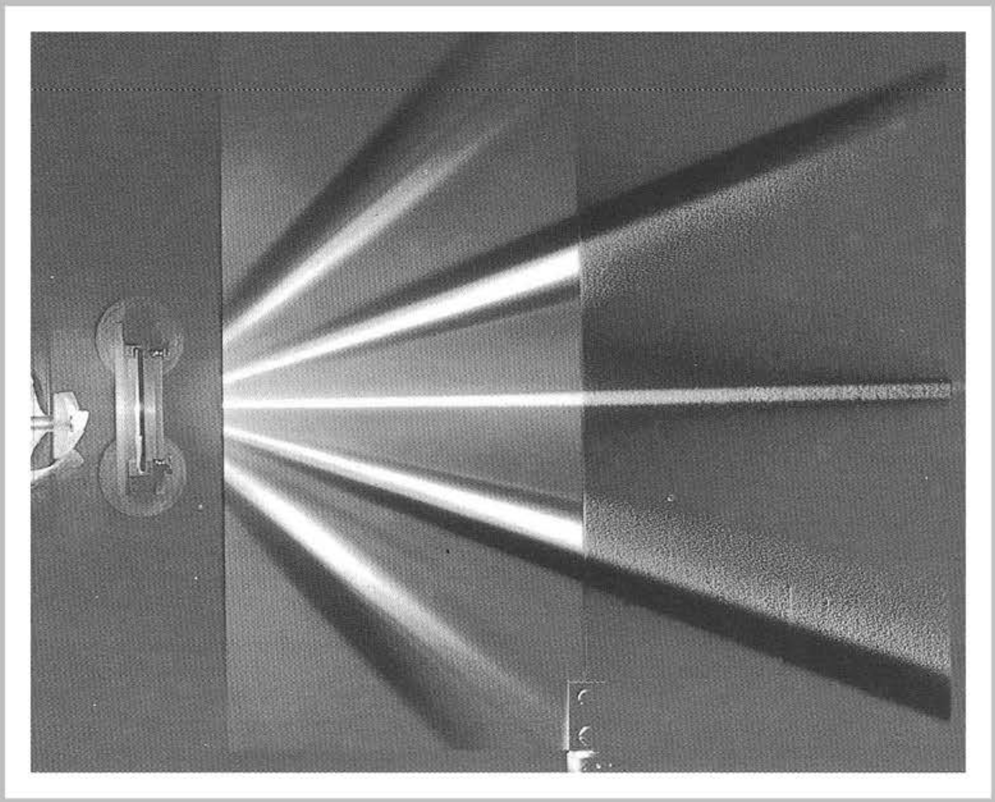
©BLACKBOARD OPTICS AND ACCESSORIES



First and second order spectra cast on the blackboard by a diffraction grating with an incandescent lamp source. The right side of the screeen is coated with fluorescent paint to display the ultraviolet region. This is one of the multiple application of the Blackboard Optics Set.

KLINGER
EDUCATIONAL PRODUCTS

www.KlingerEducational.com

Bulletin 114-95

ORDERING DATA

KO4100 ©Blackboard Optics Basic Kit (Suction)
KO4100M ©Blackboard Optics Basic Kit (Magnetic)

Cat. No.		Description
KO4101	(2 pcs)	Ray Projector
KO4102	(2 pcs)	Holder for Projector
KO4103	(2 pcs)	Clamping Bar, 33 cm
KO4104	(1 pc)	Clamping Bar, 38 cm
KO4105	(1 pc)	Planoconvex Lens, 20cm x 5cm thick
KO4106	(1 pc)	Planoconcave Lens, 20cm x 5cm thick
KO4107	(1 pc)	Semicircular Lens, dia. 20cm x 5cm thick
KO4108	(1 pc)	Parallel-sided Block, 10 x 20cm thick
KO4109	(1 pc)	Prism, Right Angle, 20cm short side x 5cm thick
KO4110	(2 pcs)	Plane Mirror, 20cm x 5cm high
KO4111	(1 pc)	Curved Mirror, concave/convex
KO4112	(1 pc)	Projector Lamp, spare 12V, 35W
KO4118	(1 pc)	Cushioned storage cabinet

The above items comprise the basic kit

KE5369 Transformer cased and mounted
12 volts at 100 watts
(Recommended for low voltage illuminators.)

KO4100A Accessories for additional experiments in optics (Suction)
KO4100AM Accessories for additional experiments in optics (Magnetic)

KO4113	(2 pcs)	Clamping Bar, double screw 33cm
KO3071A	(1 pc)	Prism, flint glass, mounted
KO4115	(1 pc)	Screen for projection, 30 x 30cm
KO4116	(1 pc)	Holder, for screen
KO3105	(1 pc)	Replica diffraction grating, 6000/cm
KO4117	(1 pc)	Holder, for grating, filters, and slits
KO3086	(1 set)	Color filters, red, blue, green
KO3101	(1 pc)	Slit, double
KO4119	(1 pr)	Polarizing filters
KO4122	(1 pc)	Prism, equilateral, 20cm side x 5cm thick
KO4105	(1 pc)	Planoconvex lens, 20cm x 5cm thick
KO4106	(1 pc)	Planoconcave lens, 20cm x 5cm thick
KO4121	(1 pc)	Planoconvex lens, long focus
KO4125	(1 pc)	Multiple Ray Projector
KO4126	(1 pc)	Multiple Ray Projector lamp, spare 12V, 55W

The above items comprise the accessory kit

KLINGER EDUCATIONAL PRODUCTS
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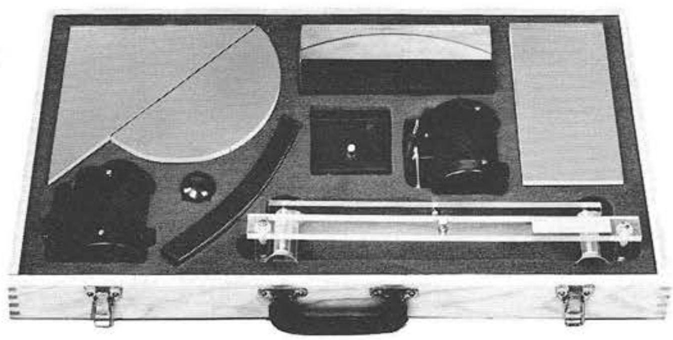
K04100 and
K04100M

and accessories

The Klinger laboratories proudly offer to teachers of physics and related fields a revolutionary new approach to the presentation of concepts in geometrical and physical optics.

The Blackboard Optics kit is an assembly of large Acrylite®* components which may be secured singly or in combination to any classroom blackboard by means of unique suction cup supports. Lenses, mirror, prisms, and light sources may be positioned in seconds; components may be rotated without shifting the supporting brackets. Actual experiments and measurements are then performed directly on the blackboard without darkening the room.

Visibility, even in large lecture halls, is assured because the plastic optical pieces are 2 inches thick and 8 inches high. The ray projectors which form part of the kit may be arranged to provide a thin pencil of light or a divergent cone by means of a simple fingertip adjustment. The path of the light in air and through the optical components is traced by skimming rays along the blackboard. With the equipment in position, the teacher can then chalk in axes, normals, tangents, virtual rays, angle identification symbols, equations, and any other information he needs to complete a vivid and dynamic demonstration.



The information in this booklet is arranged in two sections. In Section 1, a complete basic course in optics is presented in picture form. Each of these experiments may be set up by means of the **Basic Kit** (inside front cover) without additional accessories. Section 2 deals with extended applications for which one or more parts are required as indicated in the accessory listing. For example, lenses of various focal lengths, slits, diffraction gratings, and special prisms may be purchased separately for the more elaborate demonstrations, such as the telescope, microscope, camera, eye defects, and the correction of eye defects; experiments involving ultraviolet radiation in the spectrum are enhanced by accessories such as the projection screen (K04115) described in the accessory listing.

LIST OF EXPERIMENTS
SECTION 1
(Basic Kit)

Reflection

1. The Law of Reflection
2. Virtual Image in a Plane Mirror
3. Focal Length of a Concave Mirror
4. Focal Length of a Convex Mirror
5. Real Image Formed by a Concave Mirror
6. Virtual Image Formed by a Convex Mirror

Refraction

7. Simple Refraction – Less Dense to More Dense Medium
8. Simple Refraction – More Dense to Less Dense Medium
9. Parallel Displacement by a Rectangular Block
10. Semi-circular Body – Light Incident at Center of Disc
11. Semi-circular Body – Light Incident at Right Angles to Tangent
12. Semi-circular Body – Critical Angle
13. Triangular Prism – Total Internal Reflection, 90° Deviation
14. Triangular Prism – Total Internal Reflection, 180° Deviation
15. Reversing Prism
16. Angle of Minimum Deviation

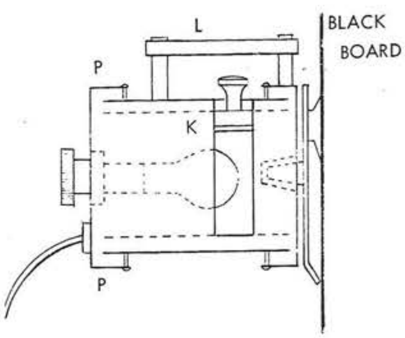
Lenses

17. Focal Length of a Plano-Convex Lens
18. Focal Length of a Plano-Concave Lens
19. Virtual Image Formed by a Concave Lens
20. Thick lens, double convex
21. Thick lens, concavo-convex

GENERAL INSTRUCTIONS

IMPORTANT: When suction cup clamping is used, the cups must be moistened with ordinary glycerine to insure holding power. Water tends to evaporate quickly and is not recommended as a moistening agent. The magnetic clamping method requires no preparation of the clamps or steel-based blackboard. However, please remove keepers (metal coin at bottom of magnet) prior to use and replace when storing.

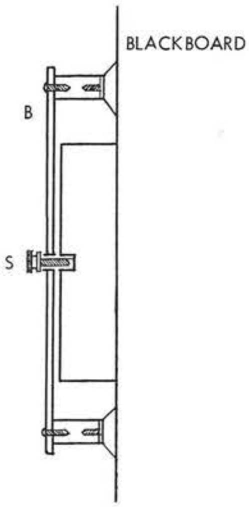
USING THE RAY PROJECTOR



The projector lamp requires a power source rated at 12 volts and at least 35 watts, AC or DC.

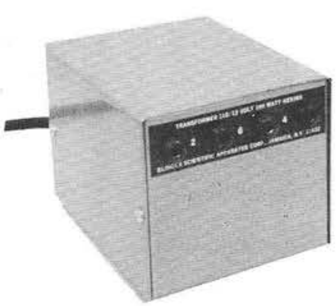
The ray projector consists of an inner rotatable cylinder insulated from the outer housing. When the cylinder is rotated so that the light emerges on the side opposite the plastic lens, a divergent beam of controllable width is obtained. A fine pencil of light may be projected by rotating the cylinder so that the light passes through the plastic collimating lens. The diagram shows the proper method of mounting a ray projector with suction cup clamping. Glycerine should always be used to moisten the cups since it is non-evaporating and may easily be removed with water. Holders employing magnetic clamping are mounted in a similar manner but without previous clamp or blackboard preparation, but do require steel-based blackboards.

USING THE OPTICAL COMPONENTS

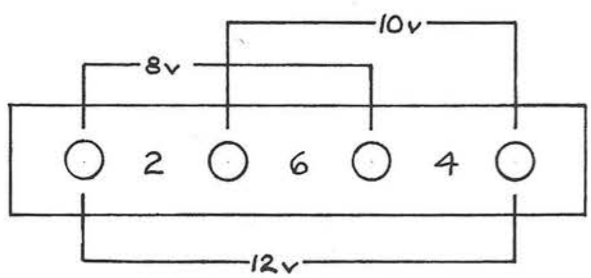


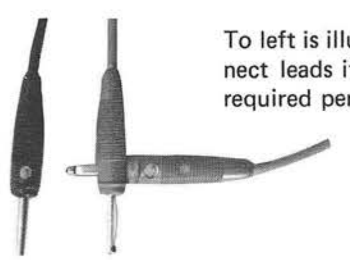
The following procedure is recommended for securing the optical components to the blackboard: (1) With the bracket only in the desired position, fasten it to the blackboard with its moistened suction cups or its magnetic clamps. (Suction cup clamping is shown in the illustration.) (2) Retract the screw (S) and slide the component under the bracket, yellow side toward the blackboard. Align the hole in the component with screw S, and insert the screw in the hole until the component is flat against the blackboard but can still rotate freely. NOTE: the longer bracket (15 inch) is normally used with the large prisms to permit 360 degree rotation but may be used for other components when required. (3) Clamping bar K04113 (may be ordered as an accessory) is required for experiments which involve combinations of plano lenses to form double lens types in a number of the experiments illustrated in Section 2. This bar is fastened to the blackboard in the same manner as the single screw types.

USING THE KE5369 TRANSFORMER



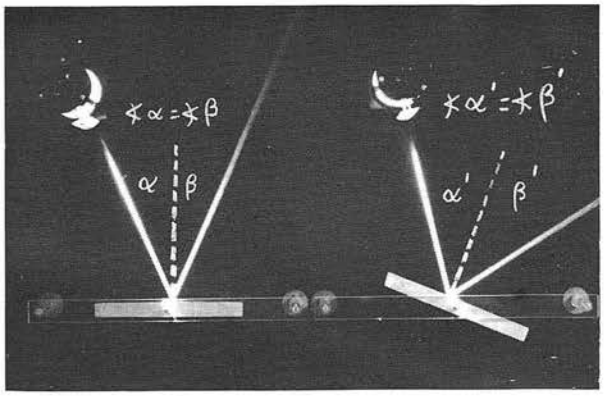
Transformer, 2 to 12 volts AC in two volt steps. This unit will supply up to 100 watts at any voltage setting, with standard banana jack output terminals isolated from line supply for use on 115 volt AC line. Recommended for use with low voltage illuminators.





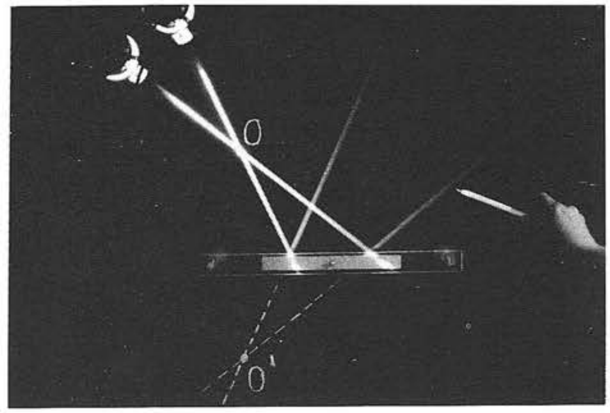
To left is illustration of how to connect leads if more than one plug is required per terminal.

In order to get the desired voltage output, span the terminals so the sum of the imprinted numbers, between the terminals, equals the desired voltage.



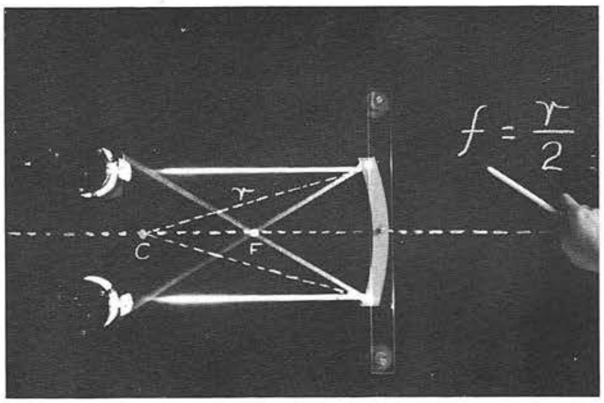
Experiment 1: The Law of Reflection

An incident ray is projected obliquely to the mirror surface producing a reflected ray as in the left picture. The mirror line and normal are added to show that the angle of incidence (α) equals the angle of reflection (β). The mirror is then rotated to a second position and the same relationship noted.



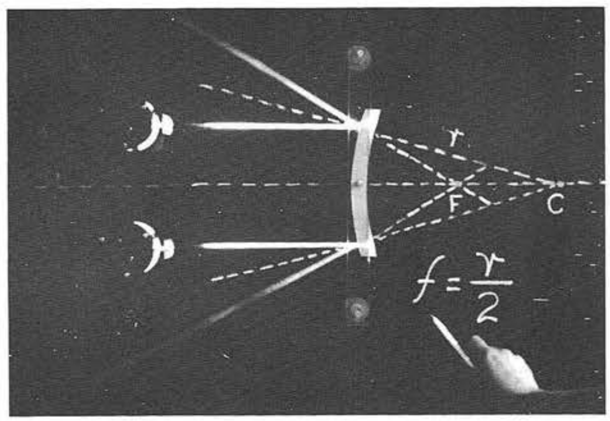
Experiment 2: Virtual Image in a Plane Mirror

A pair of ray projectors are arranged to send two beams of light through a chalked object point O to the plane mirror. Extensions of the reflected ray are drawn in chalk behind the mirror until they intersect to locate the image point O′.



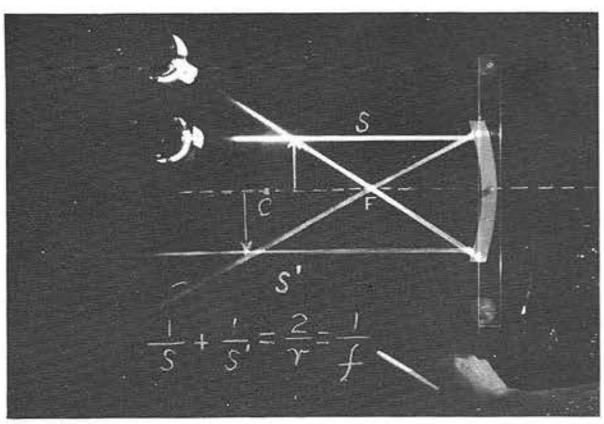
Experiment 3: Focal Length of a Concave Mirror

The center of curvature (C) of the concave mirror is located by means of a ray which reflects back on itself. (This ray is not shown in the photograph.) Rays parallel to the principal axis reflect through F (principal focus) located midway between C and the vertex of the mirror on the principal axis.



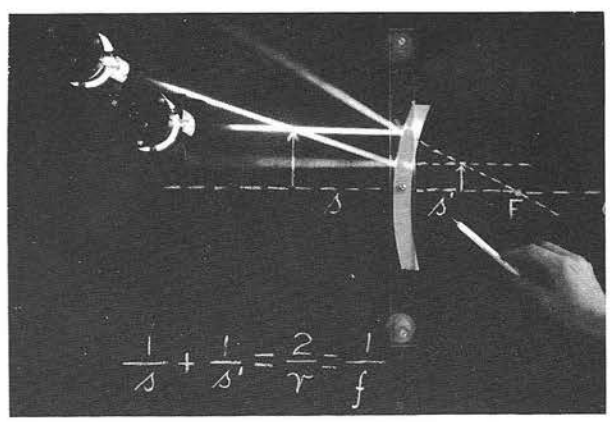
Experiment 4: Focal Length of a Convex Mirror

The center of curvature (C) is again found by means of a ray which reflects back on itself; this ray is extended behind the mirror until it intersects the axis. To locate F, virtual rays originating in the reflected rays of the two incident parallel projections are drawn behind the mirror until they intersect as shown.



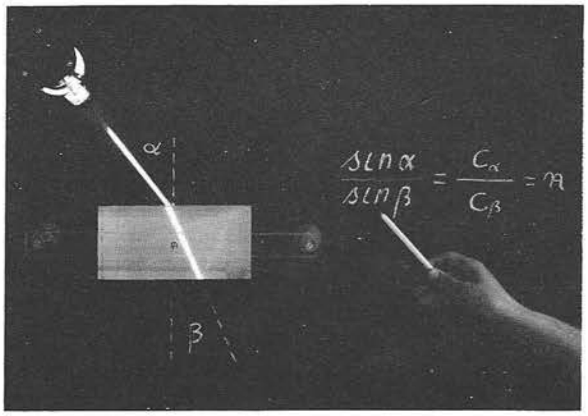
Experiment 5: Real Image Formed by a Concave Mirror

Pencils of light from two ray projectors are made to intersect at the object point (head of upright arrow). These are predictable rays: one parallel to the principal axis and the other through the principal focus (F). The point of convergence locates image point (head of inverted arrow).



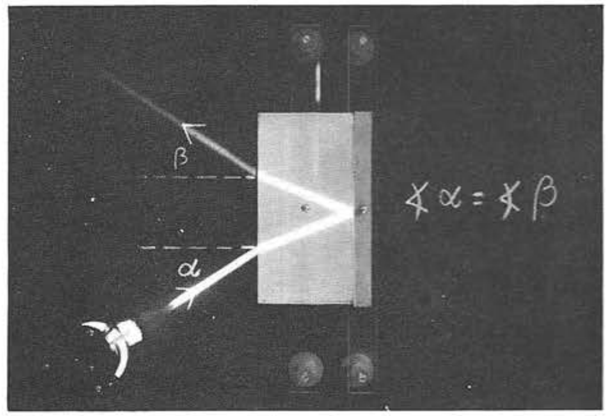
Experiment 6: Virtual Image Formed by a Convex Mirror

The virtual image produced by a convex mirror is found by using the two predictable rays as above, and then chalking in the extensions of the reflected rays so that they intersect behind the mirror. The image is virtual, erect, and smaller than the object.



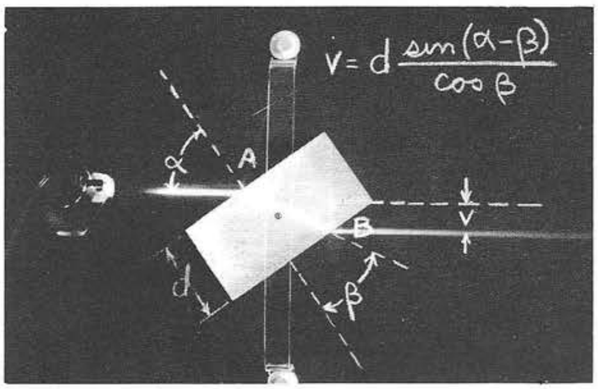
Experiment 7: Simple Refraction — Less Dense to More Dense Medium

The lower edge of the parallel-sided prism is made opaque by taping a sheet of paper to it. The phenomenon of refraction is then clearly visible in an uncomplicated fashion when a pencil of light is projected obliquely at the upper face. The chalked normal and extension of the refracted ray enable the teacher to label the angle of incidence (α) and the angle of refraction (β).



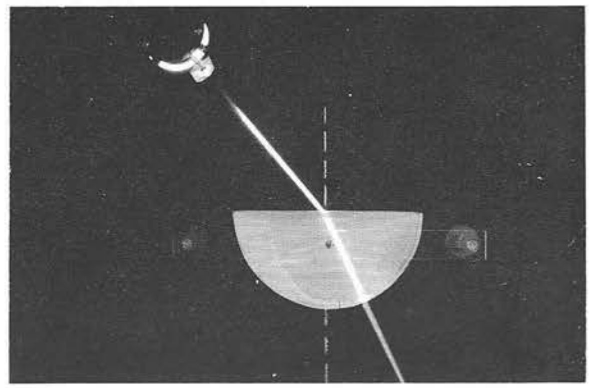
Experiment 8: Simple Refraction — More Dense to Less Dense Medium

The opaque paper is replaced by the plane mirror. This produces a return pencil of light which demonstrates the deviation away from the normal as the ray passes from the more dense to the less dense medium. Note how distinctly the apparatus shows the equality of the incident angle (α) and the emergent angle (β).



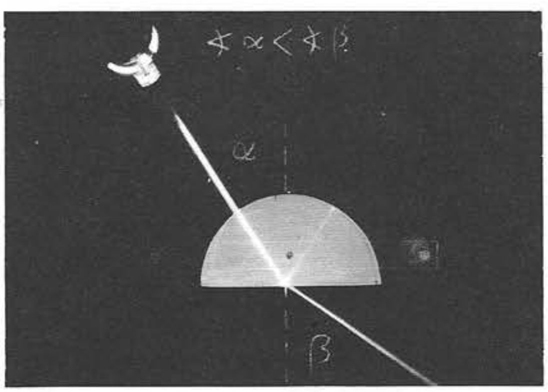
Experiment 9: Parallel Displacement by a Rectangular Block

By leaving both faces of the parallel-sided prism free, the displacement of a pencil of light is clearly demonstrated. The absence of deviation is also readily apparent.



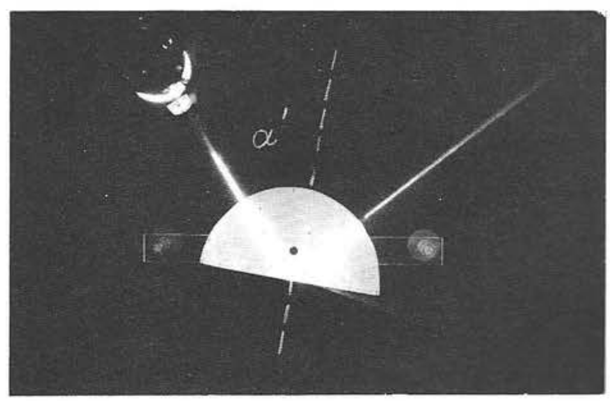
Experiment 10: Semi-circular Body — Light Incident at Center of Disc

When used as illustrated above, the semi-circular disc shows that any pencil of light incident at the center of curvature will be refracted so that it emerges perpendicular to the tangent at the point of emergence, hence will undergo no second deviation.



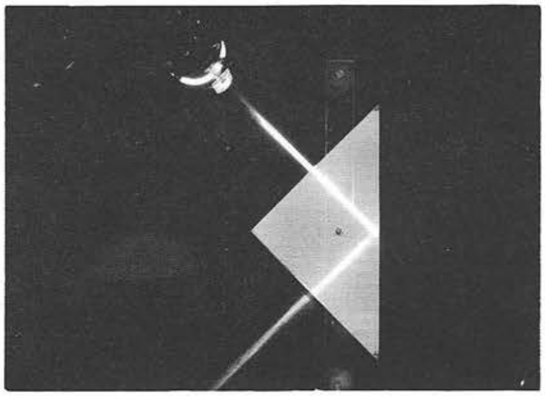
Experiment 11: Semi-circular Body — Light Incident at Right Angles to Tangent

This arrangement clarifies several important concepts: (1) light incident normal to the tangent is undeviated; (2) light passing from more dense to less dense optical medium is deviated away from the normal; (3) partial internal reflection occurs at incident angles smaller than the critical angle in the dense medium.



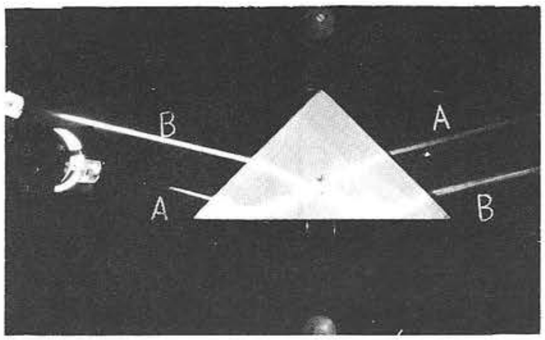
Experiment 12: Semi-circular Body — Critical Angle

The projector is placed so that the pencil of light lies along an extension of a radius of the disc. The semi-circular body is then rotated until total internal reflection occurs. By chalking in the appropriate normal, the critical angle α' for this material is readily measured.



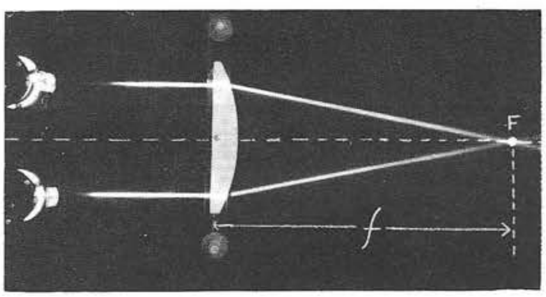
Experiment 13: Triangular Prism — Total Internal Reflection, 90° Deviation

A single internal reflection in the large triangular prism is obtained in the manner shown. The 90° deviation thus produced is used in the design of some types of modern periscopes.



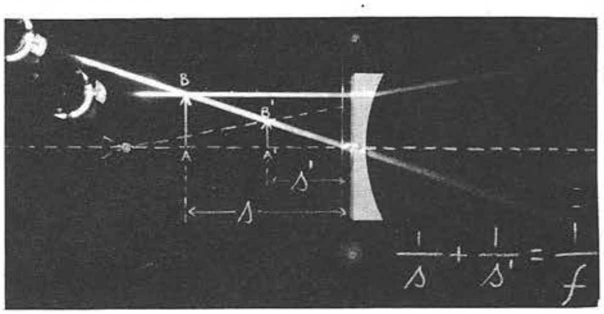
Experiment 15: Reversing Prism

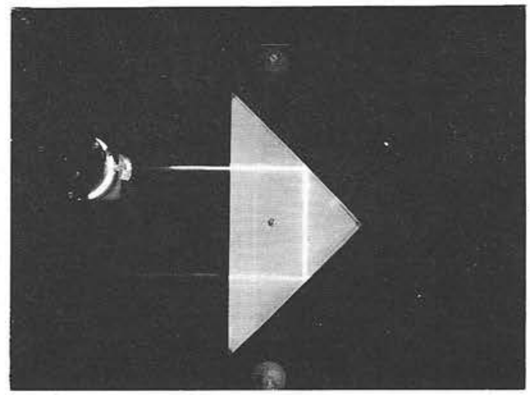
An interesting application of a triangular prism in which refraction and total internal reflection cooperate to reverse the positions of two parallel rays.



Experiment 17: Focal Length of a Plano-Convex Lens

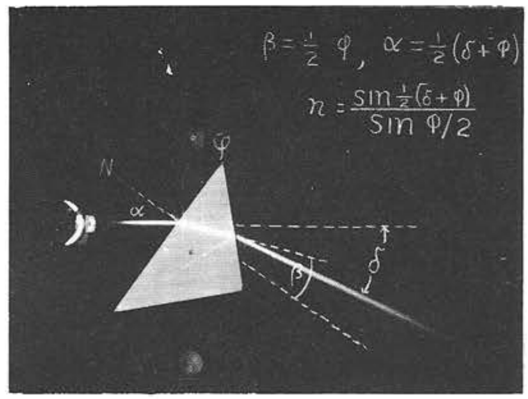
The focal length of the plano-convex lens is determined by means of a pair of pencils of light parallel to the principal axis. If care is taken in establishing parallelism, the point of intersection of the refracted pencils will also locate the principal axis which may then be chalked in as illustrated.





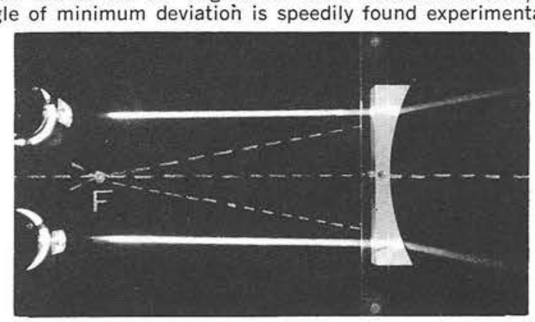
Experiment 14: Triangular Prism — Total Internal Reflection, 180° Deviation

Reorientation of the prism results in a total deviation of 180° achieved by two internal reflections. The basic principle of prism binoculars is thus demonstrated; these demonstrations also show that the critical angle for plexiglass is smaller than 45°.



Experiment 16: Angle of Minimum Deviation

The deviation of a pencil of light through the prism is most easily observed when the light passes through the prism just below one of the 45° angles. For more advanced classes, the angle of minimum deviation is speedily found experimentally.

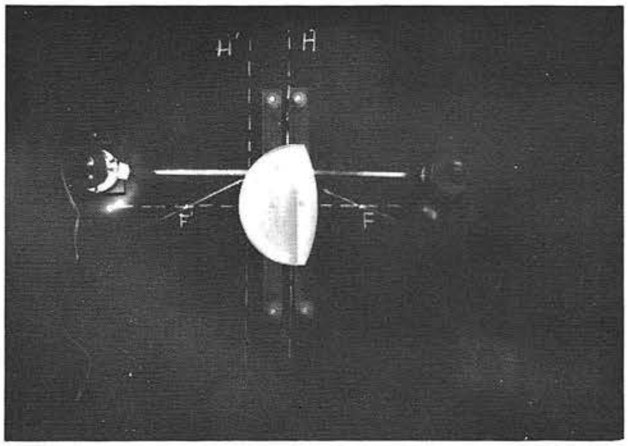


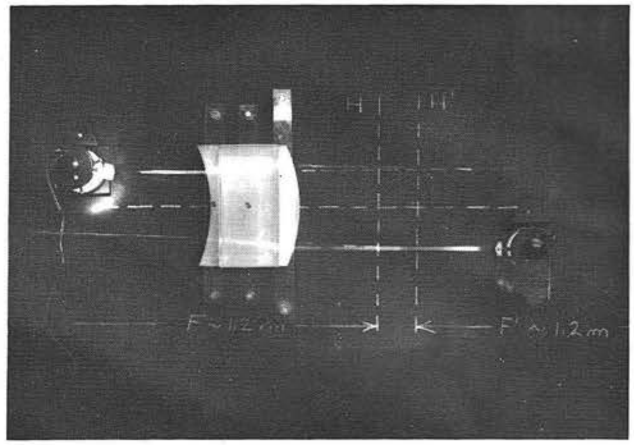
Experiment 18: Focal Length of a Plano-Concave Lens

Similarly, parallel pencils of light are employed to pinpoint the principal focus of the concave lens. In this case, virtual rays are chalked in as extensions of the refracted rays behind the lens until they intersect at F.

Experiment 19: Virtual Image Formed by a Concave Lens

Two pencils of light, one parallel to the principal axis and the other directly through the optical center, are arranged so that both pass through the object point (B). The refracted ray due to the parallel pencil is then extended back until it intersects the incident ray heading for the optical center. The virtual image is then A′B′ and is smaller than the object AB.





Experiment 20: Thick Lens, Double convex

This double convex thick lens is formed of the semicircular and planoconvex components to show the behavior of such an arrangement when light enters from opposite directions.

Experiment 21: Thick Lens, Concavo-convex

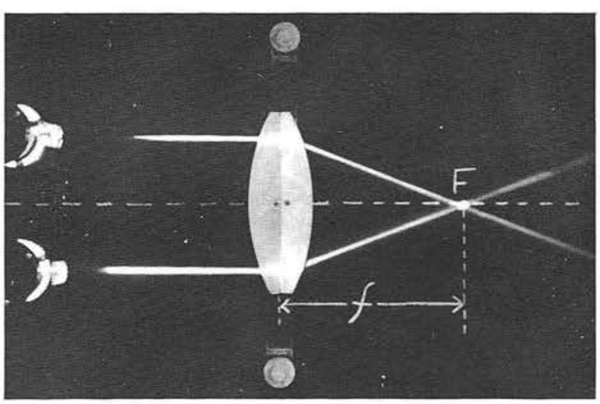
A concavo-convex thick lens is examined for conjugate action with the help of two ray projectors, one mounted on each side of the assembly. This system is representative of a thick "meniscus" lens.

LIST OF EXPERIMENTS

Section 2

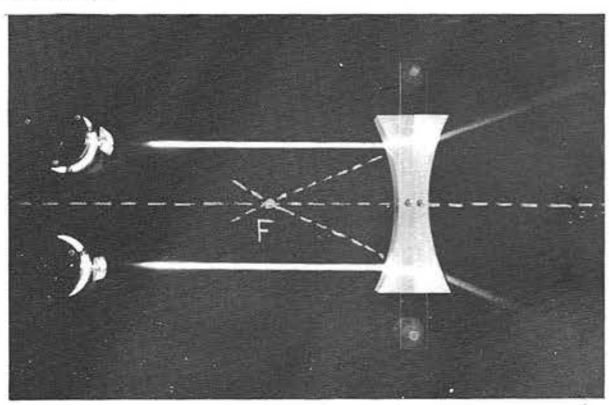
22. Focal Length of a Double Convex Lens
23. Focal Length of a Double Concave Lens
24. Real Image Formed by a Double Convex Lens – Light Pencil Method
25. Real Image Formed by a Double Convex Lens – Cone of Light Method
26. Nearsighted and Farsighted Eye
27. Simple Magnifier
28. The Telescope
29. The Compound Microscope
30. Spherical Aberration
31. Dispersion – Spectrum Using Flint Glass Prism
32. Dispersion – Spectrum Using Diffraction Grating
33. Young's Double Slit Experiment
34. Angle of Minimum Deviation with Equilateral Prism
35. Spectrum with Equilateral Prism
36. Real Image Formed by a Concave Mirror
37. Focal Length of a Concave Mirror
38. Focal Length of a Convex Mirror
39. Focal Length of a Plano-Convex Lens
40. Focal Length of a Plano-Concave Lens
41. Virtual Image formed by a Concave Lens

Experiments – SECTION 2



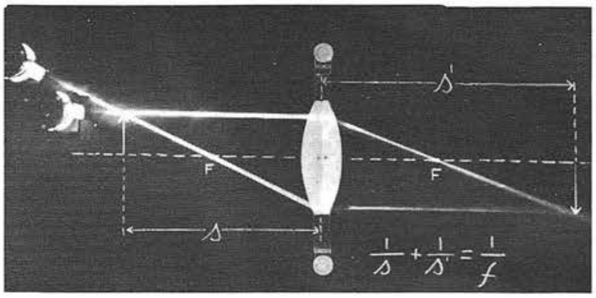
Experiment 22: Focal Length of a Double Convex Lens

Two plano-convex lenses supported in contact by clamping bar KO4113 form a double convex lens. The relationship between total lens curvature and focal length is easily noted when this experiment is compared with number 17.



