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This handbook is an adjunct to the "Laboratory Manual for Advanced Physical Science 2," and is intended to assist teachers in organizing laboratory experiences. Information for each experiment includes (1) Introduction, (2) Scheduling, (3) Time required, (4) Materials needed , (5) Precautions, (6) Laboratory hints, (7) Sample data, and (8) Derived results. Also included is a detailed commentary on a set of astronomy slides. (DH)

TEACHER'S HANDBOOK FOR
ADVANCED PHYSICAL SCIENCE 2

LOS ANGELES CITY SCHOOLS

1967

TEACHER'S HANDBOOK

FOR

ADVANCED PHYSICAL SCIENCE 2

LOS ANGELES CITY SCHOOLS
Division of Instructional Planning and Services
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FOREWORD

This handbook is intended to assist teachers in organizing laboratory exercises for Advanced Physical Science 2. In addition, detailed descriptions of the contents of a set of 35 mm. slides to enrich the unit on astronomy has been included. The handbook is designed to be used in conjunction with the *Laboratory Manual for Advanced Physical Science 2* and the Outline Course of Study.

EVERETT CHAFFEE
Associate Superintendent
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and Services

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TEACHER INFORMATION FOR STUDENT EXPERIMENTS

Advanced Physical Science is a laboratory course. Its objectives may be achieved most effectively through the performance of meaningful laboratory experiments by the student. Through such laboratory work, skills are best developed in the application of scientific methods, in the use of accurate observation, and in the collection and interpretation of data.

Information sheets for use with each laboratory experiment listed in the *Advanced Physical Science 2 Laboratory Manual* have been designed to assist the teacher in implementing the laboratory work. The information sheet for each experiment includes the following:

Introduction
A concise statement of the main purpose of the experiment

Scheduling
Information that will enable the teacher to coordinate the laboratory experiment with the Units and Parts of the Outline Course of Study

Time Required
Approximate time required for student to complete the experiment

Materials
A list of materials required for each experiment

Precautions
Descriptions of difficult procedures and safety precautions

Laboratory Hints
Helpful information, sample data, and calculations of laboratory problems

Sample Data
Sample data for tabulated laboratory observations

Derived Results
Derivation of chemical constants and use of typical formulas

The information sheets should be reviewed early in the semester so that required materials for each experiment can be obtained. Each information sheet should be referred to again about five days before the students perform the experiment to assure that preparations are complete.

Evidence indicates that time spent in preparation for meaningful laboratory work by students is well worth the effort. More than 90 per cent of scientific progress, as revealed by the selection of Nobel Laureates, is achieved by scientists performing experimental work in laboratories.

UNIT FIVE: STATIC ELECTRICITY AND MAGNETISM

EXPERIMENT 32

ELECTRIFYING OBJECTS AND INDUCING A CHARGE

INTRODUCTION

The student is now ready to explore the mystery and fascination of the unseen world of electricity and magnetism. For many students, electricity and magnetism will be the most exciting, challenging, and practical work of the year. Historically, electricity had its beginning in the investigation of charges and forces. It is appropriate for students to begin in this way. The study prepares the student for the following experiment in which a familiarity with simple electrostatics has been assumed. From Experiment 32, the student should acquire an understanding of insulators, conductors, charges, leakage, electroscopes, and induction of charge.

SCHEDULING

Use this experiment as an introduction to Unit Five, Part I.A

TIME REQUIRED

45 minutes

MATERIALS FOR EACH STUDENT

1 cotton cloth
2 cellulose acetate strips
(See Laboratory Hint No. 3.)
1 ringstand (36", if possible)
1 clamp holder
1 electroscope
(may share with other students)

2 beakers
Aluminum foil
1 wool cloth
2 vinylite strips
1 rod or dowel 24"
Masking or cellulose tape (scotch)
2 metal rods 6"
Thread

PRECAUTIONS

When the humidity is high, leakage occurs across even the best insulators. Dirt and dust on the surface absorb water and form a thin conducting layer of electrolyte. Keep surfaces as clean as possible. If the cellulose acetate or vinylite becomes dirty, it should be washed in soap and water.

LABORATORY HINTS

1. Note that the success of this experiment depends upon the relative humidity. If it is 80 per cent or more, the experiment will be very difficult. The relative humidity can be measured by a student who is proficient in the use of a sling psychrometer.
2. To reduce leakage in high humidity, store the apparatus in a large box heated by an electric bulb, or in a heated room. Remove the apparatus just before use.
3. Vinylite and cellulose acetate are common transparent plastics. P.S.S.C. Physics rooms have a supply; however, desk blotter protectors, celluloid, notebook page protectors, acetate sheet protectors or upholstery vinyl can be substituted. Cut them into 1 x 8 inch strips. Be sure you have one type to give a positive charge and one type to give a negative charge. Vinylite takes on a negative charge when rubbed with wool, and cellulose acetate becomes positive when rubbed with cotton.
4. Notch the plastic strips in a manner that allows the students to distinguish the two types.

5. Since the charge cannot be easily removed from plastic strips by rubbing the surface with the hand, try passing the strips quickly over a flame.

   Cellulose acetate is included on the Los Angeles City Schools supply list as stock number 216480 cover, for 3-ring binder sheets, 8½" x 11", transparent cellulose acetate. The price is $ .047. The acetate is a little too thin, but it can be utilized.

6. Be sure that the two different strips are far apart and far enough from the metal of the ring stand to avoid interactions and induction effects from the ring stand.

7. Remember that students may need help in understanding the concept of induction. It is difficult to understand until they have studied it in the text.

   Most insulators will assume a charge when rubbed. The charge can be identified by comparison with the vinylite and acetate.

8. Note that the general conclusions resulting from this experiment are as follows:

   a. There are two types of electric charges.

   b. Two neutral objects rubbed together acquire opposite charges.

   c. Unlike charges attract, and like charges repel.

   d. It makes no difference which charge is called plus, or whether the charges are called a and b.

   e. Unrubbed objects are attracted to all rubbed objects (by induction). This does not involve a third kind of charge.

9. In question a, substitute similar objects, such as spoons, table knives, or metal tubing pieces, if rods are not available. Avoid objects with sharp points or sharp edges, since they lead to corona discharge or spark discharges. If sparking occurs, the rods must be discharged and the experiment repeated.

10. Point out that small bits of paper and thread are attracted by charged objects because of the separation of charge, like that in a conductor rather than the distortion of charges in individual molecules, which is known as polarization.

EXPERIMENT 33

MEASURING ELECTRIC REPULSION FORCE

INTRODUCTION

This is an important experiment and should not be omitted unless the humidity is too high (60 to 70 per cent is the upper limit). The student will investigate electric force quantitatively. Hopefully, many students will discover for themselves the inverse-square nature of electric forces. However, the experiment is difficult and delicate. A few practice runs are advisable so that a quick final run can be made to avoid excessive leakage. This experiment simulates the discovery of Coulomb's Law, essentially as it was done by him in 1784.

SCHEDULING

Use this experiment in Unit Five, Part I.D.

TIME REQUIRED

45 minutes

MATERIALS FOR EACH LABORATORY STATION

2 balls, lightweight, ½" dia. (styrofoam, pith, etc.)
1 nylon filament or thread 24"
1 point source lamp with socket, cord, and support
Quick drying glue
Dag 154 alcohol suspension of graphite (aguaday)

1 ringstand
1 flask clamp
1 clamp holder
1 piece of heavy cardboard

OR

1 cardboard carton 2' x 2' x 2'

1 clothespin, pinch
1 board 1" x 1" x 12"
2 pieces of graph paper or a ruler (translucent)
Cellulose or masking tape

PRECAUTIONS

Again keep equipment clean to avoid excessive leakage.

LABORATORY HINTS

1. If drafts are a problem, enclose the apparatus in a cardboard carton 2' x 2' x 2'. Cut windows slots in the box for the various parts to be manipulated and viewed.
2. Under very humid conditions, heat the inside of the box with an infrared lamp for three minutes before the experiment is performed. If needed, apply the heat again during the experiment.
3. Coat the balls with colloidal graphite (commercially known as Dag 154 or aquaday) or india ink. Aluminum paint is **not** a good conductor.
4. If possible, use single nylon monofilament as fine as a hair for the ball suspension. The filament can be attached to the ball with a drop of rubber cement or with quick-drying glue. If the thread is too heavy, it will hang in a curve, and the deflection will not be proportional to the force exerted.
5. Note that the support for the pith ball that slides over the surface of the table should be a good insulator, like low-molecular weight polyethylene (a wax like plastic). It can be sharpened to a point and stuck into the pith ball. If the clothespin is screwed to a wood block 3" square, it will be less likely to tip over.
6. Note that Coulomb's laws holds for point charges; therefore, if the spheres are brought closer than two diameters, it may seem as though the law does not apply. At close range the spheres cease to act as point charges.
7. For this experiment, organize the class into teams of two members each.

UNIT SIX: ELECTRICITY AND MAGNETISM AT WORK

EXPERIMENT 34

CONSTRUCTING A VOLTAIC CELL

INTRODUCTION

This is the student's first experience with current electricity. It is important because he will learn about open and closed circuits and switches, ammeters, cells and voltmeters. Knowledge regarding these fundamental components of electric circuits will be needed repeatedly in his study of electricity.

SCHEDULING

Use this experiment soon after introducing direct-current electricity in Unit Six, Part I.A.

TIME REQUIRED

45 minutes

MATERIALS FOR EACH LABORATORY STATION

1 beaker 250 ml or larger
1 switch
1 carbon rod
Wire
1 ammeter 1, 3, or 5 ampere full scale
1 each, strips of Zn, Cu, Pb
Sulfuric acid, dilute
1 voltmeter, 1.5 to 5 volt, full scale

PRECAUTIONS

Caution students about the danger of getting sulfuric acid on clothes, skin, etc. Check instruments with cells in advance of the class meeting to be sure that they are appropriate for the currents and voltages to be encountered. This procedure will avoid causing meters to be burned out

LABORATORY HINTS

1. Rub a drop of mercury into the surface of the zinc to prevent local action.
2. Improvise the cell cover with a small wood board and clothespins.
3. Organize class into teams of two members each.

EXPERIMENT 35

USING ELECTRIC CURRENT TO COUNT ATOMS

INTRODUCTION

This is the only experiment directly concerned with the atomicity of electric charges. Therefore, it has high priority. Students should be reminded that electric current is the flow of electric charges. In wires, current is composed of negative charges; in electrolytes, it is composed of positive and negative ions. A current of 6.25×10^{18} elementary charges per second passing a given point in a circuit is defined as 1 ampere. The ammeter is like a turnstile, counting elementary charges (electrons) per second.

SCHEDULING

Use this experiment with Unit Six, Part I.A.2.

TIME REQUIRED

45 minutes

MATERIALS FOR EACH LABORATORY STATION

1 500 ml flask
1 ring clamp to fit flask
1 flask or buret clamp
Glass tubing
1 pinch clamp
1 glass tray, battery jar, plastic tray, or enameled pan
3 clip leads 2'
1 power supply, D.C. 5-10 amps 6-12 volts
Steel wool or fine sandpaper
Clock
Paper towels and rags
Pliers
1 ringstand
1 8-oz. bottle with two hole stopper
1 brick or C - clamp
Rubber tubing
Copper sheet #28 gauge, about 1" x 6"
Wire, insulated
1 liter of 5% sulfuric acid
1 ammeter; may be included with power supply case
Several beakers and graduates
Pan balance
1 variable resistor if there is no control on the power supply

PRECAUTIONS

Remind students to pour concentrated acid into water to avoid spattering and that they should stir constantly because much heat is generated. Do not allow acid to touch skin nor clothing. Do not allow students to put acid into metal containers, such as galvanized troughs.

LABORATORY HINTS

1. Use a very thin copper sheet for the anode so that the small loss in its mass will be a reasonable fraction of its original mass. A good shape for the anode is a 1" x 2" rectangle, with a 4" strip ¼" wide. It should extend from one end to bend over the side of the container like a handle.
2. Designate teams of two or three students each.
3. You may wish to dilute the acid yourself prior to the laboratory period. Add acid slowly to water.
4. At the cathode connection, wrap the copper wire around the end of the cathode, and pinch the wire tight with pliers. Use wire with waterproof plastic insulation to avoid the liberation of hydrogen outside the flask.
5. Clean both electrodes with fine sandpaper or steel wool and then wipe them clean. The anode should be weighed after cleaning.

6. If the students are sufficiently familiar with the gas laws, you can permit them to make the corrections for pressure, temperature, and water vapor pressure. Otherwise, use 25.5 l for the gram molecular volume of hydrogen instead of 22.4 l. The 25.5 l figure for mole volume of a gas is desirable for use at room temperature and for atmospheric pressures at elevations up to 1500 feet.

SAMPLE DATA AND CALCULATIONS

Data

Current I = 4.7 amperes
Time Δ t = 14.0 minutes = 840 seconds
Original mass of anode 8.1 g
Final mass of anode 6.7 g
Decrease in anode mass Δ M = 1.4 g
Volume of hydrogen V, = 520 ml = .520 l.

Charge transferred

$$q = 6.25 \times 10^{18}\ I \times t = 6.25 \times 10^{18}\ (4.7)\ (840) = 2.5 \times 10^{22} \text{ elementary charges}$$

Moles of Copper ions

$$N_{Cu} = \frac{\Delta M}{\text{Atomic mass of Cu}} = \frac{1.4}{63.5} = .022 \text{ moles}$$

Number of Copper ions

$$N_{Cu} = (\text{Avogadro's number})\ (N_{Cu}) = 6.02 \times 10^{23}\ (.022) = 1.3 \times 10^{22} \text{ ions}$$

Number of elementary charges per copper ion

$$\frac{q}{N_{Cu}} = \frac{2.5 \times 10^{22}}{1.3 \times 10^{22}} = 1.9 \text{ or approx. 2 elementary charges per ion.}$$

Number of elementary charges per hydrogen ion

Using 25.5 l for the mole volume

$$\frac{q}{N_H} = \frac{q}{6.02 \times 10^{23} \times \frac{V}{25.5}} = \frac{2.5 \times 10^{22} \times 25.5}{6.02 \times 10^{23} \times .520} = 1.97$$

The figure 1.97 represents approximately 2 elementary charges per molecule, or 1 elementary charge per hydrogen ion.

EXPERIMENT 36

FINDING ELECTROMOTIVE FORCE (EMF) IN A SIMPLE CIRCUIT

INTRODUCTION

This experiment directs the attention of the student to the relationship of resistance to voltage drop in a simple circuit. He is able to observe the increase in EMF when two cells are connected in series.

SCHEDULING

Use this experiment to begin Part I.A.3 of Unit Six.

