LIGHT BOX & OPTICAL SET - 'Hodson'

Cat: HL2060-001 Light Box book

KIT COMPONENTS:

Light Box & Collimating Lens	Rectangular Block
Three Slit Former Plates	Half Round Block
Set of 8 Colour Filters & Plates	45^o 45^o 90^o Prism
Colours:	60^o 30^o 90^o Prism
Red Orange	60^o 60^o 60^o Prism
Yellow Green	Bi-Concave Lens
Blue Violet	Bi-Convex Lens
Cyan Magenta	Bi-Convex Lens (thick)
Spare Lamp: Axial, 12V.30W	Plane Mirror
Foam Housing of 3 parts	Half Round Mirror
Experiment Book	Parabolic Mirror

IMPORTANT NOTE The 'Hodson' Light Box is virtually unbreakable and is not affected by heating during prolonged operation. However care should be taken to ensure that the colour filters do not remain in position for long periods otherwise radiant heat from the lamp may affect them.

To ensure correct ventilation whilst using three colour filters simultaneously, the 'