>Standard Limits</td>
<td>Limits of Clearance</td>
<td>Standard Limits</td>
<td>Limits of Clearance</td>
<td>Standard Limits</td>
</tr>
<tr>
<td></td>
<td>Hole H5</td>
<td>Shaft g4</td>
<td>Hole H6</td>
<td>Shaft g5</td>
<td>Hole H7</td>
<td>Shaft f6</td>
</tr>
<tr>
<td>Over To</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0-0.12</td>
<td>0.1</td>
<td>+0.2</td>
<td>-0.1</td>
<td>0.1</td>
<td>+0.25</td>
<td>-0.1</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>-0.25</td>
<td>0.55</td>
<td>0.3</td>
<td>-0.35</td>
<td>0.95</td>
</tr>
<tr>
<td>0.12-0.24</td>
<td>0.15</td>
<td>+0.2</td>
<td>-0.15</td>
<td>0.15</td>
<td>+0.3</td>
<td>-0.15</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>-0.3</td>
<td>0.65</td>
<td>0.5</td>
<td>-0.35</td>
<td>1.12</td>
</tr>
<tr>
<td>0.24-0.40</td>
<td>0.2</td>
<td>+0.25</td>
<td>-0.2</td>
<td>0.2</td>
<td>+0.4</td>
<td>-0.2</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>-0.35</td>
<td>0.25</td>
<td>0.45</td>
<td>0.45</td>
<td>1.5</td>
</tr>
<tr>
<td>0.40-0.71</td>
<td>0.25</td>
<td>+0.3</td>
<td>-0.25</td>
<td>0.25</td>
<td>+0.45</td>
<td>-0.25</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>-0.45</td>
<td>0.95</td>
<td>0.6</td>
<td>-0.45</td>
<td>1.7</td>
</tr>
<tr>
<td>0.71-1.19</td>
<td>0.3</td>
<td>+0.4</td>
<td>-0.3</td>
<td>0.3</td>
<td>+0.5</td>
<td>-0.3</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
<td>-0.55</td>
<td>1.2</td>
<td>0.7</td>
<td>2.1</td>
<td>0.0</td>
</tr>
<tr>
<td>1.19-1.97</td>
<td>0.4</td>
<td>+0.4</td>
<td>-0.4</td>
<td>0.4</td>
<td>+0.6</td>
<td>-0.4</td>
</tr>
<tr>
<td></td>
<td>1.1</td>
<td>-0.7</td>
<td>1.4</td>
<td>0.8</td>
<td>2.6</td>
<td>0.0</td>
</tr>
<tr>
<td>1.97-3.15</td>
<td>0.4</td>
<td>+0.5</td>
<td>-0.4</td>
<td>0.4</td>
<td>+0.7</td>
<td>-0.4</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>-0.7</td>
<td>1.6</td>
<td>0.9</td>
<td>3.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

(NOTE: From ANSI B4.1-1967, R1974. For larger diameters and other tables see the standards, appendixes in drafting textbooks, or Machinery's Handbook.)

A. To conserve space, all values for limits of holes and shafts in standard fit tables are expressed in thousandths of an inch.

Example: Reading of +0.2 would be plus two ten-thousandths of an inch (+.0002); .14 would be read as minus fourteen ten-thousandths (-.0014).

(NOTE: These may be converted by multiplying by one thousandth; therefore, +0.6 x .001 = +.0006.)
B. How to use the standard fit table to determine tolerance

Example: Find the limits if an RC2 fit is required for 1 3/4" nominal size

1. Locate the RC2 fit column in the table
2. Find the nominal size range of the hole and shaft; 1.750 falls between 1.19 - 1.97
3. Read across to the RC2 column
4. From the limits given for the hole (+0.6 and 0), and shaft (-0.4 and -0.8), add and subtract these to the basic size
5. Assign limit dimensions to drawings

C. How to check limits of clearance or interference of fits after calculations have been made

Example: 1. Allowance = 1.7500 - 1.7496 = 0.0004 = 0.4
          Maximum clearance = 1.7506 - 1.7492 = 0.0014 = 1.4
2. Read from RC2 limits of clearance table; 0.4 and 1.4
3. Calculations are correct
VIII. Types of dimensioning systems (Transparency A)

A. Chain-Features are dimensioned from point to point, such as holes, and may accumulate tolerances that exceed specifications

(NOTE: This is not normally used.)

B. Datum-Features are dimensioned individually from a datum or zero line and avoids accumulation of tolerances
Types of Tolerances

TOLERANCE EXPRESSED AS LIMITS

TOLERANCE EXPRESSED AS VARIATION

NOTE GOVERNING TOLERANCE

Indicating tolerances on drawings

Indicating BASIC dimensions

Indicating reference dimensions
Application of Dimensioning

1.876
1.874

.499-.501 DIA.
3 Holes

.374-.376 DIA.
6 Holes

.625
.623

.531-.529 DIA.
2 Places
Types of Fits

- Clearance Fit
- Interference Fit
- Transition Fit
Types of Dimensioning Systems

Accumulates

\[ \pm 0.001 \quad \pm 0.003 \quad \pm 0.004 \quad \pm 0.003 \quad \pm 0.001 \]

\[ .625 \quad 1.000 \quad 0.8750 \quad 1.0000 \quad 0.8750 \quad 1.000 \]

\[ X \quad 2.750 \pm 0.003 \quad Y \]

Point-to-Point or Chain Dimensioning

\[ 4.750 \pm 0.001 \]

\[ 2.875 \pm 0.001 \]

\[ 1.875 \pm 0.001 \]

\[ 1.000 \pm 0.001 \]

\[ .625 \]

Datum Dimensioning

\[ 2.750 \pm 0.001 \]
BASIC TOLERANCING
UNIT V

ASSIGNMENT SHEET #1--INTERPRET DECIMAL TOLERANCE DIMENSIONS

Premise: Limit dimensioning with decimals is used so that parts that require extreme accuracy can be held between very close maximum and minimum limits. Limits are also used when parts can fit very loosely and still function properly. The dimension is called out as liberal as possible leaving the machinist a margin which increases production and lowers cost. Decimal tolerance dimensions can be expressed by any one of the methods in the following example.

Example:

1. 

\[ \frac{0.487}{0.485} \]

- .487 Maximum limit above line
- .485 Minimum limit below line
- .002 = Tolerance

2. 

\[ \frac{486 \pm 0.001}{486 \pm 0.004} \]

- .487 Maximum limit
- .482 Minimum limit

3. 

\[ \frac{486 \pm 0.002}{486 \pm 0.000} \]

- .488 Maximum limit
- .486 Minimum limit

4. Shaft basic size 0.750

NOTE: Tolerances ± .002 unless otherwise specified

\[ \frac{7.52}{7.52} \]

- .004 = Tolerance
ASSIGNMENT SHEET #1

5.

BASIC DIAMETER - 0.625
SHAFT +0.000
-0.002
HOLE +0.002
-0.000

Directions: Determine decimal tolerance dimensions for the following problems.

Problem A:
\[ \pm \frac{378}{372} \]
Maximum limit = 
Minimum limit = 
Tolerance = 

Problem B:
\[ 1.740 \pm 0.002 \]
Maximum limit = 
Minimum limit = 
Tolerance = 

Problem C:
\[ \pm 0.995 \pm 0.005 \]
Maximum limit = 
Minimum limit = 
Tolerance = 

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ASSIGNMENT SHEET #2--CALCULATE AND DIMENSION CLEARANCE FIT TOLERANCES OF MATING PARTS

Directions: Calculate the tolerances and dimension the following problems.

Problem A:

**BASIC DIAMETER--1.00**

**SHAFT** $\pm 0.002$

**HOLE** $\pm 0.002$

Tolerance for shaft =

Tolerance for hole =

Allowance =

Maximum clearance =
Problem B:

**ASSIGNMENT SHEET #2**

BASIC DIAMETER = 0.875

SHAFT = -0.003

TOLERANCE FOR SHAFT = TOLERANCE FOR HOLE = ALLOWANCE = +0.004

HOLE = -0.000

MAXIMUM CLEARANCE =

Directions: Calculate the tolerances and dimension the following word problems.

Problem C: Dimension the shaft to have a tolerance of .004 and a clearance fit with an allowance of .006

**BASIC DIAMETER = 1.250**

TOLERANCE FOR SHAFT = .004

TOLERANCE FOR HOLE =

ALLOWANCE = .006
Problem D: Dimension the hole to have a tolerance of .010 and a clearance fit with an allowance of .012.

BASIC DIAMETER - 1.70

Tolerance for shaft =  ____________
Tolerance for hole = .010
Allowance = .012
ASSIGNMENT SHEET #3 - CALCULATE AND DIMENSION INTERFERENCE FIT TOLERANCES OF MATING PARTS

Directions: Calculate the tolerances and dimension the following problems.

Problem A:

BASIC DIAMETER - 1.25

SHAFT + .002

Tolerance for shaft = ____________

HOLE + .002

Tolerance for hole = ____________

Interference = ____________

Problem B:

BASIC DIAMETER - C 1.5

SHAFT + .001

Tolerance for shaft = ____________

HOLE + .003

Tolerance for hole = ____________

Interference = ____________
ASSIGNMENT SHEET #3

Directions: Calculate the tolerances and dimension the following word problems.

Problem C: Dimension the hole to have a tolerance of .006 and an interference of .007

Basic Diameter = 0.500

Tolerance for shaft =  
Tolerance for hole = .006
Interference = .007

Problem D: Dimension the shaft to have a tolerance of .006 and an interference of .009

Basic Diameter = 2.25

Tolerance for shaft = .006
Tolerance for hole =  
Interference = .009
BASIC TOLERANCING
UNIT V

ASSIGNMENT SHEET #4—CALCULATE AND ASSIGN TOLERANCES TO MATING PARTS USING STANDARD FIT TABLES

Directions: Calculate and assign tolerances for the problems given below. Standard fit tables are on the next page or use the Machinery's Handbook.

Problem A: [Diagram]

Problem B: [Diagram]

Problem C: [Diagram]

NOMINAL SIZE IS 1\frac{1}{2} DIA.
TOLERANCE FOR FN2

NOMINAL SIZE IS 2 DIA.
TOLERANCE FOR LT2

NOMINAL SIZE IS 3 DIA.
TOLERANCE FOR LC2

Problem D: [Diagram]

Problem E: [Diagram]

Problem F: [Diagram]

NOMINAL SIZE IS 1\frac{1}{4} DIA.
TOLERANCE FOR RCI

NOMINAL SIZE IS 1\frac{1}{8} DIA.
TOLERANCE FOR LN2

NOMINAL SIZE IS 1\frac{1}{2} DIA.
TOLERANCE FOR FN2
### ASSIGNMENT SHEET #4

<table>
<thead>
<tr>
<th>Nominal Size Range Inches</th>
<th>Class RC 2</th>
<th>Class LC 2</th>
<th>Class LN 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Limits of Clearance</td>
<td>Limits of Clearance</td>
<td>Limits of Clearance</td>
</tr>
<tr>
<td></td>
<td>Hole H6</td>
<td>Shaft g5</td>
<td>Hole H7</td>
</tr>
<tr>
<td>1</td>
<td>0.1</td>
<td>0.25</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
<td>0.35</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>0.2</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>0.25</td>
<td>0.5</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>0.3</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>6</td>
<td>0.35</td>
<td>0.7</td>
<td>0.35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nominal Size Range Inches</th>
<th>Class FN 1</th>
<th>Class FN 2</th>
<th>Class LT 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Limits of Clearance</td>
<td>Limits of Clearance</td>
<td>Limits of Clearance</td>
</tr>
<tr>
<td></td>
<td>Hole H6</td>
<td>Shaft 16</td>
<td>Hole H8</td>
</tr>
<tr>
<td>1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>0.25</td>
<td>0.4</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>0.3</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>6</td>
<td>0.35</td>
<td>0.6</td>
<td>0.35</td>
</tr>
</tbody>
</table>
Directions: Construct and dimension the following problem in the space below. Each hole distance from datum is ± .001. Change fractions to decimal dimensions and use datum system.
BASIC TOLERANCING
UNIT V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Maximum limit = .375
   Minimum limit = .372
   Tolerance = .003

B. Maximum limit = 1.742
   Minimum limit = 1.738
   Tolerance = .004

C. Maximum limit = 0.995
   Minimum limit = 0.990
   Tolerance = + .005

Assignment Sheet #2

A. Tolerance for shaft = .002
   Tolerance for hole = .002
   Allowance = .000
   Maximum clearance = .004
   shaft dimensions = 1.000
   hole dimensions = 1.002

B. Tolerance for shaft = .002
   Tolerance for hole = .004
   Allowance = .003
   Maximum clearance = .009
   shaft dimensions = .872
   hole dimensions = .879

C. Tolerance for hole = .004
   shaft dimensions = 1.240
   1.236

D. Tolerance for shaft = 0.010
   hole dimensions = 1.698
   1.688

Assignment Sheet #3

A. Tolerance for shaft = .002
   Tolerance for hole = .002
   Interference = .00
   hole dimensions = 1.250
   shaft dimensions = 1.248

B. Tolerance for shaft = .001
   Tolerance for hole = .002
   Interference = .001
   hole dimensions = 0.624
   shaft dimensions = 0.622

C. Tolerance for shaft = .006
   hole dimensions = .490
   .484
ANSWERS TO ASSIGNMENT SHEETS

D. Tolerance for hole = .006
   
   shaft dimensions = \frac{2.271}{2.265}

Assignment Sheet #4

A. Shaft = \frac{.508}{.506}
   Hole = \frac{.504}{.500}

B. Shaft = \frac{.759}{.746}
   Hole = \frac{.762}{.750}

C. Shaft = \frac{.625}{.621}
   Hole = \frac{.632}{.625}

D. Shaft = \frac{.872}{.8695}
   Hole = \frac{.879}{.875}

E. Shaft = \frac{1.138}{1.133}
   Hole = \frac{1.133}{1.125}

F. Shaft = \frac{1.274}{1.268}
   Hole = \frac{1.260}{1.250}

Assignment Sheet #5
BASIC TOLERANCING
UNIT V

NAME _______________________

TEST

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

   a. System designed to control dimensions to allow interchangeability in manufacturing
   
   b. The condition that refers to a part made to limit dimensions so that it will fit any part similarly manufactured
   
   c. A theoretically exact value used to describe the size, shape, or location of a feature
   
   d. A portion of a part, such as a diameter, hole, keyway, or flat surface
   
   e. Untoleranced dimensions placed on drawings for the convenience of engineering and manufacturing
   
   f. 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
   
   g. The classification size given to manufactured products such as pipe or lumber
   
   h. The size of a part determined by engineering and design requirements from which the limits of size are determined
   
   i. The measured size of an object
   
   j. The minimum intentional difference in the dimensions of mating parts to provide for different classes of fits
   
   k. Degree of tightness or looseness between mating parts

   1. Feature
   
   2. Reference dimension
   
   3. Nominal size
   
   4. Bilateral tolerance
   
   5. Fit
   
   6. Clearance fit
   
   7. Tolerancing
   
   8. Interference fit
   
   9. Actual size
   
   10. Interchangeability
   
   11. Transition fit
The size of a feature after an allowance for clearance has been applied and tolerances have been assigned.

The extreme permissible dimensions of a part resulting from the application of a tolerance.

The total amount of variation permitted in limit dimension of a part.

The extent to which or the range in which a dimension or size varies.

The variation is in only one direction from the specified dimensions.

The variations permitted are in both directions from the specified dimensions.

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

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

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

Measurements given on a drawing such as size and location.

Method of dimensioning where only the maximum and minimum dimensions are given.

Successive dimensions that extend from one feature to another, rather than each originating at a datum.

Method where features are dimensioned individually from a datum.

The basic size of the shaft is the design size and the allowance is applied to the hole.

The basic size of the hole is the design size and the allowance is applied to the shaft.

12. Allowance
13. Dimension
14. Basic dimension
15. Datums
16. Variation
17. Limit dimensioning
18. Chain dimensioning
19. Basic size
20. Datum dimensioning
21. Basic shaft system
22. Design size
23. Basic hole system
24. Tolerance
25. Unilateral tolerance
26. Limits
2. Illustrate the systems of dimensioning tolerances on drawings.
   a. Limits
   b. Plus and minus
   c. Notes

3. List the general types of fits.
   a. ____________________________
   b. ____________________________
   c. ____________________________
4. Complete the following chart of standard fits.

<table>
<thead>
<tr>
<th>LETTER SYMBOL</th>
<th>CLASS NAME</th>
<th>DESIGNED USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC1</td>
<td>Close sliding fit</td>
<td>Parts that will assemble without play</td>
</tr>
<tr>
<td>RC2</td>
<td>Precision running fit</td>
<td>Greater clearance than RC1</td>
</tr>
<tr>
<td>RC3</td>
<td>Close running fit</td>
<td>Close fits for slow speeds and light shaft pressure</td>
</tr>
<tr>
<td>RC4</td>
<td>Loose running fit</td>
<td>Accurate machinery with moderate surface speeds</td>
</tr>
<tr>
<td>RC5</td>
<td>Medium running fit</td>
<td></td>
</tr>
<tr>
<td>RC6</td>
<td>Free running fit</td>
<td>Accuracy is not essential or where large temperature variations exist</td>
</tr>
<tr>
<td>RRA &amp; RRB</td>
<td>Wide commercial tolerances if needed</td>
<td></td>
</tr>
</tbody>
</table>

**Locational Fits**

| ICI thru ICF21 | Locational clearance fits | Parts which can be freely assembled or disassembled |
| IFA thru IFB4 | Locational interference fits | Provides accuracy of location for parts requiring rigidity and alignment |

**Force Fits**

| IF1           | Medium drive fits | Parts requiring light assembly pressures |
| IF2           | Medium drive fits | For ordinary steel parts or shrink fits on light sections |
| IF3           | Heavy drive fits | Heavier steel parts or shrink fits in medium sections |
| IF4 & IF5     | Parts which can be highly stressed | |
5. Determine clearance fit tolerance of mating parts using standard fit tables below for an RC4 fit with a basic diameter of 0.625". Dimension to four decimals. Place answers in the drawing.

<table>
<thead>
<tr>
<th>NOMINAL SIZE RANGE</th>
<th>CLASS FN 2 LIMITS</th>
<th>NOMINAL SIZE RANGE</th>
<th>CLASS LT 1 LIMITS</th>
<th>CLASS RC 4 LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over To</td>
<td>Hole H7</td>
<td>Shaft S6</td>
<td>Hole H7</td>
<td>Shaft j6</td>
</tr>
<tr>
<td>0.24-0.40</td>
<td>0.1</td>
<td>+0.6</td>
<td>+1.4</td>
<td>0.24-0.40</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>-0</td>
<td>+1.0</td>
<td>-0.4</td>
</tr>
<tr>
<td>0.40-0.56</td>
<td>0.1</td>
<td>+0.7</td>
<td>+1.6</td>
<td>0.71-1.19</td>
</tr>
<tr>
<td></td>
<td>0.8</td>
<td>-0</td>
<td>+1.2</td>
<td>0.71-1.19</td>
</tr>
</tbody>
</table>

6. Determine interference fit tolerance of mating parts using standard fit tables accompanying question 5 for an FN 2 fit with a basic diameter of 0.56". Dimension to four decimals. Place answers in the drawing.
7. Determine the limit dimensions of mating parts using standard fit tables accompanying question 5 for an LT 1 fit with a basic diameter of 0.750" Dimension to four decimals. Place answers in the drawing.

8. Distinguish between the types of dimensioning systems by placing an "X" next to the chain dimensioning system.
   a. Features are dimensioned from point to point, such as holes, and may accumulate tolerances that exceed specifications.
   b. Features are dimensioned individually from a datum or zero line and avoid accumulation of tolerances.

9. Demonstrate the ability to:
   a. Interpret decimal tolerance dimensions.
   b. Calculate and dimension clearance fit tolerances of mating parts.
   c. Calculate and dimension interference fit tolerances of mating parts.
   d. Calculate and assign tolerances to mating parts using standard fit tables.
   e. Construct a drawing using datum dimensioning.

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

ANSWERS TO TEST

1. a. 7  n. 24
da. 10  o. 16
c. 14  p. 25
d. 1  q. 4
e. 2  r. 6
f. 15  s. 8
g. 3  t. 11
h. 19  u. 13
i. 9  v. 17
j. 12  w. 18
k. 5  x. 20
l. 22  y. 21
m. 26  z. 23

2. Evaluated to the satisfaction of the instructor

3. a. Clearance
b. Interference
c. Transition

4. | LETTER | CLASS          | DESIGNED USE                                      |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Running and Sliding Fits</td>
</tr>
<tr>
<td>P.1</td>
<td>Close sliding fit</td>
<td>Parts that will assemble without play</td>
</tr>
<tr>
<td>RC2</td>
<td>Sliding fit</td>
<td>Greater clearance than P.1</td>
</tr>
<tr>
<td>RC3</td>
<td>Precision running fit</td>
<td>Close fits for slow speeds and light shaft pressure</td>
</tr>
<tr>
<td>RC4</td>
<td>Close running fit</td>
<td>Accurate machinery with moderate surface speeds</td>
</tr>
<tr>
<td>RC5 &amp; RC6</td>
<td>Medium running fit</td>
<td>High running speeds or heavy shaft pressures</td>
</tr>
<tr>
<td>RC7</td>
<td>Free running fit</td>
<td>Accuracy is not essential or where large temperature variations exist</td>
</tr>
<tr>
<td>RC8 &amp; RC9</td>
<td>Loose running fit</td>
<td>Wide commercial tolerances if needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Locational Fits</td>
</tr>
<tr>
<td>LC1 thru LC11</td>
<td>Locational clearance fits</td>
<td>Parts which can be freely assembled or disassembled</td>
</tr>
<tr>
<td>LT1 thru LT6</td>
<td>Locational transition fits</td>
<td>Medium fit between clearance and interference fit</td>
</tr>
<tr>
<td>LM1 thru LM3</td>
<td>Locational interference fits</td>
<td>Provides accuracy of location for parts requiring rigidity and alignment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Force Fits</td>
</tr>
<tr>
<td>FW 1</td>
<td>Light drive fits</td>
<td>Parts requiring light assembly pressures</td>
</tr>
<tr>
<td>FW2</td>
<td>Medium drive fits</td>
<td>For ordinary steel parts or shrink fits on light sections</td>
</tr>
<tr>
<td>FW3</td>
<td>Heavy drive fits</td>
<td>Heavier steel parts or shrink fits in medium sections</td>
</tr>
<tr>
<td>FW4 &amp; FW5</td>
<td>Force fits</td>
<td>Parts which can be highly stressed</td>
</tr>
<tr>
<td></td>
<td>Hole</td>
<td>Shaft</td>
</tr>
<tr>
<td>---</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>5</td>
<td>0.6258</td>
<td>0.6242</td>
</tr>
<tr>
<td></td>
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<td>0.5612</td>
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<tr>
<td>7</td>
<td>0.7500</td>
<td>0.7503</td>
</tr>
<tr>
<td></td>
<td>0.7500</td>
<td>0.7488</td>
</tr>
</tbody>
</table>

8. a

9. Evaluated to the satisfaction of the instructor
AUXILIARY VIEWS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to label points and surfaces, construct auxiliaries of lines, points, planes, and curved surfaces, determine true angle between planes, and determine shortest distance between lines. 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 auxiliary views with their correct definitions
2. Select true statements concerning uses of auxiliary views
3. Name the views from which a primary auxiliary can be projected.
4. Select true statements concerning projection of measurements in a primary auxiliary view.
5. List the different locations of a reference line.
6. Select true statements concerning projection of measurements in a secondary auxiliary view.
7. Demonstrate the ability to:
   a. Label points and planes of a three view object.
   b. Construct a primary auxiliary of an inclined plane.
   c. Construct a true size auxiliary of a curved surface.
   d. Construct true length of an oblique line.
   e. Determine the true angle and slope of a line.
   f. Determine the true angle between two planes.
   g. Determine visibility of crossing skew lines in space.
   h. Determine the visibility of a line and a plane that cross in space.
   i. Locate piercing point of a line and a plane.
j. Construct a secondary auxiliary view of an object.

k. Construct point view of a line.

l. Determine true angle between two planes in a secondary auxiliary.

m. Construct a true size auxiliary of an oblique plane.

n. Determine shortest distance between a point and a line.

o. Determine shortest distance between two skew lines.