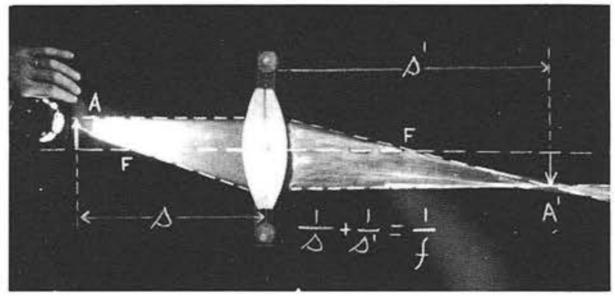
Experiment 23: Focal Length of a Double Concave Lens

The double-concave lens is built up of a pair of plano-concave types held to the blackboard by clamping bar KO4113. Clearly, the focal length is considerably shorter for the combination than for either of the components. Note the use of virtual rays to locate the principal focus.



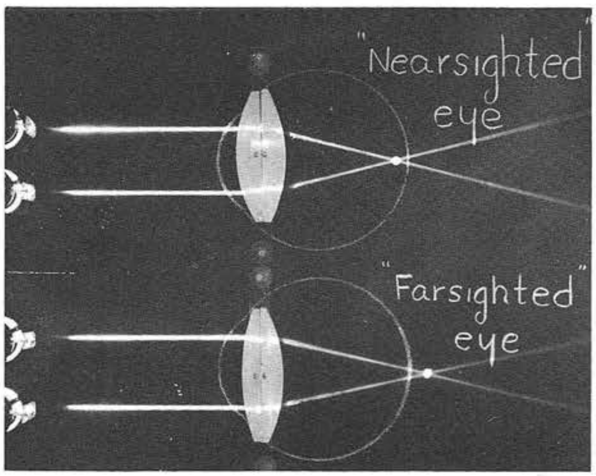
Experiment 24: Real Image Formed by a Double Convex Lens — Light Pencil Method

The use of a double convex lens rather than the plano variety makes it possible to produce a clear cut real image diagram on a relatively small blackboard because of the reduced focal length. In this illustration the object is between F and 2F, causing the image point to lie beyond 2F on the remote side of the lens.



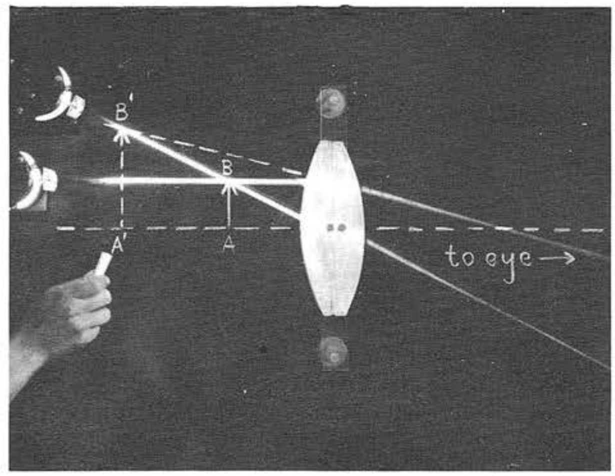
Experiment 25: Real Image Formed by a Double Convex Lens — Cone of Light Method

In this alternative method of producing the convergence which locates the image point (A'), only one source of light is needed. If the cone is considered to be made up of an infinite number of rays, students can then appreciate the fact that the lens brings all of them to a common focus.



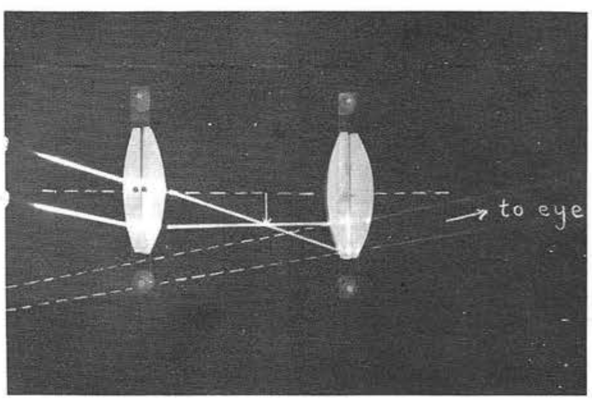
Experiment 26: Nearsighted and Farsighted Eye

The explanation of visual disorders of this nature is self-evident from this experiment. The nearsighted eyeball is too long and the farsighted one is too short for an eye lens which cannot accommodate properly. Correction of such defects can also be shown by using the proper lens types.



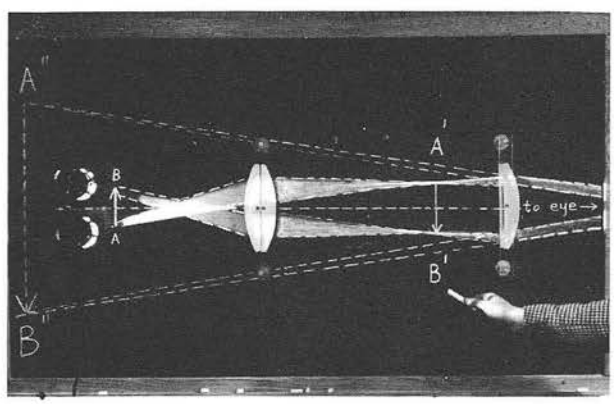
Experiment 27: Simple Magnifier

The use of the double-convex arrangement is recommended for this experiment because greater magnification is possible due to the shorter focal length thus obtained. The virtual image point (B') is located by chalking in the extension of the refracted ray due to the original parallel pencil of light.



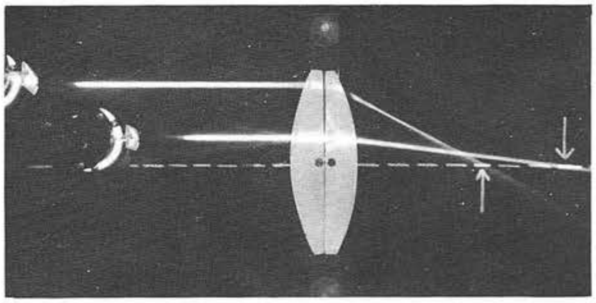
Experiment 28: The Telescope

By tracing the rays through the pair of double-convex lenses, it is seen that the final virtual image will be very much enlarged and inverted. This is a model of an astronomical telescope in which the objective (left lens) forms a real image near the principal focus of the eyepiece. The latter then yields a virtual image, acting as a simple magnifier.



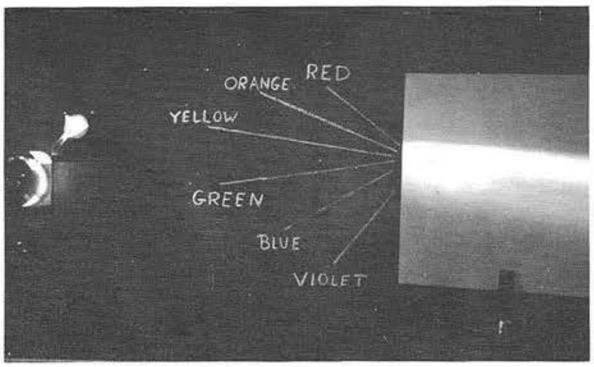
Experiment 29: The Compound Microscope

Light cones tell the story of the operation of this instrument. The object AB near the objective lens produces a real image inside the focus of the eyepiece A'B'. A virtual image A"B" very much enlarged, is then produced by the eyepiece lens.