TIME REQUIRED

30 minutes

MATERIALS

1 voltmeter 0-5 volts D.C.
1 socket for flashlight bulb
2 dry cells
1.5 volt. No. 6 size, large
1 flashlight bulb
1 piece of nichrome resistance wire
1 switch
Wire

LABORATORY HINTS

1. Note that the resistance coil can be a coil of nichrome wire. Use a piece of sufficient size and resistance to reduce the bulb to about half brilliance when it is placed in series.
2. Using a lamp bulb of either a 3-volt miniature screw base type or series type Christmas tree light, mount the miniature screw base sockets on a small board. A string of Christmas tree sockets can be cut apart and also used.
3. Keep in mind that the open-circuit voltage of the cells is slightly greater than the closed-circuit working voltage because of internal resistance within the cell. This produces a slight voltage drop within the cell. The latter is the basis for the answer to Question No. 4.
4. Instruct the students to work individually or in pairs.
5. Caution students that EMF is not really a force. It is the energy per elementary charge, supplied by the cell chemical reactions. The voltage drop across a resistance is the amount of energy lost to the resistance per elementary charge. One electron volt is the amount of energy supplied to an elementary charge by a cell EMF of 1 volt. One electron volt of energy is dissipated in a resistance by an elementary charge if the voltage drop is one volt. When 6.28×10^{18} electrons have passed a resistor whose voltage drop is 1 volt, then one joule of energy has been dissipated by the resistance.

EXPERIMENT 37

PASSING CURRENTS THROUGH PARALLEL AND SERIES LOADS

INTRODUCTION

The student now explores some of the practical and useful aspects of electricity. He will gain valuable experience in assembling a circuit correctly, and he will have an opportunity to study the laws of simple resistance. This is an appropriate time to introduce Kirchoff's Laws, which stipulate that the total current entering any point in a circuit is equal to the total current leaving that point. This law applies to the flow of electricity at the junctions in parallel circuits. The algebraic sum of the voltage drops around a closed path is zero. This principle is useful in the study of a series circuit. The voltage drop across a resistance is negative compared to that of a battery.

SCHEDULING

Use with Unit Six, Part I.A.3.

TIME REQUIRED

30 minutes

MATERIALS FOR EACH LABORATORY STATION

1 power supply or batteries, 6 volts
3 resistors 3 - 5 ohms, or
small lamps with sockets

1 ammeter 3 - 5 amp.
(may be included in power supply)
1 switch
1 voltmeter 6 - 10 volts

PRECAUTIONS

Check all circuits before switches are closed to prevent damage to instruments or power supply.

LABORATORY HINTS

1. Point out the following:

   a. According to Kirchoff's Laws, the EMF (V) across the power supply in Fig. 37-1, Advanced Physical Science Laboratory Manual, Volume 2, will be equal to the sum of the voltage drops (V_1, V_2, V_3) across the resistors R_1, R_2, R_3, respectively. $V = V_1 + V_2 + V_3$.

   b. In Fig. 37-2, Advanced Physical Science Laboratory Manual, Volume 2, the current passing through the power supply (I) will be equal to the sum of the currents in the branches I_1, I_2, and I_3. $I = I_1 + I_2 + I_3$.

2. Suggest to the students that they substitute a small d.c. motor, like those used in toys, in place of one resistance.

EXPERIMENT 38

MEASURING MAGNETIC FIELDS INSIDE A CURRENT LOOP

INTRODUCTION

This experiment is very fundamental and instructive. The student investigates the relationship of electric current to a magnetic field. The concepts of field and vector are explored and used. The student uses a convenient quantitative approach to the study. This experiment is worth taking time to do well. Proper results lead to the discovery that magnetic field B is proportional to current I, $B = kI$. The constant, k, varies with the size of the loop.

SCHEDULING

Although this experiment properly is included in Unit Five, Part II, B.2., schedule it after the student has studied electric currents. Use the experiment following Unit Six, Part I.A.3.

TIME REQUIRED

45 minutes

MATERIALS

1 rack to hold the loops (non-magnetic)
1 compass, magnetic
1 dry cell #6, or power supply 1½ volt
Alternate for light bulb 1 ammeter, 3 amp.

30' of insulated wire
1 flashlight bulb, #41, and socket
1 sheet of polar or rectilinear graph paper
1 variable resistor, 10 ohm, 4 watt
1 ammeter, 3 amp.

PRECAUTIONS

Caution students not to leave the current on longer than necessary because of the high energy drain which it creates.

LABORATORY HINTS

1. Note that:
   a. The apparatus is known as a tangent galvanometer.
   b. All parts of the apparatus must be non-magnetic. P.S.S.C. physics classes have aluminum racks for this experiment. Wood racks are desirable.
   c. The whole 30' of wire remains in the circuit at all times. Loops can be added to or subtracted from the frame without disconnecting the wire from the circuit.
2. As an interesting extension of this experiment, try to align the loop's magnetic field with the earth's magnetic field in such a way that its force is exerted in the opposite direction. Then adjust the current carefully so that the fields cancel each other. Aimless wandering of the compass needle is sufficient indication of a zero magnetic field.
3. Be sure to make clear the right-hand rule for determining the direction of the magnetic field and the direction in which the north end of the compass will point. Wrap the fingers of the right hand around the coil parallel to the wires, with the fingers pointing in the direction of positive current flow (from plus to minus). The normal position of the thumb will then indicate the direction in which the north pointing end of the compass needle will point.

EXPERIMENT 39

TRANSFERRING ENERGY THROUGH A MAGNETIC FIELD

INTRODUCTION

In contrast with Experiment 38, which concerns the controlled analysis of Theory, Experiment 39 is more practical. Student interest will be high if there is sufficient equipment to conduct the experiment. In electromagnetism, there is an element of magic and mystery which is stimulating to students. Lenz's law is important and should be emphasized and explained. "An induced EMF tends to set up a current whose action opposes the change that caused it." This is in agreement with the principle of conservation of energy.

SCHEDULING

Use this experiment following Part I.B. of Unit Six.

TIME REQUIRED

45 minutes

MATERIALS FOR EACH LABORATORY STATION

2 solenoids
1 switch (push button or knife switch)
Wire
2 bar magnets
1 galvanometer
2 dry cells #6
1 St. Louis motor generator (dissectable)
1 iron rod

PRECAUTIONS

Impress students with the sensitivity of a galvanometer. It cannot be used as a voltmeter or ammeter unless shunt or series resistance is added. A current of about 50 micro amperes is the maximum that a galvanometer can carry safely.

LABORATORY HINTS

Note that:

1. Push button switches mounted on small boards and supplied with binding posts or spring clip connectors are useful. Neatness in circuit construction should be stressed since it increases the safety factor.
2. Wire leads should be short or formed into a coil. This can be done by wrapping them around a pencil and then stretching them out like a spring.

UNIT SEVEN: WAVE MOTION

EXPERIMENT 40

SENDING ENERGY THROUGH A METAL SPRING

INTRODUCTION

The study of wave energy propagation is relatively new at the high school level. The concepts are easily comprehended by high school students. Knowledge of wave behavior aids greatly in the understanding of light, radio, sound, heat, x-rays, electricity, and matter. The study of wave behavior has become a separate field of investigation because of its wide applications. The student begins his study of waves with pulse or wave propagation in a spring. Many children have propelled a pulse along a rope while playing "jump rope." Therefore, this first wave experiment will have a characteristic of familiarity.

SCHEDULING

Use with Unit Seven about the time that wave characteristics will be introduced.

TIME REQUIRED

45 minutes

MATERIALS

1 flat-wire coiled spring (slinky) 4" long 3" diam.
1 round-wire coiled spring 1.75 m long 2 cm diam.
String or thread

LABORATORY HINTS

1. Note that parts of this experiment can profitably be performed as demonstrations. For instance, the part that requires the use of two coils hooked together can be effective as a short demonstration. The partial reflection and transmission at the junction is best observed when the two springs are stretched to the same length. This can be achieved if only one-third of the large coil is used. A smooth floor is essential.
2. When stretching the spring, instruct students to tie a thread to one end. Holding only the thread allows the spring to unwind while it is being stretched out. Allowing the spring to unwind prevents later distortion of the pulses.
3. Caution the class that the springs must be handled carefully to avoid tangling.
4. Point out that the speed of the pulse is independent of the size of the pulse. The speed of the pulse increases as the tension in the spring increases. When pulses collide, they seem to pass through each other. The maximum displacement of the spring when the pulses meet is equal to the algebraic sum of the separate amplitudes. At a junction between two coil springs, partial reflection and partial transmission occur. Pulses traveling on the small spring are reflected right side up. Pulses traveling on the large spring are reflected upside down. Pulses reflect upside down from a fixed end, and right side up from a loose end held only by a long string.

EXPERIMENT 41

MEASURING SHORT-TIME INTERVALS WITH A SLOTTED WHEEL

INTRODUCTION

In this experiment, students measure short-time intervals with a stroboscope and a vibrating bell clapper. Both of these instruments perform a repetitive motion with a very brief period. Of course, students also will use a watch or clock which has a very long period. After the instruments are calibrated, they can be used to measure brief lengths of time which are not necessarily repetitive.

SCHEDULING

Use this experiment at the beginning of Unit Seven, Part I.B.

TIME REQUIRED

45 minutes

MATERIALS FOR EACH LABORATORY STATION

1 hand stroboscope
1 vibrator timer
1 paper timer tape
1 C - clamp
1 large second-hand clock (one per room), or stop watches
1 fan, or a rotating wheel (one per room)
1 carbon paper disc
1 dry ceil #6 size

LABORATORY HINTS

1. Assure that the lighting is bright during the stroboscope operation because of the brief periods of observation and the use of the narrow slits.
2. Instruct students to work in pairs.
3. Caution students that C - clamps may bend the timers if the clamps are tightened too much.
4. Direct class members to observe the vibrator through slits that are parallel to the vibrator clapper.
   a. When the student is observing slower vibrations, he may find it convenient to cover slits on the stroboscope with black tape. Of course, the open slits always should be evenly spaced to that the time intervals between observations are equal.
   b. The period of the vibrator timers is about 1/40 second. The duration varies with the setting of the make-and-break contacts and with the condition of the battery. Only one timer should be connected to a battery at a time.
5. In addition, instruct class members as follows:
   a. The most convenient way to calibrate the vibrator timer is to pull paper tape through it for 5 or 10 seconds, count the marks, and divide the total time by the total number of marks. It is not necessary to pull the tape at a constant speed.
   b. Some adjustment of the clapper may be necessary to assure that it will strike the tape hard enough to leave visible carbon marks. The clapper arm can be adjusted by careful bending. The carbon paper disc should rotate easily as the tape is pulled through. This procedure assures that there will be fresh carbon under the tape at all times.
   c. It may be necessary to mark one blade of the fan with a piece of white masking tape before the students try to measure its period. Otherwise, they will obtain a variety of periods, each a multiple of another.
   d. When tape is pulled through the timer, the period is shorter by about 5 per cent.

EXPERIMENT 42

INTERPRETING THE BEHAVIOR OF WAVES

INTRODUCTION

Performance of Experiments 41 and 42 provides the student with a gradual transition from the study of pulses on a line to that of periodic waves in a plane. The student will become familiar with the relation $V = ft$. He investigates the interference effects with water waves. Experiment 42 is aesthetically pleasing to many students. It captures and holds their interest and attention.

SCHEDULING

Use this experiment approximately midway through Part I.B. of Unit Seven.

TIME REQUIRED

90 minutes

MATERIALS

1 ripple tank with support
4 paraffin blocks
1 dowel ¾" dia. and 18" length
1 paper screen 2' square
1 clock with sweep second hand

Accessories for ripple tank include:
1 wave generator bar and support
1 support dowel for lamp
1½ - volt toy motor

1 lamp 150 watt clear glass straight filament with shield, cord, and socket.
1 thick-walled rubber tubing 18" long
1 dry cell #6 size
2 hand stroboscopes
1 ruler

4 dampers
1 nichrome wire for motor control

LABORATORY HINTS

Note the following:

1. Many of the wave images can be improved by adjustment of the depth of the generator bar.
2. A ruler can be used to make straight pulses.
3. The end of the tank opposite to the generator bar can be used as a reflector.
4. Circular pulses can be made with drops from an eye dropper.
5. To obtain clear waves, the battery should be connected so that the motor turns in a direction away from the tank.
6. The wave length of a standing wave is half the wave length of the traveling wave.
7. Syphoning is the safest way to empty the ripple tanks.
8. The demonstration wave machine can be borrowed from the Science Center, Instructional Materials Center, Sentous Branch.

EXPERIMENT 43

DETERMINING THE SPEED OF SOUND

INTRODUCTION

In this experiment, students experiment with unseen waves. This is an opportunity to apply the mathematical relationships between velocity, wave lengths, and frequency. Sound produces waves that are 0.5 meter to 20 meters in length. Resonance of the reflected wave "in-phase" with the incident wave produces a reinforced sound of greater amplitude. Actually, the resonance is an example of standing waves. At conditions other than resonance, there is much cancellation of waves and reduced sound intensity.

SCHEDULING

Use this experiment with Unit Seven, Part I.C.1.

TIME REQUIRED

30 minutes

MATERIALS FOR EACH LABORATORY STATION

1 large glass cylinder 250 ml or larger
1 aluminum cylinder open at both ends
2 tuning forks of different frequency
1 ruler

LABORATORY HINTS

1. Request that aluminum tubes be cut in 12" to 15" lengths in metal shop classes. These should fit loosely inside the glass cylinder.
2. Instruct students to prepare hammers by inserting a 7" piece of dowel in a one-hole No. 5 rubber stopper. This is used to strike the tuning fork.
3. Caution class members to exercise great care in measuring the resonance length of the air column.

EXPERIMENT 44

RETURNING LIGHT FROM A FLAT MIRROR

INTRODUCTION

The student begins his study of geometric optics with this experiment involving use of a plane mirror. The concept of images is introduced. Images will be located and measu d by line-of-sight methods.

SCHEDULING

Use this experiment in Unit Seven, Part I.C.2.

TIME REQUIRED

30 minutes

MATERIALS FOR EACH STUL NT

1 plane mirror 2" x 6"
1 ruler
1 block of wood with slot 1" x 1" x 1"
1 nail (large head roofing nail works well)

LABORATORY HINTS

Instruct students to perform the laboratory work on a clean sheet of paper. Ask for this original work sheet and not a copy. Its use will save the students time and permit him to devote additional attention to the more important study of his text.

EXPERIMENT 45

RETURNING LIGHT FROM A CONCAVE MIRROR

INTRODUCTION

In this experiment, the student acquires familiarity with images formed by concave mirrors. He works with focal length and its relationship to D_o and D_i, the object and image distance as measured from the principal focus.