8. Construct various auxiliary views.
AUXILIARY VIEWS
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 sheet.
VI. Construct a "Glass Box Model" to demonstrate auxiliary projection.
VII. Bring in other blocks or objects.
VIII. Explain the use and need for auxiliary views.
IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Primary Auxiliary
      2. TM 2--Primary Auxiliary (Continued)
      3. TM 3--Auxiliary View Projection
      4. TM 4--Need for Auxiliary View
      5. TM 5--Possible Reference Plane Locations
   D. Assignment sheets
      1. Assignment Sheet #1--Label Points and Planes of a Three View Object
      2. Assignment Sheet #2 Construct a Primary Auxiliary of an Inclined Plane
      3. Assignment Sheet #3--Construct a True Size Auxiliary of a Curved Surface
      4. Assignment Sheet #4--Construct True Length of an Oblique Line
5. Assignment Sheet #5--Determine the True Angle and Slope of a Line
6. Assignment Sheet #6--Determine the True Angle Between Two Planes
7. Assignment Sheet #7--Determine Visibility of Crossing Skew Lines in Space
8. Assignment Sheet #8--Determine the Visibility of a Line and a Plane that Cross in Space
9. Assignment Sheet #9--Locate Piercing Point of a Line and a Plane
10. Assignment Sheet #10--Construct a Secondary Auxiliary View of an Object
11. Assignment Sheet #11--Construct Point View of a Line
12. Assignment Sheet #12--Determine True Angle Between Two Planes in a Secondary Auxiliary
13. Assignment Sheet #13--Construct a True Size Auxiliary of an Oblique Plane
14. Assignment Sheet #14--Determine Shortest Distance Between a Point and a Line
15. Assignment Sheet #15--Determine Shortest Distance Between Two Skew Lines

E. Answers to assignment sheets
F. Test
G. Answers to test

II. References:

AUXILIARY VIEWS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. Edge view--A line representing the inclined plane
B. Auxiliary view--A view or surface that is not perpendicular or right angle to
the plane of projection
C. Line of sight--Direction from which an object is being viewed
D. Partial auxiliary--Shows only the true size and detail of the inclined plane
   (NOTE: Hidden lines are omitted.)
E. Inclined plane--A plane that is foreshortened in two principal viewing planes
   and edge view in one other principal viewing plane
F. Foreshortened--To appear shorter to the eye than it actually is
G. Primary auxiliary view--A first projection of an inclined plane from one of
   the principal views
H. Secondary auxiliary view--Oblique plane or line projected from a primary
   auxiliary view and one of the principal views
I. True size--A surface that is shown in its actual size
   (NOTE: This is based upon the scale used.)
J. Oblique plane--A plane that is foreshortened in all three principal viewing
   planes
K. Transfer--Take from one point or view and put in another view
L. True length line--A line that appears in its actual length
M. Perpendicular line--A line at 90° to a given plane of projection
N. Reference line--A common line on back side, center, front side, or between
   views from which depth measurements are taken
O. Fold line--A theoretical line between two views where viewing planes fold
P. Symmetrical--Has same shape and size on opposite sides of a center line
Q. Grade--The degree of inclination of a slope
R. Slope--The angle a line makes with the horizontal plane
INFORMATION SHEET

S. True angle—An angle formed by two intersecting planes
   (NOTE: This is often referred to as a dihedral angle.)

T. Skew lines—Nonintersecting lines, not parallel to each other or to the principal views

II. Uses of auxiliary views
   A. Determine clearance distances and angles between manufactured parts
   B. Describe inclined surfaces of manufactured parts
   C. Determine percent of slope on pipelines, sewer lines, and grades on highway construction
   D. Determine "dip" or slope angle of geological formations
   E. Determine true length of structural members

III. Views from which a primary auxiliary can be projected—All six views

IV. Projection of measurements in a primary auxiliary view (Transparencies 1, 2, 3, and 4)
   A. Depth and height measurements are transferred with a scale or dividers in their true length from one of five views
   B. Measurements cannot be made from view with edge view
   C. Length measurements are projected in their true length perpendicular from edge view to primary auxiliary

V. Different locations of a reference line (Transparency 5)
   A. Back edge of view
   B. Center line
   C. Front edge of view
   D. Between views

   (NOTE: These are referred to as fold lines)

VI. Projection of measurements in a secondary auxiliary view
   A. Depth measurements are transferred from the edge view of one of the principal views
   B. Length measurements are projected from primary auxiliary view
Primary Auxiliary

Depth Equal in Top and Auxiliary Views

ISOMETRIC VIEWS

ORTHOGONAPHIC VIEWS
Primary Auxiliary
(Continued)

ISOMETRIC VIEWS

Height Equal in Front and Auxiliary View

True size of sloped surface.
Auxiliary View Projection

Length

Top Plane

True size of sloped surface in auxiliary plane.

Depth

Height
Need for Auxiliary View

True size and shape of surface not shown in any regular view.
Possible Reference Plane Locations

- Back Side
- Middle
- Front Side
- Fold Line
- Between Object
AUXILIARY VIEWS
UNIT VI

ASSIGNMENT SHEET #1—LABEL POINTS AND PLANES
OF A THREE VIEW OBJECT

Premise: When two planes meet, they form a line; when two lines meet, they form a point. An object is made of lines, points, and planes. In drawing auxiliary views of an object, it becomes necessary to label these lines, points, and planes with letters or numbers to be absolutely sure that the auxiliary views are formed correctly. Labeling points is not used in all of auxiliary view drawing, but it is beneficial on hard-to-visualize objects. Points and planes of a three view object can be labeled by using the procedure in the following example.

Example:

1. Use given two views of an object with a pictorial showing location of all points

2. Start with top view and label all points that make up the corners of the top plane
   (NOTE: Use lower case letters; if two corners are on the same point, put the letter outside the object to indicate point closest to observer.)

3. Label points that are away from observer by putting their point callout letters inside the object.
ASSIGNMENT SHEET #1

4. Use same procedure to locate point letter callouts in front view

(NOTE: Points closest go outside the object; those behind go inside the object.)

Directions: Label points of the object below using lower case letters. Start at point a.

Problem:
ASSIGNMENT SHEET #2—CONSTRUCT A PRIMARY AUXILIARY OF AN INCLINED PLANE

Premise: Many objects have a plane that is inclined; if this plane needs to be dimensioned, it will be necessary to draw it true size. A primary auxiliary of an inclined plane can be constructed by using the procedure in the following example.

Example:

1. Use given top and front view; draw auxiliary view of plane abcde

2. Determine line of sight perpendicular to edge view of plane abcde to be drawn to true size

3. Locate reference line in the top view in either of the following places: back, middle, front, or between views

   (NOTE: The back of the top view was used for this example.)
ASSIGNMENT SHEET #2

4. Locate reference line in auxiliary view perpendicular to line of sight at an adequate distance from edge of front view

5. Draw light projection lines from points of plane to be drawn to true size

6. Locate points on or in relation to reference plane by transferring measurements from top view with dividers

7. Connect points in auxiliary view that appear to be connected in top view, darken lines
ASSIGNMENT SHEET #2

Directions. Label points and draw an auxiliary view of the inclined planes. Leave all construction lines.

Problem A:
ASSIGNMENT SHEET #2

Problem B:

Problem C:
ASSIGNMENT SHEET #3—CONSTRUCT A TRUE SIZE AUXILIARY OF A CURVED SURFACE

Premise: A curved surface such as a circle is divided up into a series of points, and points are used to plot the true size of the curved surface. A true size auxiliary of a curved surface can be constructed by using the procedure in the following example.

Example:

1. Given an object that has a surface in the front view that is cut at an angle, divide the top view up into a series of points and number or letter each point.

2. Assume a line of sight perpendicular to the edge of the sloped surface.

3. Project points of circle in top view to edge of surface in front view.
4. Project these points of intersection perpendicular to the surface edge and introduce reference plane center line

5. Transfer points from top view center line to auxiliary view center line

Directions: Construct a true size auxiliary view of the following inclined surfaces.

Problem A:
Problem B:

Problem C:
Premise: When a line is oblique to any principal views, an auxiliary view is required to find the true length. True length of an oblique line can be constructed by using the procedure in the following example.

Example:

1. Use given two views of a skewed line a-b

2. Assume a 90° line of sight from any one of the four directions shown

3. Select a line of sight with least amount of congestion and most drawing space
ASSIGNMENT SHEET #4

4. Assume reference line at a convenient distance perpendicular to line of sight; project points a-b through reference plane.

5. Transfer points a and b from top view and connect points to form true length line.
Directions: Construct true length of the lines given below. Label line TL.

Problem A:

Problem B:

Problem C:

Problem D:
AUXILIARY VIEWS  
UNIT VI  

ASSIGNMENT SHEET #5: DETERMINE THE TRUE ANGLE AND SLOPE OF A LINE

Premise: The slope of a line is the angle the line makes with the top view. The slope may be expressed in percent or degrees of grade. When the line of slope is oblique to principal views, a primary auxiliary is needed to find true length of line. The slope of pipeline systems must be specified on drawings for gravity flow. The true angle and slope of a line can be determined by using the procedure in the following example.

Example:

1. Use given top and front view of slope of line A-B

2. Construct reference line RL1 parallel to line AF-BF
ASSIGNMENT SHEET #5

3. Project end points perpendicular to line $A_F$, $B_F$ and transfer distances from top view to establish true length line

4. Construct a line parallel and perpendicular to reference line to establish run and rise to slope

5. Use scale to mark divisions on run and rise lines; calculate percent slope

6. Measure angle with protractor

Directions: Construct the length of lines in the following problems. Calculate percent slope and measure angle
ASSIGNMENT SHEET #5

Problem A:

Problem B:

Problem C:

Problem D:
Premise: In the design and manufacture of the parts, it is sometimes necessary to determine the angle between two planes. This angle can be determined when the line of intersection is parallel to one of the principal views. The true angle between two planes can be determined by using the procedure in the following example.

Example:

1. Use given top and front views of the two planes

2. Line of intersection at \( A_T \) \( B_T \) is viewed in its true length in top view
   (Note: For this procedure that line of intersection must be parallel to one of the principal planes.)

3. Construct reference line \( RL_1 \) perpendicular to true length line
4. Project points from top view to primary auxiliary perpendicular to reference line; transfer distances from front view to primary auxiliary to establish edge view of planes.

5. Measure true angle between the two planes.

Directions: Determine the true angle between two planes in the following problems. Measure angle with protractor. Label corners of planes. Leave construction lines.

Problem A:
Problem B

T         F

1 2 3 4 5 6
ASSIGNMENT SHEET #7--DETERMINE VISIBILITY OF CROSSING SKEW LINES IN SPACE

Premise: In the example of two nonintersecting pipes shown below, the visibility of the pipe nearest to the viewer cannot be determined. The procedure in the following example can be used to determine which pipe lies in front of the other.

Example:

1. Use given two views of crossing pipes with center lines labeled

2. Determine visibility of line in top view
   a. Label the crossing of lines $A_T, B_T,$ and $C_T, D_T,$ as 1, 2
   b. Project the crossing point to the front view, establishing points 1, 2
   c. Point 1 is closer to reference line, therefore, line $A_T, B_T$ is nearer in top view and is visible
ASSIGNMENT SHEET #7

3. Determine the visible line in front view
   a. Label the crossing of lines AF, BF, and CF, DF as 3, 4
   b. Project the crossing point to the top view, establishing points 3, 4
   c. Point 4 is closer to reference line; therefore, line AF, BF is nearer in front view and is visible

Directions: Determine which pipe is closer to the viewer in the following views. Complete the shape of pipes and leave projection lines.

Problem A:

Problem B.
ASSIGNMENT SHEET #7

Problem C:

Problem D:
AUXILIARY VIEWS
UNIT VI

ASSIGNMENT SHEET #8.-DETERMINE THE VISIBILITY OF A LINE
AND A PLANE THAT CROSS IN SPACE

Premise: Determining the visibility of a line and a plane that cross in space is similar to that of crossing lines. The visibility of a line and a plane that cross in space can be determined by using the procedure in the following example.

Examples:

1. Use given two views of plane ABC and line XY crossing in space.

2. Determine visibility of line in top view
   a. Label the crossing of line X_T, Y_T with plane A_T, B_T, C_T, as 1, 2
   b. Project the crossing points to the front view, establishing points 1, 2
   c. The projected lines intersect line X_F, Y_F before they intersect the plane; therefore, line X_F, Y_F is nearer to top view and is visible.
3. Determine visibility of line in front view
   a. Label the crossing of line $X_F Y_F$ with plane $A_F B_F C_F$ as 3, 4
   b. Project the crossing points to the top view, establishing points 3, 4
   c. The projected lines intersect the plane before they intersect the line; therefore, line $X_F Y_F$ is hidden in the front view

   (NOTE: The plane is nearer to the front view and line $XY$ crosses behind plane $ABC$.)

Directions: Complete the following two view drawings showing the visible and hidden lines. Leave projection lines.

Problem A:

Problem B:
ASSIGNMENT SHEET #8

Problem C.

Problem D:
AUXILIARY VIEWS
UNIT VI

ASSIGNMENT SHEET #9-LOCATE PIERCING POINT
OF A LINE AND A PLANE

Premise: The piercing point of a line and a plane may be located by constructing a primary auxiliary view. An edge view of a plane and a line is projected from one of the plane and a line is projected from one of the principal views to show intersection. The point where the line intersects the plane is projected to the principal views. The procedure for determining visibility of line is given in Assignment Sheets 7 and 8. The piercing point of a line and a plane can be located by using the procedure in the following example.

Example:

1. Use given views of line XY and plane ABC

2. Construct line AT DT in top view parallel to reference line RL1; then project point DT to front view, locating point DF

(NOTE: Line AD may be constructed parallel to RL1 in front view.)
3. Project true length line $AF\ DF$ as line of sight; construct reference line $RL2$ perpendicular to it.

4. Project points $AF\ BF\ CF\ XF\ YF$ to auxiliary and transfer distances from top view to establish piercing point $D$. 
ASSIGNMENT SHEET #9

5. Project the piercing point to front and top views

6. Determine visibility of line XY
Directions: Determine piercing point of a line and a plane in the following problems. Leave construction lines and determine visibility of lines.

Problem A:

Problem B:

Problem C:

Problem D:
AUXILIARY VIEWS
UNIT VI

ASSIGNMENT SHEET #10--CONSTRUCT A SECONDARY AUXILIARY VIEW OF AN OBJECT

Premise: An infinite number of views can be taken from any view of an object. The first auxiliary off the orthographic view is called a primary auxiliary view. An auxiliary off a primary auxiliary view is called a secondary auxiliary. A secondary auxiliary view can be constructed by using the procedure in the following example. An auxiliary can be drawn of any angle desired or needed for this procedure.

Example:

1. Use given top and front view of a simple object, assume a line of sight at angle indicated

   ![Top View](image1)
   ![Front View](image2)
   Ref. Line

2. Project each point to auxiliary view and transfer point distances from front view

   (NOTE. Always skip a view for transfer of measurements)

   ![Top View](image3)
   ![Front View](image4)

   Primary Auxiliary
3. Assume another line of sight for view number two; transfer dimensions from top view.

(Note: This process can go on indefinitely from any view in any direction. The principle is the same and the basic steps are the same.)

Directions: Construct auxiliary views at lines of sight indicated.

Problem:

Ref. Line

Ref. Line

Ref. Line

Ref. Line

Ref. Line

Ref. Line

Ref. Line

Ref. Line

Ref. Line
ASSIGNMENT SHEET #11 - CONSTRUCT POINT VIEW OF A LINE

Premise: Determining the point view of a line is basic for projection of a secondary auxiliary view. The procedure given in the example is for determining point view of only one line. The procedure for finding point view of oblique lines is the same. Point view of a line can be constructed by using the procedure in the following example.

Example:

1. Use given top and front view of line AB

2. Construct reference line RL1 parallel to line AF BF
   (NOTE: Top view could have been used.)

3. Find true length of line AF TF by projecting end points from front view, then transfer from top view
ASSIGNMENT SHEET #11

4. Construct reference line RL2 perpendicular to true length line A₁ B₁

5. To find point view of line, transfer distance from front view and project line A₁ B₁ to secondary auxiliary view

Directions: Construct a point view of a line in the following problems. Label end points of lines in construction. Leave construction lines.

Problem A:
Problem B:

\[ \text{Diagram with lines connecting points labeled } T, F, C, \text{ and } D. \]
ASSIGNMENT SHEET #12--DETERMINE TRUE ANGLE BETWEEN TWO PLANES IN A SECONDARY AUXILIARY

Premise: When the line of intersection between two planes is an oblique line, a secondary auxiliary view is required. True angle between two planes in a secondary auxiliary can be determined by using the procedure in the following example.

Example:

1. Use given top and front views of the two planes

2. Construct primary auxiliary view of planes to determine true length of line of intersection
3. Construct a secondary auxiliary view to determine point view of line of intersection

4. Locate points B₂, D₂ by projecting from primary auxiliary view; transfer distances from top view

5. Measure true angle between line of intersection of two planes with protractor

Directions: Determine the true angle between two planes in the following problems. Measure angle with protractor or drafting machine. Leave construction lines.

Problem A:
ASSIGNMENT SHEET #12

Problem B:

\[ \text{Diagram showing two triangles with point } D \text{ and point } A \text{ connected by a line segment.} \]
Premise: An oblique plane is at an angle to three principal views. It will not appear true size in any of the views; therefore, it is necessary to draw an auxiliary view of it. Oblique planes are not uncommon on many types of drawings. A simple example is given, but the basic principles will apply for all situations. A true size auxiliary of an oblique plane can be constructed by using the procedure in the following example.

Example:

1. Use given surface abcd, top and front view

2. Construct a horizontal line either in the top or front view at point a or c in top or point b or d in front; in this example use point d in front and extend it horizontally to line bc making a new point e
ASSIGNMENT SHEET #13

3. Project point e to top view until it crosses line bc and draw line d-e in top; line d-e is true length

4. Assume a line of sight looking into the end of line d-e, draw reference line perpendicular to line of sight

5. Project points abcd through reference line and transfer measurements from front view

(NOTE: Points abcd will form a straight line which is an edge view of plane.)
ASSIGNMENT SHEET #13

6. Assume a line of sight perpendicular to edge view and draw a true size view of plane abcd by transferring point distances from top view to true size auxiliary view.

7. Connect points to form true size of plane.

Directions: Construct true size view of the oblique planes in the problems given.

Problem A:
ASSIGNMENT SHEET #13

Problem B:

Problem C:
ASSIGNMENT SHEET #14 - DETERMINE SHORTEST DISTANCE BETWEEN A POINT AND A LINE

Premise: In the manufacture of equipment, it is necessary to determine the clearance distance between parts. The shortest distance is determined by secondary auxiliary view. A distance between a point and a line can be determined by using the procedure in the following example.

Example:

1. Use given front and right side views of the line and point

2. Construct reference line RL2 parallel to line ARS

3. Construct true length of line AB by projecting end points from right side view, then transfer distance from front view

4. Construct point P in primary auxiliary

5. Construct reference line RL3 perpendicular to line A1B1

6. Transfer distances M1 N1 from primary auxiliary to establish point P2 and point view of line A2 B2
7. Distance between point $P_2'$ and point view of line $A_2$ $B_2$ is the shortest distance.

**Directions:** Using secondary auxiliary procedure, determine shortest distance between a point and a line in the problems given. Measure distance with full size scale.

**Problem A:**

**Problem B:**
Premise: Crossing lines in space are not necessarily intersecting lines. Sometimes it becomes necessary to determine clearance distance between two lines. Shortest distance between two skew lines in a secondary auxiliary can be determined by using the procedure in the following example.

Example:

1. Use given top and front views of two skew lines:

2. Construct reference line RL2 parallel to line AF BF in front view.

   (NOTE: Top view may be used if reference line is constructed parallel to one of the lines.)

3. Construct primary auxiliary of line AF BF to determine true length line

4. Construct reference line RL3 perpendicular to true length line
ASSIGNMENT SHEET #15

5. Transfer distances from front view to secondary auxiliary view, then project points from primary auxiliary to secondary auxiliary to establish line and point view of a line.

6. Distance between line $C_2 \ D_2$ and point view of line $A_2 \ B_2$ is shortest distance.

Directions: Determine shortest distance between two skew lines in the problems given. Measure the distance with full size scale.

Problem A:
Problem B:

ASSIGNMENT SHEET #15

Diagram with points labeled as $A_T$, $D_T$, $C_T$, $B_T$, $A_F$, $D_F$, $C_F$, $B_F$. The diagram includes lines connecting these points in a specific configuration.
AUXILIARY VIEWS
UNIT VI

Assignment Sheet #1

Assignment Sheet #2

A.

B.
Assignment Sheet #3

A.

B.
## AUXILIARY VIEWS
### UNIT VI

## NAME

## TEST

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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. A line representing the inclined plane</td>
<td>1. Partial auxiliary</td>
</tr>
<tr>
<td>b. A view or surface that is not perpendicular or right angle to the plane of projection</td>
<td>2. Inclined plane</td>
</tr>
<tr>
<td>c. Direction from which an object is being viewed</td>
<td>3. True size</td>
</tr>
<tr>
<td>d. Shows only the true size and detail of the inclined plane</td>
<td>4. Symmetrical</td>
</tr>
<tr>
<td>e. A plane that is foreshortened in two principal viewing planes and edge view in one other principal viewing plane</td>
<td>5. Auxiliary view</td>
</tr>
<tr>
<td>f. To appear shorter to the eye than it actually is</td>
<td>6. Oblique plane</td>
</tr>
<tr>
<td>g. A first projection of an inclined plane from one of the principal views</td>
<td>7. Perpendicular line</td>
</tr>
<tr>
<td>h. Oblique plane or line projected from a primary auxiliary view and one of the principal views</td>
<td>8. Edge view</td>
</tr>
<tr>
<td>i. A surface that is shown in its actual size</td>
<td>9. Fold line</td>
</tr>
<tr>
<td>j. A plane that is foreshortened in all three principal viewing planes</td>
<td>10. Line of sight</td>
</tr>
<tr>
<td>k. Take from one point or view and put in another view</td>
<td>11. Slope</td>
</tr>
<tr>
<td>l. A line that appears in its actual length</td>
<td>12. True length line</td>
</tr>
<tr>
<td>m. A line at 90° to a given plane of projection</td>
<td>13. True angle</td>
</tr>
<tr>
<td>n. A common line on back side, center, front side, or between views from which depth measurements are taken</td>
<td>14. Foreshortened</td>
</tr>
<tr>
<td>o. A theoretical line between two views where viewing planes fold</td>
<td>15. Grade</td>
</tr>
<tr>
<td>p. Has same shape and size on opposite sides of a center line</td>
<td>16. Primary auxiliary view</td>
</tr>
<tr>
<td>q. Nonintersecting lines, not parallel to each other or to the principal views</td>
<td>17. Skew lines</td>
</tr>
<tr>
<td></td>
<td>18. Transfer</td>
</tr>
<tr>
<td></td>
<td>19. Reference line</td>
</tr>
<tr>
<td></td>
<td>20. Secondary auxiliary view</td>
</tr>
</tbody>
</table>
The degree of inclination of a slope
The angle a line makes with the horizontal plane
An angle formed by two intersecting planes

Select true statements concerning uses of auxiliary views by placing an "X" in the appropriate blanks.

- Determine clearance distances and angles between manufactured parts
- Describe inclined surfaces of manufactured parts
- Determine percent of slope on pipelines, sewer lines, and grades on highway construction
- Determine percent of slope on geological formations
- Project any length of structural members

Name the views from which a primary auxiliary can be projected.

Select true statements concerning projection of measurements in a primary auxiliary view by placing an "X" in the appropriate blanks.

- Depth and height measurements are transferred with a scale or dividers in their true length from one of the views
- Make all measurement views from the edge view
- Length measurements are projected in their true length perpendicular from edge view to primary auxiliary

List the different locations of a reference line.

Select true statements concerning projection of measurements in a secondary auxiliary view by placing an "X" in the appropriate blanks.

- Depth measurements are transferred from the edge view of one of the principal views
- Length measurements are projected from edge view
7. Demonstrate the ability to:
   a. Label points and planes of a three view object.
   b. Construct a primary auxiliary of an inclined plane.
   c. Construct a true size auxiliary of a curved surface.
   d. Construct true length of an oblique line.
   e. Determine the true angle and slope of a line.
   f. Determine the true angle between two planes.
   g. Determine visibility of crossing skew lines in space.
   h. Determine the visibility of a line and a plane that cross in space.
   i. Locate piercing point of a line and a plane.
   j. Construct a secondary auxiliary view of an object.
   k. Construct point view of a line.
   l. Determine true angle between two planes in a secondary auxiliary.
   m. Construct a true size auxiliary of an oblique plane.
   n. Determine shortest distance between a point and a line.
   o. Determine shortest distance between two skew lines.

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

8. Construct the following auxiliary views.
   a. Construct a primary auxiliary of an inclined plane.
b. Construct a true size auxiliary of a curved surface.

c. Determine the true angle between two planes.
AUXILIARY VIEWS
UNIT VI

ANSWERS TO TEST

1. a. 8   h. 20   o. 9  
b. 5   i. 3   p. 4  
c. 10   j. 6   q. 17  
d. 1   k. 18   r. 15  
e. 2   l. 12   s. 11  
f. 14   m. 7   t. 13  
g. 16

2. a, b, c

3. All six views

4. a, c

5. a. Back edge of view  
b. Center line  
c. Front edge of view  
d. Between views

6. a

7. Evaluated to the satisfaction of the instructor

8. a.
SECTIONAL VIEWS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to construct material symbols, full, half, offset, broken-out, removed, revolved, rib, aligned, and assembly sections. The student should also be able to construct conventional breaks. 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 sectional views with their correct definitions.
2. Identify types of sectional views.
3. Identify material symbols in section.
4. Match types of sections with their correct uses.
5. Identify line thickness used in sectional drawings.
6. Select the most commonly used form of cutting plane lines.
7. Select true statements concerning general rules in sectioning.
8. Identify types of conventional breaks.
10. Select true statements concerning use of unlined sections.
11. List methods used to aid equal spacing of section lining.
12. Select true statements concerning labeling sectional views.
13. Demonstrate the ability to:
   a. Construct various material symbols in section.
   b. Construct a full section of an object.
   c. Construct a half section of an object.
   d. Construct an offset section of an object.
   e. Construct a broken-out section of an object.
   f. Construct a removed section of an object.
g. Construct a revolved section of an object.

h. Construct a rib section of an object.

i. Construct an aligned section of an object with holes, ribs, or spokes.

j. Construct adjacent parts in assembly section.

k. Construct conventional breaks.

l. Construct an assembly section.

SECTIONAL VIEWS
UNIT VII

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. Construct "cutaway models" of various objects to illustrate sectional views.

VII. Display cutaway parts of sectional views in classroom for students to inspect.

VIII. Discuss the use of sectional views.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters
   1. TM 1--Full Section
   2. TM 2--Half Section
   3. TM 3--Offset Section
   4. TM 4--Broken-Out Section
   5. TM 5--Removed Section
   6. TM 6--Revolved Section
   7. TM 7--Aligned Section
   8. TM 8--Aligned Section (Continued)
   9. TM 9--Rib Section
   10. TM 10--Assembly Section
11. TM 11--Material Symbols in Section
12. TM 12--Direction of Section Lines
13. TM 13--Materials in Assembly Section
14. TM 14--Visible Lines
15. TM 15--Hidden Lines
16. TM 16--Hidden and Symmetry Line Application
17. TM 17--Thin Sections
18. TM 18--Outline Section
19. TM 19--Errors in Making Section Lines

D. Assignment sheets
1. Assignment Sheet #1--Construct Various Material Symbols in Section
2. Assignment Sheet #2--Construct a Full Section of an Object
3. Assignment Sheet #3--Construct a Half Section of an Object
4. Assignment Sheet #4--Construct an Offset Section of an Object
5. Assignment Sheet #5--Construct a Broken-Out Section of an Object
6. Assignment Sheet #6--Construct a Removed Section of an Object
7. Assignment Sheet #7--Construct a Revolved Section of an Object
8. Assignment Sheet #8--Construct a Rib Section of an Object
9. Assignment Sheet #9--Construct an Aligned Section of an Object with Holes, Ribs, or Spokes
10. Assignment Sheet #10--Construct Adjacent Parts in Assembly Section
11. Assignment Sheet #11--Construct Conventional Breaks
12. Assignment Sheet #12--Construct an Assembly Section

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:


SECTIONAL VIEWS
UNIT VII

INFORMATION SHEET

1. Terms and definitions

A. Sectional view: The imaginary cutting away from front viewing portion of the object to show the interior detail.

B. Full section: The cutting plane passes completely through an object and the cross section behind the cutting plane line is exposed to view.