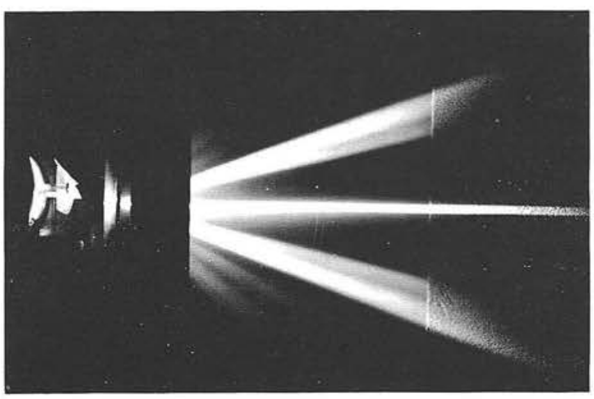
Experiment 30: Spherical Aberration

One projector is arranged to produce a paraxial ray and the other a marginal ray. The shift of focus is immediately visible as indicated by the arrows on the right side of the lens.



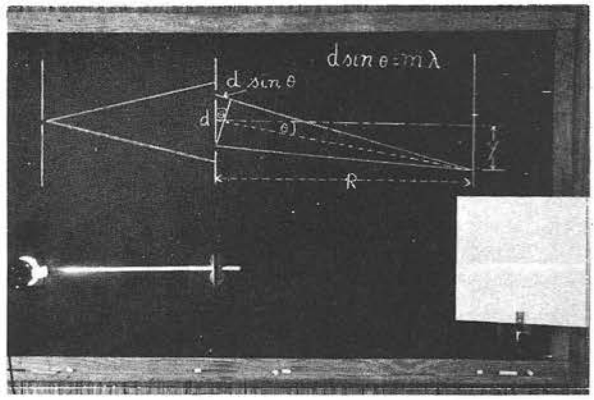
Experiment 31: Dispersion – Spectrum Using Flint Glass Prism

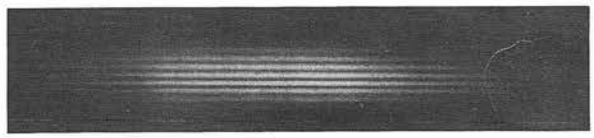
With the flint glass prism oriented close to the angle of minimum deviation, a broad clearly-defined continuous spectrum is obtained. It is displayed on the white screen offered as an accessory (KO4114).



Experiment 32: Dispersion – Spectrum Using Diffraction Grating

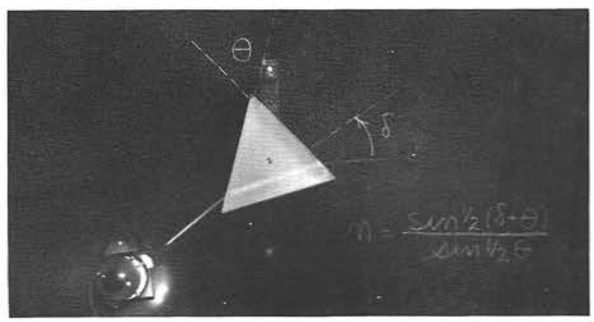
Diffraction grating KO3104 and screen KO4115 work nicely together to display both the visible spectrum and a portion of the ultraviolet. Students will also observe the reversal of deviation angles in the colors of this spectrum as compared with that produced by the flint glass prism.





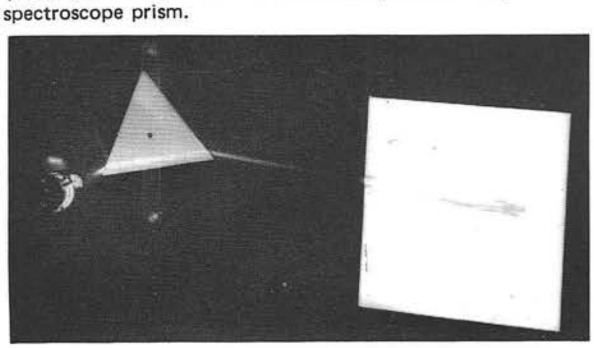
Experiment 33: Young's Double Slit Experiment

The single slit from the ray projector serves as a line source; the wavelets from this slit reach each of the pair of slits immediately beyond in phase, hence these slits form coherent sources. The white screen is placed several feet away; Young's interference fringes become clearly visible within the central bright pencil of light.



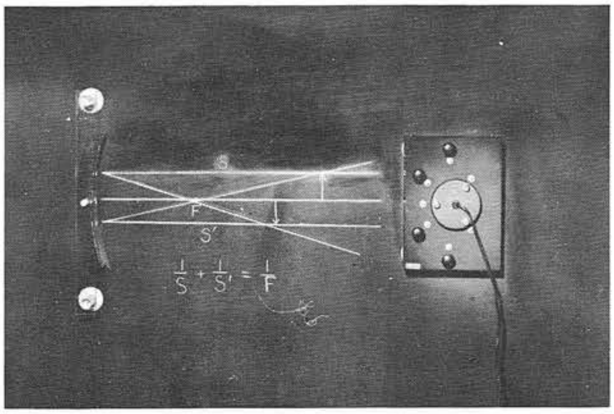
Experiment 34: Angle of Minimum Deviation with Equilateral Prism.

Angle of minimum deviation experiment using the equilateral plastic prism duplicates the conditions present in adjustable spectroscope prism.



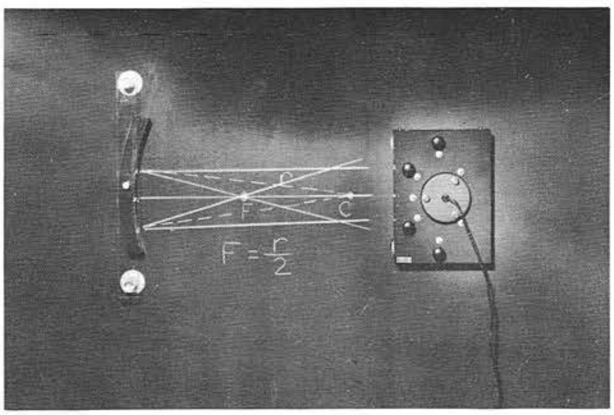
Experiment 35: Spectrum with Equilateral Prism.

Spectrum obtained by means of the equilateral plastic prism, one ray projector, and the white screen.



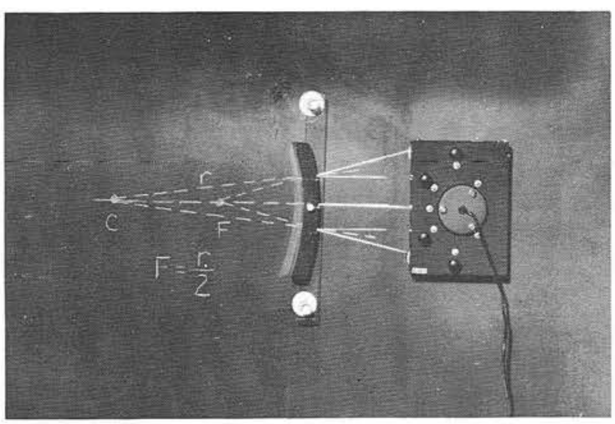
Experiment 36: Real image formed by a Concave Mirror

Two pencils of light from the upper half of the multiple ray projector are made to intersect at the object point (head of upright arrow.) These are predictable rays: one parallel to the principal axis and the other through the principal focus (F). The point of convergance locates the image point (head of inverted arrow.)