SCHEDULING

Use this experiment with Unit Seven, Part I.C.2.

TIME REQUIRED

40 minutes

MATERIALS FOR EACH LABORATORY STATION

1 concave mirror
1 dry cell #6
Wire
1 lump of clay
1 bulb and socket 2-3 volt
1 ruler

LABORATORY HINTS

1. If concave mirrors of good quality are not available, use lenses and modify instructions to the students in relation to the requirements of the lens.
2. In measuring the focal length f, note that use of a small mirror will introduce large errors in the object and image distances because these are measured from the principal focus.
3. Instruct students to find the principal focus by locating the image of any object more than 5 meters distant. The image will be located at the principal focus.
4. Point out that the bulb can be held in a porcelain or plastic socket or in a dial light socket mounted in a wood strip. Another alternative is to use the bulb simply soldered to two wires and held by a lump of clay.
5. Inform the class that the filament of the bulb and the center of the mirror should be placed at the same height above the table.
6. Arrange for each team to use a work area 1 meter long. If the focal length of the mirror is greater than 15 cm, a larger area will be needed.
7. Note that a paper strip fastened to the table with tape will aid in marking positions and measuring distances.

EXPERIMENT 46

BENDING LIGHT BY SENDING IT FROM AIR INTO WATER

INTRODUCTION

In this experiment, the students are introduced to Snell's Law, $\frac{\text{Sin i}}{\text{Sin r}}$ = constant. It is preferable that they discover it in the laboratory before reading about it in the textbook. Knowledge of Snell's Law is fundamental to the study of all refraction in lenses, prisms, and optical instruments. If the students are familiar with sines, the experiment can be performed more accurately and rapidly than it can with semi-chords. However, many students have not had sufficient mathematics to enable them to find the ratio of sines, so the semi-chord ratio is described in the student laboratory manual.

SCHEDULING

Use this experiment with Unit Seven, Part I.C.2.b.

TIMED REQUIRED

45 minutes

MATERIALS FOR EACH STUDENT

1 semi-circular plastic box, transparent
1 sheet of soft cardboard
1 ruler
2 florist pins or hat pins
1 proctractor
1 compass

LABORATORY HINTS

1. Note the following:
   a. Semi-chords are proportional to sines; therefore, use of the semi-chord ratio will produce the same results as those obtained with the sine ratio.
   b. The vertical scratch on the plastic box is more easily observed when it is darkened with a red pencil.
2. Instruct half the members of the class to use a liquid such as mineral oil. The results should be compared later. Other suitable liquids are glycerine, motor oil, salt solution, and sugar solution. Do not permit students to use carbon tetrachloride, carbon disulfide, turpentine, acids, or bases.
3. Utilize the plastic boxes which are available in P.S.S.C. physics classes, or obtain cheese boxes that are suitable.

UNIT EIGHT: THE UNIVERSE

EXPERIMENT 47

INVESTIGATING CIRCUMFERENCE

INTRODUCTION

Many of the questions that students ask are basic and direct, such as "How do you weigh the earth?", "How do you measure the earth's circumference?", and "How do you predict eclipses?" This experiment presents the Eratosthenes method (developed circa 250 B.C.) of measuring the earth's circumference. Although it will be performed on a small scale in the classroom, the same method will be utilized.

SCHEDULING

Use this experiment with Unit Eight, Part II A.1.

TIME REQUIRED

30 minutes

MATERIALS FOR EACH TEAM OF FIVE

1 tee sighting frame with protractor, nail and string attached
1 chalk and string
1 meter stick
1 lamp

LABORATORY HINTS

1. Arrange for this experiment to be performed outdoors on wide sidewalks or on a black top. A hallway also may be used.
2. In place of a lamp, use a tree or post as the distant reference sighting point.
3. Point out that Eratosthenes used sunlight shining down a deep well shaft for a reference direction and a weight on a string to indicate the direction of the earth's center. He also used two locations in Egypt which were separated by several hundred miles.
4. Instruct students to build the sighting frames several days in advance from materials obtained from the woodshop. Protractors can be ordered from the supply requisition list.

EXPERIMENT 48

RANGE FINDING

INTRODUCTION

This is another experiment in which an attempt is made to answer the students' basic questions about the universe such as "How do we know the distance to a star or planet?" The parallax method of ranging is utilized. It is extremely versatile and requires use of only very simple apparatus. The method is useful in determining distances from a few centimeters to 650 light years. To measure astronomical distances, however, the base line must be long. The diameter of the earth's orbit often is used as an appropriate base line.

SCHEDULING

Use this experiment with Unit Eight, Part II.A.1.

TIME REQUIRED

45 minutes

MATERIALS FOR EACH TEAM OF TWO

1 parallax viewer
1 metric rule
1 meter stick

LABORATORY HINTS

1. Arrange for students to perform this experiment outdoors, where they can observe suitable reference points at least two miles away. For this purpose, it is often appropriate to use the top two rows in the grandstand on the athletic field.
2. Note the following:
   a. The parallax viewers can be used more effectively when they are resting on a firm surface, such as that provided by the grandstand seats.
   b. Long pins of the type used by florists can be used conveniently to mark the positions of the reference point and of the nearby object.
   c. Centimeter-calibrated tape is useful in preparing scales.
3. Obtain the parallax viewers by ordering from the regular non-consumable supply list. The viewers also can be made easily by students in woodworking classes.
4. Keep in mind that students often need assistance in sighting and with the logic of the parallax method.

EXPERIMENT 49

RELATING LIGHT BRIGHTNESS TO STAR DISTANCE

INTRODUCTION

The student investigates the relationship between radiation intensity and distance to the observer. This experiment is primarily a study of the inverse square law. Radiation intensity is proportional to 1 over the distance squared. The student should learn that this principle can be used to determine the distances to very remote stars and other stellar objects. During the experiment, the class should be divided into several groups, each of which is concerned with a different type of radiation or a different type of detector. The methods from which to select are as follows:

Energy type	Detector
1. visible light	photoelectric light meter
2. gamma rays	Geiger counter
3. radio waves	wave meter
4. visible light	solar cell with voltmeter
5. visible light	paraffin photometer comparator

Depending on the schedule, the teacher may find that there is sufficient time to rotate the assignments of the student groups.

SCHEDULING

Use this experiment with Unit Eight, Part II.A.2.

TIME REQUIRED

25 minutes for each method utilized

MATERIALS FOR EACH LABORATORY STATION

METHOD I

1 lamp in socket
1 light meter (Photographic type will suffice.)
1 meter stick

METHOD II

1 gamma or beta emitter sample
1 Geiger counter (e.g. ''Classmaster'')
1 meter stick

METHOD III

1 radio frequency oscillator (unshielded) (Certain radio receivers can be used.)
1 wavemeter (from electronics shop) may be easily built by student from directions in *Radio Amateur's Handbook*
1 meter stick

METHOD IV

1 solar cell (ordered from supply requisition list)
1 resistor 500 - 2000 ohms

1 voltmeter 0 - 2 volts
1 lamp
1 meter stick

METHOD V

2 paraffin blocks (regular size)
1 aluminum foil 3" x 3"
6 candles
1 meter stick

LABORATORY HINTS

1. Begin early to collect the equipment needed for this experiment, and check it personally for deficiencies. Assure that the room lighting is adequate.
2. Prior to the day of the experiment, determine the placement of the apparatus to minimize interference in the activities of the various student groups.
3. Explain that all the methods involve the same kind of energy but that the human eye is capable of receiving only a small band of the electro-magnetic spectrum. In addition, point out that the different frequencies require structurally different emitters and detectors.
4. It is probably best to plot intensity of radiation as a function of $\frac{1}{d^2}$, where d is the distance from emitter to detector. The student then is able to recognize the direct proportion as a straight line sloping up to the right.

EXPERIMENT 50

PROBING THE MYSTERIES OF SATELLITE ORBITS

INTRODUCTION

The purpose of this experiment is to help the student discover the properties of satellite motions in circular orbits. The student will learn the relationships among velocity, centripetal force, mass, and radius for circular motion in general. Activities lead to the discovery that $F_c \propto v^2$ if m and R are constant. The student also may find other relationships, if time permits. The equation resulting is $F_c = \frac{mv^2}{R}$. With minor changes, the student may plot period T (time for one revolution) and Frequency f, (number of revolutions per second) instead of velocity. In this case, the equation would be $F_c = \frac{4\pi^2 mR}{T^2}$ or $F_c = 4\pi^2 mRf^2$.

SCHEDULING

Use this experiment with Unit Eight, Part IV, B.2., and Part IV.C.

TIME REQUIRED

45 minutes

MATERIALS FOR EACH TEAM OF THREE

1 glass tube handle
1 cord, fish line, 2 meters long
20 washers, all alike
1 alligator clip
1 rubber stopper
2 sheets of graph paper
1¼" dowel or pencil
1 meter stick
1 stop watch or clock with sweep second hand
1 paper clip

PRECAUTIONS

The glass tube used in this experiment should be wrapped with tape to prevent injury in the event that it should break.

LABORATORY HINTS

1. Emphasize that it is not necessary to use standard units of measure to discover fundamental laws. Here, arbitrary units of force and mass are utilized. Centripetal force is measured in washers, and mass in measured in stoppers.
2. Point out that the experiment can be performed at home or outdoors.
3. Inform the class that the size of the glass tube is not critical, but that the ends must be smoothly fire polished.
4. To minimize friction, use fisherman's hard nylon, braided 12-lb. test casting line.

ASTRONOMY SLIDES*

INTRODUCTION

Through the cooperation of the Audio-Visual Section, Instructional Services Branch, a set of Astronomy Slides has been placed, on long-term loan, in the science department of each high school offering Advanced Physical Science. The slides were produced by the California Institute of Technology and include actual photographs made at the Mt. Wilson and Mt. Palomar Observatories. The following slide descriptions contain detailed explanations of the contents of the slides.

SLIDE DESCRIPTIONS

I. INSTRUMENTS AND TOOLS OF ASTRONOMY

Slide No. S-2. A striking photograph of the Palomar 200-inch Hale telescope and dome taken at night by moonlight. The shutters are open, and the telescope is seen pointing toward the zenith. Palomar observatory is located at an altitude of 5,600 feet. The metal dome, which revolves on steel tracks, is 137 feet in diameter and 135 feet in height. It weighs about 2,000,000 pounds.

Slide No. S-3. An outstanding interior photograph, showing the 200-inch Hale telescope on Palomar Mountain. An astronomer and assistant standing on the floor beneath the mirror cell give an excellent indication of the immense size of the telescope. The aluminizing tank is seen in the background, and the central control panel of the telescope is shown between the piers of the north polar axis.

Slide No. S-4. Interior photograph, showing the 200-inch Hale telescope on Palomar Mountain pointing toward the west. An astronomer is sitting in the ingenious elevating chair, and he is placing a plate holder into position at the Cassegrain focus of the telescope.

Slide No. S-5. View looking up at the 200-inch Hale telescope's mirror cell. A portion of the north bearing is shown in this medium close photograph. The astronomer in the Cassegrain chair is inserting the plate-holding device.

Slide No. S-6. Close-up photograph of an astronomer beneath the 200-inch Hale mirror cell at the Cassegrain focus. This photo shows part of the counter-balancing system, which gives uniform support to the great weight of the mirror. This system is essential to provide the support to keep the optical perfection of the 14½-ton Pyrex mirror, the "eye" of the telescope, no matter what the position of the telescope. Also shown clearly are the red fan blades of the mirror's ventilating system, which helps prevent distortion of the mirror because of uneven temperature change.

Slide No. S-7. Photograph showing an astronomer in the elevator, which carries him to the prime focus cage of the 200-inch Hale telescope on Palomar. The upper end of the telescope tube is shown with the prime focus cage supported in the center of the tube. The telescope tube is moved into a vertical position, from which the astronomer can easily step out of the elevator and into the cage. The observer rides in this cage while exposing his photographic plates at the prime focus.

Slide No. S-9. The upper part of the tube and cage of the 200-inch Hale telescope on Palomar is seen in a vertical position and pointing toward the zenith. An astronomer is shown getting into the observer's cage from the prime focus elevator, which has reached a position near the top of its run inside the huge dome of the observatory.

Slide No. S-11. Close-up view of the inside of the prime focus cage of the 200-inch Hale telescope on Palomar mountain. An astronomer has a plate in position, and a slide is out ready for photographing. A guiding eyepiece and hand-held telescope controls are used to keep the star images exactly centered on the plate while the exposure is being made. Details of the inside of the cage, the pedestal, and the plate-holding device are clearly shown.

Slide No. S-12. An astronomer is shown at the coude eyepiece of the Palomar 200-inch Hale telescope, centering the star to be photographed. He is holding the controlling device which moves the telescope and brings the star image into proper position.

*Adapted from *Design of The Cosmos*, with permission of Holt, Rinehart, and Winston, Inc., New York, 1965, pp. 185-205.

Slide No. S-13. A photograph of the interior of the coude observing room of the 200-inch Hale telescope on Palomar shows various accessories at the slit of the large coude spectrograph. During exposures, the image of the star is held on the slit either by the astronomer, using the eyepiece and telescope controls, or automatically, by the photoelectric guider.

Slide No. S-14. Photographed here is a portion of the interior of the coude grating spectrograph of the Palomar 200-inch Hale telescope, showing the Schmidt camera of 18-inch focus. An astronomer is putting a plate-holder into position.

Slide No. S-15. A view within the coude spectrograph in a room at the south end of the polar axis of the 200-inch Hale telescope on Palomar. The 12-inch diameter composite grating is seen near the center. An astronomer is putting a plate-holder into position at the focus of the 18-inch camera.

Slide No. S-16. The 48-inch Schmidt telescope on Palomar Mountain is photographed with an astronomer at the eye piece of the refracting-type guide telescope. This telescope has a mirror 72 inches in diameter and a correcting plate 48 inches in diameter. The Palomar 48-inch Schmidt acts as a ''scout'' for the 200-inch Hale telescope's program. The night assistant is seen in the background at the control panel of the telescope.

Slide No. S-17. The night assistant is shown placing the plate-holder into the loading mechanism; this automatically positions the plate-holder at the focus of the telescope and withdraws the slide, making ready for exposure.