C. Section lining: A line symbol that is drawn on exposed cut surface; sometimes called cross hatching.

D. Section symbols: Symbolic section lining used for indication of various materials.
   (NOTE: Do not use on microfilm drawings; use standard cast iron symbol.)

E. Cutting plane: An imaginary plane used to cut through an object.

F. Half section: The cutting planes are passed at right angles to each other along the center lines and one-fourth of object is removed.

G. Offset section: Has a cutting plane line to pick up features that are not along a common cutting plane.

H. Broken-out section: An area broken out of a view that shows only a portion of that view in section.

I. Removed section: A revolved section drawn off the principal view and placed in another convenient location.

J. Revolved section: A cutting plane line is passed through an area and then the image is revolved 90° in position.

K. Aligned section: Used to align features such as spokes, holes, and ribs along a common plane so that they can be detailed more easily.

L. Thin section: Materials too thin for section lining are shown solid.

M. Unlined section: Used for clarity in sections of assembly drawings of standard parts where the axis of the part lies in the cutting plane.
   (NOTE: When the axis lies at right angle to cutting plane, the part is sectioned.)

N. Conventional break: Used in making a shortened view of a long simple object.
   (NOTE: Do not remove holes from object in shortened view.)
INFORMATION SHEET

O. Assembly section--Shows all parts of an object as one unit and drawn using section lining to make the individual parts stand out.

P. Outline sectioning--Section lines are shown along the borders of a large part for clarity and to save time.

Q. Rib section--Method of not showing the ribs section lined eliminates the impression of solidity.

R. Symmetry--Having the same shape and size on opposite sides of a center line.

S. Subtitles--Labeling with capital letters the sectional view which has a removed section.

II. Types of sectional views:

A. Full section (Transparency 1)

B. Half section (Transparency 2)

C. Offset section (Transparency 3)

D. Broken-out section (Transparency 4)

E. Removed section (Transparency 5)

F. Revolved section (Transparency 6)

G. Aligned section (Transparencies 7 and 8)

H. Rib section (Transparency 9)

I. Assembly section (Transparency 10).

III. Material symbols in section (Transparency 11):

A. Cast iron

   (NOTE: Where only one material is used on drawing, cast iron symbol is used and material noted in notes.)

B. Steel

501
C. Brass, bronze, or copper

D. Zinc, lead, and alloys

E. Magnesium, aluminum, and alloys

IV. Types of sections and their uses

A. Half section--To show both interior and exterior features of a symmetrical object

B. Revolved section--To show the true shape of the cross section of a long object such as a bar, spoke, rib, or arm

C. Offset section--To show features that are not in a straight line

D. Broken-out section--To show interior detail of objects where less than half section is required

E. Removed section--Used for clarity and for easier dimensioning

F. Full section--Replaces an exterior view in order to show some interior details

B. Aligned section--Used when true projection would be confusing for spokes, ribs, and holes

V. Line thickness used in sectional drawings

A. Thin line, thin--

B. Short break line, thick--

C. Long break line, thin--

D. Cutting plane line, thick--
INFORMATION SHEET

VI. Forms of cutting plane lines

A. 

B. Most commonly used form--

C. 

VII. General rules in sectioning

A. Hidden lines behind the cutting plane should be omitted unless needed (Transparencies 2 and 14)

B. Sections which are too thin for effective section lining are shown solid (Transparency 17)

C. Large surfaces are often sectioned only along the edge of the part (Transparency 18)

D. If two or more sections appear on the same drawing, the cutting plane lines are labeled and the view is subtitled (Transparency 5)

E. Section lines are thin parallel lines drawn at 45° to main outline of the view (Transparencies 11 and 12)

F. In assembly sectional view, the adjacent parts section lines should be drawn at a 30°, 45°, or 60° angle to the edge of object (Transparency 10)

G. Section lines are uniformly spaced from approximate .06 to .125 (Transparencies 11 and 12)

(Note: Minimum space of .18 is used for microfilm.)
I. Where two or more thin sections are shown, a space should be left between them.

(NOTE: For microfilm process see Transparency 17.)

H. Arrowheads at the ends of the cutting plane line indicate the direction in which the section is viewed (Transparency 1).

J. When the cutting plane offsets, a line is not shown in the sectioned view to present the offset (Transparency 3).

K. When objects have one major center line, the cutting plane line may be omitted (Transparency 14).

L. Except for revolved sections, section views should be projected in the normal orthographic view (Transparencies 1, 2, 3, 4, 5, 9, and 10).

M. When dimensions on sectioned areas are unavoidable, the section lining should be omitted for the numerals or lettering (Transparency 12).

N. A center line or a visible line may be used to divide the sectioned half from the unsectioned half (Transparency 2).

O. Hidden lines may be added to unsectioned half for dimensioning (Transparency 2).

P. Visible lines behind cutting plane line should not be omitted (Transparency 13).

VIII. Types of conventional breaks

A. Round bar

B. Rectangular solid

C. Long break
INFORMATION SHEET

D. Round tubular

E. Rectangular tubular

(NOTE: Some companies remove cross hatching from conventional breaks.)

IX. Common errors in making section lines (Transparency 19)
A. Irregular spacing
B. Varying line weight
C. Lines too thick
D. Lines short or over run visible lines

X. Use of unlined sections (Transparencies 10, 13, and 17)
A. Thin parts are made solid
B. Shafts, bolts, nuts, pins, keys, rivets, gear teeth, and similar parts should not be sectioned if axis lies in cutting plane
C. Broken-out section of shaft may be made to indicate ciearness of key, keyseat, and pin

XI. Methods used to aid equal spacing of section lining
A. Visual spacing
B. Line guide
   (NOTE: Scribed line on triangle may be used.)
C. Trace lines from a grid sheet
D. Measure with scale

XII. Labeling sectional views (Transparency 5)
A. More than one removed section view should be labeled with letters corresponding to the ends of the cutting plane line
INFORMATION SHEET

B. Sectional views should be arranged in alphabetical order from left to right on the drawing
C. Section letters should be used in alphabetical order
D. Letters "I", "O", and "Q" should not be used
Full Section

Cutting Plane

Direction of Sight

Top View

Edge View of Cutting Plane

Section Lines

Front View
Half Section

Cutting Plane

Edge View of Cutting Plane

Remove One Quarter

Center Line or Visible Line
Hidden Lines Omitted
Unless Used for Dimensioning
Offset Section

Top View

Removed Portion

Offset Line Not Shown

Front View
Broken-Out Section

Cutting Plane

Broken-Out Portion

Break Line

Front View with Broken-Out Section
Aligned Section

Continued

Rib

TRUE PROJECTION

PREFERRED
Rib Section

The Cut Surfaces

Cutting Plane and Front Part Removed

Omit Hidden Line

Do Not project offset but show as though a continuous full section.
Assembly Section

Key

Broken Section

Set Screw

Pin

Revolved Section

Nut

Rib

Rivet

Shaft

Break (Round Section)
Material Symbols in Section

.06 -.12

.18 Min for Microfilm

Cast Iron

Steel

Brass-Bronze-Copper

Zinc-Lead-Babbitt

Aluminum-Magnesium
Direction of Section Lines

Correct

Incorrect

Incorrect
Materials in Assembly Section

Materials in Section

Adjacent Parts
Visible Lines

CORRECT

INCORRECT

Visible Lines Omitted
Hidden Lines

Cutting Plane Line
May be Omitted

Hidden Lines
Not Shown

GOOD

NOT GOOD
Hidden and Symmetry Line Application

Hidden Lines Omitted unless Used for Dimensioning

Enlarged Details

---

\[ \begin{align*}
1 & \quad 2 & \quad 3 & \quad 4 \\
5 & \quad 6 & \quad 7 & \quad 8
\end{align*} \]
Thin Sections

Structural Shapes

Thin Material

Gasket
Outfitter Section
Errors in Making Section Lines

- Uneven Spacing
- Uneven Line Weight
- Lines Too Thick
- Overrun Lines
SECTIONAL VIEWS
UNIT VII

ASSIGNMENT SHEET #1--CONSTRUCT VARIOUS MATERIAL SYMBOLS IN SECTION

Premise: The quality of any drawing reproduction depends on the quality of line work. Open space between two adjacent parallel lines should be thin, dark, and consistent. Light section lines tend to "fade out." A minimum of section lining is sufficient to clarify a sectional view.

Directions: Duplicate the given symbols for materials in section in the spaces provided below. Label under each space in 1/8" letters the name of the material.

Cast Iron  Steel  Brass-Bronze-Copper
Aluminum-Magnesium  Zinc-Lead-Babbitt
Premise: A full section view of an object can be constructed by using the procedure in the following example.

Example:

1. Imagine cutting an object all the way across with a hacksaw.

2. Think of the saw cut as an imaginary cutting plane.

3. With the front half removed, visualize what the front view would look like.

(NOTE: This is a full section.)
4. On a drawing you would show the complete top view and its cutting plane line; the area actually cut by the hacksaw would be represented with section lines.

5. On an actual drawing, the two views would be drawn lightly as in orthographic projection with hidden lines, etc; then the drafter would visualize the internal features of the object and draw that view in section omitting hidden lines.
ASSIGNMENT SHEET #2

Directions: Change the front views of objects below to full section views.

Problem A:

Problem B:

Problem C:

V PULLEY

BELT DRIVE

HOLDING BRACKET
Directions: Complete the right side views of the following problems to full section views.

Problem D:

Problem E:
ASSIGNMENT SHEET #3-CONSTRUCT A HALF SECTION OF AN OBJECT

Premise: A half section view of an object can be constructed by using the procedure in the following example.

Example:

1. Think of an imaginary plane cutting halfway through an object.

2. Remove that section and assume a line of sight looking into the area cut by the plane.

3. Construct top view with a cutting plane line that passes halfway through the object: project lines to front view and determine areas to be sectioned.
ASSIGNMENT SHEET #3

Directions: Construct section lines in the part of the view behind the cutting plane line.

Problem A:

Problem B:

Problem C:

BUSHING

BRACKET BASE

SHAFT SUPPORT
ASSIGNMENT SHEET #3

Directions: Complete top views for the following problems to half sections.

Problem D:

Problem E:
ASSIGNMENT SHEET #4--CONSTRUCT AN OFFSET SECTION OF AN OBJECT

Premise: An offset section of an object can be constructed by using the procedure in the following example.

Example:

1. Decide which features about this object are not in a common line but should be shown in section

2. Remove the portion in front and look into the object
3. A drawing of the top view would show the offset of the cutting plane; the front section view would show the object as if the slot and holes were all on the same center line.

(NOTE: The offsets in the cutting plane are not shown with a line in the front section.)

Directions: Construct the front view in section.

Problem A
Directions: Complete the front views to offset sections for the following problems.

Problem B:

Problem C:
Directions: Construct the cutting plane in top view and complete the front view to an offset section.

Problem D:
ASSIGNMENT SHEET #5--CONSTRUCT A BROKEN-OUT SECTION OF AN OBJECT

Premise: A broken-out section needs to be used only when a portion of the whole object needs to be sectioned. A broken-out section of an object can be constructed by using the procedure in the following example.

Example:

1. Pass an imaginary cutting plane through the area to be sectioned

   (NOTE: Cutting plane line is not shown on drawing.)

2. Remove the portion by breaking it off and visually lifting it out of position

   Broken-Out Portion

   ""
3. On a drawing, the area cut by the plane would appear in section and the broken area would be represented with a short break line; draw the top and front view lightly, then remove the portion that needs to be sectioned.

Directions: Construct broken-out sections in front view for the following problems.

Problem A: Bronze material
Problem B: Cast iron material
ASSIGNMENT SHEET #5

Directions: Construct a broken-out section of the view below.

Problem C: Material as described by instructor

Directions: Construct a broken-out section in right side view.

Problem D: Material as described by instructor
ASSIGNMENT SHEET #6--CONSTRUCT A REMOVED SECTION OF AN OBJECT

Premise: A removed section is used to illustrate an area separate from its view by passing an imaginary plane through an area and then drawing it in section and labeling it to correspond to its cutting plane. Removed sections are often used when several sections are taken through one view of an object. A removed section of an object can be constructed by using the procedure in the following example.

Example:

1. Determine the area to be sectioned and pass a cutting plane line through it

   (NOTE: Label the cutting plane lines A-A, B-B, etc.)

2. Construct the sections indicated by the cutting plane lines on any area of the drawing where space is available but keep axis of section the same as the view it was taken from, if possible
Assignment Sheet #6

Directions: Pictured below are two views of an object with a series of sections cut through it. Pictured beside it are three of its sections. Complete the other two sections D-D and E-E. Type of material will be assigned by instructor.

Problem A:
ASSIGNMENT SHEET #6

Directions: Construct the removed sections indicated by cutting plane lines for the following problems. Type of material will be assigned by instructor.

Problem B:

Problem C:
ASSIGNMENT SHEET #7-CONSTRUCT A REVOLVED SECTION OF AN OBJECT

Premise: A revolved section is used to illustrate an area of an object without drawing a separate view. A revolved section of an object can be constructed by using the procedure in the following example.

Example:

1. Pass an imaginary plane through the area

2. Indicate cutting plane line and rotate plane in front view

3. The section can be shown in one of two ways (a) drawn in context, or (b) object broken away from section
Directions: Construct a section view in the area indicated for the offset bracket and the extension mount.

Problem A:

Offset Bracket

Problem B:

Extension Mount
ASSIGNMENT SHEET #8 - CONSTRUCT A RIB
SECTION OF AN OBJECT

Premise: A rib section of an object can be constructed by using the procedure in the following example.

Example:

1. When sectioning an area that has a rib or spoke, the cutting plane line offsets in front of the rib

2. Remove front portion and look into the object

3. Show cutting plane as illustrated in top view; section front view as shown omitting section lines on rib

Omit Hidden Line
ASSIGNMENT SHEET #8

Directions: Construct the right side view with rib sectioned properly for the following problems.

Problem A:

Problem B:
SECTIONAL VIEWS
UNIT VII

ASSIGNMENT SHEET #9: CONSTRUCT AN ALIGNED SECTION OF AN OBJECT WITH HOLES, RIBS, OR SPOKES

Premise: When the offset is in line with the rest of the object, there is no problem in sectioning. However, when the offsets are not in line, a true projection would be misleading. An aligned section of an object with holes, ribs, or spokes can be constructed by using the procedure in the following example.

Example:

1. Introduce cutting plane line

2. Rotate cutting plane to horizontal axis

3. Draw in sections as if they were all on horizontal cutting plane
ASSIGNMENT SHEET #9

Directions: Construct front views as aligned sections for the following problems.

Problem A:

Problem B:
ASSIGNMENT SHEET #9

Directions: Construct the right side into aligned section for the following problems.

Problem C:

Problem D:
Premise: Adjacent parts in assembly section can be constructed by using the procedure in the following example.

Example:

1. Section lines are constructed at an angle of 45° to the main outline of the object

2. On adjacent parts, section lines should be 45° in the opposite direction

3. For more than two parts adjacent to each other, section lines should be drawn at an angle of 30° or 60°

   (NOTE: Section lines should not be drawn to meet at common lines.)

4. Different materials can be used to represent different parts in section
ASSIGNMENT SHEET #10

Directions: Complete this assembly as a section using the proper symbols.

Problem A:

Directions: Complete front view as a section using the symbols indicated.

Problem B
ASSIGNMENT SHEET #11-CONSTRUCT CONVENTIONAL BREAKS

Premise: In constructing a long bar or tubing with uniform cross section, it is usually not necessary to construct its full length. A break is made, sectioned, and the true length of the object is indicated by a dimension. The conventional breaks for cylindrical bars and tubing are known as "S" breaks and may be constructed with templates or free hand. The procedure in the following example is for the use of templates.

Example:

1. Use given rectangular view for bar or tube

2. Lay off fractional radius widths on end to be sectioned

3. Using ellipse template or irregular curve, construct "S" breaks

   (NOTE: Construct "S" break free hand on small diameter bar or tubing.)
ASSIGNMENT SHEET #11

4. Add section lining to visible sectioned part

(NOTE: When "S" break is shown with stock continuing on both sides of break, the sectioned faces are diagonally opposite.)

5. Short or long break symbols are used on rectangular solids

Directions: Construct conventional breaks in the parts below.

Problem A: Cylindrical - Cast iron

Problem B: Rectangular - Steel

Problem C: Tubular - Brass
Premise: Shafts, bolts, nuts, rods, rivets, keys, pins, and similar parts are not sectioned if the axis lies in the cutting plane. A broken-out section may be used to clarify the key and keyseat.

Directions: Complete a full section of the following coupling assembly using proper material symbols.

- STEEL
- CAST IRON
- STEEL
- CAST IRON
- STEEL
- STEEL
- STEEL
SECTIONAL VIEWS
UNIT VII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1--Evaluated to the satisfaction of the instructor
Assignment Sheet #2

A. 

B. 

C. 

D. 

570
Assignment Sheet #4

A.

B.

D.
Assignment Sheet #6

A

SECT D-D

SECT E-E

B

SECTION A-A

SECTION B-B
Assignment Sheet #6

C.

SECTION A-A

SECT B-B

SECT C-C

Assignment Sheet #7--Evaluated to the satisfaction of the instructor

Assignment Sheet #8

A.

B.
Assignment Sheet #9

A.

B.

C.

D.
Assignment Sheet #10

A. [Diagram]

Assignment Sheet #11--Evaluated to the satisfaction of the instructor

Assignment Sheet #12--Evaluated to the satisfaction of the instructor
1. Match the terms on the right with their correct definitions.

   a. The imaginary cutting away from front viewing portion of the object to show the interior detail
   b. The cutting plane passes completely through an object and the cross section behind the cutting plane line is exposed to view
   c. A line symbol* that is drawn on exposed cut surface; sometimes called cross hatching
   d. Symbolic section lining used for indication of various materials
   e. An imaginary plane used to cut through an object
   f. The cutting planes are passed at right angles to each other along the center lines and one-fourth of object is removed
   g. Has a cutting plane line to pick up features that are not along a common cutting plane
   h. An area broken out of a view that shows only a portion of that view in section
   i. A revolved section drawn off the principal view and placed in another convenient location
   j. A cutting plane line is passed through an area and then the image is revolved 90° in position
   k. Used to align features such as spokes, holes, and ribs along a common plane so that they can be detailed more easily
   l. Materials too thin for section lining are shown solid

1. Section lining
2. Offset section
3. Cutting plane
4. Thin section
5. Aligned section
6. Subtitles
7. Sectional view
8. Symmetry
9. Broken-out section
10. Removed section
11. Rib section
12. Full section
13. Revolved section
14. Unlined section
15. Half section
16. Outline sectioning
17. Assembly section
18. Conventional break
19. Section symbols
m. Used for clarity in sections of assembly drawings of standard parts where the axis of the part lies in the cutting plane

n. Used in making a shortened view of a long simple object

o. Shows all parts of an object as one unit and drawn using section lining to make the individual parts stand out

p. Section lines are shown along the borders of a large part for clarity and to save time

q. Method of not showing the ribs section lined eliminates the impression of solidity

r. Having the same shape and size on opposite sides of a center line

s. Labeling with capital letters the sectional view which has a removed section

2. Identify types of sectional views.
6. Select the most commonly used form of cutting plane lines by placing an "X" in the appropriate blank.

   a. 
   
   b. 
   
   c. 

7. Select true statements concerning general rules in sectioning by placing an "X" in the appropriate blanks.

   a. Hidden lines behind the cutting plane should be omitted unless needed
   b. Sections which are too thin for effective section lining are shown as broken lines
   c. Large surfaces are often sectioned only along the edge of the part
   d. If two or more sections appear on the same drawing, labeling is not necessary
   e. Section lines are thick wavy lines drawn vertical to main outline of the view
   f. Section lines are uniformly spaced 1" apart
   g. Where two or more thin sections are shown, a space should be left between them
   h. When the cutting plane offsets, a line is always shown in the sectioned view to present the offset
   i. When objects have one major center line, the cutting plane line may be omitted
   j. A center line or a visible line may not be used to divide the sectioned half from the unsectioned half
   k. Hidden lines cannot be added to unsectioned half for dimensioning
   l. Visible lines behind cutting plane line should not be omitted

8. Identify types of conventional breaks

   a. 
   b. 

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3. Identify material symbols in section.
   a. 
   b. 
   c. 
   d. 

4. Match types of sections on the right with their correct uses.
   a. To show both interior and exterior features of a symmetrical object
   b. To show the true shape of the cross section of a long object such as a bar, spoke, rib, or arm
   c. To show features that are not in a straight line
   d. To show interior detail of objects where less than half section is required
   e. Used for clearess and for easier dimensioning
   f. Replaces an exterior view in order to show some interior details
   g. Used when true projection would be confusing for spokes, ribs, and holes

5. Identify line thickness used in sectional drawings.
   a. 
   b. 
   c. 
   d. 5S2
3. Identify material symbols in section.

a. 

b. 

c. 

d. 

4. Match types of sections on the right with their correct uses.

a. To show both interior and exterior features of a symmetrical object

b. To show the true shape of the cross section of a long object such as a bar, spoke, rib, or arm

c. To show features that are not in a straight line

d. To show interior detail of objects where less than half section is required

e. Used for clearness and for easier dimensioning

f. Replaces an exterior view in order to show some interior details

g. Used when true projection would be confusing for spokes, ribs, and holes

5. Identify line thickness used in sectional drawings.

a. 

b. 

c. 

d. 

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9. List three common errors in making section lines.
   a. 
   b. 
   c. 

10. Select true statements concerning use of unlined sections by placing an "X" in the appropriate blanks.
   a. Thin parts are made solid
   b. Shafts, bolts, nuts, pins, keys, rivets, gear teeth, and similar parts should always be sectioned if axis lies in cutting plane
   c. Broken-out section of shaft may be made to indicate clearness of key, keyseat, and pin

11. List three methods used to aid equal spacing of section lining.
   a. 
   b. 
   c. 

12. Select true statements concerning labeling sectional views by placing an "X" in the appropriate blanks.
   a. More than one removed section view should be labeled with letters corresponding to the ends of the cutting plane line
   b. Sectional views should be arranged in alphabetical order from right to left on the drawing
   c. Section letters should be used in alphabetical order
   d. Letters "B", "C", and "X" should not be used

13. Demonstrate the ability to:
   a. Construct various material symbols in section.
   b. Construct a full section of an object.
c. Construct a half section of an object.
d. Construct an offset section of an object.
e. Construct a broken-out section of an object.
f. Construct a removed section of an object.
g. Construct a revolved section of an object.
h. Construct a rib section of an object.
i. Construct an aligned section of an object with holes, ribs, or spokes.
j. Construct adjacent parts in assembly section.
k. Construct conventional breaks.
l. Construct an assembly section.

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

14 Construct various sectional views.
a. Complete front view as a full section.

![](image)

b. Complete right side as a half section

![](image)
c. Complete front view as an offset section
SECTIONAL VIEWS
UNIT VII

ANSWERS TO TEST

1. a. 7  j. 13  s. 6
   b. 12  k. 5
   c. 1  l. 4
   d. 19  m. 14
   e. 3  n. 18
   f. 15  o. 17
   g. 2  p. 16
   h. 9  q. 11
   i. 10  r. 8

2. a. Half section
   b. Offset section
   c. Removed section
   d. Aligned section

3. a. Cast iron
   b. Steel
   c. Brass, bronze, or copper
   d. Zinc, lead, and alloys

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

5. a. Section line, thin
   b. Short break line, thick
   c. Long break line, thin
   d. Hidden line, thin

6. a.
7. a, c, g, i, l

8. a. Round bar  
   b. Rectangular solid  
   c. Long break  
   d. Round tubular

9. Any three of the following:  
   a. Irregular spacing  
   b. Varying line weight  
   c. Lines too thick  
   d. Lines short or over run visible lines

10. a, c

11. Any three of the following:  
    a. Visual spacing  
    b. Line guide  
    c. Trace lines from a grid sheet  
    d. Measure with scale

12. a, c

13. Evaluated to the satisfaction of the instructor

14. a. 

   ![Diagram](image)

   b. 

   ![Diagram](image)

   c. 

   ![Diagram](image)
UNIT OBJECTIVE

After completion of this unit, the student should be able to select types of inks, their quality requirements, properties, and performance and types of pen points. The student should also be able to draw and erase ink lines on various media and clean, fill, and refill various types of pens. 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.