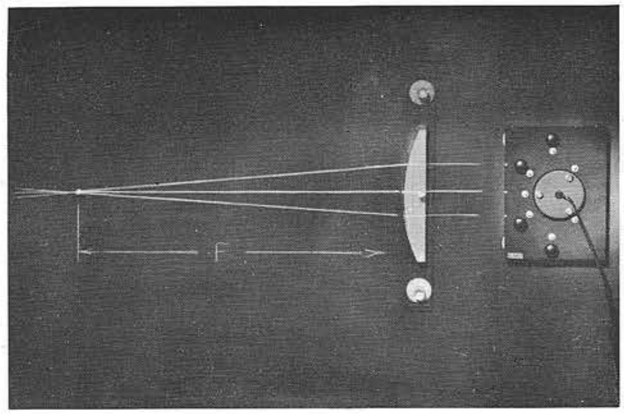
Experiment 37: Focal Length of a Concave Mirror

The center of curvature (C) of the concave mirror is located by means of a ray which reflects back on itself. (This ray is not shown in the photograph.) Rays parallel to the principal axis reflect through F (principal focus) located midway between C and the vertex of the mirror on the principal axis.



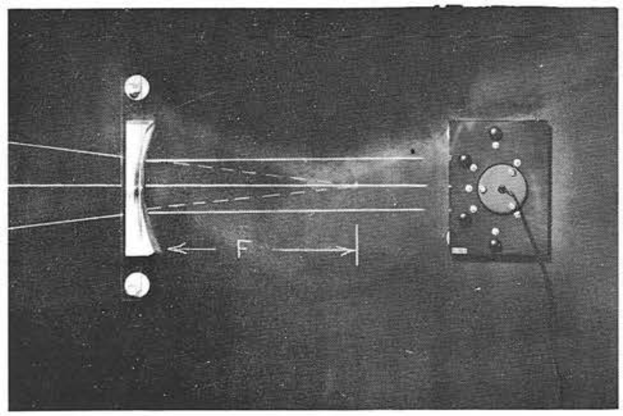
Experiment 38: Focal Length of a Convex Mirror

The center of curvature (C) is again found by means of a ray which reflects back on itself; this ray is extended behind the mirror until it intersects the axis. To locate F, virtual rays of the two incident parallel projectors are drawn behind the mirror until they intersect as shown.



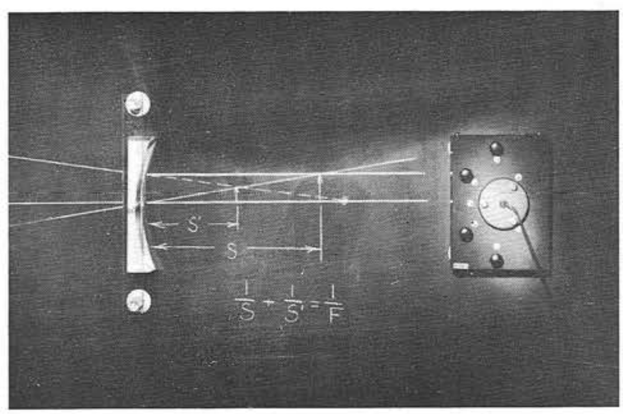
Experiment 39: Focal Length of a Plano-Convex Lens

Three parallel pencils of light from the multiple ray projector are directed at the lens. Care should be taken to insure that the center pencil passes through the center of the lens; this ray will define the principal axis. The point of intersection of the refracted pencils with the principal axis defines the focal point.



Experiment 40: Focal Length of a Plano-Concave Lens

Similarly, parallel pencils of light are employed to determine the principal focus of the concave lens. In this case, virtual rays are chalked in as extensions of the refracted rays behind the lens until they intersect at distance F.



Experiment 41: Virtual Image formed by a Concave Lens

Three pencils of light, one defining the principal axis, one parallel to the principal axis and the other directly through the optical center, are arranged so that the upper two pass through the object point (head of upright arrow at S.) The refracted ray traveling parallel to the axis is then extended back until it intersects the incident ray heading for the optical center. The virtual image is then formed at S.

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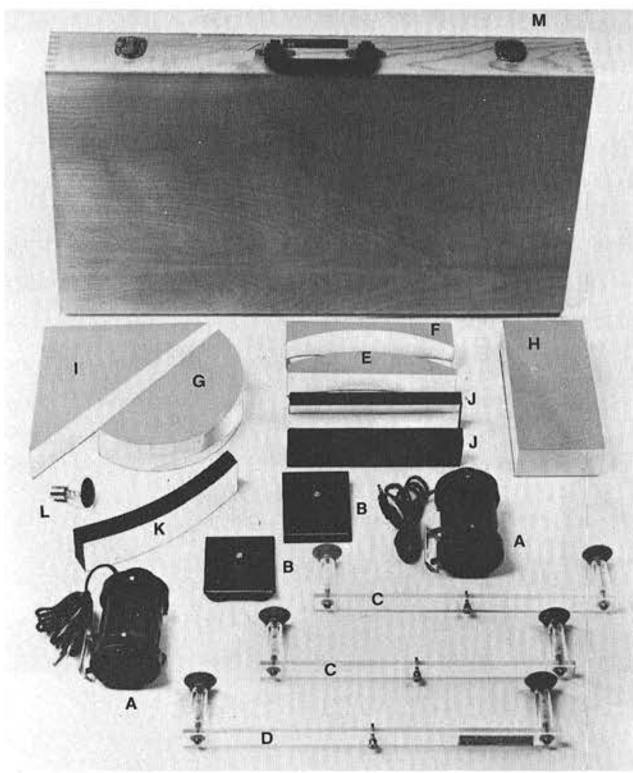

COMPONENTS

KO4100 - ©Blackboard Optics basic kit

A.	KO4101	Ray Projector	(2 pcs)
B.	KO4102	Holder for Projector	(2 pcs)
C.	KO4103	Clamping bar, 13 inch	(2 pcs)
D.	KO4104	Clamping bar, 15 inch	(1 pc)
E.	KO4105	Plano convex lens	(1 pc)
F.	KO4106	Plano concave lens	(1 pc)
G.	KO4107	Semicircular lens	(1 pc)
H.	KO4108	Parallel-sided block	(1 pc)
I.	KO4109	Prism, right angle	(1 pc)
J.	KO4110	Plane mirror	(2 pcs)
K.	KO4111	Curved mirror, double	(1 pc)
L.	KO4112	Projector lamp, spare	(1 pc)
M.	KO4118	Cushioned storage cabinet	(1 pc)

KO4100A - ©Blackboard Optics Accessories Set

N.	KO4113	Clamping bar, double screw 13 inch bar	(2 pcs)
O.	KO3071A	Prism, flint glass	(1 pc)
P.	KO4115	Screen, for projection	(1 pc)
Q.	KO4116	Holder, for screen	(1 pc)
R.	KO3105	Grating, replica, 6000/cm	(1 pc)
S.	KO4117	Holder, for grating	(1 pc)
T.	KO3086	Filters, set	(1 pc)
U.	KO3101	Slit, double	(1 pc)
V.	KO4122	Prism, equilateral	(1 pc)
W.	KO4105	Planoconvex lens	(1 pc)
X.	KO4106	Planoconcave lens	(1 pc)
Y.	KO4121	Planoconvex lens, long focus	(1 pc)
Z.	KO4125	Multiple Ray Projector	(1 pc)
ZZ	KO4126	Replacement lamp, for above	(1 pc)