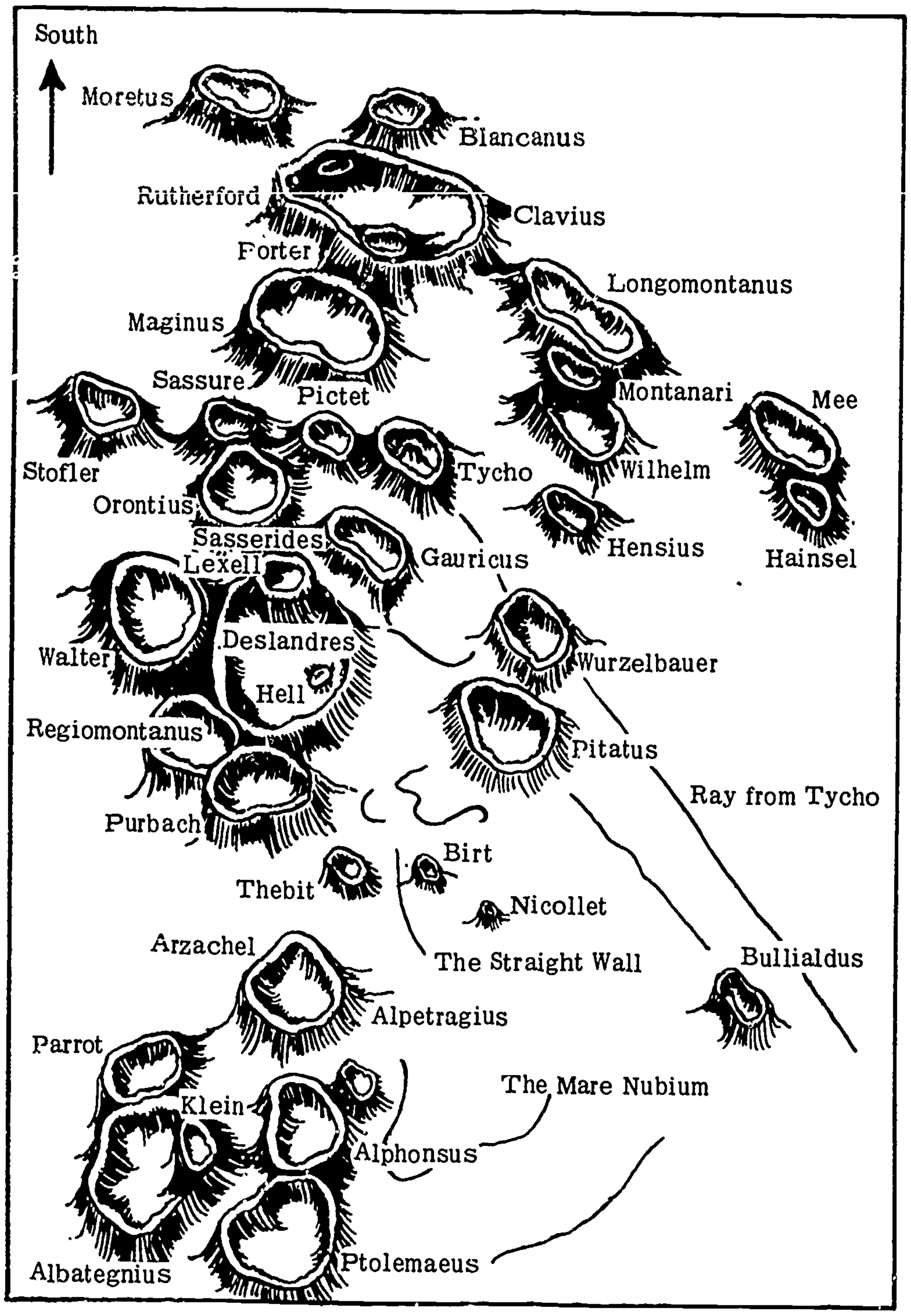
Slide No. S-18. A close-up of a night assistant loading a 14" × 14" plate-holder into the loading mechanism of the Palomar 48-inch Schmidt telescope. Details of the plate-holder and loading mechanism are shown.

II. THE MOON

Slide No. 258. The Southern Region of the Moon from Ptolemaeus to the Southern Limb. The term ''limb of the moon'' refers to the edge as seen against the background of the sky. There is another term ''the terminator,'' which is that name for the sunset-sunrise line or darkness-daylight line. It is along the terminator that the best shadows are seen, and the astronomer can study the height and depth of the lunar features. The largest crater on the lunar visible surface is seen in this slide. It is the crater Clavius with a diameter of 145 miles and a wall height of 12,000 feet. Conspicuous on this slide is the Straight Wall in the Mare Nubium. This is called a fault scarp. There is a ray that emanates from the crater Tycho and streaks to the northeast that is faintly visible. The key chart to the slide identifies the following features and dimensions:

Crater	Diameter (miles)	Height of walls
Blancanus	57	12,000 ft.
Rutherford	25	
Clavius	145	12,000 ft.
Maginus	110	
Sassure	30	8,000 ft.
Tycho	50	13,000 ft.
Longomontanus	90	
Hainzel	60	9,000 ft.
Hell	20	
Regiomontanus	80	7,000 ft.
Purbach	75	8,000 ft.
Birt	12	6,000 ft.
Nicollet	10	
Gauricus	40	9,300 ft.
Wurselbauer	50	5,000 ft.
Pitatus	50	
Wilhelm	60	11,000 ft.
Arzachel	60	13,500 ft. on west
Alpetragius	27	12,000 ft. (6,000 ft. mt. in center)
Alphonsus	70	7,000 ft.
Ptolemaeus	90	9,000 ft.
Parrot	40	5,000 ft.
Albategnius	80	10,000 to 14,000 ft.
Bullialdus	39	8,000 ft.

The Mare Nubius (sea of clouds)
The Straight Wall 60 miles in length; 800 ft. lower on the east



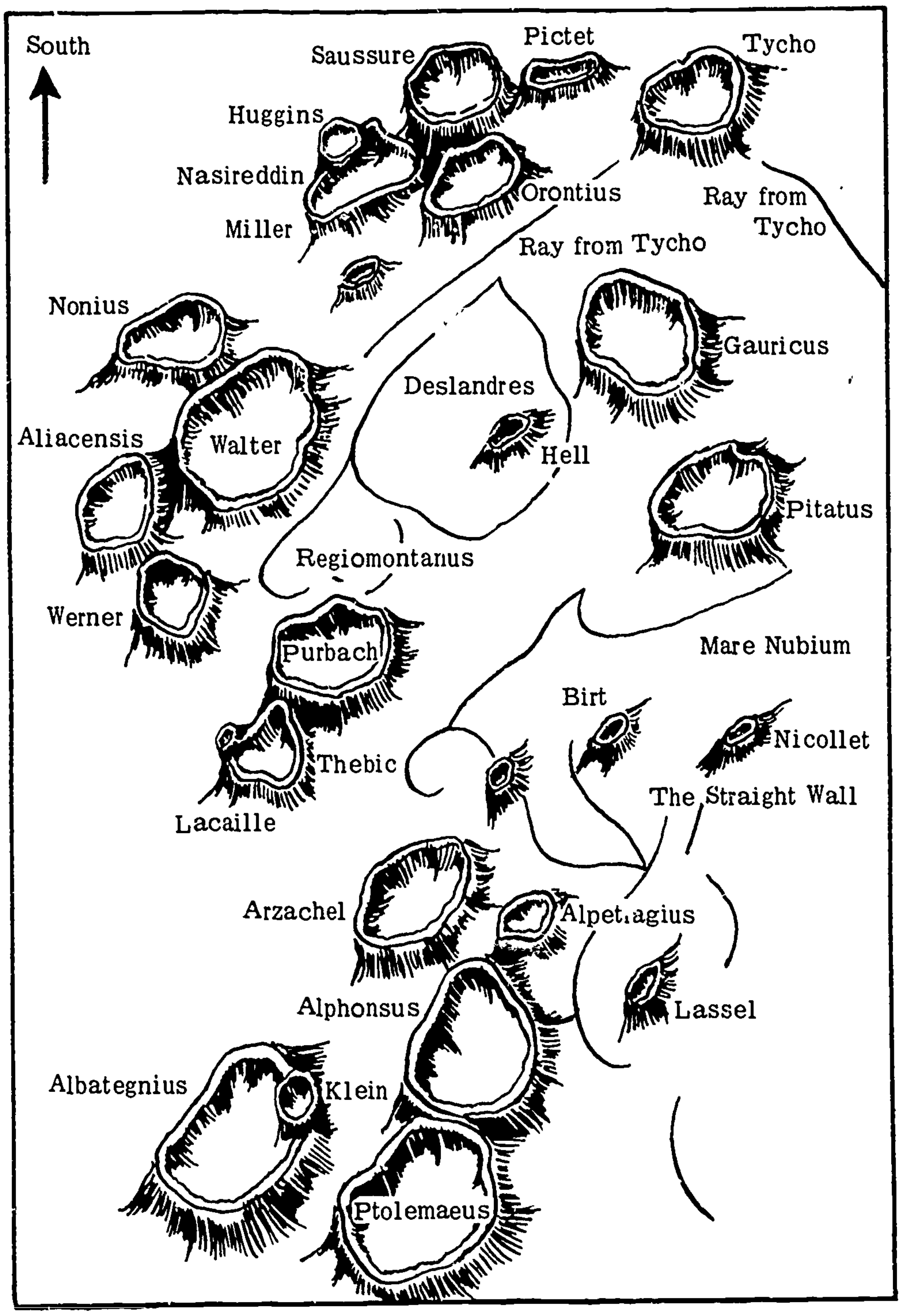
Key Chart to Slide No. 258 - The southern regions of the moon, from Ptolemaeus to the Southern Limb.

Slide No. 259. The South Central Region of the Moon from Ptolemaeus to Tycho. This very rugged area of the moon contains some very interesting features. The flat plain in the lower part of the photograph is the Mare Nubium, or the Sea of Clouds. In this area, there is an interesting fault scarp, or wall. This is called "The Straight Wall." In this photograph, the sun is in the direction of the Mare Nubium (coming from the right); the wall shows a bright line. At other times, when the direction of the sun is from the left, the straight line appears to be dark. The line is 60-70 miles in length and is known to be 800 feet lower on the east. Prominent objects in the slide and their dimensions are:

Crater	Diameter (miles)	Height of walls
Tycho	50	13,000 ft.
Pictet	40	
Sassure	30	8,000 ft.
Aliancensis	52	16,500 ft.
Nonius	20	
Werner	45	15,000 ft.
Regiomontanus	80	7,000 ft.
Purbach	75	8,000 ft.
Hell	20	
Gauricus	40	9,300 ft.
Pitatus	50	

Birt	12	6,000 ft.
Nicollet	10	
Arzachel	60	13,500 ft. on the west
Ptolemaeus	90	9,000 ft.
Alphonsus	70	7,000 ft.
Alpetragius	27	12,000 ft.
Lassell	14	
Albategnius	80	10,000 to 14,000 ft.

On the night of November 3, 1958, a Russian astronomer, Dr. N.A. Kozyrev of the Pulkova Observatory at Leningrad, was making a systematic spectroscopic search of the lunar surface, using the 50-inch reflector of the Crimea Observatory. The slit of his spectrograph was extended east and west across the central high, steep peak of Alphonsus and extended into areas beyond the crater. From this view, he was able to detect a ½ hour long discharge of gas from the craterlet atop the central mountain. What he observed was the luminescence caused by solar radiation on the gases. For a detailed account, refer to "The Alphonsus Story" by Dinsmore Alter in *The Griffith Observer* (March, 1959); and to "Observation of a Volcanic Process on the Moon," by Nikolai A. Kozyrev in *Sky and Telescope* (February, 1959).



Key Chart to Slide No. 259 - South central region of the moon.

Slide No. 260. The Crater Copernicus and the surrounding region. Copernicus is a walled crater with a diameter of 56 miles. There are seven individual peaks in its center. The outer walls of the crater rise to 12,000 feet on the west side. The inner slope of the wall is terraced, and the outer slopes of the wall are very rugged with evidence of vast landslides. North of Copernicus are the Lunar Carpathians. This is a mountain range rising to heights of 7,000 feet. (See chart on page 31.) Prominent objects shown on the slide and their dimensions are:

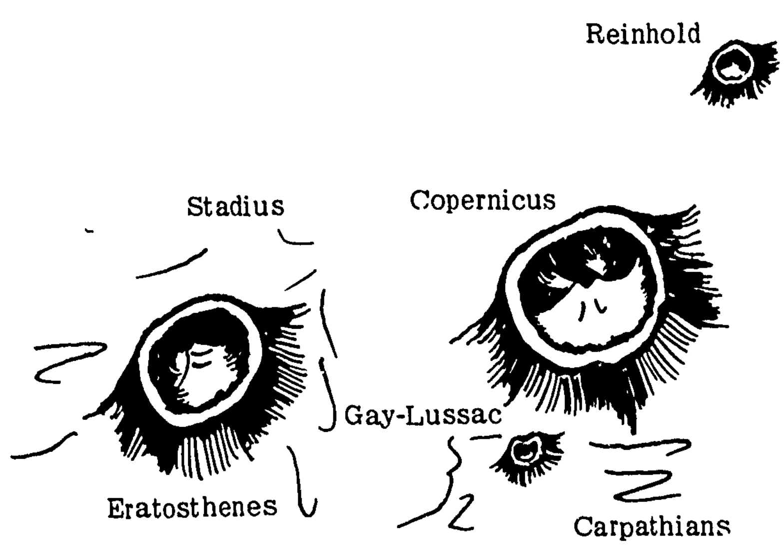
Crater	Diameter (miles)	Height of walls
Eratosthenes	38	16,000 ft.
Gay Lussac	15	
Lansberg	25	
Pytheas	12	
Reinhold	30	
Stadius	Stadius seems to have been a crater once; it has been filled almost to the rim of its walls.	

Slide No. 264. The Lunar Crater Clavius. This is a photograph of the largest visible crater on the moon and was taken with the 200-inch Palomar reflector. Clavius is 145 miles in diameter. Its walls are 12,000 feet in height, with peaks ranging to 17,000 feet above the floor of the crater. On the lower (to the bottom of the slide) wall of Clavius is the crater Porter, which has a diameter of 25 miles. On the upper wall of Clavius is the crater Rutherford which has a diameter of 25 miles. On the slide is shown the crater Blancanus. It is 57 miles across, with walls extending to a height of 12,000 feet. Klaproth, the crater shown in the very upper right-hand corner of the slide, is 60 miles across, and Gruemberger in the upper left is 58 miles in diameter. This is a rough, mountainous region.