SPECIFIC OBJECTIVES

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

1. Match terms related to inking tools and techniques with their correct definitions.
2. Select types of drawing inks.
3. Select quality requirements of good drawing ink.
4. Select true statements concerning the properties and performance of drawing inks.
5. List three types of pen points.
6. Select true statements concerning the ways to properly use and care for technical pens.
7. Complete statements concerning procedures for matching microfilmed drawings.
8. List ways to properly use technical pens with programmed automated digital plotters.
9. Select true statements concerning precautions when using ink on vellum or tracing cloth.
10. Select true statements concerning characteristics of polyester film and procedures for using ink on polyester film.
11. Select factors that contribute to making a line heavier with a ruling pen.
12. Select factors that contribute to making a line thinner with a ruling pen.
13. Discuss useful tips for working with ink.
14. Complete a chart of the alphabet of ink lines.
15. Demonstrate the ability to:

a. Draw and erase ink lines on vellum or tracing cloth.
b. Draw and erase ink lines on polyester film.
c. Complete steps in inking a drawing or a tracing.
d. Fill clean technical and pocket model pens.
e. Refill a technical pen.
f. Clean technical and pocket model pens using the standard cleaning method.
g. Clean a technical pen with an ultrasonic cleaner.
INKING TOOLS AND TECHNIQUES
UNIT VIII

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. Demonstrate the use of and the advantages and disadvantages of the electric eraser and the ultrasonic pen cleaner.
VIII. Complete Job Sheet #1 before starting assignment sheets.
IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1—Technical Pen Parts
      2. TM 2—Pen Point
      3. TM 3—Manual Lettering Device
      4. TM 4—Calligraphic Lettering and Ruling Pens
      5. TM 5—Visible, Hidden, Center, and Symmetry Lines
      6. TM 6—Section, Extension, Dimension, and Leader Lines
      7. TM 7—Cutting Plane, Short Break, and Long Break Lines
      8. TM 8—Phantom, Stitch, Chain, and Border Lines
      9. TM 9—Line Applications
D. Assignment sheets

1. Assignment Sheet #1--Draw and Erase Ink Lines on Vellum or Tracing Cloth
2. Assignment Sheet #2--Draw and Erase Ink Lines on Polyester Film
3. Assignment Sheet #3--Complete Steps in Inking a Drawing or a Tracing

E. Job sheets

1. Job Sheet #1--Fill Clean Technical and Pocket Model Pens
2. Job Sheet #2--Refill a Technical Pen
3. Job Sheet #3--Clean Technical and Pocket Model Pens Using the Standard Cleaning Method
4. Job Sheet #4--Clean a Technical Pen With an Ultrasonic Cleaner

F. Test

G. Answers to test

II. References:


IN KING TOOLS AND TECHNIQUES  
UNIT VIII  

INFORMATION SHEET  

I. Terms and definitions  

A. Opaque--Does not allow light to pass through  
B. Transparent--Has the property of transmitting or allowing light to pass through  
C. Vellum--Tracing paper which has been treated with a transparentizing agent which normally consists of waxes, oils, and similar substances  
D. Tracing cloth--Fabric that has undergone a transparentizing process and is sized with a type of starch compound or plastic to provide a good working surface for pencil or ink  
(NOTE: Although tracing cloth is commonly referred to as linen, it is usually made of muslin.)  
E. Polyester drafting film--A tough translucent plastic drafting medium, usually made by bonding a matte surface to one or both sides of a clear polyester sheet  
(NOTE: Polyester drafting film is dimensionally stable and its size changes very little as humidity and temperature change; it withstands much erasing, is almost impossible to tear, and is moisture resistant.)  
F. Matte--Lacking or deprived of gloss or lustre  
G. Ink--A liquid composed mainly of carbon in colloidal suspension (latex or solutions of special shellac) and gum.  
(NOTE: Fine particles of carbon give ink its deep dark black appearance, and the gum makes it quick to dry and waterproof.)  
H. Technical pen--Usually consists basically of a pen holder, ink cartridge, a point, and a cap (Transparency 1)  
(NOTE: This is sometimes referred to as a technical fountain pen.)  
I. Nib--Pen point  
J. Pen point--Device which consists of a shoulder of metal or plastic in a cylinder placed in a plastic color-coded point tube with an air channel and vent hole, a wire-weight, and a wire-weight safety cap (Transparency 2)  
(NOTE: Pen point width size may vary with the manufacturer; for example, Koh-I-Noor 6 x 0 to 14, Staedtler Mars 5 x 0 to 6.)  
K. Adhesion--Firm or steady attachment
INFORMATION SHEET

L. Compatible--Capable of forming an homogenous (single) mixture that does not separate or alter by chemical interaction with each individual substance or material.

M. Feathering--Occurs when an ink line spreads in an uneven fashion; usually due to drawing on the wire side of the vellum.

N. Wire side--Side of the paper that is down when paper goes through a papermaking machine.

(Note: This wire side can usually be determined by the watermark being backwards.)

O. Felt side--Side of the paper that is up when paper goes through a papermaking machine.

(Note: The felt side can usually be determined by being able to read the watermark properly.)

P. Watermark--A distinctive mark or design produced by the raised pattern of the dandy roll on the wet sheet; usually used as a trademark.

Q. Dogboning--When ink lines spread out at the beginning and end of a line.

R. Ultrasonic pen cleaner--Device which uses millions of microscopic bubbles to clean the point of a technical pen.

S. Ink triangle--A straight-edged three sided device whose total angles equal 180° made of thin, flat plastic, or metal with acute angles of 45° or angles of 30° and 60° with one or both sides bevelled so that ink will not run under triangle.

T. Ink riser--Thin plastic template placed under a template or triangle so that ink will not run under template or triangle.

U. Compass adapter--A device for technical pens to hold the pen in the proper position in a compass (Transparency 2).

V. Manual lettering device--An instrument consisting of a lettering template, scribe, and a tubular pen or a technical pen made for scribe use (Transparency 3).

W. Tubular pen--Pen device that fits into a scribe; consists of a pen point and a cleaning pin (Transparency 3).

(Note: Tubular pen sizes vary from 4 x 0 to 14 depending on the manufacturer.)
X. Calligraphic lettering pen—A fast lettering, freehand drawing pen with an ink reservoir; it is used for calligraphic (beautiful or elegant) handwriting by card writers, commercial artists, drafters, and letterers (Transparency 4)

(NOTE: The Speedball (registered trademark) lettering pen is a typical calligraphic lettering pen.)

Y. Ghosting—A smudged area or image on a reproduction copy of a drawing caused by a damaged surface due to erasing or mishandling of the original

II. Types of drawing inks

A. Washable, opaque
B. Permanent or waterproof black
C. Transparent colors
D. Opaque colors

(NOTE: Acetate-based ink should not be used in a technical pen unless the pens are specifically made for acetate-based inks or damage to the pen will result. Acetate-based inks have a tendency to dry out faster and therefore will clog up the nib faster requiring more frequent cleaning.)

III. Quality requirements of good drawing ink

A. Must be flowing
B. Must be opaque
C. Must have good adhesion to the media surface
D. Must be fast-drying
E. Must dry to sufficient hardness to resist chipping and flaking
F. Must be able to be erased easily at any later date without severe damage to the media surface

(NOTE: Experimentation is sometimes desirable to determine the choice of inks, since not all are compatible with media surfaces. Check with manufacturer for use.)

IV. Properties and performance of drawing inks

(NOTE: The history of China or India ink dates back as far as 2500 B.C.)

A. During manufacturing, drawing inks undergo many chemical and physical tests
B. Salts and other impurities can cause the carbon particles to settle out of the ink and seriously affect the ink mixture.

C. The solvents in ink will rapidly evaporate and result in thickened ink unless the bottle of ink is capped after each use.

D. When using drawing materials that are not chemically compatible, the ink lines tend to flake, chip, feather, and lose sharpness.

E. In recent years manufacturers of drawing ink have started using latex as a binder to replace shellac; this causes the ink to be waterproof after curing and produces an extremely dense black ink line.

F. Ballpoint pens use an offset ink which is pasty and requires considerable pressure to draw a line; it leaves an irregular line and produces poor contrast.

G. Ballpoint pens should not be used for hand drawing; however, they are sometimes used in programmed automated digital plotters when accuracy is not required.

V. Types of pen points

A. Stainless steel (for hand use and programmed automated digital plotters)
   (NOTE: Stainless steel pen points encased in plastic for hand use are available in larger sizes such as Staedtler Mars #6.)

B. Jewel (for hand use and programmed automated digital plotters)
   (NOTE: The jewel point can fracture if it is dropped, or if the point should meet with impact on a hard surface; therefore, do not tap a pen with a jewel point on the desk top.)

C. Tungsten-Carbide (for use with programmed automated digital plotters)
   (NOTE: Manufacturers of technical pens and pen points include the following: 1) Koh-i-Noor Rapidograph, Inc., 2) J.S. Staedtler, Inc., 3) Keuffel & Esser Co., 4) Castell, 5) Reform Reforgraph, 6) Polygraph, and other brands which may be available in your location. Check with your local technical pen dealer or manufacturer for technical assistance.)

VI. Ways to properly use and care for technical pens

A. The proper way to hold the technical pen is vertically, with a very light touch.

B. While drawing, always pull the technical pen; never push it.

C. The air channel allows air to enter the ink cartridge in order to replace the ink that has been used.
INFORMATION SHEET

D. The technical pen should always be capped when not in use (even if not used for a short period of time).

E. The wire-weight should never be removed during cleaning, especially sizes .30mm #00 or smaller (Transparency 2).

F. When a technical pen is to be stored for an extended period of time, it should be cleaned well and filled with pen cleaning solution.

   (NOTE: Check with the manufacturer for recommendation.)

G. Before using a pen that has been stored a long time, flush it with warm water, thoroughly dry it, and refill it with ink.

VII. Procedures for matching microfilmed drawings

A. When reducing a microfilmed drawing to the next lower size, use a pen point one size smaller than was used on the original drawing.

   Example: When a .70 mm (2 1/2") pen has been used on an E size original drawing and the reproduction is to be blown back to a D size drawing, a .50 mm (2) pen should be used.

B. When enlarging a microfilm drawing to the next larger size, use a pen point one size larger than was used on the original drawing.

   Example: When a .70 mm (2 1/2") pen has been used on a D size original drawing and the reproduction is to be blown back to an E size drawing, a .80 mm (3) pen should be used.

VIII. Ways to properly use technical pens with programmed automated digital plotters

A. Plotter pen points require instantaneous start-up and shut-off of ink flow.

B. Jewel and tungsten points are usually recommended for automatic plotter used on polyester film.

C. The wire-weight should never be removed during cleaning, especially in sizes .30 mm #00 or smaller.

D. The average speed for hand drafting is 4 inches per second, but some automated plotters draw as fast as 40 inches per second, and this requires exacting pen performance.

IX. Precautions when using ink on vellum or tracing cloth

A. Be sure felt side of vellum is up; feathering will result if linework is placed on the wire side.

B. Be sure dull side of tracing cloth is up.
INFORMATION SHEET

C. Before putting any linework on vellum or tracing cloth, they should be cleaned and the cleaning material removed.

D. Ink is difficult to remove from vellum or tracing cloth because they are porous materials, so work with care.

E. When linework is erased, it may leave a "ghosting" effect when reproduced, so erase with care.

X. Characteristics of polyester film and procedures for using ink on polyester film

A. If the polyester film is matte on both sides, draw on either side; if it is matte on only one side, place the matte (dull) side up for drawing.

B. Before putting any linework on polyester film, the film should be wiped clean with a moist paper towel.

(NOTE: For serious soils, use a liquid film cleaner.)

C. Ink can be easily removed from polyester film because the ink does not penetrate into the film.

D. When desired, old ink lines can be removed easily from polyester film.

E. Ink lines will flake or chip off the drafting film when some foreign materials are present between the ink line and the polyester film (Transparency 4).

F. The matte coating (sometimes called tooth) is applied to polyester film so a line will adhere securely to the surface.

G. For hand drafting, the most common thickness used is 3 mil.

XI. Factors that contribute to making a line heavier with a ruling pen (Transparency 4)

A. Moving the pen too slowly.

B. Overfilling the pen.

C. Dull nibs.

D. Leaning the pen toward the paper.

E. Soft working surface.

F. Dried ink particles caked on the nibs.

XII. Factors that contribute to making a line thinner with a ruling pen (Transparency 4)

A. Moving the pen too fast.

B. Not enough ink in the pen.
INFORMATION SHEET

C. Nibs too sharp
D. Pen held to nearly vertical
E. Hard working surface
F. Clean pen and fresh ink

(NOTE: A clean, freshly-filled pen should be tested on the same media you will be drawing on, and it should be tested with a straight edge, never freehand.)

XIII. Useful tips for working with ink

A. If an ink triangle is not available, use pennies or drafting tape on one side of the triangle to raise the triangle off the paper

(NOTE: This can also be done with an irregular curve.)

B. If an ink riser is not available, place another triangle under the one being used to prevent ink from flowing under the triangle.
C. Periodically check the technical pen for leaking around the tip to prevent your hands from smearing the drawing; also check the tip for a drop of ink on the tip.

D. If an ink riser is not available, place the template over a triangle to raise the template off the paper; the triangle gives good support and adequate clearance to prevent ink from running under template.
XIV. Alphabet of ink lines (Transparencies 5, 6, 7, and 8)

<table>
<thead>
<tr>
<th>Name of line</th>
<th>Dimension</th>
<th>Approximate Width in in.</th>
<th>Recommended Pen size and number</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible line</td>
<td>Thick</td>
<td>.030-.038</td>
<td>.50 mm 2</td>
<td></td>
</tr>
<tr>
<td>Hidden line</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Center line (Symmetry line)</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Section line</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Dimension line</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Extension line</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Leader line</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Viewing plane or Cutting plane</td>
<td>Thick</td>
<td>.030-.038</td>
<td>.50 mm 2</td>
<td></td>
</tr>
<tr>
<td>Short break line</td>
<td>Thick</td>
<td>.030-.038</td>
<td>.50 mm 2</td>
<td></td>
</tr>
<tr>
<td>Long break line</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Phantom line or Adjacent part line</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Stitch line</td>
<td>Thin</td>
<td>.015-.022</td>
<td>.35 mm 0</td>
<td></td>
</tr>
<tr>
<td>Chain line</td>
<td>Thick</td>
<td>.030-.038</td>
<td>.50 mm 2</td>
<td></td>
</tr>
<tr>
<td>Border line</td>
<td>Thick</td>
<td>.038+</td>
<td>.80 mm 3</td>
<td></td>
</tr>
</tbody>
</table>

(NOTE: Symmetry lines are used in partial views or sections and are indicated by two short, thick parallel lines drawn at right angles to the center line.)
Technical Pen Parts

- Color - Coded Cap
- Spring Seal Mechanism
- Tubular Drafting Point
- Wire Weight
- Air-Pulse Ink-Feed System
- Pocket Clip
- Metal Cylinder
- Air-Tight Seal
- Color-Coded Point Tube
- Safety Cap
- Ink Cartridge
- Pen Holder (Barrel)
- Point Key

Courtesy of J. S. Staedtler, Inc.
Pen Point

Point
Tube
Cleaning Wire
Air Channel and Vent Hole
Safety Cap
Wire-Weight
Shoulder
Point

Courtesy of Koh-I-Noor Rapidograph, Inc.

Technical Pen Attachment for Compass
Manual Lettering Device

Pen

Scriber

Tubular Pen

Template

ABCDEFGHJKLMNOPQRSTUVWXYZ
Calligraphic Lettering and Ruling Pens

Calligraphic Lettering Pen Nibs

Ruling Pen

Good Ink Adhesion

Poor Ink Adhesion
Visible, Hidden, Center, and Symmetry Lines

Types of Lines Width and Character of Lines Applications

Visible Line

**THICK**

**APPROXIMATE WIDTH** .030 – .038
(0.75 – 0.96 mm)
**PEN 2** (.50 mm)

1/32 0.3 (0.8 mm)

1/8 .12 (3.2 mm)

Hidden Line

**THIN**

**APPROXIMATE WIDTH** .015 – .022
(0.38 – 0.55 mm) **PEN 0** (.35 mm)

3/4 to 1 1/2 .75 – 1.50
(19 – 38 mm)

1/8 .12 (3.2 mm)

Center Line

**THIN**

**APPROXIMATE WIDTH** .015 – .022
(0.38 – 0.55 mm) **PEN 0** (.35 mm)

Symmetry Line

---

**Notice**: The content includes diagrams and annotations typically used in technical drawings to represent different types of lines and their applications in various contexts such as engineering and drafting. The text provides specifications for visible, hidden, and center lines along with their approximate widths and pen sizes.
Section, Extension, Dimension, and Leader Lines

Types of Lines Width and Character of Lines Application

Section Line

THIN
APPROXIMATE WIDTH .015-.022
(0.38 - 0.55 mm)
PEN 0 (0.35 mm)

Leader Line
THIN APPROXIMATELY .010 WIDE
(SHOULDER OPTIONAL APPROXIMATELY 1/4" LONG)

Dimension Line

3.50

3.50

Extension Line
Cutting Plane, Short Break, and Long Break Lines

Types of Lines / Width and Character of Lines / Applications

Viewing Plane or Cutting Plane Lines

1/8 .12 (3.2 mm) — 3/4 to 1 1/2 .75-1.50
1/16 .06 (1.6 mm) — (19-38 mm)
THICK
APPROXIMATE WIDTH .030-.038
PEN 2 (.50 mm) (0.75 - 0.96 mm)
1/16 .06 (1.6 mm) — THICK — 1/4 .25
(6.4 mm)
APPROXIMATE WIDTH .030-.038
(0.75 - 0.96 mm)
PEN 2 (.50 mm)

Short Break Line

THICK
FREEHAND
APPROXIMATE WIDTH .030-.038
(0.75 - 0.96 mm)
PEN 2 (.50 mm)

Long Break Line

THIN
FREEHAND
APPROXIMATE WIDTH .015-.022
(0.38 - 0.55 mm)
PEN 0 (.35 mm)
Phantom, Stitch, Chain, and Border Lines

Phantom Line

<table>
<thead>
<tr>
<th>THIN</th>
<th>APPROXIMATE WIDTH</th>
<th>1/8 .12 (3.2 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3/4 to 1 1/2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.75 - 1.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(19 - 38 mm)</td>
</tr>
</tbody>
</table>

Stitch Line

<table>
<thead>
<tr>
<th>THIN</th>
<th>APPROXIMATE WIDTH</th>
<th>1/64 .016 (0.35 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1/16 .06 (1.6 mm)</td>
</tr>
</tbody>
</table>

Chain Line

<table>
<thead>
<tr>
<th>THICK</th>
<th>APPROXIMATE WIDTH</th>
<th>1/8 .12 (3.2 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3/4 to 1 1/2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.75 - 1.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(19 - 38 mm)</td>
</tr>
</tbody>
</table>

Border Line

<table>
<thead>
<tr>
<th>THICK</th>
<th>APPROXIMATE WIDTH</th>
<th>0.030 - 0.038</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.75 - 0.96 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PEN 3 (.80 mm)</td>
</tr>
</tbody>
</table>
Line Applications

- VIEWING PLANE LINE
- DIMENSION LINE
- CENTER LINE
- HIDDEN LINE
- BREAK LINE
- CUTTING PLANE LINE
- VISIBLE LINE
- CENTER LINE (PATH OF MOTION)
- LEADER
- PHANTOM LINE

SECT A-A
VIEW B-B
INKING TOOLS AND TECHNIQUES
UNIT VIII

ASSIGNMENT SHEET #1-DRAW AND ERASE INK LINES ON VELLUM OR TRACING CLOTH

Premise: Ink lines can be drawn and erased on vellum or tracing cloth by using the procedures in the following examples.

Example A: Drawing on vellum or tracing cloth
1. Use ink and media size determined by instructor
2. Decide which side of media to use
   (NOTE: Place felt side of vellum up or dull side of tracing cloth up.)
3. Tape media down on drawing table
4. Clean media if necessary
5. Draw the needed line
   (NOTE: A visible line is used in this example.)

   VISIBLE LINE
   APPROXIMATE WIDTH .030-.038
   (0.75-0.96 mm)
   Pen size .50mm 2

6. Letter the name of the line above the line in vertical upper case lettering using a manual lettering device
7. Letter in below the line the words "Approximate width" and the approximate width figures in English and metric
8. Letter in the recommended pen size in slant lower case lettering

Example B: Erasing on vellum or tracing cloth
1. Check type of eraser to make sure that it is one of the recommended types for use on vellum or tracing cloth
   a. Recommended types for manual use
      1) Plastic embedded with erasing fluid
         (NOTE: These should be stored in air-tight containers.)
ASSIGNMENT SHEET #1

2) Soft, white plastic
3) Soft, white vinyl
4) Soft, pink rubber
   (NOTE: Use of this type will be time consuming.)
5) Soft, green
   (NOTE: This type effectively removes dirt without smudging and will not weaken newly dried ink lines if properly used.)

b. Recommended types for cord or cordless electric erasing machines
   1) Soft, white plastic
   2) Soft, white vinyl
   3) Soft, pink rubber
   4) Soft, green
      (CAUTION: A grey, abrasive eraser strip should not be used because the speed of the eraser coupled with heavy hand pressure will tear a hole in the media surface.)
      (NOTE: Because some vellums and tracing cloths are porous, it is wise to experiment to determine the best eraser for the job.)

2. Erase carefully with an electric eraser or an eraser for manual use

   **VISIBLE LINE**
   APPROXIMATE WIDTH .030 - .038
   (0.75 - 0.96 mm)
   Pen size .50 mm

   (NOTE: In this example only half of the original line drawn in Example A is erased.)

3. Reproduce on blueline print machine to check "ghosting"

DIRECTIONS: Draw and label appropriately the complete alphabet of ink lines. Erase one-half of the drawn lines and reproduce on blueline to check "ghosting." Refer to objective XIV of information sheet for a listing of the alphabet.
ASSIGNMENT SHEET #2—DRAW AND ERASE INK LINES ON POLYESTER FILM

Premise: Ink lines can be drawn and erased on polyester film by using the procedure in the following examples.

Example A: Drawing on polyester film
1. Use ink and polyester film size determined by instructor
2. Place matte side of polyester film up
3. Tape film down on drawing table
4. Clean film if necessary
5. Draw the needed line

(NOTE: A visible line is used in this example.)

**VISIBLE LINE**

**APPROXIMATE WIDTH .030-.038**

(0.75–0.96 mm)

*Pen size .50 mm 2*

6. Letter the name of the line above the line in vertical upper case lettering using a manual lettering device
7. Letter in below the line the words "Approximate width" and the approximate width figures in English and metric
8. Letter in the recommended pen size in slant lower case lettering

Example B: Erasing on polyester film
1. Check type of eraser to make sure that it is one of the recommended types for use on polyester film
   a. Recommended types for manual use
      1) Plastic embedded with erasing fluid
         (NOTE: These should be stored in air-tight containers to prevent evaporation.)
      2) Soft, white vinyl
         (NOTE: For best results, moisten the tip.)
ASSIGNMENT SHEET #2

3) Soft, white plastic
4) Soft, pink rubber
5) Soft, green

b. Recommended type for cord or cordless electric erasers—soft, white vinyl

(NOTE: A great deal of caution should be used with electric erasers because the speed of the eraser and heavy hand pressure produce friction and heat which may damage the matte surface. Some manufacturers of polyester film do not recommend the use of an electric eraser.)

(CAUTION: A grey, abrasive eraser strip should never be used because it will totally damage the matte surface.)

2. Erase carefully with a recommended type of eraser or use erasing fluid

a. First, a small amount of erasing fluid is placed on a sponge
b. Next, a special eraser is dabbed onto the sponge
c. Then, the eraser is used on the film in the standard fashion

Example: Koh-I-Noor Rapidraw eraser kit

(NOTE: For large areas extra strength erasing fluid can be applied to a soft paper towel.)

Example: Koh-I-Noor's Koh-I-Lar

VISIBLE LINE

APPROXIMATE WIDTH .030-.038
(0.75-0.96 mm)

Pen size .50 mm 2

(NOTE: In this example only half of the original line drawn in Example A is erased.)

3. Reproduce on blueline print machine to check "ghosting"

Directions: Draw and label appropriately the complete alphabet of ink lines. Erase one-half of the drawn lines and reproduce on blueline to check "ghosting." Refer to objective XIV of information sheet for a listing of the alphabet.
Premise: A drawing or tracing can be inked by using the procedure in the following example.

Example:

1. Ink all arcs and circles first, by centering the ink lines over the pencil lines

   ![Correct and Incorrect Drawing Lines]

2. Ink all straight lines, next, doing the horizontal, then the vertical, and last the inclined lines

   (NOTE: It is far easier to join straight lines to arcs than to join arcs to straight lines.)

3. Ink all extension, dimension, and center lines

   (NOTE: Some drafters prefer to ink center lines before making compass center. This helps to keep ink from running through the holes in the media surface.)

4. Ink in all arrowheads and lettering

   (NOTE: Draw guidelines for lettering directly on the media surface.)

5. Be PATIENT; allow ink to dry before inking adjacent lines

6. If an error is made, wait until it dries; then use an erasing shield to protect line work near the error

Directions: On media and size determined by the instructor, ink all parts of the drawing.
INKING TOOLS AND TECHNIQUES
UNIT VIII

JOB SHEET #1--FILL CLEAN TECHNICAL AND POCKET MODEL PENS

I. Tools and materials
   A. Clean technical pen
   B. Clean pocket model technical pen
   C. Ink filler bottle
   D. Lint-free cloth or tissue

II. Procedure
   A. Fill a clean technical pen
      1. Remove cap
      2. Grip clamp ring and unscrew holder (barrel)
      3. Using light finger pressure, unscrew and remove clamp rings
      4. Hold pen point upright and pull off ink cartridge
      5. Hold cartridge at a slight tilt while filling cartridge, then turn cartridge upright
JOB SHEET #1

6. Fill cartridge from ink filler bottle to a line 1/4" from the top, but not past the 1/4" line

(NOTE: If permanent ink should spill on clothing, wash area immediately with soap and cold water.)

7. Keep cartridge upright and reassemble pen

8. Press filled cartridge slowly onto pen body to prevent residual ink from entering air channel

9. After assembly, wipe off excess ink with a lint-free cloth or tissue

10. With cap off, gently shake pen horizontally several times to start ink flow

(NOTE: Always keep cartridge more than half full of ink for proper flow.)

B Fill a clean pocket model technical pen

1. Remove cap

2. Unscrew and remove filler knob cap
JOB SHEET #1

3. Submerge entire pen point into ink and turn filler knob counterclockwise until resistance is felt and threads are exposed.

4. Turn knob clockwise until resistance is felt (NOTE: Pen barrel is now 3/4 full.)

5. With the point still in the ink, again turn knob counterclockwise, then clockwise to completely fill barrel.

6. Wipe off excess ink with lint-free cloth or tissue.

7. With cap off gently shake pen horizontally several times to start ink flow.

(NOTE: Always keep barrel more than half full of ink for proper flow.)

All illustrations for this job sheet courtesy of Koh-I-Noor Rapidograph, Inc.
INKING TOOLS AND TECHNIQUES
UNIT VIII

JOB SHEET #2--REFILL A TECHNICAL PEN

I. Tools and materials
   A. Partially filled technical pen
   B. Ink filler bottle
   C. Lint-free cloth or tissue

II. Procedure
   A. Grip clamp ring and unscrew pen holder (barrel)
   B. Using light finger pressure, unscrew and remove clamp ring
   C. Hold pen point upright and pull off ink cartridge
   D. Lightly tap the rear portion of the pen body on absorbent paper to remove excess ink
   E. Hold cartridge at a slight tilt while refilling, then turn cartridge upright
JOB SHEET #2

F. Fill cartridge from ink filler bottle to a line 1/4" from the top, but not past the 1/4" line

(NOTE: If permanent ink should spill on clothing, wash area immediately with soap and cold water.)

G. Keep cartridge upright and reassemble pen

H. Press filled cartridge slowly onto pen body to prevent residual ink from entering air channel

I. After assembly, wipe off excess ink with a lint-free cloth or tissue

J. With cap off gently shake pen horizontally several times to start ink flow

(NOTE: Always keep cartridge more than half full of ink for proper flow.)

All illustrations for this job sheet courtesy of Koh-I-Noor Rapidograph, Inc.
JOB SHEET #3--CLEAN TECHNICAL AND POCKET MODEL PENS USING THE STANDARD CLEANING METHOD

Tools and materials
A. Technical pen
B. Pocket model technical pen
C. Lint-free cloth or tissue
D. Cleaning solution

II. Procedure
A. Clean a technical pen
   1. Remove ink cartridge
   2. Pour out ink and flush out excess ink with water
   3. Remove the nib from its holder with a key
      (NOTE: Some technical pens have the key built into the pen holder.)
      (CAUTION: Nib disassembly is not recommended unless absolutely necessary, and a .30 mm #00 nib or smaller should never be disassembled.)
   4. Remove nib safety cap and hold nib point up to allow the wire-weight to fall out into hand
      (CAUTION: NEVER PULL a wire-weight to remove it.)
   5. Carefully clean the wire-weight and the nib
   6. Hold nib point down and carefully drop the wire-weight into the writing tube of the nib
JOB SHEET #3

7. Jiggle the pen carefully to allow the wire-weight to fall back into place, but DO NOT FORCE the wire-weight back into place.

8. Replace nib safety cap.

9. Soak cartridge and entire nib in pen cleaner until the dried ink dissolves (overnight if necessary).

10. Remove cleaning solution from all pen parts by rinsing with warm water.

11. Clean pen body and cap by flushing with warm water.

12. Check air channel and vent hole to make sure they are thoroughly clean.

13. Dry all parts thoroughly with a paper towel.

(Note: A bellows or ear syringe is handy to use for air drying the nib.)
JOB SHEET #3

14. If pen is to be used in the near future, use standard procedure to refill the ink cartridge.

15. If pen will not be used for an extended period of time, fill the ink cartridge with cleaning solution.

16. Hold cartridge upright and reassemble pen.

17. Press filled cartridge slowly into the body of the pen to prevent residual ink from entering the air channel.

18. After assembly, wipe off excess ink with a lint-free cloth or tissue.

19. With cap off, gently shake pen horizontally several times to start ink flow.

   (NOTE: Pens in normal use should be cleaned on a regular basis, and pens in use should always have cartridges more than half full of ink to insure ink flow.)

B. Clean a pocket model technical pen

1. Expel ink by turning filler knob counter-clockwise.

   Water in Sink
2. Remove nib with nib key

(CAUTION: Nib disassembly is not recommended unless absolutely necessary and a nib .30 mm #00 or smaller should never be disassembled.)

3. Remove safety cap and hold point up to allow wire-weight to fall into hand

(CAUTION: NEVER PULL wire-weight to remove it.

4. Carefully clean wire-weight and nib

5. Hold nib point down and carefully drop wire-weight into writing tube of nib

6. Jiggle pen carefully to allow wire-weight to fall back into place, but do not force the wire-weight back into place

7. Replace safety cap

8. Turn filler knob clockwise as far as it goes

9. Hold barrel upright and fill half-way with liquid pen cleaner
10. With thumb over open end, gently shake barrel horizontally, then flush with warm water

11. Clean cap by flushing with warm water

12. Air dry all parts thoroughly with bellows or ear syringe before reassembling pen and refilling with ink

(NOTE: If the pen must be used before it is completely air dried, flush ink through the reassembled point and barrel by filling and expelling ink several times before the final fill; under no circumstances should the pen be used until all cleaning fluid and water have been removed in this fashion.)
JOBSHEET #4--CLEAN A TECHNICAL PEN WITH AN ULTRASONIC CLEANER

I. Tools and materials
   A. Technical pen
   B. Ultrasonic cleaner
   C. Ultrasonic cleaning fluid
   D. Lint-free cloth or tissue

II. Procedure
   A. Without removing ink, submerge pen up to 10 threads in cleaning solution for 30 seconds
   B. Blot the cleaning solution from the air channel with a paper wipe
   C. With the technical pen, draw on a scrap piece of vellum or other media material to remove the cleaning solution from the writing tube

(NOTE: This preventative maintenance should be performed daily after each work session, if the pen was used, if the pen point is extremely dirty, follow the standard cleaning method.)

(CAUTION: Do not submerge the entire pen point in the ultrasonic cleaner for an extended time period or damage to the pen point and ultrasonic cleaner will result)

All illustrations for this job sheet courtesy of Koh I Noor Rapidograph, Inc.
1. Match the terms on the right with their correct definitions.

   _____ a. Does not allow light to pass through
   _____ b. Has the property of transmitting or allowing light to pass through
   _____ c. Tracing paper which has been treated with a transparentizing agent which normally consists of waxes, oils, and similar substances
   _____ d. Fabric that has undergone a transparentizing process and is sized with a type of starch compound or plastic to provide a good working surface for pencil or ink
   _____ e. A tough translucent plastic drafting medium, usually made by bonding a matte surface to one or both sides of a clear polyester sheet
   _____ f. Lacking or deprived of gloss or lustre
   _____ g. A liquid composed mainly of carbon in colloidal suspension and gum
   _____ h. Usually consists basically of a pen holder, ink cartridge, a point, and a cap
   _____ i. Pen point
   _____ j. Device which consists of a shoulder of metal or plastic in a cylinder placed in a plastic color-coded point tube with an air channel and vent hole, a wire-weight, and a wire-weight safety cap
   _____ k. Firm or steady attachment
   _____ l. Capable of forming an homogenous mixture that does not separate or alter by chemical interaction with each individual substance or material

   1. Manual lettering device
   2. Ink
   3. Dogboning
   4. Pen point
   5. Vellum
   6. Technical pen
   7. Nib
   8. Calligraphic lettering pen
   9. Ultrasonic pen cleaner
   10. Ghosting
   11. Compass adapter
   12. Tracing cloth
   13. Watermark
   14. Opaque
   15. Wire side
   16. Polyester drafting film
   17. Ink triangle
   18. Transparent
   19. Compatible
   20. Adhesion
   21. Matte
   22. Ink riser
   23. Feathering
   24. Tubular pen
   25. Felt side
m. Occurs when an ink line spreads in an uneven fashion; usually due to drawing on the wire side of the vellum

n. Side of the paper that is down when paper goes through a paper-making machine

o. Side of the paper that is up when paper goes through a paper-making machine

p. A distinctive mark or design produced by the raised pattern of the dandy roll on the wet sheet; usually used as a trademark

q. When ink lines spread out at the beginning and end of a line

r. Device which uses millions of microscopic bubbles to clean the point of a technical pen

s. A straight-edged three sided device whose total angles equal 180° made of thin, flat plastic, or metal with acute angles of 45° or angles of 30° and 60° with one or both sides bevelled so that ink will not run under triangle

t. Thin plastic template placed under a template or triangle so that ink will not run under template or triangle

u. A device for technical pens to hold the pen in the proper position in a compass

v. An instrument consisting of a lettering template, scriber, and a tubular pen or a technical pen made for scriber use

w. Pen device that fits into a scriber, consists of a pen point and a cleaning pin

x. A fast lettering, freehand drawing pen with an ink reservoir, it is used for calligraphic hand writing by calligraphic artists, commercial artists, drafters, and letterers

y. A smudged area or image on a reproduction copy of a drawing caused by a damaged surface due to erasing or mishandling of the original
2. Select types of drawing inks by placing an "X" in the appropriate blanks.

   a. Transparent colors
   b. Stamp pad ink
   c. Tempera ink
   d. Washable, opaque
   e. Permanent or waterproof black
   f. Opaque colors

3. Select quality requirements of good drawing ink by placing an "X" in the appropriate blanks.

   a. Must be flowing
   b. Must be transparent
   c. Must have good adhesion to the media surface
   d. Must be slow-drying
   e. Must dry to sufficient hardness to resist chipping and flaking
   f. Must be able to be erased easily at any later date without severe damage to the media surface

4. Select true statements concerning the properties and performance of drawing inks by placing an "X" in the appropriate blanks.

   a. During manufacturing, drawing inks undergo many chemical and physical tests
   b. Salts and other impurities do not seriously affect the ink mixture
   c. The solvents in ink will rapidly evaporate and result in thickened ink unless the bottle of ink is capped after each use
   d. Drawing materials that are not chemically compatible have no influence on the quality of the ink line
   e. In recent years manufacturers of drawing ink have started using latex as a binder to replace shellac; this causes the ink to be waterproof after curing and produces an extremely dense black ink line
   f. Ballpoint pens may be used for hand drawing when accuracy is necessary
5 List three types of pen points.

a. 

b. 

c. 

6. Select true statements concerning the ways to properly use and care for technical pens by placing an "X" in the appropriate blanks

a. The proper way to hold the technical pen is horizontally, with a very heavy touch

b. While drawing, always push the technical pen, never pull it

c. The air channel allows air to enter the ink cartridge in order to replace the ink that has been used

d. The technical pen may be left uncapped when not in use for short periods of time

e. The wire weight should always be removed during cleaning

f. When a technical pen is to be stored for an extended period of time, it should be cleaned well and filled with pen cleaning solution

g. Before using a pen that has been stored a long time, flush it with warm water, thoroughly dry it, and refill it with ink

7 Complete the following statements concerning procedures for matching microfilmed drawings

a. When reducing a microfilmed drawing to the next lower size, use a pen point than was used on the original drawing

b. When enlarging a microfilm drawing to the next larger size, use a pen point than was used on the original drawing

8 List two ways to properly use technical pens with programmed automated digital plotters

9
9. Select true statements concerning precautions when using ink on vellum or tracing cloth by placing an "X" in the appropriate blanks.

   a. Be sure wire side of vellum is up
   b. Be sure shiny side of tracing cloth is up
   c. Before putting any linework on vellum or tracing cloth, they should be cleaned and the cleaning material removed
   d. Ink is easy to remove from vellum or tracing cloth because they are non-porous materials
   e. When linework is erased, it may leave a "ghosting" effect when reproduced, so erase with care

10. Select true statements concerning characteristics of polyester film and procedures for using ink on polyester film by placing an "X" in the appropriate blanks.

   a. If the polyester film is matte on only one side, place the shiny side up for drawing
   b. Before putting any linework on polyester film, the film should be wiped clean with a moist paper towel
   c. Ink is difficult to remove from polyester film
   d. Ink lines will flake or chip off the drafting film when some foreign materials are present between the ink line and the polyester film
   e. The matte coating is applied to polyester film so a line will adhere securely to the surface
   f. For hand drafting, the most common thickness used is 15 mil

1. Select factors that contribute to making a line heavier with a ruling pen by placing an "X" in the appropriate blanks.

   a. Moving the pen too fast
   b. Overfilling the pen
   c. Nibs too sharp
   d. Leaning the pen toward the paper
   e. Hard working surface
   f. Dried ink particles caked on the nibs
12. Select factors that contribute to making a line thinner with a ruling pen by placing an "X" in the appropriate blanks.

   a. Moving the pen too fast
   b. Overfilling the pen
   c. Dull nibs
   d. Pen held to nearly vertical
   e. Hard working surface
   f. Dried ink particles caked on the nibs

13. Discuss useful tips for working with ink.

14. Complete the following chart of the alphabet of ink lines. Be sure to fill in every blank line.
15. Demonstrate the ability to:

a. Draw and erase ink lines on vellum or tracing cloth.
b. Draw and erase ink lines on polyester film.
c. Complete steps in inking a drawing or a tracing.
d. Fill clean technical and pocket model pens.
e. Refill a technical pen.
f. Clean technical and pocket model pens using the standard cleaning method.
g. Clean a technical pen with an ultrasonic clearer.

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

ANSWERS TO TEST

1. a. 14
   b. 18
   c. 5
   d. 12
   e. 16
   f. 21
   g. 2
   h. 6
   i. 7
   j. 4
   k. 20
   l. 19
   m. 23
   n. 15
   o. 25
   p. 13
   q. 3
   r. 9
   s. 17
   t. 22
   u. 11
   v. 1
   w. 24
   x. 8
   y. 10

2. a, d, e, f

3. a, c, e, f

4. a, c, e

5. a. Stainless steel
   b. Jewel
   c. Tungsten-Carbide

6. c, f, g

7. a. One size smaller
   b. One size larger

8. Any two of the following:
   a. Plotter pen points require instantaneous start-up and shut-off of ink flow
   b. Jewel and tungsten points are usually recommended for automatic plotter used on polyester film
   c. The wire-weight should never be removed during cleaning, especially in sizes .30 mm #00 or smaller
   d. The average speed for hand drafting is 4 inches per second, but some automated plotters draw as fast as 40 inches per second, and this requires exacting pen performance

9. c, e

10. b, d, e

11. b, d, f

12. a, d, e
13. Discussion should include:
   
a. If an ink triangle is not available, use pennies or drafting tape on one side of the triangle to raise the triangle off the paper.

b. If an ink riser is not available, place another triangle under the one being used to prevent ink from flowing under the triangle.

c. Periodically check the technical pen for leaking around the tip to prevent your hands from smearing the drawing; also check the tip for a drop of ink on the tip.

d. If an ink riser is not available, place the template over a triangle to raise the template off the paper; the triangle gives good support and adequate clearance to prevent ink from running under the template.

14.|
---|---|---|---|
Name of line| Dimension| Approximate Width in in| Recommended Pen size and number
---|---|---|---|
Visible line| Thick| 0.030-0.038| 50 mm 2
Hidden line| Thin| 0.015-0.022| 35 mm 0
Center line (Symmetry line)| Thin| 0.015 0.022| 35 mm 0
Section line| Thin| 0.015-0.022| 35 mm 0
Dimension line| Thin| 0.015 0.022| 35 mm 0
Extension line| Thin| 0.015 0.022| 35 mm 0
Leader line| Thin| 0.015 0.022| 35 mm 0
Viewing plane or Cutting plane| Thick| 0.030 0.038| 50 mm 2
Short break line| Thick| 0.030 0.038| 50 mm 2
Long break line| Thin| 0.015 0.022| 35 mm 0
Phantom line or Adjacent part line| Thin| 0.015 0.022| 35 mm 0
Stitch line| Thin| 0.015 0.022| 35 mm 0
Chain line| Thick| 0.030 0.038| 50 mm 2
Border line| Thick| 0.038| 80 mm 3

15. Evaluated to the satisfaction of the instructor
UNIT OBJECTIVE

After completion of this unit, the student should be able to identify isometric axis line positions and plane surfaces on isometric drawings. The student should also be able to center in a working space, box in, construct angles, construct circles, measure in, and dimension an isometric drawing. 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 axonometrics with their correct definitions.
2. List three types of axonometric drawings.
3. Identify positions used as axis lines for isometric drawings.
4. Identify plane surfaces on isometrics.
5. Select true statements concerning rules in constructing an isometric drawing.
6. Match common errors made in isometric drawing with their correct drawings.
7. Distinguish between the advantages and disadvantages of isometric drawing.
8. Select methods of dimensioning an isometric.
9. Select true statements concerning rules in dimensioning an isometric drawing.
10. Demonstrate the ability to:
   a. Sketch an isometric drawing.
   b. Sketch isometric circles
   c. Construct an axonometric drawing by box method.
   d. Construct angles on an isometric.
   e. Construct isometric circles and arcs.
   f. Construct isometric curves by coordinates.
g. Measure in isometric by offsets.

h. Construct an isometric in the center of a drawing media.

11. Construct isometric drawings of various objects.
AXONOMETRICS
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. Show filmstrips or films which cover the fundamentals of isometric drawings. Refer to additional material for suggested teaching aids.
VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Types of Axonometric Drawings
      2. TM 2--Positions of Isometric Axis Lines
      3. TM 3--Surfaces on an Isometric
      4. TM 4--Errors on Isometrics
      5. TM 5--Errors on Isometrics (Continued)
      6. TM 6--Methods of Dimensioning Isometrics
      7. TM 7--Dimensioning Procedures
   D. Assignment sheets
      1. Assignment Sheet #1--Sketch an Isometric Drawing
      2. Assignment Sheet #2--Sketch Isometric Circles
3. Assignment Sheet #3--Construct an Axonometric Drawing by Box Method
4. Assignment Sheet #4--Construct Angles on an Isometric
5. Assignment Sheet #5--Construct Isometric Circles and Arcs
6. Assignment Sheet #6--Construct Isometric Curves by Coordinates
7. Assignment Sheet #7--Measure in Isometric by Offsets
8. Assignment Sheet #8--Construct an Isometric in the Center of a Drawing Media

E. Answers to assignment sheets
F. Test
G. Answers to test

II. References:


III. Additional materials:

A. Filmstrip/cassette--"Drafting Series I and II." Doubleday Multimedia; 1371 Reynolds Avenue; Santa Ana, CA 92705.

B. Transparencies--"The ABC's of Drafting." DCA Educational Products: DCA Incorporated, Warrington, PA 18976.

C. Filmstrip/cassette--"Drafting/Mechanical Drawing." Prentice Hall Media; Serv Code VD354; 150 White Plains Road; Tarrytown, NY 10591.
Terms and definitions

A. Axonometric A type of pictorial with each of the three planes and axes at any angle and not equal to 90°

B. Pictorial Suggesting a picture or mental image

(Note: Three types of pictorials are axonometric, oblique, and perspective)

C. Isometric A type of axonometric drawing with each of the three planes and axes equal to each other

D. Dimetric A type of axonometric drawing with two planes on equal axes to each other and a third plane of a different angle

E. Trimetric A type of axonometric drawing with all three planes and axes not equal to each other

F. Foreshortened To appear shorter to the eye than it actually is

G. Axis lines The lines used to represent surfaces or planes coming together

H. Projection To extend from one point to another

I. Isometric lines The lines that run parallel to the isometric axis lines

J. Non-isometric lines The lines that do not run parallel to the isometric axis lines

K. Ellipse A foreshortened circle with a major and minor diameter

L. Offset coordinates A method of locating a point from a horizontal and a vertical line

Types of axonometric drawings (Transparency 1)

A. Isometric

B. Dimetric

C. Trimetric
INFORMATION SHEET

III. Positions used as axis lines for isometric drawings (Transparency 2)
   A. Top  
      (NOTE: The top position is most commonly used.)
   B. Bottom
   C. Right side
   D. Left side

IV. Plane surfaces on isometrics (Transparency 3)

V. Rules in constructing an isometric drawing
   A. All measurements are made parallel to the main edges of the isometric axis lines
   B. Angles are measured by coordinate offsets and cannot be transferred in degrees
   C. Hidden lines are omitted in isometric drawings if possible
   D. A drawing should be centered in the work space and boxed in before adding details
   E. If isometric templates are not available, then approximate ellipses must be constructed to represent circles
   F. Always block in a circle before constructing its arcs
   G. The sight direction that best represents the object should be used for the isometric position
   H. If lines are parallel in two successive orthographic views, they are parallel in isometric views

VI. Common errors made in isometric drawing (Transparencies 4 and 5)
   A. Object viewed from wrong direction
   B. Circle arcs not tangent to each other
INFORMATION SHEET

C. Ellipses not in proper plane
D. Tangent lines missing from circles and arcs
E. Rear ellipse of a hole missing
F. Lines of isometric omitted
G. Angles not measured correctly
H. Dimensions not measured parallel to isometric axis lines

VII. Advantages and disadvantages of isometric drawing
A. Advantages
   1. Easy to construct
   2. Three sides of an object may be shown in one view
   3. Circles are not very distorted
B. Disadvantages
   1. Long objects appear distorted
   2. Symmetrical type drawing causes some lines to meet or overlap, confusing the viewer

VIII. Methods of dimensioning an isometric (Transparency 6)
A. Aligned
B. Unidirectional

IX. Rules in dimensioning an isometric drawing (Transparencies 6 and 7)
A. Dimensions must all be put in by the aligned method or the unidirectional method
B. Use guidelines for all notes
C. Dimension and extension lines should be parallel to the plane being dimensioned
D. Keep dimensions off object if possible
E. Dimensions should all be to visible surfaces if possible
F. Dimension size of holes with notes and leaders
G. Keep dimension lines evenly spaced and not crowding the drawing
H. Notes should be parallel to the horizontal plane
Types of Axonometric Drawings

- **Isometric**
  - $\angle d = \angle e = \angle f = 120^\circ$

- **Diametric**
  - $\angle e = \angle f$
  - $\angle d \ not \ equal$

- **Trimetric**
  - $\angle d, \angle e, \angle f \ are \ not \ equal$
Positions of Isometric Axis Lines

Top

Right Side

Bottom

Left Side
Surfaces on an Isometric

Top View

Left Side View

Right Side View

Bottom View
Errors on Isometrics

CORRECT
Object viewed from wrong direction

INCORRECT

Circle arcs not tangent to each other

Ellipse not in proper plane
Errors on Isometrics
Continued

- Tangent lines and rear ellipse missing
- Isometric lines missing
- Angles not measured correctly
- Dimensions not measured parallel to isometric axis
Methods of Dimensioning Isometrics

ALIGNED

1 Drill

UNIDIRECTIONAL

1 Drill

3

2

1 1/4

1 1/4

1/2

1/2

3 1/4

2
Dimensioning Procedures

**CORRECT**

3/4 Drill

2 Holes

**INCORRECT**

3/8 Drill

1/2 Drill
ASSIGNMENT SHEET #1: SKETCH AN ISOMETRIC DRAWING

Premise: This type of sketching can be drawn from an actual object or from any multi-view type drawing. An isometric sketch is drawn with both sides slanting back at a 30° angle. In sketching, this 30° angle is approximate. An isometric drawing can be sketched by using the procedure in the following example.

Example:

1. Use given actual object of multiview drawing and determine height, width, and depth

2. Lay off height, width, and depth as shown

3. Box in the outline of the object

4. Locate object features such as slots, holes, and grooves
ASSIGNMENT SHEET #1

5. Complete shape of object

6. Erase construction lines and darken outline

Directions: Sketch an enlarged isometric of the object below.
Premise: An isometric circle can be in the top, right side, or left side. In any case the circle should always be boxed in and then its individual arcs sketched to make the complete isometric circle. Isometric circles can be sketched by using the procedure in the following example.

Example:
1. Lay out center lines

2. Mark off radius points

3. Box in circle outlines

4. Sketch in arcs lightly
5. Erase construction lines and darken circles

Directions: Make enlarged isometric sketches of the objects below in the space at the right.

Problem A.

Problem B.
AXONOMETRICS
UNIT IX

ASSIGNMENT SHEET #3-CONSTRUCT AN AXONOMETRIC DRAWING BY BOX METHOD

Premise: Axonometric drawings can be constructed by using the procedure in the following example. The same procedure is used for isometrics, dimetrics, and trimetrics except that the axis lines will differ.

Example:

1. Attach sheet to drawing surface in alignment with working edge

2. Select position of isometric axis lines

3. Locate axis lines on drawing media for the type of axonometric to be drawn

(NOTE: The lines are not centered on this example media.)
ASSIGNMENT SHEET #3

ANY ANGLE EXCEPT
30° AND EQUAL

25° 25°

 ANY ANGLE BUT NOT EQUAL
SUM OF TWO LESS THAN 30°

20° 50°

b. Dometric
c. Trimetric

4. Extend lines from these axis lines with 30° 60° triangle or drafting machine

5. Measure overall width, depth, and height on these projected axis lines and mark point

6. Complete box with 30° 60° triangle or drafting machine making sure lines are parallel to main axis lines

(NOTE: The following drawing is isometric. Dimetric and trimetric axis lines will be parallel at different angles.)

Parallel at 30°
7. Add details to object by removing parts of box not needed.

Directions: Construct an isometric drawing of the following object. Use top axis position.

Problem A:

Directions: Construct a dimetric drawing of the following object. Use top axis position and 20° angles.

Problem B:

Directions: Construct a trimetric drawing of the following object. Use top axis position and 20° and 50° angles.

Problem C:
AXONOMETRICS
UNIT IX

ASSIGNMENT SHEET #4—CONSTRUCT ANGLES ON AN ISOMETRIC

Premise: Angles on an isometric can be constructed by using the procedure in the following example. The example will use the dimensions of the following object on the left to construct the object on the right.

Example:

1. Box in overall dimensions of the object in isometric

2. Use dividers to lay out offset dimensions of angle and connect points

3. Complete the other side after extending lines across with 30° 60° triangle or drafting machine
 ASSIGNMENT SHEET #4

Directions: Construct the following object in isometric using the correct method to construct angles. Use top axis position and construct long dimension to left.
ASSIGNMENT SHEET #5—CONSTRUCT ISOMETRIC CIRCLES AND ARCS

Premise: A circle can appear as an ellipse in the top, left side, or right side. The procedure for constructing the ellipses is the same but each is in a separate plane. Isometric circles and arcs can be constructed by using the procedures in the following examples. Examples are given for constructing circles in top and side planes using a 30° 60° triangle or drafting machine and ellipse templates. Examples are also given for constructing arcs using a 30° 60° triangle or drafting machine and ellipse template.

Example A: Circle in top plane

1. Locate center of circle and lay out center lines with a 30° 60° triangle or drafting machine

2. Locate diameter of circle by measuring its radius from the center point along the center lines

3. Erect perpendicular bisectors to each side, using the 30° 60° triangle or drafting machine as shown; these perpendiculars will intersect at four points, which will be centers for the four circular arcs
ASSIGNMENT SHEET #5

4. Draw the two large arcs, with radius R, from the intersections of the perpendiculars in the two closest corners of the parallelogram as shown

5. Draw the two small arcs, with radius r, from the intersections of the perpendiculars within the parallelogram, to complete the ellipse

Example B. Circle in side plane

(NOTE: The method for constructing isometric circles is the same for both sides of the box. In this example the right side plane will be used.)