Slide No. 261. The Central Region of the Moon. Prominent craters and their dimensions are listed below:

Crater	Diameter (miles)	Height of walls
Arzachel	60	13,500 ft.
Alpetragius	27	12,000 ft. (6,000 ft. central mts.)
Alphonsus	70	7,000 ft.
Ptolemaeus	90	9,000 ft. highest peaks
Albategnius	80	10,000 to 14,000 ft.
Hipparchus	100	4,000 ft.
Copernicus	56	12,000 ft. on west
Eratosthenes	38	16,000 ft.
Archimedes	50	4,200 ft.
Reinhold	30	9,000 ft.
Timocharis	25	7,000 ft.
Stadius	obscure	
The Mare Imbrium		

Slide No. 265. The Crater Copernicus and its immediate region. Copernicus is a magnificent example of a large lunar crater. The dimensions are measured from the apparent diameter, in relation to the distance of the moon from earth. The heights are measured by the length of the shadow that is thrown by the object. The astronomer knows the altitude of the sun for any longitude on the moon at a time instant. The length of shadow is therefore a function of the height of the edifice if the angle of the sun's rays is known. Eratosthenes, which is shown on the slide, is 38 miles in diameter. The filled ring of Stadius is to the left of Copernicus, as are the numerous little so-called "crater pits" that seem to make a chain north (to the bottom) of Stadius. North is at the lower part of the slide and south is at the top. This is a result of the fact that the astronomical telescope inverts the objects, as the astronomer views the photographs of the lunar surface as he would see it through the telescope. The image could be turned right-side up again, but it would take a number of lenses to do so.

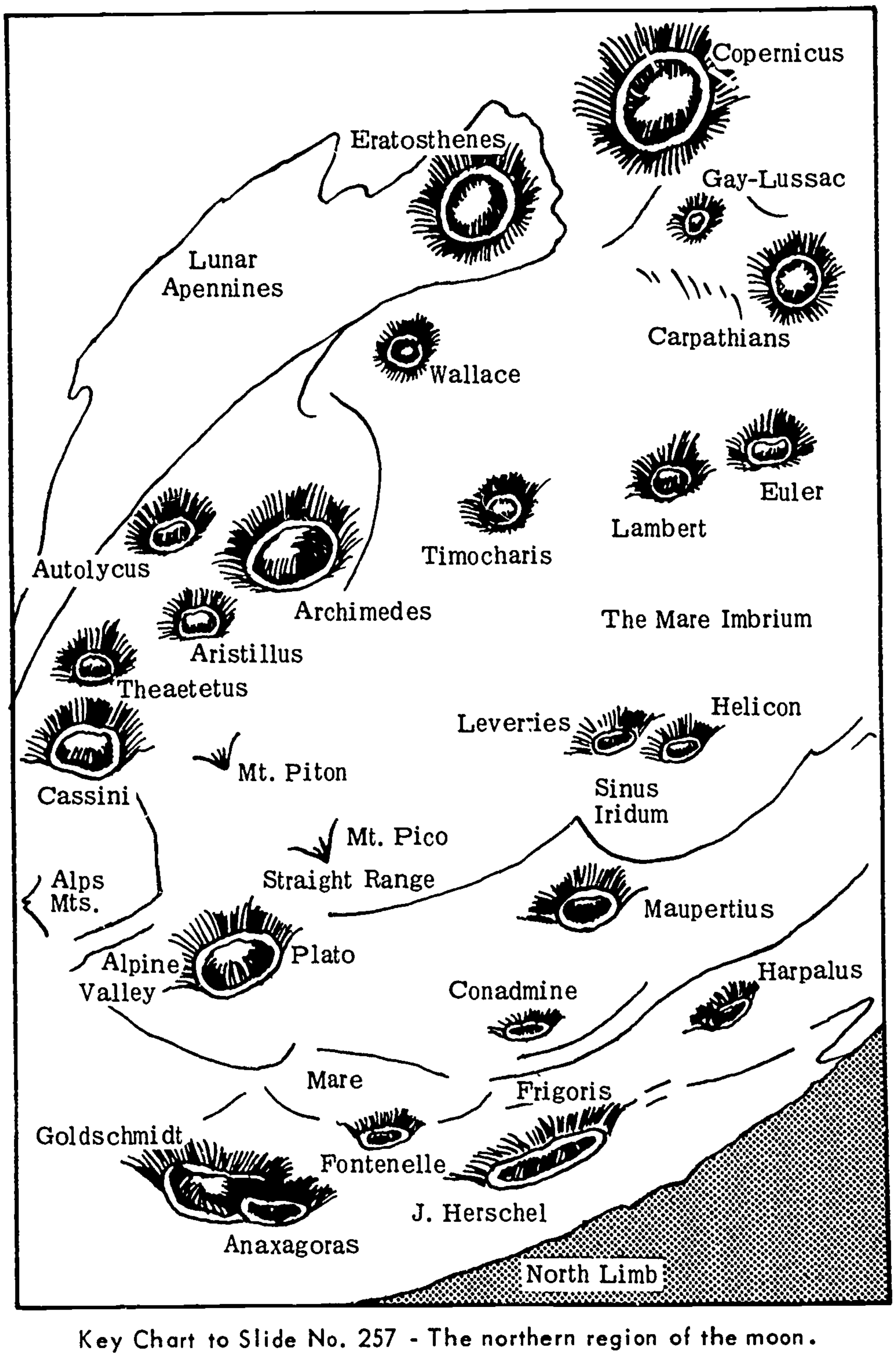


Key Chart to Slide No. 265 - The crater Copernicus.

Slide No. 257. The Northern Region of the Moon. Prominent craters and two mountains are clearly visible on this slide. Dimensions listed below refer to the key chart of the slide:

Crater	Diameter (miles)	Height of walls
Copernicus	56	12,000 ft. on the west
Eratosthenes	38	16,000 ft.
Timocharis	25	7,000 ft.
Lambert	18	3,000 ft. mountain on w. wall
Archimedes	50	4,200 ft.
Autolycus	24	9,000 ft.
Aristillus	35	11,000 ft. peaks
Cassini	36	
Plato	60	3,500 ft.
Anaxagaros	32	10,000 ft.
Mt. Pico		8,000 ft. in height
Mt. Piton		7,000 ft. in height

This is a closeup view of the general region of the Mare Imbrium. The student may want to refer to slide 263, which shows the entire last quarter, to observe the section that is shown here. The Alpine Valley in the Alps Mountains, shown on the lower left part of the slide, is interesting. It seems to be a long trough through the mountains. It is 80 miles in length and approximately 7 miles wide. The Lunar Appennines are shown in the upper left part of the slide. This range borders the Mare Imbrium. The highest peak in the range is Mt. Huygens at 18,500 feet. There are numerous other peaks almost as high. The Sinus Iridum, or the "Bay of Rainbows", is seen in the lower right-hand quarter of the slide. It is a semi-circular area formed by the high Jura Mountains. The two capes forming the bay are 134 miles apart. There are heights in the Jura Mountains of 20,000 feet.



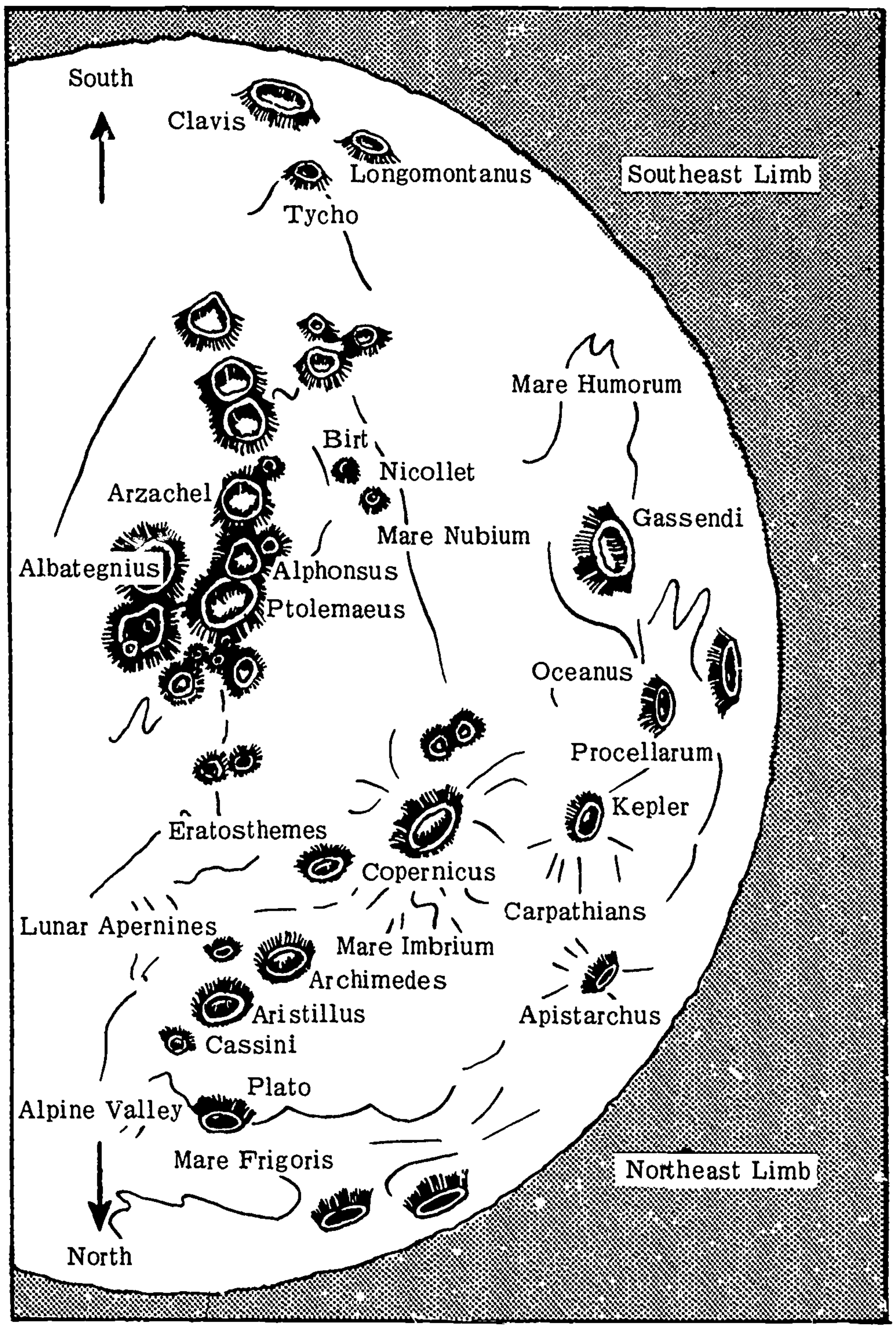
Key Chart to Slide No. 257 - The northern region of the moon.

Slide No. 263. The Moon at Last Quarter. This slide has been made fro. . photographs taken with the 100-inch reflecting telescope at the Mount Wilson Observatory. The last quarter moon is one that is 21 days old. The age of the moon is computed from the number of days that have passed since the new moon. The moon at last quarter is then 90° west of the sun and rises at midnight. The sun illuminates 180° of the surface of the moon, but only 90° of that area is turned toward the earth.

The following features are well placed on the slide for observation:

The largest of the plains, or level areas on the surface of the moon, is the Mare Imbrium. The term "mare" is derived from the Latin and means sea. This is a misnomer, for it is known that the moon does not have seas nor oceans, but the persons who originally gave names to some of the features were not aware of this fact. The Mare Imbrium is 750 miles from east to west and 690 miles fro.n north to south. The *Griffith Observer* calls this "The Queen of the Uncharted Seas."

Among the larger craters visible on the slide ate Ptolemaeus, Copernicus, Plato, Tycho and Clavius. Also visible are the Mare Nubium, the Mare Humorum, and the Oceanus Procellarum. (These translate into the Sea of Clouds, the Sea of Humors and the Ocean of Storms.) All of these are large flat expanses of the lunar topography. Prominent mountain ranges visible are the Lunar Apennines, the Alps, and the Carpatheias.



Key Chart to Slide No. 263 - The moon at last quarter.

Slide No. 253. The Full Moon. The full moon is the poorest time for observation, if one desires to note the craters and features that are best seen in a shadowed condition. The full moon appears the same as a flat, lighted photograph and has very little detail. However, the full moon is the best time to detect the lunar rays, the white streaks that appear around the craters. Also, the full moon is the best time to observe the very brightest craters, such as Proclus at the edge of the Mare Crisium and Aristarchus in the Oceanus Procellarum. The full moon is the time also to see the total picture of the Maria as they are related to one another. At this time, the Maria appears to be quite dark in relation to the other parts of the bright rugged surface.

III. THE MILKY WAY GALAXY

Slide No. S-23; NGC 1976 Messier 42. The Great Nebula in the Constellation Orion. This object can be seen with the unaided eye as a hazy spot. It lies in the sword of Orion, the second star from the tip of the sword. Actually it is a tremendous cloud of gas in space. Its distance is about 1600 light years, and its diameter is about 30 light years. Its distance has been derived from knowledge of some of the stars enmeshed within it. These are very hot B and A type stars that cause the gases to emit light by ultra-violet excitation. However these stars cannot be observed in this slide. To obtain a picture of the gases, very long exposures required; the stars are enmeshed in the very bright portions of the nebula, just to the left of the dark lanes. The density of the gases involved is very low. The entire nebula probably has a mass of 1000 suns. This means that the density is less than the best vacuum produced by man here on the earth, 10^3 to 10^4 hydrogen atoms/cm^3. This great nebula is well known because it is typical of the great clouds of gases that can be observed in the universe. Views of it appear in nearly every popular book on astronomy. It can be seen with the smallest telescopes. One can find its position from any good map of the Orion region. Use of this kind of color transparency of astronomical objects is relatively new. One should make mention of the fact that the stars are seen as being different in color. This is a result of their temperatures. The hotter stars will be blue-white. The cooler stars are red or orange. Most of the stars near to and enmeshed in the nebula are of high energy, of class B and have very high temperatures.

Slide No. S-25; NGC 6523 Messier 8. The Lagoon Nebula in the Constellation Sagittarius. This slide is based upon a photograph taken through a 200-inch telescope. The same object is shown in color on slide S-25. This is a great cloud of dust and gases that surrounds a cluster of stars. These hot, high-energy stars emit great quantities of ultra-violet radiation. The radiations excite the gases in the nebula and cause the emission of light that makes visible the great nebulous clouds. If this material were away from the bright stars, they would appear to be dark as many of the nebulae do. Messier 8 is at a distance of 2300 light years from us. The density of the gases in the nebula is of the order of 10^3 to 10^4 atoms per cubic centimeter, which is probably at a lower density that that of most of the good vacuums produced on earth. This object is a fine one telescopically and can even be detected as a hazy nebulous spot in western-central Sagittarius. It is about 5° west of the star Lambda Sagittarii and is on the meridian at 10 p.m. about the middle of July. Binoculars are sufficient to show its position as a nebulous spot. In Norton's *Star Atlas,* its position is indicated by 8M.

Slide No. S-25; NGC 6523 Messier 8. The Lagoon Nebula in the Constellation Sagitturius. The slide is of the same object as that shown in slide 36; however, this view is in color. Comparison of the black and white photograph with the color is interesting. Astronomers hardly expected the bright hues of color that are evident. The dark lanes of obscuring materials are beautifully shown in the slide.

Slide No. S-29; NGC 6514 Messier 20. The Trifid Nebula in the Constellation Sagittarius. Trisected with dark rifts of cosmic dusts which form non-luminous clouds between us and the stars, this is one of the most striking of the diffuse nebula. The Milky Way contains vast amounts of finely divided interstellar dusts. Most of it is concentrated in clouds ranging from round, black, compact globules a tenth to a hundredth of a light year across to enormous aggregations of gas and dusts several hundred light years in diameter, such as the great clouds in Orion, Taurus, Cygnus and Sagittarius. The great clouds of dusts and gases are associated with the spiral arms of the galaxy. In the direction of the center of the galaxy, they grow very numerous and thick. The Trifid nebula is one of the great clouds that can be observed toward the central regions of the galaxy. Its distance is estimated to be 200 light years. It gives off radiation because it is near enough to extremely hot stars to be excited into emission. A single O-type star may ionize all the hydrogen within a sphere with a 400-light year radius. A cooler star, such as type BO, ionizes all gas to a distance of 80 light years. The student also must think three dimensionally, for all the gases and obscuring material are not at the same distance from the earth.

Slide No. 151; NGC 2237. The Rosette Nebula in the Constellation Monoceros. This beautiful slide shows the association between hot stars and gaseous material. This is a gaseous nebula that surrounds an open-type cluster. The cluster stars can be seen in the center of the nebula. These are very hot O, B, and A type stars. The ultra-violet radiation from them causes the nebula to radiate visible radiations. This is called excitation. The ultra-violet radiations cause the electrons to move into higher energy shells. When they return to their ground states, they emit radiations of longer wave-lengths. These are visible. Of prime importance in this slide is the conspicuous lane of globules located in the first quadrant of the nebula. Astronomers now tend to believe that stars evolve from nebula and are continuously in the process of evolving in the gaseous regions. To some astronomers, these globules are the protostars, or stars in the process of

formation. The average diameter of the globules are in the order of 0.1 parsec (0.326 l.y.). They are sufficiently opaque that their densities must be at least 10-22 gms/cm^3. Their masses are therefore an appreciable fraction of a solar mass, and some may exceed that of the sun. The gravitation of such objects is sufficient to hold them as a mass, and it has been suggested that these may slowly contract and develop into stars. The distance to the nebula is about 2500 l.y.; its diameter is 50 light years.

Slide No. 10; The Cone Nebula in the Constellation Monoceros. This beautiful gaseous phenomenon is located in the south outer region of the Nebula NGC 2264. This photograph was taken through the 200-inch Palomar reflector. This object appears to be a tremendous admixture of both bright and dark nebulosity. In the left-hand part of the slide, the clouds of bright nebula are shown to be excited by the stars that the nebula surrounds. From the left side of the slide, a great promontory of intruding opaque matter points from the abyss of space. This finger of dark material seems like a dark cloud with a silver lining because of the great illuminated areas that lie behind it. The distance is approximately 4000 light years.

Slide No. 108; NGC 6960. The Western Loop of the Veil Nebula. The bright object that appears very near to the nebula is the star 52 Cygni.

Slide No. S-20; NGC 6992. The Eastern Loop of the Veil Nebula in the Constellation Cygnus, is shown in color. It was discovered visually in 1784 by William Herschel. Wisps of gases appear to make a circle when they are joined by an imaginary line. This is the reason that these objects are considered as being the remnants of a super-nova. By the measurement of the velocity of some of the streamers by the Doppler shifts of spectrum lines, it has been determined that the gases are expanding at the rate of 45 kilometers per second. It is also known that the nebula is growing in its linear diameter by .06 seconds of arc per year. From this information, we can calculate its distance from earth as 1000 light years. It is estimated from these facts that the nebula may be about 30,000 years old. The Veil Nebula is a bright object and is difficult to see. Long-exposure photographs are needed to observe the details

Slide No. 156; NGC 7000. The North American Nebula in the Constellation Cygnus is shown in color. The objects that appear so evenly distributed over the field of the photograph are foreground stars, nearer to earth than to the nebula. This region of the nebula seems to be fairly free of obscuring matter.

The Pleiades Cluster in the Constellation Taurus might be shown, since this cluster is enmeshed in nebula. The descriptive material relative to the Pleiades is under the heading of galactic cluster. See slide S-30.

Slide No. S-21; NGC 6720 Messier 57. The Ring Nebula in the Constellation Lyra. This object is the prototype of the Planetary Nebula. The nomenclature of such objects is discussed under slide number 106. There are now some 500 known planetary nebula in our galaxy, the most remote being about 33,000 light years from earth. There must be many more in the galaxy that are hidden by the clouds of dusts and gases. It is probable that there are as many as 10,000 in the galaxy. By their distribution, these objects show a concentration toward the galactic center. Inside the typical planetary nebula is a very hot central star, which has a temperature of about 50,000 to 100,000 degrees Kelvin. This star is smaller than our sun but has about the same mass. Planetary nebulae are expanding with velocities of approximately 10 to 50 km/sec. Their densities are very low, of about 10^4 atoms per cubic centimeter. From their appearance, it seems that most of the material in the nebulae are in a relatively thin shell. It is certain that this kind of object is not the remains of nova. The planetary nebulae contain at least 1/10 as much matter as the sun, whereas it is known that the novae released a mass of expanding gases of about 10^{-5} or 10^{-6} the mass of the sun. Expansional velocities of the novae are relatively high, whereas the expansional velocity of the planetary nebulae are low. The ring nebula shown here is a typical planetary nebula. The radius of the expanding shell of gas is somewhat less than 100,000 astronomical units. It is believed that, at 200,000 astronomical units, the gases in these objects would begin to break up. Based upon the expansional velocities of the nebulae, the possible lifetime for a planetary nebula will not exceed 20,000 years. Diameters of planetary nebulae range from 20,000 to 200,000 A.U.

The ring nebula can be seen with a six-inch telescope. However, the larger the aperture of the instrument, the brighter will be the ring. The object is not easy to see, because of its apparently small diameter. It is located between the stars Beta and Gamma Lyra and is marked as 57M in Norton's *Star Atlas*.

Slide No. 48; NGC 7293. The Great Planetary Nebula in the Constellation Aquarius, "The Burst." This photograph was taken through the 200-inch telescope at Mt. Palomar. Like the several hundred planetary nebula that are known, this ring-shaped mass of gas and dust is illuminated by excitation from a very hot central star. The ultra-violet emissions from the star cause the nebula to shine by fluorescence. This

object's distance is about 600 light years. It is one of the nearest and brightest of planetary nebulae. It may be seen with a small telescope as a nearly featureless ring. Peculiar spoke-like details appear near the inner rim of the ring. This peculiar structure was first observed in photographs taken with the 100-inch telescope. It is not known yet whether the spokes are falling toward the central star, or whether they have been ejected from it. Comparison of photographs taken a few years hence compared with the earlier plates from Mt. Wilson may settle the question.

Slide No. S-26; NGC 6853 Messier 27. The Dumbell Nebula in the Vulpecula. This is one of the largest and brightest planetary nebula in the entire sky. It is an enormous expanding cloud of highly rarified gas and is excited to emit light by a very faint hot central star. The distance of Messier 27 from earth is estimated at 1000 light years. The term "planetary nebula" is unrealistic, since it has no connection at all with planets. Some time ago, little was known about the gaseous nebula and the great galaxies. At that time, telescopes were fairly small and objects like Messier 27 had a more or less disc-shaped appearance. The name planetary nebula was applied. The Ring Nebula in Lyra, Messier 57, is the ideal prototype of this class of object. The slide also shows stars of various colors, which is a clue to their temperatures. The hotter stars are blue-white; the cooler stars are red. The high-temperature star that excites M27 into emission is seen directly at the center of the nebula. This object can be observed in the smaller telescopes (6" aperture) by pointing toward Gamma Sagittae and then moving in declination 3½° northward. In Norton's *Star Atlas,* it is labeled 27M.

Slide No. S-22; NGC 1952 Messier 1. The Crab Nebula in the Constellation Taurus. This is a bright, diffuse nebula which emits light from the hot star in the center. The object is very interesting in that it appears to be the remains of the Supernova of 1054 A.D. The object was discovered by Messier in 1764, when he was cataloguing objects that he could confuse with comets. Study of the spectrum of the Crab Nebula and comparison with plates taken quite some years ago indicate that it is expanding at a rate of some 600 miles per second. Extrapolating this backward in time, astronomers conclude that the expansion must have started some 800 or 900 years ago. Lundmark, a Swedish astronomer, made this discovery in 1054 A.D. Chinese and Japanese astronomers had observed and recorded a very bright nova in the exact position now occupied by the Crab Nebula. Its brightness was equal to that of Jupiter (magnitude –2). Since the distance of the nebula is known to be 5000 to 6000 light years, the absolute magnitude can be calculated to be –13. Clearly, it was a supernova, and a nebula was its offspring. Two faint stars are detected near its center, one being the remnant of the supernova. The Crab Nebula is also a very powerful radio emission source. This nebula is very difficult to observe in small telescopes because of the faintness of its image. It is marked in Norton's *Star Atlas* as 1M. It is just (approximately 1°) northwest of the star Zeta Tauri.

Slide No. 201. The Milky Way in the Constellation Sagittarius. Astronomers have concluded that, when we look toward the Sagittarius region, we are looking in the direction of the center of the galaxy. In this slide, one can note the great aggregations of stars that form the Milky Way in that direction. We cannot observe the center which is about 32,000 light years from earth. We possibly see some 6000 to 10,000 light years in the direction of the center. There are numerous clouds of the dark, obscuring material that block the stars from our view. The stars themselves appear to be nearer together toward the center of the galaxy. On the slide, one can observe the increase in the linear width of the Milky Way, which is likely the bulge of the nucleus of the galaxy.

Slide No. 204a. The Milky Way in the Sagittarius Region. The slide shows the dark, obscuring material that occupies the median plane of the Milky Way. It is well to remember this kind of material because photographs of other galaxies show the same phenomenon. The galaxies themselves seem to be built on a pattern. The Milky Way, which is our own galaxy observed from our inner position, is no different.

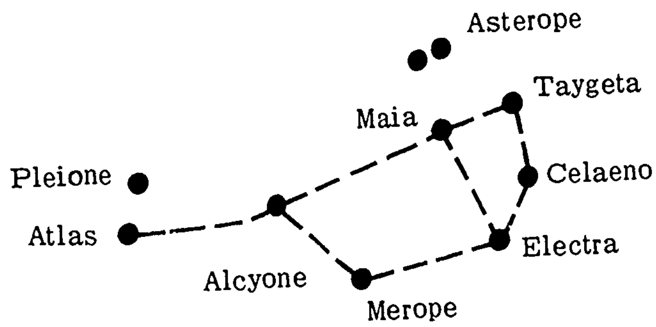
Slide No. 204b. The Milky Way in the Constellations Serpens and Aquila. We have moved to the left from the Sagittarius regions, away from the direction of the center of the galaxy. The ever-present clouds of dark, obscuring materials that shield our view into the beyond can still be observed. On the right central edge of the slide are globular clusters that are a part of the galaxy. These clusters and their distribution are the first real evidence that the sun is not at the center of the galaxy.

Slide No. 204c. The Milky Way in the Constellation Cygnus. We are looking out in the 90° direction from the galactic center. The bright star shown on the slide is Vega. With care, the entire Constellation of Lyra can be observed. The North American Nebula (Slides 156 and S-19) is very prominent, with the star

Deneb to its right. Near the center of the slide, the Veil Nebula (Slide 109 and S-20) are shown. In the lower right-hand corner, one can discern the constellation of Delphinus the Dolphin.

Slide No. 204d. The Milky Way in the Constellations Cygnus and Cassiopeia. The North American Nebula and Deneb are located on the right and are shown in slide No. 204c. The Constellation Cassiopeia is located on the left in the Milky Way. The great galaxy in Andromeda is evident in the corner of the photograph. It is the subject of slide number 150.

Slide No. S-30; NGC 1432. The Pleiades Cluster in the Constellation Taurus. This little group of stars is often mistaken for the Little Dipper. The latter, which is more correctly called Ursa Minor (The Small Bear), is actually in the north circumpolar sky as seen from latitudes in the United States. The Tail of the Little Bear, or the end of the handle of the Little Dipper, is the North Star Polaris. The cluster known as the Pleiades is contained within a circle having a diameter of twice that of the apparent disk of the moon. This slide shows the inner or central region of the cluster. Throughout history, this group has attracted attention. There are many myths and legends about the stars. In the stories, there always seem to be references to seven sisters, representing the seven visible stars. Yet, to the unaided eye, there are only six stars visible under average conditions. Keen eyes are at times able to observe others in the group.



The names of the brighter members of the cluster are:

Star	Magnitude
Alcyone	2.96
Atlas	3.80
Electra	3.81
Maia	4.02
Merope	4.25
Taygeta	4.37
Pleione	5.18
Celaeno	5.43
Asterope	5.85

The fact that these stars are known to belong to a group gravitationally involved lies in the detection of of motion of the group. They all seem to be moving in parallel paths through the galaxy. Therefore, the stars can be likened to a flock of geese flying in one direction, and a physical connection can be implied. There are 250 known or proved members and as many as 500 probable. The very brightest stars in the Pleiades, have nearly the same kind of spectra. For example, the nine brightest have either B5 or B8 spectra. This corresponds to a temperature of 13,000° Kelvin. The Sun is a G type star, with a temperature of 6000° Kelvin. If the sun were as remote as the Pleiades, it would appear as a star of magnitude 11. This is how bright the G type stars in the Pleiades appear to be. The absolute magnitude of the sun is approximately +5, which is its apparent magnitude at a distance of 33 light years. Stars like our sun in the Pleiades are therefore 6 magnitudes fainter than the sun would appear at 33 light years. Six magnitudes correspond to a difference in brightness of 250 times. Since brightness decreases with the square of the distance and the square root of 250 is about 16, the Pleiades must be 16 times 33 light years distance, or approximately 500 light years away. The space between the stars is not quite empty. In the photograph, there are clouds surrounding them. This nebulosity shines by reflected light. The nebulous material must be finely divided dust or very small solid particles, for the spectrum of the nebula is merely that of the stars embedded in it.

The entire cluster has a linear diameter of about 50 light years. In this volume, these are estimated to be some 500 stars. This means that the stellar density of the space occupied by the cluster is at least three times as great as the stellar density of the region near our sun.