Right Side

1. Locate center of circle and lay out centerlines with 30° 60° triangle or drafting machine

Centerline Vertical

Centerline 30°
2. Locate diameter of circle by measuring its radius from the centerpoint along the center lines.

3. Erect perpendicular bisectors to each side as shown; use the intersecting points as centers for the arcs.

4. Draw the two large arcs with radius R, from the intersection of the perpendiculars from the two closest corners.
ASSIGNMENT SHEET #5

5. Draw the two small arcs, with radius \( r \), from the intersection of the perpendicular lines within the parallelogram to complete the figure.

Example C: Circles with ellipse template

(NOTE: For convenience and time saving, isometric ellipse templates (35° 16' should be used. These ellipses have centerline marks that are parallel to two of three major axis lines on the isometric drawing.)

1. Construct isometric centerlines that are parallel to two axis lines
2. Select template marked isometric ellipses
3. Select correct diameter marked on template
4. Position template so that the four line-up marks are at a 30° angle from horizontal
5. Line up ellipse template marks on center lines; construct ellipse
6. To position the ellipse on the center lines in the other planes, use the same marks; place two of them vertically and the other two marks are at a 30° angle from horizontal.

Example D: Arcs

(Note: Arcs in isometric pose another problem in determining which plane to lay out the isometric box and which part of the elliptical circle to use. The required radius R is measured equally and in each case is measured from the corner where the arc is to be located as shown in the following illustration.)
ASSIGNMENT SHEET #5

1. Mark off radius points from the corners along the box lines
   (NOTE: In this example 1/4" R arcs will be constructed.)

2. Erect construction lines inside the circle perpendicular to each of the lines on which the radius points are marked
3. Set compass at radius of line intersections and put in arcs as shown on all four corners.

4. If plane where arcs are needed should be in the top, the procedure is the same; after points are located, swing arcs from intersecting lines as shown.

Example E: Arcs with ellipse template

1. Mark off radius points from corners along the box lines
2. Construct isometric center lines parallel to box lines
3. Select correct ellipse size for radius
ASSIGNMENT SHEET #5

4. Position template line-up marks on center lines; construct required arc

(NOTE: Arc lengths greater than or less than one-fourth circle are determined by
marking tangent points.)

Directions: Construct an isometric circle with a diameter of 2" using the procedure outlined
in Example A.

Problem A:

Directions: Construct isometric circles in right and left plane in the boxes below using the
procedure outlined in Example B.

Problem B:
ASSIGNMENT SHEET #5

Directions: Construct isometric circles on the following center lines using isometric ellipse template and procedure outlined in Example C.

Problem C:

Directions: Construct 1/2" radius arcs in the corners of the following boxes using procedure outlined in Example D.

Problem D:
ASSIGNMENT SHEET #5

Directions: Construct 1/2" radius arcs in the corners of the following boxes using circle template and procedure outlined in Example E.

Problem E:
Premise: Circles and arcs that are not regular make it necessary to use points to lay out the curve. Isometric curves such as in the following illustration can be constructed by coordinates using the procedure in the following example.

Example:

1. Locate coordinate points along the curve as at A, B, C, and D

2. Mark distance a and b as shown on top view of orthographic

3. Draw isometric box in position desired to illustrate object
ASSIGNMENT SHEET #6

4. Along right and left edges lay out coordinate distances a and b from orthographic view in step #2; this locates point A

5. Locate points B, C, and D in the same manner as point A was located

6. Use irregular curve to connect points

7. Locate curve points at bottom edge by dropping them down the thickness of the object
8. Use irregular curve to put in bottom edge; darken visible lines

Directions: Construct an isometric drawing of the following object beginning with point A.

Problem:
Assignment Sheet #7: Measure in Isometric by Offsets

Premise: Isometrics can be measured by offsets using the procedure in the following example.

Example:

1. Box in outline of top and front view

   Top View
   \[ \text{Top View} \]
   \[ A \quad B \]
   \[ a \quad b \]

2. Locate points on outline of box as at a and b

   Front View
   \[ \text{Front View} \]
   \[ C \]

3. Lay out isometric box with same height, width, and depth of object

4. Locate points on isometric box by locating them on their correct plane; all measurements must be made parallel to isometric lines, such as the outline of the box

   \[ \text{Isometric View} \]
   \[ A \quad B \quad C \]
   \[ a \quad b \quad c \]
ASSIGNMENT SHEET #7

5. Erase construction lines and darken outline of the object

Directions: Construct the two views as an isometric.

Problem:
ASSIGNMENT SHEET #8-CONSTRUCT AN ISOMETRIC IN THE CENTER OF A DRAWING MEDIA.

Premise: It is important that isometric drawings be located somewhere near the center of the drawing media that is available to allow room for dimensions, notes, and to add to the neatness of the object. Isometrics can be constructed in the center of a drawing media by using the procedure in the following example.

Example:

1. Make an isometric box sketch of the overall dimensions of the object to be drawn

```
<table>
<thead>
<tr>
<th>Height 3&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth 2&quot;</td>
</tr>
<tr>
<td>Width 4&quot;</td>
</tr>
</tbody>
</table>
```

2. Find center of drawing media by using diagonals from corners

3. From the center of the work area, measure vertically 1/2 the height of the object (1 1/2" in this example)

4. At a 30° angle down and to the left, measure 1/2 the width of the object (2" in this example)

5. At a 30° angle to the right and down, measure 1/2 the depth of the object (1" in this example); this point is the front corner of the object to be drawn

Step #3: 1/2W = 2
Step #4: 1/2H = 1 1/2"
Step #5: 1/2D = 1"
6. From this point, complete the object as an ordinary isometric by boxing in the outline, adding features, and erasing construction lines.

Look at the isometric object in the space below with longest dimension to left.

Problem A:
ASSIGNMENT SHEET #8

Directions: Center and construct isometrics for the following problems on "A" size vellum. Use standard borders and title block. Omit dimensions and erase construction lines. Start with point A.

Problem B:

Problem C:
ASSIGNMENT SHEET #8

Directions: Center and construct an isometric of the following object on "A" size vellum. Use standard borders and title block. Dimension the drawing.

Problem D:

\[ \text{\( \frac{3}{8} \) DIA 3 HOLES} \]

\[ 60^\circ \]

\[ 30^\circ \]
Assignment Sheet #3

A.

B.

C.

Assignment Sheet #4
Assignment Sheet #5

C.

Assignment Sheet #6

Assignment Sheet #7

Assignment Sheet #8

B.
AXONOMETRICS  
UNIT IX  

NAME  ____________________________  

TEST

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

   a. Suggesting a picture or mental image
   b. A type of axonometric drawing with each of the three planes and axes equal to each other
   c. A type of axonometric drawing with two planes on equal axes to each other and a third plane of a different angle
   d. A type of axonometric drawing with all three planes and axes not equal to each other
   e. To appear shorter to the eye than it actually is
   f. The lines used to represent surfaces or planes coming together
   g. To extend from one point to another
   h. The lines that run parallel to the isometric axis lines
   i. The lines that do not run parallel to the isometric axis lines
   j. A foreshortened circle with a major and minor diameter
   k. A type of pictorial with each of the three planes and axes at any angle and not equal to 90°
   l. A method of locating a point from a horizontal and a vertical line

   1. Offset coordinates
   2. Axis lines
   3. Axonometric
   4. Pictorial
   5. Ellipse
   6. Projection
   7. Foreshortened
   8. Dimetric
   9. Isometric
   10. Trimetric
   11. Isometric lines
   12. Non-isometric lines

2. List three types of axonometric drawings.

   a. ________________________________
   b. ________________________________
   c. ________________________________
3. Identify the positions used as axis lines for isometric drawings.

a. 

b. 

c. 

4. Identify plane surfaces on isometrics below.

a. 

b. 

c. 

d. 

e. 

f. 

5. Select true statements concerning rules in constructing an isometric drawing by placing an "X" in the appropriate blanks.

   a. All measurements are made parallel to the main edges of the isometric axis lines

   b. Angles are measured with a protractor in isometrics

   c. Hidden lines are always shown on isometric drawings

   d. Isometric drawings are detailed and then centered in their space

   e. Always block in a circle before constructing its arcs

   f. The sight direction that best represents the object should be used for the isometric position

   g. If lines are parallel in two successive orthographic views, they will never be parallel in isometric views
6. Match common errors made in isometric drawing below with their correct drawings.
   a. Lines of isometric omitted
   b. Ellipses not in proper plane
   c. Angles not measured correctly
   d. Tangent lines missing from circles and arcs
   e. Circle arcs not tangent to each other
   f. Dimensions not measured parallel to isometric axis lines
   g. Rear ellipse of a hole missing
   h. Object viewed from wrong direction

7. Distinguish between the advantages and disadvantages of isometric drawing by placing an "A" for advantage and a "D" for disadvantage in the appropriate blanks.
   a. Easy to construct
   b. Long objects appear distorted
   c. Symmetrical type drawing causes some lines to meet or overlap, confusing the viewer
   d. Three sides of an object may be shown in one view
   e. Circles are not very distorted
8. Select methods of dimensioning an isometric by placing an "X" in the appropriate blanks.

   a. Template
   b. Aligned
   c. Unidirectional

9. Select true statements concerning rules in dimensioning an isometric drawing by placing an "X" in the appropriate blanks.

   a. Notes should be parallel to dimension lines
   b. Use guidelines for all notes
   c. Dimension size of holes with notes and leaders
   d. Dimension and extension lines should be parallel to the horizontal line
   e. All dimensions must be put in by the aligned method
   f. Dimensions should be to hidden surfaces
   g. Keep dimensions off object if possible
   h. Keep dimension lines evenly spaced and not crowding the drawing

10. Demonstrate the ability to:

   a. Sketch an isometric drawing.
   b. Sketch isometric circles.
   c. Construct an axonometric drawing by box method.
   d. Construct angles on an isometric.
   e. Construct isometric circles and arcs.
   f. Construct isometric curves by coordinates.
   g. Measure in isometric by offsets.
   h. Construct an isometric in the center of a drawing media.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
11. Construct isometric drawings of the following objects. Begin each drawing at point A. Omit the dimensions.

a. 

b. 
AXONOMETRICS
UNIT IX

ANSWERS TO TEST

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

2. a. Isometric
   b. Dimetric
   c. Trimetric

3. a. Top   c. Bottom
   b. Right side

4. a. Top   d. Left side
   b. Left side e. Right side
   c. Right side f. Bottom

5. a, e, f

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

7. a. A   d. A
   b. D   e. A
   c. D

8. b, c

9. b, c, g, h

10. Evaluated to the satisfaction of the instructor

11. a.

   b.
OBLIQUE
UNIT X

UNIT OBJECTIVE

After completion of this unit, the student should be able to select axis line position and box in an object in the center of a working space. The student should also be able to measure in oblique, construct angles, construct circles, and construct oblique drawings of various objects. 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 oblique with their correct definitions.
2. List three types of oblique drawings.
3. Identify the positions used as axis lines on oblique drawings.
4. Name the two most common positions used as axis lines.
5. Select true statements concerning rules in constructing an oblique drawing.
6. Match common errors made in oblique drawing with their correct drawings.
7. List two methods of dimensioning an oblique.
8. Select true statements concerning rules in dimensioning an oblique drawing.
9. Demonstrate the ability to:
   a. Sketch an oblique.
   b. Construct an oblique drawing by box method.
   c. Measure in oblique.
   d. Construct angles on an oblique object.
   e. Construct oblique circles.
   f. Construct oblique circles in depth plane.
   g. Construct an oblique drawing in the center of a drawing space.
10. Construct a cavalier oblique drawing of a given object.
11. Construct a cabinet oblique drawing of a given object.
OBLIQUE
UNIT X

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. Discuss the uses of oblique drawings and how the student decides when to make an oblique drawing.

VII. Show filmstrips or films which cover the fundamentals of oblique drawings. Refer to additional materials for suggested teaching aids.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters
   1. TM 1--Types of Oblique Drawings
   2. TM 2--Positions of Oblique Axis
   3. TM 3--Common Errors on Oblique Drawings
   4. TM 4--Common Errors on Oblique Drawings (Continued)
   5. TM 5--Dimensioning Obliques

D. Assignment sheets
   1. Assignment Sheet #1--Sketch an Oblique
   2. Assignment Sheet #2--Construct an Oblique Drawing by Box Method
   3. Assignment Sheet #3--Measure in Oblique
   4. Assignment Sheet #4--Construct Angles on an Oblique Object
5. Assignment Sheet #6--Construct Oblique Circles

6. Assignment Sheet #6--Construct Oblique Circles in Depth Plane

7. Assignment Sheet #7--Construct an Oblique Drawing in the Center of a Drawing Space

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:


III. Additional materials:

A. Transparencies--"The ABC's of Drafting." DCA Educational Products: DCA Incorporated; Warrington, PA 18976.

B. Filmstrip/cassette--"Drafting/Mechanical Drawing." Prentice Hall Media; Serv Code VD354; 150 White Plains Road; Tarrytown, NY 10591
OB LIQUE
UNIT X

INFORMATION SHEET

I. Terms and definitions
   A. Pictorial--Suggesting a picture or mental image
      (NOTE: Three types of pictorials are axonometric, oblique, and perspective.)
   B. Oblique--A type of pictorial drawing with front plane true size and parallel to frontal plane, the other two at any angle to the front
   C. Cavalier--A type of oblique drawing with all axis lines drawn true length
   D. Cabinet--A type of oblique drawing with the depth axis drawn half scale and the other axis lines drawn true length
   E. General--A type of oblique drawing with the depth axis drawn at any scale
   F. Foreshortened--To appear shorter to the eye than it actually is
   G. Axis lines--The lines used to represent where planes come together
   H. Project--To extend from one point to another
   I. Oblique lines--The lines that run parallel with one of the oblique axis lines
   J. Non-oblique lines--The lines that do not run parallel to one of the oblique axis lines
   K. Ellipse--A foreshortened circle with a major and minor diameter

II. Types of oblique drawings (Transparency 1)
   A. Cavalier
   B. Cabinet
   C. General

III. Positions used as axis lines on oblique drawings (Transparency 2)
   A. Up to right
   B. Down to right
   C. Up to left
   D. Down to left
INFORMATION SHEET

IV. Most common positions used as axis lines
   A. Up to left
   B. Up to right

V. Rules in constructing an oblique drawing
   A. All measurements are made parallel to the main axis edges of the oblique axis lines
   B. Angles are measured by coordinate offsets
   C. Hidden lines are omitted in oblique drawings if possible
   D. A drawing should be centered in the work space and boxed in before adding details
   E. Use the approximate ellipse method on circles that cannot be drawn as regular circles or if no templates are available
   F. Always box in a circle before constructing its arcs
   G. Always face contours toward the frontal plane where they appear in true size and shape and can be drawn with compass
   H. Draw long objects with the long axis perpendicular to the line of sight
   I. Keep all arcs and lines tangent to each other
   J. Include the rear ellipse or circle of a hole if it is visible

VI. Common errors made in oblique drawing (Transparencies 3 and 4)
   A. Wrong axis selected
   B. Arcs not tangent
   C. Tangent lines omitted
   D. Rear circle or ellipse omitted
   E. Line missing
   F. Plane with the longest dimension not in front plane

VII. Methods of dimensioning an oblique (Transparency 5)
   A. Aligned
   B. Unidirectional
INFORMATION SHEET

VIII. Rules in dimensioning an oblique drawing

A. Dimensions must be put in by the aligned method or the unidirectional method

B. Use guidelines for all notes

C. Dimension and extension lines should be parallel to the plane being dimensioned

D. Keep dimensions off object if possible

E. Dimensions should all be made to visible surfaces if possible

F. Dimension size of holes with notes and leaders

G. Keep dimension lines evenly spaced and not crowding the drawing
Types of Oblique Drawings

Front surface is parallel to frontal plane

Cavalier
- True Depth
- True Width

Cabinet
- 1/2 Size
- True Width
- True Height

General
- True Width
- True Depth
- Any Scale Depth
Positions of Oblique Axis

Depth angle can be at any angle but usually between 30° and 60°.
Common Errors on Oblique Drawings

Wrong Axis Selected

Correct

Incorrect

Arcs Not Tangent

Tangent Line Omitted
Common Errors on Oblique Drawings (Continued)

- Rear Circle Omitted
- Key Line Missing
- Correct
- Incorrect
Methods of Dimensioning Obliques

Aligned

Unidirectional
Premise: An oblique can be sketched by using the procedure in the following example.

Example:

1. Take the object and block in a front view
2. Next, the receding lines should be drawn parallel to each other at a 45° angle or any convenient angle and the lines should be cut so the depth looks correct. (NOTE: If receding lines are 1/2 their full length, the sketch is a cabinet sketch; if the receding lines are full length, the sketch is a cavalier sketch.)
3. Use an art gum eraser to dim construction lines and darken in visible lines

Directions: Make a full size oblique sketch of the following object.
OBLIQUE
UNIT X

ASSIGNMENT SHEET #2—CONSTRUCT AN OBLIQUE
DRAWING BY BOX METHOD

Premise: An oblique can be constructed by box method using the procedure in the follow-
ing example. The same procedure is used for cavalier, cabinet, and general obliques.

Example:

1. Attach sheet to drawing surface in alignment with working edge using a parallel bar or
drafting machine

2. Select either of the following positions of oblique axis lines
   a. 45°
   b. 60°

3. Locate axis lines on drawing media so that contours and circles are in best position

4. Measure overall width, depth, and height on these projected axis lines
ASSIGNMENT SHEET #2

5. Complete box parallel to main axis lines

6. At this point details can be added to complete shape of object

Directions: Construct a cavalier oblique drawing of a box with the following dimensions: H = 1", D = 2", W = 3". Use the axis line shown by instructor.

Problem A:
ASSIGNMENT SHEET #2

Directions: Construct a cabinet oblique drawing of the following object. Depth axis is up to right 45°.

Problem B:

Directions: Construct a general oblique drawing of the following object. Depth axis is up to left 45° and 3/8" scale.

Problem C:
Premise: An oblique can be constructed with measurements by using the procedure in the following example.

Example:

1. Sketch necessary views of object to be drawn

2. Lay out axis lines selecting axis best for object

3. Measure dimensions on axis lines

4. Box in object

5. Add arc at right side of box
ASSIGNMENT SHEET #3

6. Add arcs at left side of box

7. Add circle in object

8. Darken visible lines

Directions: Construct the object below in cavalier. Depth axis is up to right 45°.
OBLIQUE
UNIT X

ASSIGNMENT SHEET #4-CONSTRUCT ANGLES ON AN OBLIQUE OBJECT

Premise: Angles on an oblique object can be constructed by using the procedure in the following example.

Example:

1. Box in overall dimensions of the object in oblique

2. Use dividers or scale to lay out offset dimensions of angle

3. Connect points and complete the shape of the object
ASSIGNMENT SHEET #4

Directions: Draw the following object in cavalier. Depth axis is up to left 45°.
ASSIGNMENT SHEET #5-CONSTRUCT OBLIQUE CIRCLES

Premise: A circle can appear in any one of the three planes shown at right. In the front plane the circle is drawn as a true circle with the compass. The other two planes are drawn using the four-center ellipse method which makes drawing easier and more legible. Oblique circles can be constructed by using the procedure in the following example.

Example:

1. With this object all circles can be drawn from the front plane; determine depths, heights, and diameters of circles and arcs

   (NOTE: All circles are either in the front plane or parallel to the front plane.)

2. Box in overall shape
ASSIGNMENT SHEET #5

3. Locate center point of circle in front surface

4. Lay out skeleton framework of object by locating circle center points

5. Use center points to draw in circles and arcs using circle template or compass

6. Put in lines tangent to circle arcs
ASSIGNMENT SHEET #5

7. Add other features and darken lines

Directions: Construct a cavalier drawing of the following object. Depth axis is up to left 45°.
OBLIQUE
UNIT X

ASSIGNMENT SHEET #6—CONSTRUCT OBLIQUE CIRCLES IN DEPTH PLANE

Premise: Oblique circles in depth planes can be constructed by using the procedure in the following example. In oblique drawings, the depth angle can be at any angle, usually 30°, 60°, or 45°.

Example:

1. Locate center of circle and lay out center lines at angle desired
   (NOTE: A 45° will be used in this example, but the method is the same for all angles.)

2. Mark off radius points and box in, making sides parallel to center lines
ASSIGNMENT SHEET #6

3. Erect perpendicular bisectors to each side until lines intersect outside box; use these points as radius

(NOTE: Little box indicates lines perpendicular to each other.)

4. Swing arc from points where these lines intersect inside the box

5. Darken circle ellipse and erase construction lines

(NOTE: The same procedure is used for an ellipse on the side plane.)
ASSIGNMENT SHEET #6

6. The same procedure applies to arcs; project perpendicular lines from the radius tangent points.

Directions: Draw an oblique circle in the box below.

Problem A:

Directions: Use points indicated to draw arcs in angles below.

Problem B:
Premise: It is important that oblique drawings be located somewhere near the center of the drawing space that is available to allow room for dimensions, notes, and to add to the neatness of the object. An oblique drawing can be constructed in the center of the drawing space by using the procedure in the following example.

Example:

1. Box in an oblique sketch of the overall dimensions of the object to be drawn

2. Find center of drawing space by using diagonals from corners
ASSIGNMENT SHEET #7

3. From the center of the work area, measure vertically 1/2 the height of the object (1 1/2" in this example)

4. At some angle down and to the left, measure 1/2 the depth of the object (1" in this example)

5. At a horizontal direction to the right, measure 1/2 the length of the object (2" in this example)

6. Complete the shape of the box
ASSIGNMENT SHEET #7

Directions: Center and construct the following oblique in the space below. Use dividers and drafting machine to transfer dimensions.

Problem A:
ASSIGNMENT SHEET #7

Directions: Center and construct a cavalier drawing of the following object on "A" size vellum with standard border and title block. Omit dimensions and erase construction lines.

Problem B:

Directions: Center and construct a cabinet drawing of the following object on "A" size vellum with standard border and title block. Construct 45° up to right. Dimension drawing and erase construction lines.

Problem C:
Assignment Sheet #1

Assignment Sheet #2

B.

C.
Assignment Sheet #7

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

   a. To extend from point to another
   1. General
   b. Suggesting a picture or mental image
   2. Cavalier
   c. To appear shorter to the eye than it actually is
   3. Oblique
   d. The lines used to represent where planes come together
   4. Cabinet
   e. The lines that run parallel with one of the oblique axis lines
   5. Foreshortened
   f. The lines that do not run parallel to one of the oblique axis lines
   6. Axis lines
   g. A foreshortened circle with a major and minor diameter
   7. Project
   h. A type of oblique drawing with all axis lines drawn true length
   8. Oblique lines
   i. A type of oblique drawing with the depth axis drawn half scale and the other axis lines drawn true length
   9. Non-oblique lines
   j. A type of oblique drawing with the depth axis drawn at any scale
   10. Ellipse
   k. A type of pictorial drawing with front plane true size and parallel to frontal plane, the other two at any angle to the front
   11. Pictorial

2. List three types of oblique drawings.

   a. 
   b. 
   c. 

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3 Identify the positions used as axis lines on oblique drawings.

a. 

b. 

c. 

d. 

4 Name the two most common positions used as axis lines.

a. 

b. 

5 Select true statements concerning rules in constructing an oblique drawing by placing an "X" in the appropriate blanks.

a. All measurements are made parallel to the main axis edges of the oblique axis lines

b. Angles are measured by coordinate offsets

c. Hidden lines are always used on oblique drawings

d. It isn't necessary to center an oblique drawing

e. The concentric circle method is always used for drawing oblique circles

f. Always construct arcs before boxing in a circle

g. Face circles and contours toward the top plane of an oblique drawing, rather than the front

h. Draw long objects with the long axis perpendicular to the line of sight

i. Keep all arcs and lines tangent to each other

j. Include the rear ellipse or circle of a hole if it is visible
6. Match common errors made in oblique drawing below with their correct drawings.
   a. Wrong axis selected
   b. Arcs not tangent
   c. Line missing
   d. Rear circle or ellipse omitted
   e. Tangent lines omitted
   f. Plane with the longest dimension not in front plane

7. List two methods of dimensioning an oblique.
   a. 
   b. 

8. Select true statements concerning rules in dimensioning an oblique drawing by placing an "X" in the appropriate blanks.
   a. Dimensions must always be put in by the unidirectional method
   b. Use guidelines only for dimensions
   c. Dimension and extension lines should be parallel to the plane being dimensioned
d. Keep dimensions on object  
e. Dimensions should be made to hidden surfaces  
f. Dimension size of holes with notes and leaders  
g. Keep dimension lines evenly spaced and not crowding the drawing

9 Demonstrate the ability to:
   a. Sketch an oblique.  
b. Construct an oblique drawing by box method.  
c. Measure in oblique.  
d. Construct angles on an oblique object.  
e. Construct oblique circles.  
f. Construct oblique circles in depth plane  
g. Construct an oblique drawing in the center of a drawing space

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

10 Construct a cavalier oblique drawing of the object below in the space at right. Begin with point A and double dimensions with dividers.

11 Construct a cabinet oblique drawing of the object below in the space at right. Begin with point A and double dimensions with dividers.
OBLIQUE
UNIT X

ANSWERS TO TEST

1. a. 7  g. 10
    b. 11  h. 2
    c. 5  i. 4
    d. 6  j. 1
    e. 8  k. 3
    f. 9

2. a. Cabinet
    b. Cavalier
    c. General

3. a. Up to left
    b. Down to left
    c. Up to right
    d. Down to right

4. a. Up to left
    b. Up to right

5. a, b, h, i, j

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

7. a. Aligned
    b. Unidirectional

8. c, f, g

9. Evaluated to the satisfaction of the instructor

10.

11.
UNIT OBJECTIVE

After completion of this unit, the student should be able to list perspective types, identify views, list types of equipment, and select the uses of perspectives. 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 perspective with their correct definitions
2. List three types of perspectives.
3. Identify the types of perspective views.
4. List three types of perspective equipment.
5. List the use of each type of perspective.
6. Identify the lines and points in a two point perspective.
7. Select true statements concerning the steps in sketching a one point perspective.
8. Select true statements concerning the steps in sketching a two point perspective.
9. Match terms with their correct letter designations.
10. Demonstrate the ability to:
    a. Sketch a one point perspective.
    b. Sketch a two point perspective.
    c. Construct a one point perspective.
    d. Construct a two point perspective.
    e. Construct curves in a perspective.
PERSPECTIVE
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. Have students do a perspective for building trades program.
VII. Visit architectural delineator's office.
VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1-Types of Perspectives
      2. TM 2-Perspective Views
      3. TM 3-Perspective Equipment
      4. TM 4-Two Point Perspective
         Overlay 4A-Two Point Perspective
      5. TM 5-Perspective Terms
      6. TM 6-One Point and Two Point Perspective Sketching
   D. Assignment sheets
      1. Assignment Sheet #1-Sketch a One Point Perspective
      2. Assignment Sheet #2-Sketch a Two Point Perspective
      3. Assignment Sheet #3-Construct a One Point Perspective
4. Assignment Sheet #4-Construct a Two Point Perspective

5. Assignment Sheet #5-Construct Curves in a Perspective

E. Test

F. Answers to test

II. References:


I. Terms and definitions

A. Perspective - Pictorial drawing made by the intersection of the picture plane with lines of sight meeting from points on the object to the point of sight

B. Delineation - Process of drawing pictures for display as opposed to making detailed working drawings

C. One point perspective - Has only one vanishing point and the frontal plane of the object is parallel to the picture plane

D. Two point perspective - Has two vanishing points

E. Three point perspective - Has three vanishing points

F. Perspective grid - Graph oriented method for making accurate perspectives without having to establish vanishing points and measure lines

G. Perspective board - Has variety of scales and permits direct reading for layout of perspectives

H. Horizon line - Eye level of the person viewing the drawing and the line on which the vanishing points are located

I. Ground line - Bottom of the object being drawn

J. Picture plane - Projection plane of the plan view of the object being drawn

K. Station point - Assumed plan view point representing the observer's eye

L. Vanishing point - A point on the horizon at which receding parallel lines seem to meet

M. Vanishing lines - Lines of the object which meet on the vanishing points

N. Visual ray lines - Lines of sight from selected points on the object which pierce the picture plane on their way to the station point

O. Vertical measuring line - Part of the object closest to the person viewing the object on which true heights are measured

II. Types of perspectives (Transparency 1)

A. One point

B. Two point

C. Three point
III Types of perspective views (Transparency 2)
A. Above horizon (Worm's eye view)
B. Horizon (Man's eye view)
C. Below horizon (Bird's eye view)

IV. Types of perspective equipment (Transparency 3)
A. Grids
B. Board
C. Machine

V. Uses of each type of perspective
A. One point--Represents the interior of an object
B. Two point--Represents the exterior of an object
C. Three point--Represents the exterior of an object

VI. Lines and points in a two point perspective (Transparency 4)
A. Picture plane
B. Horizon line
C. Ground line
D. Visual ray lines
E. Station point
F. Vanishing point left
G. Vanishing point right
H. Vertical measuring line
I. Vanishing lines

VII. Steps in sketching a one point perspective (Transparency 5)
A. Take the object, block in a front view, and select a vanishing point
B. Sketch all receding lines to the vanishing point
C. Estimate the depth of the object and sketch in the back portion of the object
D. Use an art gum eraser to dim construction lines and darken in visible lines
INFORMATION SHEET

VIII Steps in sketching a two point perspective (Transparency 5)
A. Sketch the front corner of the object in the true height
B. Locate the VPL and VPR on the horizon line
   (NOTE: The distance to the horizon line may vary.)
C. Estimate the depth and width of the object
D. Block in all detail of remaining items
   (NOTE: Most lines will go to either the VPL or VPR.)
E. Use an art gum eraser to dim construction lines and darken in visible lines

IX Terms and their letter designations (Transparency 6)
A. Picture plane - PP
B. Horizon line - HL
C. Ground line - GL
D. Vanishing lines - VL
E. Visual ray lines - VRL
F. Vanishing points - VP
G. Vanishing point left - VPL
H. Vanishing point right - VPR
I. Vertical measuring line - VML
J. Station point - SP
Types of Perspectives

One Point

Ground Line

Two Point

Horizon Line

Three Point

VP
Perspective Views

Above Horizon

Worm's Eye View

Man's Eye View

Bird's Eye View

Below Horizon
Perspective Equipment

Tektronix 4956 Digitizer

Tektronix 4051 Graphics System

Tektronix 4662 Plotter

Grids

Board

Machines
Two Point Perspective

- Picture Plane
- Visual Ray Lines
- Vanishing Point Right
- Horizon Line
- Station Point
- Ground Line
- Elevation View
- Vanishing Point Left
- Vanishing Line
- Vertical Measuring Line

Plan View
**Perspective Terms**

- **Picture Plane (PP)**
- **Visual Ray Lines (VRL)**
- **Station Point (SP)**
- **Length of Building Recorded on (PP)**
- **Horizon Line (HL)**
- **Ground Line (GL)**
- **Height of Building Recorded on Picture Plane**
- **Plan View**
  - 2 x Length Min.
- **Elevation**
  - Length from Plan View
  - Height from Elevation View
  - Picture Recorded on Picture Plane as Seen by Viewer
- **Vanishing Point Left (VPL)**
- **Vanishing Point Right (VPR)**
- **Vanishing Lines (VL)**
- **Vertical Measuring Line (VML)**

The diagram illustrates the relationship between these terms in perspective drawing.
One Point and Two Point Perspective Sketching

VPL

VPL

 VP
TP

Estimate Depth

NOTE: W and D estimated to look correct

True height

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PERSPECTIVE
UNIT XI

ASSIGNMENT SHEET #1--SKETCH A ONE POINT PERSPECTIVE

Premise: A one point perspective can be sketched by using the procedure in the following example. Refer to Transparency 6 if needed.

Example:

1. Take the object, block in a front view, and select a vanishing point

2. Sketch all the receding lines to the vanishing point

3. Estimate the depth of the object and sketch in the back portion of the object

4. Use an art gum eraser to dim construction lines and darken in visible lines
ASSIGNMENT SHEET #1

Directions: Make a one point perspective of the following object.
Premise: A two point perspective can be sketched by using the procedure in the following example. Refer to Transparency 6 if needed.

Example:

1. Sketch the front corner of the object in the true height

2. Locate the VPL and VPR on the horizon line
   (NOTE: The distance to the horizon line may vary.)

3. Estimate the depth and width of the object

4. Block in all detail of remaining items
   (NOTE: Most lines will go to either the VPL or VPR.)

5. Use an artgum eraser to dim construction lines and darken in visible line
ASSIGNMENT SHEET #2

Directions: Make a two point perspective of the following object.
ASSIGNMENT SHEET #3--CONSTRUCT A ONE POINT PERSPECTIVE

Premise: A one point perspective can be constructed by using the procedure in the following example. A one point perspective illustration is included with this assignment sheet for visual guidelines.

Example:

1. Construct the picture plane near the top of the vellum
   (NOTE: Provide space for the plan view.)

2. Construct one plane of the object on the picture plane so it will be drawn in its true size and shape; then complete plan view

3. Locate the station point far below to the left or right of the plan view
   (NOTE: The visual ray lines that will enclose the object on an angle should not be greater than 30°.)

4. Construct the horizon line near the station point

5. Construct the ground line below the horizon line
   (NOTE: Provide enough distance between ground line and horizon line for elevation view.)

6. Construct the bottom of the elevation view on the ground line at the left or right side of vellum

7. Project a line from station point above to intersect horizon line
   (NOTE: This will provide the vanishing point.)

8. Construct lines from station to the corners of the plan view

9. Construct vertical lines downward where these lines intersect the picture plane

10. Project horizontal lines from the elevation view to intersect the vertical lines from plan view

11. Connect all points of intersection
   (NOTE: Corners and the required shape of the one point perspective will now be formed.)
ASSIGNMENT SHEET #3

Directions: Construct a one point perspective on media recommended by instructor with standard borders and title block for the following problems.

Problem A: Problem B:

[Diagram of Problem A]

[Diagram of Problem B]
One Point Perspective

- Horizon
- Plan View
- Picture Plane
- Visual Ray Lines
- Vanishing Point
- Station Point
- Elevation View
- Ground Line
- Vertical Measuring Line
ASSIGNMENT SHEET #4: CONSTRUCT A TWO POINT PERSPECTIVE

Premise: A two point perspective can be constructed by using the procedure in the following example. Refer to Transparency 4 if needed.

Example:

1. Construct the picture plane near the top of the vellum
   (NOTE: Provide space for the plan view.)

2. Construct the plan view of the object so that the corner touches the picture plane
   (NOTE: Rotation should not be more than 30°.)

3. Locate the station point below and far enough in front of the picture plane
   (NOTE: A short distance will give a distorted view. It should be above the elevation view.)

4. Construct the horizon line near the station point

5. Construct the ground line below the horizon line
   (NOTE: Provide enough distance between ground line and horizon line for elevation view.)

6. Construct the bottom of the elevation view on the ground line

7. Construct parallel lines parallel to edges of plan view from station point to intersect picture plane
   (NOTE: The included angle between these lines is 90°.)

8. Construct perpendicular lines from picture plane intersection to horizontal line
   (NOTE: This will locate the two vanishing points for the perspective.)

9. Construct lines from corners of the object to station point piercing with picture plane

10. Construct horizontal lines from corners of elevation view to vertical measuring line; from these intersections construct lines to vanishing points
    (NOTE: These lines are the heights of the perspective.)
ASSIGNMENT SHEET #4

11. Construct vertical lines from picture plane to intersect vanishing lines.
   (NOTE: This represents the perspective box of the object.)

12. Proceed in the following order to cut out the box or find a point in the object.
   a. Construct heights of the object in the perspective and then project to vanishing points to form edges of a plan in the box
   b. Construct a line from a point or cut to near edges of the plan view; then project picture plane to the lines just drawn on the perspective, and then to the vanishing points
   (NOTE: Their intersection is the end of cut or point.)

13. Proceed in the following order to find any true height not in the picture plane:
   a. Construct a line from a point not on the picture plane parallel to plan view lines to the picture plane
   b. Project this line to the ground line
   c. Project the height of the point from elevation view to intersect this line; from these intersections project to vanishing point
   (NOTE: This is the true height of the point in the perspective.)

14. Connect all points of intersection
   (NOTE: The corners and required shape of the two point perspective will then be formed)

Directions. Construct two point perspectives for the following problems

Problem A

Problem B

[Diagram of Problem A and Problem B]
Problem C
Premise: Curves can be constructed in a perspective by using the procedure in the following example. An illustration is included on the next page for visual guidelines.

Example:

1. Refer to Assignment Sheet #2 for directions for construction of a perspective of an object
2. Construct a square grid on the elevation and plan views
3. Construct this grid in perspective
4. Project horizontal lines to intersect in perspective from common points in plan and elevation views
5. Connect the intersecting of lines in perspective with irregular curve or template to form curve

Directions: Construct curves in a perspective for the following problem.
Curves in a Perspective

Plan View

Picture Plane

Visual Ray Lines

VPL

Vanishing Lines

Horizon

Vertical Measuring Line

Station Point

Ground Line
1. Match the terms on the right with their correct definitions.

   a. Eye level of the person viewing the drawing and the line on which the vanishing points are located
   b. Bottom of the object being drawn
   c. Has only one vanishing point and the front plane of the object is parallel to the picture plane
   d. Projection plane of the plan view of the object being drawn
   e. Assumed plan view point representing the observer's eye
   f. Has two vanishing points
   g. Lines of the object which meet on the vanishing points
   h. Pictorial drawing made by the intersection of the picture plane with lines of sight meeting from points on the object to the point of sight
   i. Lines of sight from selected points on the object which pierce the picture plane on their way to the station point
   j. Has three vanishing points
   k. Part of the object closest to the person viewing the object on which true heights are measured
   l. Graph oriented method for making accurate perspectives without having to establish vanishing points and measure lines
   m. Has variety of scales and permits direct reading for layout of perspectives
   n. Process of drawing pictures for display as opposed to making detailed working drawings
   o. A point on the horizon at which receding parallel lines seem to meet

1. Vanishing lines
2. Picture plane
3. Three point perspective
4. Ground line
5. Delineation
6. Station point
7. Visual ray lines
8. Horizon line
9. Vanishing point
10. One point perspective
11. Perspective grid
12. Two point perspective
13. Perspective board
14. Vertical measuring line
15. Perspective
2. List three types of perspectives.

3. Identify the types of perspective views.

4. List three types of perspective equipment.
5. List the use of each type of perspective
   a. One point
   b. Two point
   c. Three point

6. Identify the lines and points in a two point perspective.
   a. ____________________  f. ____________________
   b. ____________________  g. ____________________
   c. ____________________  h. ____________________
   d. ____________________  i. ____________________
Select true statements concerning the steps in sketching a one point perspective by placing an "X" in the appropriate blanks.

a. Take the object, block in a top view, and select a vanishing point
b. Sketch all receding lines to the vanishing point
c. Estimate the width of the object and sketch in the front portion of the object
d. Use an art gum eraser to dim visible lines and darken in construction lines

Select true statements concerning the steps in sketching a two point perspective by placing an "X" in the appropriate blanks.

a. Sketch the front corner of the object in the true height
b. Locate the VPL and VPR on the picture plane
c. Estimate the depth and width of the object
d. Block in all detail of remaining items
e. Use an art gum eraser to dim visible lines and darken in construction lines

Match terms on the right with their correct letter designations.

1. Horizon line
2. Ground line
3. Vanishing point left
4. Station point
5. Visual ray lines
6. Picture plane
7. Vanishing lines
8. Vertical measuring line
9. Vanishing point right
10. Vanishing points
10. Demonstrate the ability to:
   a. Sketch a one point perspective.
   b. Sketch a two point perspective.
   c. Construct a one point perspective.
   d. Construct a two point perspective.
   e. Construct curves in a perspective.

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

ANSWERS TO TEST

1. a. 8 i. 7
b. 4 j. 3
c. 10 k. 14
d. 2 l. 11
e. 6 m. 13
f. 12 n. 5
g. 1 o. 9
h. 15

2. a. One point
b. Two point
c. Three point

3. a. Horizon
b. Above horizon
c. Below horizon

4. a. Grids
b. Board
c. Machine

5. a. Represents the interior of an object
b. Represents the exterior of an object
c. Represents the exterior of an object

6. a. Visual ray lines f. Vanishing point right
b. Picture plane g. Station point
c. Vanishing point left h. Horizon line
d. Vertical measuring line i. Vanishing lines
e. Ground line

7. b

8. a, c, d

9. a. 6 f. 4
b. 1 g. 8
c. 3 h. 5
d. 7 i. 2
e. 9 j. 10

10. Evaluated to the satisfaction of the instructor
UNIT OBJECTIVE

After completion of this unit, the student should be able to operate a computer-aided drafting system, store and retrieve programs from tape, operate a digitizer, and construct multi-view drawings on the plotter using BASIC. 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.

SPECIFIC OBJECTIVES

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

1. Match CAD equipment terms with their correct definitions.
2. Match CAD terminology with their correct definitions.
3. List hardware used in a CAD system.
4. Distinguish between input and output devices in a CAD system.
5. Match BASIC operator symbols or words with the correct descriptions.
6. Match BASIC statement words used for programs on tape with the correct functions.
7. Match BASIC statement words used in graphics with the correct functions.
8. Select true statements concerning operating a Tektronix CAD system.
9. Demonstrate the ability to:
   a. Program in BASIC using a micro-computer as a calculator.
   b. Create drawings on a micro-computer using plot method.
   c. Construct a two-view drawing using straight line statements.
   d. Construct a two-view drawing using straight line, circle, and hidden line statements.
   e. Start up and shut down the available CAD system.
   f. Load from and store onto tape a program.
   g. Operate a digitizer tablet.
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. Take students on a field trip to visit an industry that has a CAD or IGS system.

VIII. Survey class to determine how many students have previous typing experience. This is very helpful when working with computers and CAD systems.

IX. Demonstrate keyboard operations and BASIC on Radio Shack TRS-80, Apple computer, or similar micro-computers if equipment is available.

X. Have students perform activities on job sheets before assignment sheets are started.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Computer-Aided Drafting System -- Micro-Computer
      2. TM 2--Computer-Aided Drafting System -- Large Computer
      3. TM 3--BASIC Statement Parts
      4. TM 4--Graphic Computing System
      5. TM 5--Digital Plotter
      6. TM 6--Digitizer Tablet
D. Assignment sheets

1. Assignment Sheet #1--Program in BASIC Using a Micro-Computer As a Calculator
2. Assignment Sheet #2--Create Drawings On a Micro-Computer Using Plot Method
3. Assignment Sheet #3--Construct a Two-View Drawing Using Straight Line Statements
4. Assignment Sheet #4--Construct a Two-View Drawing Using Straight Line, Circle, and Hidden Line Statements

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Start Up and Shut Down the Available CAD System
2. Job Sheet #2--Load From and Store Onto Tape a Program
3. Job Sheet #3--Operate a Digitizer Tablet

G. Test

H. Answers to test

II. References:


CAD equipment terms and definitions

A. Computer-aided drafting (CAD) - Process system used in designing industrial products and the production of graphic drawings with the aid of the computer and its related input and output devices.

(NOTE: This system is often called the Interactive Graphics System - IGS. In this unit the computer-aided system will be referred to as CAD.)

B. Cathode ray tube (CRT) - A TV-like display that can be a storage tube, plasma display, or refresh tube display.

C. Computer - An electronic information handling machine capable of performing arithmetical calculations and making logical decisions under the control of programs.

D. Central processing unit (CPU) - The part of a computer system containing the system's arithmetic, logic, primary storage, and controls of input and output peripheral devices.

E. Peripheral devices - Various devices that are used in the CAD system in which data is input, stored, retrieved, and output from the CPU.

(NOTE: These devices are external to the CPU.)

F. Micro-computer - Small, inexpensive computer that has a CPU and one or more input/output devices.

G. Keyboard console - An input device, consisting of ASCII character keys, numeric keys, and math function keypad used by the computer operator before, during, and after running programs.

H. Plotter - An X-Y type output device, usually drum or bed form, that produces line drawings on paper with a pen controlled by instructions from CPU or tape controller.

I. Manual digitizer - An input device where digit or X-Y points are located by positioning the free moving cursor or stylus on an electromagnetic grid embedded in the digitized board.

J. Free moving cursor - Contains a sensing coil connected to the digitizer control used for sighting a drawing coordinate X-Y points on the digitizer.

K. Stylus - Used to locate coded programs of X-Y points by pressing at the point of drawing line intersect on digitizer board and input to CRT.

L. Digitizer tablet - An input device using stored graphic symbols in the CPU where a designer uses a light pen, stylus, or free moving cursor by positioning on tablet for each symbol to create a drawing on CRT.
INFORMATION SHEET

M. Light pen--An input device used with a refreshed picture display to create various edges, contours, or other features in a photographic image

N. Automated digitizer--Utilizes a television camera on an automated drafting machine to follow the line being digitized for output digits according to stored information in CPU

O. Line printer--An output device that prints one line of character information at a time from CPU

P. Hard copier--An output device that forms graphic and character images by electronic signals on paper from CPU

Q. Flexible disk--An oxide-coated plastic disk enclosed in a protective covering that can be used for storage of data

NOTE: This is commonly called a floppy disk.

R. Magnetic tape--Medium on which data is recorded in the form of magnetized spots on the surface of magnetically sensitive coated tape

S. Joy stick--Used as a graphic input and cursor positioning device to the CRT and CPU

II. CAD terminology and definitions

A. Program--Step by step instructions which cause the computer to solve a problem

B. Computer language--A set of mathematical commands such as add, divide, or multiply, or functional commands to "store in memory," "delete," or "draw"

C. Beginners All-purpose Symbolic Instruction Code (BASIC)--A symbolic English-like programming language

D. FORmula TRANslation (FORTRAN)--A high-level algebraic and logical language used in engineering and graphic systems

E. Common Business Oriented Language (COBOL)--A higher-level source programming language designed to process large files used by business

F. File--Collection of related data treated as a unit

G. Data--Facts of all kinds

H. Input--Data that is transferred to the CPU from an external peripheral device

I. Output--The results obtained from the CPU and transferred to a peripheral device
INFORMATION SHEET

J. American Standard Code for Information Interchange (ASCII) Used as a standard code of alphanumeric characters, symbols, and special control characters

K. Graphics--Computer output that is composed of lines rather than letters, numbers, or symbols.

L. Alphanumeric--The set of letters A-Z, the numerals 0-9, and various punctuation marks and special characters.

M. Software--Prepared programs that simplify CPU operations that cause hardware to function.

N. Hardware--Any physical equipment that is a part of the CAD system.

O. Interface--The interconnecting methods or devices used in the CAD hardware system.

Example: RS 232-C interface.

P. K--Symbol denoting 1024 bytes of storage.

Q. Machine language--A programming language that can be interfaced directly by the internal circuitry of the computer.

R. Routine--A sequence of instructions to carry out a certain function.

S. Statement--A complete instruction in machine language such as BASIC or FORTRAN.

T. Variable--A quantity that can take on any of a given set of values.

U. Cursor--Flashing rectangular dot or cross hair that indicates the current position on the screen.

V. Read only memory (ROM)--That portion of the system memory that cannot be changed and may be read but not written.

W. Random access memory (RAM)--Memory available to the user for writing programs and storing data.

X. Digit--Any number from 0 through 9.

Y. Bit--Binary digit, the smallest unit of information that can be recognized by a computer.

(NOTE: This will always be a 0 or a 1).

Z. Binary code--Two-digit numbering system composed of only 0 and 1.

AA. Byte--Unit of computer memory, made up of a specified number of bits, which can represent any digit, letter of alphabet, or special character.

BB. Chips--Miniaturized integrated circuits which compose ROM memory.
INFORMATION SHEET

CC. Compiler--A computer program used to translate high-level source language programs into machine language programs

DD. Menu--Graphic symbols or information arranged in software to be retrieved at some later time

EE. Resolution--A measure of the number of separately addressable positions on the coordinate grid

Example: If a 10 inch display has 1023 addressable points along each X-Y axis, the resolution is 1023/10 or 102.3 points per inch

FF. Raster scan--A CRT scanning system where the electron beam moves horizontally across all X values first at each Y level, moving down each Y level until the screen is scanned

III. Hardware used in a CAD system (Transparencies 1 and 2)

A. CPU
B. CRT
C. Keyboard console
D. Plotter
E. Manual/Automated digitizer
F. Hard copier
G. Line printer
H. Free-moving cursor/stylus/light pen
I. Joy stick
J. Magnetic tape or flexible disk drives

IV. Input and output devices in a CAD system (Transparencies 1 and 2)

A. Input
   1. CPU
   2. Digitizers
   3. Keyboard console
   4. Plotter

   (NOTE: A joy stick and an X-Y beam are used on some plotters.)
INFORMATION SHEET

5. Light pen
6. Card reader

B. Output
   1. Plotter
   2. Line printer
   3. Hard copier
   4. CRT
   5. Cursor/stylus/light pen
   6. Joy stick
   7. Magnetic tape or flexible disk drives
   8. CPU
   9. Magnetic drum

(NOTE: Some devices are both input and output.)

V. BASIC operator symbols or words and descriptions (Transparency 3)

<table>
<thead>
<tr>
<th>SYMBOL/WORDS</th>
<th>DESCRIPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (</td>
<td>Left parenthesis</td>
</tr>
<tr>
<td>B. SIN, COS, TAN</td>
<td>Functions</td>
</tr>
<tr>
<td>C. + and - Monadic</td>
<td>Changing sign</td>
</tr>
<tr>
<td>D. ^</td>
<td>Exponentiation</td>
</tr>
<tr>
<td>E *</td>
<td>Multiplication</td>
</tr>
<tr>
<td>F /</td>
<td>Division</td>
</tr>
<tr>
<td>G. +</td>
<td>Addition</td>
</tr>
<tr>
<td>H -</td>
<td>Subtraction</td>
</tr>
<tr>
<td>I. Min or Max</td>
<td>Comparative</td>
</tr>
<tr>
<td>J. &lt;</td>
<td>Less than</td>
</tr>
<tr>
<td>K. &gt;</td>
<td>Greater than</td>
</tr>
<tr>
<td>L. &gt;=</td>
<td>Greater than or equal to</td>
</tr>
</tbody>
</table>
### INFORMATION SHEET

<table>
<thead>
<tr>
<th>SYMBOL/WORDS</th>
<th>DESCRIPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. &lt; =</td>
<td>Less than or equal to</td>
</tr>
<tr>
<td>N. &lt; &gt;</td>
<td>Not equal to</td>
</tr>
<tr>
<td>O. =</td>
<td>Equal to</td>
</tr>
</tbody>
</table>

### VI. BASIC statement words used for programs on tape and functions

#### STATEMENT WORDS

- **A. Find**: Positions tape at beginning of desired file
- **B. Mark**: Creates on tape one or more files of desired length
- **C. Save**: Causes the entire program currently in memory to be stored on tape
- **D. B Save**: Stores memory on tape in binary code
- **E. Old**: Retrieves program on tape back into memory
- **F. Bold**: Retrieves program on tape in binary code back into memory

**NOTE**: CAD system must be equipped with binary loader ROMpack.

- **G. T List**: Determines on CRT screen how many files exist on tape
- **H. Append**: Enables changing or add-on routines to programs on tape that are in memory

### VII. BASIC statement words used in graphics and functions (Transparency 3)

#### STATEMENT WORDS

- **A. Draw**: Produces a visible line between the last position of the cursor and the X-Y coordinates specified
- **B. R Draw**: Produces a visible line to a location which is relative to its present position
### INFORMATION SHEET

#### STATEMENT

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Move</td>
<td>Allows moving cursor on the screen without making a line with X Y coordinates specified</td>
</tr>
<tr>
<td>D. R Move</td>
<td>Allows moving the cursor to a location which is relative to its present position without making a line</td>
</tr>
<tr>
<td>E. Rotate</td>
<td>Produces an angular displacement in the orientation of relative moves and draws</td>
</tr>
<tr>
<td>F. Window</td>
<td>Allows selecting whatever portion of user data space you want to see on the screen</td>
</tr>
<tr>
<td>G. View port</td>
<td>Allows using a desired portion of the screen in a window</td>
</tr>
<tr>
<td>H. Scale</td>
<td>Ratio of user data units per graphics display unit (GDU)</td>
</tr>
<tr>
<td>I. Axis</td>
<td>Draws a horizontal and vertical line through point of origin in the user data space</td>
</tr>
</tbody>
</table>

(NOTE: These statements and functions are for the Tektronix graphic system.)