Slide No. 30; NGC 5272 Messier 3. The Great Globular Cluster in the Constellation Canes Venatici. This is a photograph taken through the 200-inch Palomar telescope. It is a globular cluster similar in nature to the Great Star Cluster that is so well known in Hercules. Its distance is somewhat similar, being a little more than 30,000 light years from earth. There are some 100 of these clusters visible in the heavens. It was the distribution of the globular clusters that led Harlow Shapley to recognize the eccentric position of the sun in relation to the nucleus of the galaxy. The globular clusters form a spheroidal system of their own and surround the galaxy. Sometimes, the system is called the metropolitan galaxy. The distances to the globular clusters are well known. All of them contain RR Lyrae variable stars. Many of them are very rich in this type of variable. It is known that the RR Lyrae variables are near to absolute magnitude zero. Therefore, the distance of a cluster can be ascertained from the apparent magnitude of its variable stars. If Messier 3 were at the standard distance of 32.6 light years, its variables would appear at magniture zero, about as bright as the star Vega. In reality, they appear to be 15 magnitudes fainter, which is a factor of one millionth of the light intensity of Vega. The intensity of light falls off with the square root of 1,000,000. Thus, the cluster is about 10,000 parsecs away. A more recent determination by Harlow Shapley gives 9500 parsecs, or some 31,000 light years as the distance.

This cluster was one of the first whose stars were analyzed photoelectrically. The age of Messier 3, as determined from this type of analysis, is about 6 billion years. There are 164 variable stars in Messier 3; therefore, its distance from earth is still unknown. It is easily visible in a 6-inch reflecting telescope and labeled 3M in Norton's *Star Atlas*.

IV. GALAXIES

Slide No. 150; NGC 224 Messier 31. The Great Spiral Galaxy in the Constellation Andromeda. It is speculated that this spiral galaxy resembles our own Milky Way system. Two companion galaxies can be observed on the slide. The larger and brighter is NGC 205, and the other is Messier 32. These are to the Andromeda what the Magellanic Clouds are to our own galaxy. They are nearby attendants, but not implying a known gravitational connection. The diameter of the Andromeda galaxy is about 100,000 light years, and it contain all of the various kinds of stars and star groups and gaseous clouds that exist in our own galaxy. Its distance from earth is estimated to be between 1,500,000 and 2,000,000 light years. The distance is computed by measurement of the periods of variation of the Cepheid variable stars in the galaxy. There has been a number of Novae that have helped in the determination of the distance of Messier 31. The galaxy is only tilted 15° up from being perpendicular to our line of sight. The great galaxy in Andromeda lies about 1° from the star Nu Andromeda. It is labeled on most star maps as 31M in Norton's *Star Atlas*. It can be observed by the unaided eye as a hazy, nebulous spot. Binoculars show it well. Through telescopes, one can see the bright nucleus.

Slide No. S-24; NGC 224 Messier 31. The Great Galaxy in the Constellation Andromeda seen in Color. All of the objects shown on the slide are foreground stars belonging to our galaxy.

Slide No. 100; NGC 224 Messier 31. The Great Spiral Galaxy in the Constellation Andromeda. This slide shows the Central Region only of Messier 31. It was taken through the 100-inch telescope at Mt. Wilson. The slide shows the south edge of the Andromeda Spiral. Resolution of the arms of the spiral into stars is readily apparent, as are the knots of dark dusts and gases associated with the spiral arms of the galaxies. The brightest stars which appear on the slide are located in our own galaxy. We must look through some of the stars in our galaxy to observe the universe, no matter which direction we choose. Students often ask why a cross appears through the image of the brighter stars. This is a result of diffraction by the metal support for the secondary mirror of a reflecting telescope. There are usually four of these supports, with angles of 90° between them, which produce a pattern readily apparent through the brighter stars. It would be interesting for some student to determine why the so-called star, such as those displayed on our flag, is represented by five points. There seemingly is no counterpart for this in the heavens.

Slide No. S-28; NGC 598 Messier 33. Open Type Large Spiral Galaxy in the Constellation Triangulum. Messier 33, Messier 31 in Andromeda, and our own galaxy are the three large spiral systems comprising the "Local Group." Messier 33 is an example of the rather loosely wound spirals. A comparison of this slide with that of Messier 31 (Slide No. 150) will show the difference in the tightness of the spiral wind. Slide S-28, which was taken through the 200-inch telescope at Palomar, shows the central regions of Messier 33. The distance of Messier 33 from earth, as measured from the cepheid variables within the

spiral, is 1,500,000 light years. This also happens to be the distance to the Andromeda Galaxy. The diameter of Messier 33 is less than that of our own galaxy, probably about 40,000 light years. It is seen almost perpendicular (looking into its pole of rotation). It, too, has been resolved into stars.

Slide No. 29; NGC 5194 Messier 51. The "Whirlpool Galaxy" is located in the Constellation Canes Venatici (The Hunting Dogs). This galaxy can be observed very close to the end star in the handle of the Big Dipper. A good telescope must be used even to detect it. The galaxy is about 8 million light years from earth. This photograph was taken through the 200-inch Palomar telescope. Only the stars in the arms of the galaxy are resolved at all. The observers view is very nearly perpendicular into the pole of the galaxy.

In 1845, Lord Roose first detected the spiral pattern of the type of object in Messier 51. This discovery eventually led to the understanding that they are separate systems rather than integral parts of the Milky Way Galaxy. NGC 5195, which appears below the large spiral, is an irregular galaxy. Both galaxies are the same distance from earth.

Slide No. 18; NGC 3031 Messier 81. A Spiral Galaxy in the Constellation Ursa Major. This is a large pinwheel, which reminds one of a Fourth of July whirl-i-gig. The most recent determination of the distance of Messier 81, made by Sandage in 1953, was about 7 million light years. This estimate was the result of a study made of three kinds of stars in the galaxy, three cepheid variable, seven irregular variables, and twenty-five novae. The photograph was taken through the 200-inch telescope at Palomar and shows the resolution of the stars in the spiral arms of the galaxy. These, of course, are the very brightest giants and supergiants of blue color. The center is not resolved because the galaxy represents Population Type II, whose brightest stars are too faint to be recorded at such a great distance. The galaxy is one of a group of galaxies. Other members of the group are NGC 2976 (Slide No. 154), NGC 3034, and 3077. The latter are fainter members. The Mass of NGC 3031 is equivalent to 1.5×10^{11} solar masses.

Slide No. 24; NGC 4486 Messier 87. A Large Spheroidal Galaxy in the Constellation Virgo. This galaxy is located in the heart of the Coma-Virgo region, which is rich in galaxies. This richness is partly a result of the clear path through the galaxy, from which we view the universe. Messier 87 is the brightest elliptical galaxy of the Virgo Cluster. The apparent photographic magnitude is 9.7. This is one of the intrinsically brightest galaxies known. Its absolute magnitude is –21.0. Messier 87 has considerably more than 500 globular clusters associated with it. They are scattered over the slide and can be observed clearly in the outer regions. They appear as small fuzzy images, quite different from stellar images. The distance to this galaxy is some 8 million light years. Messier 87 is a strong radio emission object. The galaxy can be seen with a six-inch telescope; however, it will appear rather nebulous. It might be rather difficult to find because it is not located near to a bright star. In Norton's *Star Atlas,* it is labeled 87M. The galaxy is about halfway between the star Beta Leonis (Denebola) and Epsilon Virginis. Both of these stars are bright enough to be easily observed.

Slide No. 26; NGC 4594 Messier 104. The Sombrero Galaxy. A giant spiral galaxy in the Constellation Virgo, the Sombrero is a member of the Coma-Virgo cluster. The recessional velocity is 1180 kilometers per second, which indicates that its distance is 7.5 million light years. The galaxy is observed as though we were looking into its edge. Through this edge, or the equator of the galaxy, we can observe great clouds of dusts and gases. This type of dark, obscuring material is prominent in the spiral arms of the galaxies. This galaxy posses hundreds of associated globular clusters, which can be differentiated from stars in the foreground by their softness of outline. This photograph was taken through the 200-inch Palomar telescope.

Slide No. 113; NGC 4725. Supernova in the Galaxy in Constellation Coma Berenices. Two views are shown. The first, which was taken on May 10, 1940, shows no star in the position; yet, on the other plate taken on January 2, 1941, the bright star is quite evident. It is known that no star had been photographed in that position is the galaxy as long ago as 1931. There have been instances in which the supernovae actually outshown the entire galaxy in which they appeared. Supernovae represent the hierarchy of cataclysmic catastrophes.

Slide No. 138. A Montage of Six Galaxies with Identification Numbers and Types. All of these are spiral systems, with a gradual gradation in wind from So through Sc.

NGC 1201 is a typical So galaxy. It is not possible to see any spiral arms in this type. They are catalogued as Spiral type merely because they are much larger and brighter than the elliptical galaxies. In their stage of evolution, they have progressed to the point at which the spiral arms are probably absent.

In NGC 2811, a very evident difference can be noted between the nucleus and the regions of the arms. There is not a great amount of arm resolution, but there is a graduation from the So form, in which no arms are present.

NGC 488, an Sab Galaxy, has a spiral structure which can be traced very near to the central regions. As the arms wind outward, they lose their smooth texture and become lumpy with condensations. The arms are nearly circular and have dust lanes on their inner edges. The average distance between the arms in the outer regions is about 1000 parsecs.

In NGC 2841, an Sb Galaxy, the nucleus is an amorphous structure devoid of dust or spiral structure. It is tightly wound, and very similar in appearance to NGC 488.

NGC 3031, Messier 81, is a galaxy with a large, amorphous structure devoid of dust or spiral structure. It is also tightly wound, and very similar in appearance to the NGC 488.

NGC 3031, Messier 81, is a galaxy with a large, amorphous central region, with no suggestion of resolution into individual stars. There is no doubt that the present appearance could be clarified with proper instrumentation. Messier 31 in Andromeda has been resolved in the nucleus, but Messier 81 is 7 million light years distant; therefore, it is much more difficult to resolve. The arms are no longer circular, but they seem to have the same typical spiral. They are well resolved into stars and knots of gases and dusts. Lanes of dark, obscuring materials are present. Twenty-five normal novae have been discovered. There are three variables which are definitely Cepheids. These kinds of objects have been used to determine the distance to Messier 81.

NGC 628 is a galaxy of the multiple type Sc and well dispersed. The nucleus is much smaller than that of Messier 81.

Slide No. 139. A Montage of Six Barred Spiral Galaxies with Classification and Identification Numbers. The description of each follows.

NGC 2859 SBO: The bar is fuzzy and indistinct. This object appears as though it were a three-blobbed figure. One can barely trace the bar. There are no sharp boundaries anywhere. The barred spirals differ from the normal spiral galaxies in that the arms of the normal spirals lead directly along a spiral path outward from the nucleus, whereas those of the barred spirals lead or originate, from a bar that passes through the nucleus and is generally very straight.

NGC 175: The galaxy is an SBab(s). The arms are tightly wound and form a nearly complete ring. Some knots of material appear along the arms, and there is some branching of the arms.

NGC 1300: This galaxy in the Constellation Eridanus is typed as an SBb. Every bar is distinct and smooth in texture. There is a dusty lane in each. The arms, knotted and distinct, fold back again and make the galaxy have a distince elliptical appearance. The arms are considered rather tight here.

NGC 2523: This galaxy is of the SBb(r) type. The arms are more broken and tend to deviate from the elliptical shape observed in NGC 1300.

NGC 1017: This galaxy is well broken up and has two distinct arms. The rest of the galaxy appears to be a jumble of loosely grouped knots of stars.

NGC 2525: In this SBc galaxy, the bar is not resolved to knots, as is possible in later galaxies of this class. The spiral arms are well broken up, and the nucleus at the center is very small and bright.

Slide No. 25; NGC 4565. A Galaxy in the Constellation Coma Berenices. If we could transport ourselves far from our galaxy (The Milky Way System) and orient ourselves in space so that we were viewing our galaxy into its equatorial plane, it would be somewhat like the galaxy pictured here. Very prominent in this slide is the bulge of the nucleus of a galaxy and the band of obscuring dust and gas associated with the spiral arms and observed through the median plane of the galaxy.

Slide No. S-27; NGC 253. Spiral Galaxy in the Constellation Sculptor. This object is located in the southern sky. It is very near to the south pole of the galaxy. It bears no number, because Messier overlooked it while compiling his famous list of bright nebulea and clusters. The arms of the galaxy show a granular structure which is a partial resolution of the system into stars. This galaxy shows an approach velocity of 70 km/sec, the greatest of any galaxy other than our own. Its distance is about 5 million light years *(Sky and Telescope,* Oct., 1957, page 587).

Slide No. 58; NGC 2623. A Galaxy in the Constellation Cancer. A peculiar type Sc, this galaxy is wide open and a source of radio emission. This view was obtained through the 200-inch Palomar reflector.

Slide No. 54; NGC 1398. A Barred Spiral Galaxy in the Constellation Fornax. There is a bar across the nucleus, and an internal ring surrounds it. The arms emerge from this ring. There is some fine structure in the ring itself. The two principal arms, are broken into segments, or knots.

Slide No. 5; NGC 1300. A Barred Spiral in the Constellation Eridanus. This view was obtained through the 200-inch telescope at Mt. Palomar. The term barred spiral refers to the fact that the arms of the spiral galaxy originate from the ends of a lengthy bar of matter, issuing radially from the nucleus at two opposite points on a diameter.

Slide No. 1; NGC 147. Elliptical Galaxy in the Constellation Cassiopeia. The photograph for this slide was taken through the 200-inch telescope at Mt. Palomar. Elliptical galaxies are smaller and less massive than the large spiral forms. There are, however, many with this elliptical form in the universe. In our particular region of the universe in the pattern called our "Local Group," there are approximately 17 galaxies. Of these, 3 are spiral in form, and 10 are elliptical. The other 4 are classified as irregular. NGC 147 is 1,300,000 light years from earth and has a diameter of 7000 light years. The population of this type of galaxy is about a billion and a half stars, in contrast with that of the major spiral galaxies, which is about a hundred billion suns. Even though it resembles globular clusters in appearance and has no obscuring dusts and gases, the subject of this slide is much more massive and has far greater dimensions than the clusters. Resolution of NGC 147 can be observed in this photograph. The stars are large red giants of what is called Population II. This type of population is characteristic of the clearer (non-nebulous) regions of the universe.

Slide No. 154; NGC 2976. In the Constellation Ursa Major. This view shows a group of galaxies.

Slide No. 65; NGC 6027. A Group of Galaxies in the Constellation Serpens. The photograph for this slide was taken through the 200-inch telescope at Palomar. The brightest galaxy in NGC 6027 is small. Several of the sextet show tidal formations, indicating their proximity to one another. Interracting, galaxies are quite common. Other examples are shown in slide Numbers 60, 29, and 63. Three members are spirals. The distance of the system is 5.8×10^7 parsecs.