#### Operating a Tektronix CAD system

| A. Do not take the tape arrow off SAFE unless you intend to record on it |
| B. Do not type in FIND 1 on a new blank tape unless the tape has been rewound and MARK 1 entered |
| C. Do not operate computer when an electrical storm is in area because the memory may be erased |
| D. Memory will be erased if power is turned off while program is in memory |
| E. Do not grab pen while the plotter is running |
| F. Press LOAD key if you need to stop plotter |
| G. Keep cap on plotter pens when not in use |
| H. If screen is full and a flashing F is in upper left corner, press HOME/PAGE key |
Computer-Aided Drafting System
Micro-Computer

CPU

Magnetic Tape Slot

Tablet Control

Digitizer Tablet

Hard Copier

Plotter

Line Printer

Micro Computer

CRT

Key Board
Computer-Aided Drafting System
Large Computer

- Tape Drive
- Computer Storage
- Disk Drive
- CPU
- Drum Plotter
- Line Printer
- Key Board
- Light Pen
- Tablet
- Graphics Console
- Digitizer
Basic Statement Parts

LINE NUMBER
All statements must have a line number

Arithmetic Operator

120 LET A = B * C

Numeric Expression
Rational Operator
Alphabetic Variable

STATEMENT WORD
Some may be abbreviated to 3 letters
Graphic Computing System
Tektronic 4051

CRT
Graphic Display
Unit

Central Processing Unit
8K-32 Bytes

USER DEFINABLE
Keys
(1-10&11-29)

128 ASCII Keys
Upper - Lower Case

Line-Character
Edit Keys

Auto Number

Magnetic Tape Slot
BUSY-Light
V/O-Light
Power-Light 20
EJECT - tape
AUTO LOAD
REWIND
MAKE COPY

10 Key Numeric
5 Math Function
Key Pad

Stop Program

Power Switch

Note: Refer to User's Manual for Operating Procedures
Digital Plotter
Tektronic 4662

B Size Drawing Format
Power Switch
Load
Local
Pen
Call
Lower Left Set
Upper Right Set
Joy Stick
Micro Processor Based
X-Y Axis Beam
Pen Holder

Note: Refer to User's Manual for Connecting up System
Digitizer Tablet

Remote Point Stream Clear Incre Origin Stream

Free-Moving Cursor or Stylus

Tablet Control Power Switch Tablet Board

Note: Refer to User’s Manual for Connecting up System
COMPUTER-AIDED DRAFTING
UNIT XII

ASSIGNMENT SHEET #1--PROGRAM IN BASIC USING A MICRO-COMPUTER
AS A CALCULATOR

Premise: Programming computer graphics problems must begin with the execution of discovery type activities found in micro-computer manufacturer's reference manuals. The following example and problems are activities in arithmetic operations using print and input statements.

Example:

1. Use the following chart and formulas for measurement of electricity in residential construction

<table>
<thead>
<tr>
<th>W</th>
<th>Power</th>
<th>Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Voltage</td>
<td>Volts</td>
</tr>
<tr>
<td>I</td>
<td>Current</td>
<td>Ampere</td>
</tr>
</tbody>
</table>

Formulas: \( W = EI \) or \( I = W/E \) or \( E = W/I \)

2. Turn computer on

   (NOTE: Refer to manufacturer's manual for turning computer on, using special function keys, error messages, and editing statements.)

3. Type in the following program for calculating amperage

   10 CLS
   20 REM
   30 PRINT "ENTER TOTAL WATTAGE OF APPLIANCES IN WATTS."
   40 INPUT W
   50 PRINT "ENTER TOTAL VOLTAGE OF SYSTEMS IN VOLTS."
   60 INPUT E
   70 I = W/E
   80 PRINT "THE AMPERAGE IS: ";I;" AMPS."
   90 END

   (NOTE: If you make mistakes while typing in the program, either retype the line or correct it by using the method outlined in the manufacturer's manual.)

4. Type in RUN

   (NOTE: "ENTER TOTAL WATTAGE OF APPLIANCES IN WATTS." will now appear.)

5. Type in 1200 watts and press ENTER key

   (NOTE: "ENTER TOTAL VOLTAGE OF SYSTEMS IN VOLTS." will now appear.)
ASSIGNMENT SHEET #1

6. Type **120**

(NOTE: "THE AMPERAGE IS 10 AMPS" should now appear.)

7. Press the BREAK key and type in **RUN**

8. Now you are ready to add other voltage and wattage values for wattage calculations.

Directions: Solve for unknown values in an electrical system by writing the programs and substituting the known values.

<table>
<thead>
<tr>
<th>Problem A:</th>
<th>I</th>
<th>W</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1600</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>800</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2400</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problem B:</th>
<th>W</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>15</td>
</tr>
</tbody>
</table>
COMPUTER-AIDED DRAFTING
UNIT XII

ASSIGNMENT SHEET #2 - CREATE DRAWINGS ON A MICRO-COMPUTER USING PLOT METHOD

Premise: No attempt is made to teach graphics programming in BASIC in this assignment sheet. There are many books on the market about graphics. Your instructor will help you in learning programming. The example given is for using the statement SET(X,Y) in creating lines and geometric shapes. This technique makes use of a numbered grid of 6144 tiny rectangles arranged in 48 rows of 128 columns.

Example:

1. Turn the computer on
2. Type in the program listed below and press the ENTER key after each line

```
10 CLS  ; Clears screen
20 X = 64  ; Column
(NOTE: Use manufacturer's video display worksheet.)
30 Y = 30  ; Row
40 SET(X,Y)  ; Turns on point 64, 30
```

```
200 END
```

3. Type in RUN and press the ENTER key
4. Use the SET statement to draw a series of straight lines to create a square using the FOR-NEXT LOOP
5. Type in the program listed below for top line of square

```
10 CLS
20 Y = 20
30 FORX = 54 TO 73
40 SET(X,Y)  ; Y will always be 20 for this line
50 NEXT X
60 GO TO 60
70 END
```

```
RUN  ; To see top line
```

(NOTE: If you make mistakes while typing in the program, either retype the line or correct it by using the method outlined in the manufacturer's manual.)
ASSIGNMENT SHEET #2

6. Clear the screen using CLS command and type in LIST

7. Continue with program listed below

```
60 X = X + 1 Positions X on column 73
70 FOR Y = 20 TO 39
80 SET "",Y) Right side line
90 NEXT Y Positions Y on row 39
100 Y = Y + 1
110 FOR X = 72 TO 54 STEP 1 Makes line go backward
120 NEXT X X ends at 55 bottom line
130 X = X + 1; FOR Y = 38 TO 21 STEP 1; SET(X,Y): NEXT Y left side
   (NOTE: Multiple statement lines can be put on one line as shown in line 130
   by adding colons.)
140 GO TO 140
150 END
```

8. Check and correct program for errors

9. Video display should look like the following figure after typing in RUN

```
   
   
   
```

(NOTE: It looks taller than wide because the lighted points are rectangles.)

Directions: Write and make a video display drawing of the problems given.

Problem A: A square with the sides of 15 point length and the starting point at 20, 10.

Problem B: A right triangle with left side and bottom side 10 points in length.
ASSIGNMENT SHEET #3-CONSTRUCT A TWO-VIEW DRAWING USING STRAIGHT LINE STATEMENTS

Directions: Use the following procedure on a CAD system to construct a two-view drawing.

(Note: Refer to Job Sheet #1 if CAD system has not been started up.)

A. Type in the statements of the following figure

```
4 INIT
5 Q = 32
6 GO TO 100
8 INIT
9 Q = 1
10 GO TO 100
100 PAGE
110 MOVE @ Q: 0, 0
120 Scale 0.1, 0.1
125 REM John Doe
130 MOVE @ Q: 1, 1
140 RDRAW @ Q: 0, 1.25
150 RDRAW @ Q: 1.5, 0
160 RDRAW @ Q: 0, -0.75
170 RDRAW @ Q: 0, -0.50
180 RDRAW @ Q: -1, 0
190 RMOVE @ Q: 0, 0.5
200 RMOVE @ Q: 1, 0
210 RDRAW @ Q: 0, 1.25
220 RDRAW @ Q: 1.0
230 RDRAW @ Q: 0, -1.25
240 RDRAW @ Q: -1.0
250 RMOVE @ Q: 0.5
260 RDRAW @ Q: 1, 0
270 END
```

(4 is used for #1 user-definable key
32 addresses CRT screen
8 is used for #2 user-definable key
1 addresses plotter
4 is used for #1 user-definable key
32 addresses CRT screen
8 is used for #2 user-definable key
1 addresses plotter
clears screen
sets origin in lower left corner
changes to inch measurement
remark statement
moves from origin xy distance to start line a
constructs line a
line b
line c
line d
line e
line f
moves to start line g
line g
line h
line i
line j
moves to start line k
line k
end of program

(Note: Check with instructor on statement syntax errors or refer to manufacturer’s programming manual.)
ASSIGNMENT SHEET #3

B. Press USER DEFINABLE key 1

C. Check drawing on screen for errors
   (NOTE: To check for program errors, press HOME/PAGE key and type in LIST.)

D. If drawing is correct, press USER DEFINABLE key 2
   (NOTE: Remove pen cap if needed before pressing USER DEFINABLE key 2.)
ASSIGNMENT SHEET #4--CONSTRUCT A TWO-VIEW DRAWING USING STRAIGHT LINE, CIRCLE, AND HIDDEN LINE STATEMENTS

Directions: Use the following procedure on a CAD system to construct a two-view drawing.

A. Type in the routine statements of the figure below and complete missing statements.

```
4 INIT
5 Q=32
6 GO TO 110
8 INIT
9 Q=1
10 GO TO 110
110 PAGE
120 MOVE @ Q:0,0
130 SCALE 0.1,0.1
140 SET DEGREES
150 REM JOHN DOE
160 MOVE @ Q:3,3
170 RDRAW @ Q:0,3
180 RDRAW @ Q:3,0
190 RDRAW @ Q:0,-3
200 RDRAW @ Q:-3,0
210 RMOVE @ Q:5,0
220 RDRAW @ Q:0.3
230 RDRAW @ Q:1.0
240 RDRAW @ Q:0.3
250 RDRAW @ Q:-1.0
260 RMOVE @ Q:3.5,1.5
270 REM Beginning of Circle
280 Let R = 0.75
290 GIN @ Q:A,B
300 RMOVE @ Q:R,0
310 For I = 10 to 360 STEP 10
320 DRAW @ Q:R COS (I) * A, R SIN (I) * B
330 Next I
340 RMOVE @ Q:-2.50,0
350 REM Horiz Center Line
360 RDRAW @ Q:1.55,0
370 RMOVE @ Q:0.1,0
380 RDRAW @ Q:0.2,0
390 RMOVE @ Q:0.1,0
```

For construction arcs and circles:
- Center of circle
- Radius of circle
- Constructs 36 side polygon along path of circle
ASSIGNMENT SHEET #4

400 RDRAW @ 1.55,0
410 REM Vertical Center Line
420 RMOVE @ Q::-1.75,-1.75
430 RDRAW @ Q:0,1.55
440 RMOVE @ Q:0,0.1
450 RDRAW @ Q:0,0.2
460 RMQVE @ Q:0,0.1
470 RDRAW @ Q:0,1.55
480 RMOVE @ Q:3.25,-1.75
490 REM Right Horiz Center Line
500
510
520
530
540
550 REM Beginning of hidden line a
560 RMOVE @ Q:1.25,0.75
570 FOR I = 1 to 5 Step 1
580 RDRAW @ Q:0.1,0
590 RMOVE @ Q:0.1,0
600 Next I.
610
620
630
640
650
660
670 END

B. Press USER DEFINABLE key 1 to check drawing for errors on screen

C. If drawing is correct, press USER DEFINABLE key 2 for plotter to make drawing
Assignment Sheet #1
A. 13.333 amps
    6.668 amps
    20 amps
B. 840 watts
    420 watts
    1800 watts

Assignment Sheet #2
A. 10 CLS 20 Y = 10: FOR X = 20 TO 34: SET(X,Y): NEXT X
    30 X=X-1: FOR Y=11 TO 34: SET (X,Y): NEXT Y
    40 Y=Y-1: FOR X=33 TO 20 STEP 1: SET (X,Y):
    50 X=X-1: FOR Y = 23 TO 11 STEP 1: SET (X,Y): NEXT Y
    60 GO TO 60
    70 END
B. 100 CLS
    110 X = 60
    120 FOR Y = 18 TO 27
    130 SET(X,Y) Draw the left side
    140 NEXT Y
    150 Y = 27
    160 FOR X = 60 TO 69
    170 SET(X,Y) Draw the bottom
    180 NEXT X
    190 X = 60: Y = 18
    200 FOR N = 1 TO 10
    210 SET(X,Y) Draw the hypotenuse
    220 X = X + 1: Y = Y + 1
    230 NEXT N
    240 GO TO 240
    250 END
ANSWERS TO ASSIGNMENT SHEETS

PLOTTED HYPOTENUSE VALUES

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</table>

Assignment Sheet #4

500 RDRAW @ Q: 0.55,0
510 RMOVE @ Q: 0.1,0
520 RDRAW @ Q: 0.2,0
530 RMOVE @ Q: 0.1,0
540 RDRAW @ Q: 0.55,0

610 REM BEGINNING OF HIDDEN LINE b
620 RMOVE @ Q: -1, 1.5
630 FOR I = 1 to 5 Step 1
640 RDRAW @ Q: 0.1,0
650 RMOVE @ Q: 0.1,0
660 Next I
COMPUTER-AIDED DRAFTING
UNIT XII

JOB SHEET #1: START UP AND SHUT DOWN THE AVAILABLE CAD SYSTEM

(Note: The job sheets in this unit are written using a Tektronix graphic system. If other equipment is used, the procedures will need to be changed.)

I Tools and equipment
   A. Sheet of B size vellum
   B. Tektronix R 4051 graphics computer
   C. Tektronix R 4662 digital plotter
   D. 3MR DC 300A 1/4" data cartridge tape or equal

II Procedure (Transparencies 4, 5, and 6)
   A. Start up 4051 graphics computer
      1. Turn power on
      2. When screen is totally glowing, press HOME/PAGE key
   B. Start up 4662 plotter
      1. Check to see if interface cable is connected to plotter and graphics computer properly
      2. Turn power on
      3. Press down LOAD key
      4. Insert vellum and smooth out air bubbles under vellum
         (Note: Do not tape vellum to bed surface because plotter holds vellum to surface electrostatically.)
      5. Depress LOAD key
         (Note: To remove vellum, press LOAD key.)
      6. Use joy stick to move pen to lower left corner of desired drawing area and press LOWER LEFT SET until tone is heard
      7. Use joy stick to move pen to upper right corner of desired drawing area and press UPPER RIGHT SET until tone is heard
      8. Enter program in graphics computer
JOB SHEET #1

C Shut down system

1. Turn power off digitizer tablet control
2. Turn power off plotter
   (NOTE: Cap must be on pens.)
3. Press HOME/PAGE key on graphics computer
4. Eject magnetic tape if in slot
5. Turn power off graphics computer
JOB SHEET #2-LOAD FROM AND STORE ONTO TAPE A PROGRAM

I. Tools and equipment
   A. 1/4" magnetic data cartridge tape
   B. Tektronix R 4031 graphics computer

II. Procedure
   A. Load from a tape a program into memory
      1. Turn power on graphics computer
         (NOTE: This is necessary if power has not been turned on.)
      2. Using your right hand, grasp the cartridge with your thumb on the plastic side and insert the tape into the magnetic tape slot
         (NOTE: Arrow should be turned to safe mark on plastic side at all times except for storing a program on tape.)
      3. Type in FIND 1, 2, or 3 etc. and wait until BUSY light is off
         (NOTE: File number where program is stored.)
JOB SHEET #2

4. Type in OLD and wait until BUSY light is off and flashing cursor appears in upper left corner of CRT screen
   (NOTE: This is to read program from tape into the memory.)

5. Type in RUN to execute the program in memory

B. Store onto tape a program in memory

1. Set the magnetic tape cartridge SAFE mark arrow to OFF position

2. Type in TLIST to show on CRT screen file numbers and new file number

3. Insert magnetic tape cartridge into tape slot

4. Type in FIND 1, 2, or 3 etc. and wait until BUSY light is off

5. Type in MARK 1, SPA and wait until BUSY light is off
   (NOTE: The tape will be marked one file length long enough to store the program space.)

6. Type in FIND 1, 2, or 3 etc. and wait until BUSY light is off
   (NOTE: This moves the tape back to beginning of new file number where program will be stored.)

7. Type in SAVE and wait until BUSY light is off

8. Eject tape cartridge and turn arrow to SAFE mark

C. Store onto new blank tape

1. Insert new magnetic tape cartridge into tape slot with SAFE mark arrow to OFF position

2. Press REWIND key
   (NOTE: Do not type in FIND 1 because there is not a file number and tape will unwind off reel.)

3. Type in MARK 1, SPA

4. Type in FIND 1
   (NOTE: Now you are ready to store a program on tape.)
COMPUTER-AIDED DRAFTING
UNIT XII

JOB SHEET #3: OPERATE A DIGITIZER TABLET

I. Tools and equipment
   A. Tektronix® 4051 graphics computer
   B. Tektronix® 4956 graphics tablet
   C. Graphics tablet support software tape cartridge

II. Procedure
   A. Check for proper connection of the tablet and graphics computer
      (NOTE: Refer to user’s manual for proper connections.)
   B. Turn power on system
   C. Insert tablet support software tape
   D. Press AUTO LOAD key to display MENU
   E. Select PEN DISPLAY ONLY program for this procedure
   F. Type in number of program and press RETURN
   G. Press POINT on tablet control
   H. Set ORIGIN by press and hold ORIGIN button, then press pen on the tablet surface at the desired origin
   I. Release ORIGIN button
   J. Select display by typing in “g” for graphic display or “a” for coordinate display
   K. Move pen to lower left corner of digitizing window and press once
   L. Move pen to upper right corner of digitizing window and press once
   M. To digitize, begin moving and pressing pen at desired locations
   N. Program halts when USER DEFINABLE key 3 is pressed and the last point entered
   O. To START program, type in RUN
   P. Obtain MENU by pressing AUTO LOAD
1. Match CAD equipment terms on the right with their correct definitions.

   a. Process system used in designing industrial products and the production of graphic drawings with the aid of the computer and its related input and output devices
   b. A TV like display that can be a storage tube, plasma display, or refresh tube display
   c. An electronic information-handling machine capable of performing arithmetical calculations and making logical decisions under the control of programs
   d. The part of a computer system containing the system's arithmetic, logic, primary storage, and controls of input and output peripheral devices
   e. Various devices that are used in the CAD system in which data is input, stored, retrieved, and output from the CPU
   f. Small, inexpensive computer that has a CPU and one or more input/output devices
   g. An input device, consisting of ASCII character keys, numeric keys, and math function keypad used by the computer operator before, during, and after running programs
   h. An X-Y type output device, usually drum or bed form, that produces line drawings on paper with a pen controlled by instructions from CPU or tape controller
   i. An input device where digitized X-Y points are located by positioning the free-moving cursor or stylus on an electromagnetic grid embedded in the digitized board
   j. Contains a sensing coil connected to the digitizer control used for sighting a drawing coordinate X-Y points on the digitizer

   1. Keyboard console
   2. Line printer
   3. Computer
   4. Free-moving cursor
   5. Plotter
   6. Flexible disk
   7. Joystick
   8. Microcomputer
   9. Cathode ray tube
   10. Stylus
   11. Hard copier
   12. Magnetic tape
   13. Light pen
   14. Manual digitizer
   15. Digitizer tablet
   16. Computer-aided drafting
   17. Peripheral devices
   18. Central processing unit
   19. Automated digitizer
k. Used to locate coded programs of X-Y points by pressing at the point of drawing line intersect on digitizer board and input to CRT

l. An input device using stored graphic symbols in the CPU where a designer uses a light pen, stylus, or free-moving cursor by positioning on tablet for each symbol to create a drawing or CRT

m. An input device used with a refreshed-picture display to create various edges, contours, or other features in a photographic image

n. Utilizes a television camera on an automated drafting machine to follow the line being digitized for output digits according to stored information in CPU

o. An output device that prints one line of character information at a time from CPU

p. An output device that forms graphic and character images by electronic signals on paper from CPU

q. An oxide-coated plastic disk enclosed in a protective covering that can be used for storage of data

r. Medium on which data is recorded in the form of magnetized spots on the surface of magnetically sensitive coated tape

s. Used as a graphic input and cursor positioning device to the CRT and CPU

2 Match CAD terminology on the right with their correct definitions.

a. Step-by-step instructions which cause the computer to solve a problem

b. A set of mathematical commands such as add, divide, or multiply, or functional commands to "store in memory," "delete," "print out," or "draw"

c. A symbolic English-like programming language

d. A high-level algebraic and logical language used in engineering and graphic systems

e. A higher-level source programming language designed to process large files used by business

1. Digit

2. Variable

3. Alphanumeric

4. Data

5. Program

6. Chips
f. Collection of related data treated as a unit

h. Data that is transferred to the CPU from an external peripheral device

i. The results obtained from the CPU and transferred to a peripheral device

j. Used as a standard code of alphanumeric characters, symbols, and special control characters

k. Computer output that is composed of lines rather than letters, numbers, or symbols

l. The set of letters A-Z, the numerals 0-9, and various punctuation marks and special characters

m. Prepared programs that simplify CPU operations that cause hardware to function

n. Any physical equipment that is a part of the CAD system

o. The interconnecting methods or devices used in the CAD hardware system

p. Symbol denoting 1024 bytes of storage

q. A programming language that can be interfaced directly by the internal circuitry of the computer

r. A sequence of instructions to carry out a certain function

s. A complete instruction in machine language such as BASIC or FORTRAN

t. A quantity that can take on any of a given set of values

u. Flashing rectangular dot or cross hair that indicates the current position on the screen

v. That portion of the system memory that cannot be changed and may be read but not written

w. Memory available to the user for writing programs and storing data
x. Any number from 0 through 9

y. Binary digit; the smallest unit of information that can be recognized by a computer

z. Two-digit numbering system composed of only 0 and 1

aa. Unit of computer memory, made up of a specified number of bits, which can represent any digit, letter of alphabet, or special character

bb. Miniaturized integrated circuits which compose ROM memory

c. A computer program used to translate high-level source language programs into machine language programs

dd. Graphic symbols or information arranged in software to be retrieved at some later time

ee. A measure of the number of separately addressable positions on the coordinate grid

ff. A CRT scanning system where the electron beam moves horizontally across all X values first at each Y level, moving down each Y level until the screen is scanned

3. List eight hardware used in a CAD system.
   a. 
   b. 
   c. 
   d. 
   e. 
   f. 
   g. 
   h. 

4. Distinguish between input and output devices in a CAD system by placing an "X" next to the output devices.
   a. Hard copier
5. Match BASIC operator symbols or words on the right with the correct descriptions.

   a. Left parenthesis
   b. Functions
   c. Changing sign
   d. Exponentiation
   e. Multiplication
   f. Division
   g. Addition
   h. Subtraction
   i. Comparative
   j. Less than
   k. Greater than
   l. Greater than or equal to
   m. Less than or equal to
   n. Not equal to
   o. Equal to

   1. Min or Max
   2. < >
   3. /
   4. 4
   5. *
   6. (
   7. .
   8. < =
   9. +
   10. SIN, COS, TAN
   11. =
   12. > =
   13. + and · Monadic
   14. <
   15. >

6. Match BASIC statement works used for programs on tape on the right with the correct functions.

   a. Positions tape at beginning of desired file
   b. Creates on tape one or more files of desired length
   c. Causes the entire program currently in memory to be stored on tape
   d. Stores memory on tape in binary code
   e. Retrieves program on tape back into memory

   1. T List
   2. Append
   3. Mark
   4. Save
   5. B Save
   6. Old
   7. Find
   8. Bold
f. Retrieves program on tape in binary code back into memory

h. Enables changing or add-on routines to programs on tape that are in memory

7. Match BASIC statement words used in graphics on the right with the correct functions.

a. Produces a visible line between the last position of the cursor and the X-Y coordinates specified

b. Produces a visible line to a location which is relative to its present position

c. Allows moving cursor on the screen without making a line with X-Y coordinates specified

d. Allows moving the cursor to a location which is relative to its present position without making a line

e. Produces on angular displacement in the orientation of relative moves and draws

f. Allows selecting whatever portion of user data space you want to see on the screen

g. Allows using a desired portion of the screen in a window

h. Ratio of user data units per graphics display unit (GDU)

i. Draws a horizontal and vertical line through point of origin in the user data space

8. Select true statements concerning operating a Tektronix CAD system by placing an "X" in the appropriate blanks.

a. Do not take the tape arrow off SAFE unless you intend to record on it

b. Type in FIND 1 on a new blank tape before it has been rewound and MARK 1 entered

c. Do not operate computer when an electrical storm is in area because the memory may be erased

d. Memory will not be erased if power is turned off while program is in memory
e. Do not grab pen while the plotter is running
f. Press MARK key if you need to stop plotter
g. Keep cap on plotter pens when not in use
h. If screen is full and a flashing F is in upper left corner, press HOME/PAGE key

9. Demonstrate the ability to:

a. Program in BASIC using a micro-computer as a calculator.
b. Create drawings on a micro-computer using plot method.
c. Construct a two-view drawing using straight line statements.
d. Construct a two-view drawing using straight line, circle, and hidden line statements.
e. Start up and shut down the available CAD system.
f. Load from and store onto tape a program.
g. Operate a digitizer tablet.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
### COMPUTER-AIDED DRAFTING
#### UNIT XII

### ANSWERS TO TEST

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3. Any eight of the following:
   - a. CPU
   - b. CRT
   - c. Keyboard console
   - d. Plotter
   - e. Manual/Automated digitizer
   - f. Hard copier
   - g. Line printer
   - h. Free-moving cursor/stylus/light pen
   - i. Joy stick
   - j. Magnetic tape or flexible disk drives

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ANSWERS TO TEST

8. a, c, e, g, h

9. Evaluated to the satisfaction of the instructor