Slide No. 60; NGC 4038–4039. Two Galaxies in the Constellation Corvus. This object has been called the "ring-tail snorter." It is actually two galaxies that seem to be interacting. Their structural features are noticeably distorted by mutual forces. The slide shows long tidal filaments. The mechanisms concerned are very complicated and not fully understood. F. Zwicky of Mt. Wilson-Palomar reports that thousands of luminous galactic bridges between double and multiple galaxies may be observed in photographs taken through the 48-inch Schmidt telescope. The objects shown here are sources of radio emissions.

Slide No. 14; NGC 2685. A Peculiar Galaxy in the Constellation Ursa Major. The object is elliptical, but it has a circle of luminous material ringing it. The peculiar object is not fully classified nor understood.

Slide No. 63; NGC 5128. A Peculiar Galaxy in the Constellation Centaurus. This galaxy is an intense source of radio emission. It may be a peculiar elliptical galaxy. Drs. Baade and Minkowski believe this object to represent two galaxies in collision and interpret the dark band to be a spiral galaxy seen edge on. Shklovsky, however, thinks it a single galaxy with an obscuring belt. The background resembles an EO galaxy.

Slide No. 68. The Hercules Cluster of Galaxies. This slide, showing a view through the 200-inch telescope at Palomar, displays many different forms of galaxies in the group. It is a loose cluster containing about 75 bright galaxies and a large number of faint members. Of the brighter members, 70 per cent are spirals or irregulars. These galaxies are very remote being at a distance of some 400,000,000 light years.

Slide No. 55. A Faint Cluster of Galaxies at a Distance of Well Over a Billion Light Years from Us. If the Andromeda galaxy were moved out to the latter distance, it would look no larger nor brighter than the brightest object that can be observed on this slide. The limit of resolution of the 200-inch reflector at Mt. Palomar is about 2 billion light years. This photograph represents more than the half-way point in the resolution of our optical systems.

V. PLANETS AND COMETS

Slide No. 270. Six Views of the Planet Venus. The photographs for this slide were taken in 1927, with the 100-inch telescope at Mt. Wilson Observatory. Venus is a difficult object to photograph. The planet never appears more than 47° from the sun. After sunset, when the sky is dark, the planet is too low to be photographed clearly. Most photographs are taken during the daylight hours, when Venus is near the meridian with the sun above the horizon. Being an inner planet, Venus shows the same phases as does the moon. When Venus is on the other side of the sun from earth (behind the sun), it will appear very small and full. When it is practically between the earth and the sun, it will appear quite large but as a thin crescent. In between these extremes, Venus will appear to be various sizes and with varying phases. The photographs here show the planet at a phase a little less than one-half full. Venus is known to be cloud-covered. Permanent markings like those on Mars are not discernable. There have been markings on Venus, but they are cloud areas and not permanent. This is one reason why the determination of its rotation period has been difficult. It is an interesting planet, for it is the twin of the earth in size and approaches nearer to earth than any other of the major planets in the solar family. The planet's nearest point to earth is 26 million miles, at inferior conjunction.

Slide No. 282. Venus Photographed in Blue Light with the 200-inch Telescope. Here, the planet appears to be a thin crescent. From this view with the most powerful telescope in the world, there is little to observe on the planet. Spectroscopic observation is much more productive. It indicates that the atmosphere of the planet is composed of much carbon dioxide.

Slide No. 276. Two Views of the Planet Mars with the 200-inch Telescope. Again, a blue-light photograph records the atmosphere and clouds that might be in the atmosphere. The red view records a view of the surface of the planet. The blue photograph is larger than the red. The difference in image size of the two would indicate an empirical value for the depth of the atmosphere, which is considered to be 60 miles. Undoubtedly, there is atmosphere above this height, but it is not appreciable. Since the distance of the planet Mars from the sun is so great as compared to that of the earth, it is to be expected that radiant energy from the sun received by Mars is much less than that received by the earth. Thermocouple measurements of temperatures on Mars suggest that on the surface of the planet, temperatures may rise to about 80° F at noon in the equatorial regions and drop sharply to 100° F below zero at night. Measurements of temperatures in the change of state zone of the polar cap suggest a mean temperature there of 32° F. Thus, it has been inferred that there is some form of water present, probably a very thin frost.

Slide No. 275. A Montage Photograph of Mars, Jupiter, Saturn, and Pluto. The first three planets were photographed with the 100-inch Hooker reflector. Pluto was photographed with the 200-inch Hale reflector. The photographs were individual, and therefore the scale shown is not real. Jupiter, the larger, has an equatorial diameter of 89,000 miles, whereas Mars has a diameter of only 4200 miles. Of the four views we are sure that only that of Mars shows the true surface. Jupiter and Saturn are gas-covered, and the surface of Pluto could not be clearly seen even without the atmosphere.

Slide No. 273. Four Views of Jupiter Taken with the 200-inch Palomar Reflector. Photograph A shows the shadow of one of the satellites as seen on the disc of Jupiter. Photograph B shows the satellite to the right and the shadow of that satellite on the disc of Jupiter. The two photographs were taken approximately 50 minutes apart. Photographs C and D show the banded features that appear on the Planet. Jupiter is immense, with an equatorial diameter of 89,000 miles. Its surface is cloud-covered; therefore, what is shown as a visible disc represents only cloud layers.

The diameter given for the planet is that of the visible disc. One can note very distinctly the difference between the polar and equatorial diameters of the planet. Jupiter rotates in 9 hours and 50 minutes at the equator . Because of its great size, the rotational velocity at the equator is 25,000 miles per hour. The difference between its equatorial and polar diameters is nearly 6000 miles, a result of the very high equatorial rotational velocity which causes it to bulge.

Slide No. 279. A Blue-Light Photograph of the Planet Jupiter Taken with the 200-inch Hale Reflector. The photograph for this slide was taken on October 23, 1952, at 11:30 p.m. Pacific Standard Time. Jupiter appears to be inverted, with south at the top. Satellite number III, Ganymede, appears above the upper right edge of Jupiter, and its shadow is at the top of the planet's apparent disc. The dark oval marking is the Great Red Spot, which has been observed since 1878. This red spot has an elliptical shape, a major axis of 30,000 miles, and a minor axis of 7000 miles. The cause of the spot and what it really is, are not known. The white spot on the dark belt is not a satellite but the atmosphere of Jupiter. The difference in equatorial and polar diameters is very noticeable in the photograph.

Slide No. 274. The Planet Saturn Photographed with the 100-inch Reflector at Mt. Wilson Observatory. One of the most unique phenomena in the univers is the shape of Saturn, the ringed planet. In this slide, one can observe the ring system, which is 171,000 miles across. It is composed of three major rings, all concentric. In this slide is shown the division between the outer and the middle ring, called Cassini's Division. It is 5000 miles across. The rings are very thin, disappearing when the ring system is precisely in our plane of sight. It is known from this fact that the rings are not more than 15 miles in thickness. Spectroscopic evidence shows that they move as if they were composed of tiny particles. Each moves around Saturn as though it were a tiny satellite in an orbit. The inner parts of the ring show more rapid Doppler velocities than do the outer parts, which we would expect from a particle revolution in a gravitational field. The planet is belted, as is Jupiter; it is also cloud-covered, with lines of ammonia and methane present in the spectrum of its atmosphere. Saturn is accompanied by 9 satellites, none of which can be observed on the slide.

Slide No. 271. Two Fields of the Sky, Showing the Planet Pluto, the Outer Known Planet of the Solar System. The two fields shown were taken 24 hours apart. One can observe the motion of the planet relative to the star background, which does not indicate movement in the interim. The photograph for this slide was taken through a 200-inch telescope. The mean distance of Pluto from the sun is 39.5 astronomical units, which is 5910×10^6 kilometers. Its sideral period of revolution about the sun is 248.4 years. This means that it will not be seen in every constellation or area of the Zodiac until 248 years from its discovery date. The little planet was discovered in the constellation Gemini in 1930. It is now in the constellation Leo, having moved through all of Gemini and all of Cancer since the date of its discovery. The little planet appears as a 14th-magnitude star at its brightest and is therefore a very difficult object to observe. It is so tiny that there is doubt as to its true diameter, even when observed through the 200-inch telescope. One may find the diameter estimated with minimum values of 3600 miles and maximum values 8800 miles. The mass of Pluto is known from its actions on the other outer planets and is considered to be 0.95 the mass of the earth. If the mean density of Pluto is assumed to be 0.8, which is a mean of the densities of the earth, the moon, Mars, and Venus, the diameter of Pluto can be computed as 1.06 times the diameter of the earth, or nearly 8800 miles. However, Kuiper measured the visible disc in the 200-inch telescope and arrived at a value of 3600 miles. The calculation is very difficult because the planet is so far away that it does not present an appreciable disc, even when viewed with the larger instruments. If we adopt the value of 3600 miles as the diameter of the planet, its density would then be 10 times that of the earth. This would make a specific gravity of 55, or 5 times the density of lead. This seems to be a very unreasonable value. The larger figure of 8800 miles is therefore more reasonable. Pluto was discovered in 1930 by Clyde Tombaugh, than working at the Lowell Observatory at Flagstaff, Arizona. Judging from the distance the planet is from the sun, it can be assumed that the surface temperature of the planet is probably about 400° F below zero. The sun as seen from Pluto would be a tiny bright dot, not much brighter than our own full moon as seen from the earth.

Slide No. 292. Fourteen Views of Halley's Comet of 1910, Taken Between April 26 and June 11. These slides show development of the comet in size and brightness and then its subsequent fading. This famous comet was named after Edmund Halley, who was the first to recognize its periodic nature. Halley found that the comet in 1531, 1607, and 1682 was moving in practically identical paths. This was soon after Newton had applied his law of gravitation in 1680. Halley then predicted that the comet would return again in 1758, 76 years after its last appearance. Halley died in 1742 and therefore did not see his prediction come to pass. On Christmas eve of 1758, the comet was discovered, and it passed perihelion on March 12,1759. Halley's prediction, made more than 50 years previously, was confirmed. The comet appeared again in 1835 and 1910. It is due to appear in the vicinity of the sun in 1986. Knowledge of Halley's comet has now been traced back in history through the study of ancient writings and drawings. It has been known since 240 B.C. Because of the effects of the planets in the solar system, the length of time between appearances has varied. The longest period was 79 years, 4 months; the shortest was 74 years, 5 months. The average period is therefore 76 years, 9 months.

The comet was detected photographically on September 11, 1909, and additional photographs were taken until July 11, 1911. It passed across the disc of the sun, as seen from the earth, on May 18, 1910. The comet then traveled in its orbit away from the sun to its aphelion, its most remote point from the sun beyond the orbit of Neptune, in 1948. By 1968, Halley's Comet will be traveling within the orbit of Neptune as it journeys once more toward the sun. It will pass within the orbit of Uranus by 1978. Halley's Comet in 1910, when it was 2 astronomical units from the sun, had a head diameter of 200,000 miles. At maximum length, the tail was 94,000,000 miles long. Physical dimensions of comets are very large. The average head diameter is of the order of the diameter of Jupiter, or approximately 90,000 miles. Tails vary in length in relation to their distance from the sun but they may be millions of miles long. The largest head known was that of Holmes' Comet in 1892. It had a diameter of 1,400,000 miles or nearly twice that diameter of the sun. The longest tail ever observed was that of the great comet of 1843, which had a length of 200,000,000 miles. It is known from gravitatio[illegible] studies that comets weigh very little. They are tenuous enough to be called vacua.

Slide No. 291. The Head of Halley's Comet, Ph[illegible]graphed on May 8, 1910. The head at the time of the photograph was about 200,000 miles across.

Slide No. 293. Cunningham's Comet, Photographed on December 21, 1940. This comet was discovered on the night of September 15, 1940. It displayed a tail some 10,000,000 miles in length during the Christmas season.

Slide No. 296. Four Views of Comet Mrkos, in August 1957. Comet Mrkos was the second comet to be observed with the naked eye in 1957. Reaching perihelion in August, it was seen by more people than was Comet Arend-Roland.

VI. THE SUN AND SOLAR PHENOMENA

Slide No. 240. A Photograph of the Sun's Surface at Maximum of the Sunspot Cycle, Showing the Many Spots Visible on December 21, 1957. Sunspot maximum occurred in the month of December, 1957. The time of maximum or minimum is not known exactly until after it has occurred. There are slight variations in the length of the sunspot cycle, but the average is 11.21 years. Spots occur in two zones on the sun. These have solar latitudes of 5° to 35°. Seldom are spots observed nearer to the equator than 5° and in latitudes higher than 35°. The visible surface of the sun, which is shown here, is called the photosphere. It is composed of incandescent gases at a temperature of 5750° Kelvin. On the slide, a noticeable decrease in the brightness of the solar surface can be observed at the edge of the limb of the sun. Called limb darkening, this effect is the result of radiation, which must pass through deeper layers of the sun's upper atmosphere (the chromosphere and corona) to reach the earth. The sun's diameter is 864,000 miles.

Slide No. 239. Enlarged View of an Exceptionally Large Sunspot Group, Taken May 17, 1951. In this slide, one can observe the umbral (dark) and the penumbral (lighter) regions. The area that appears darker than the general photosphere represents millions of square miles. In comparison, the earth on the same scale would appear to be the size of the smallest round, dark areas. This type of phenomenon represents forces and energies that far surpass human comprehension. It is known that the temperature of the photosphere, the brighter surface of the sun, is of the order of 6000° K. Sunspot umbra, measured from spectra, are of the order of 4750° K. They appear dark because they are observed in contrast with the photosphere, which is a higher temperature. The spectrum shows the high velocity of the gases in expansion by measurements made from Doppler shifts of the spectral lines. It is known that there is a close relation between the sunspots and the solar prominences. The sunspots themselves appear to be of a cyclic nature. The mean period between consecutive maximum sunspottedness is 11.21 years. This signifies that, at these approximate intervals, the amount of spottedness (area) will be at a maximum. Related to this activity is the occurrence of the Auroa Borealis (Northern Lights) and of certain kinds of storms (magnetic in the ionosphere, which disrupt long-distance communications.

Slide No. 234. Solar Prominences Seen During a Total Eclipse. The gaseous clouds shown on this slide extend outward from the edge of the solar atmosphere. They were photographed during the total eclipse that occurred on December 9, 1919. It is known that gaseous clouds generally are thrown outward from the sun in an invisible form (too hot to radiate in the visible spectrum). After cooling, they become visible, and if they could be shown in moving pictures, the clouds would appear to be falling into the sun. In color, these brilliant gaseous extensions would be a beautiful scarlet because of the red emission of the hydrogen alpha line.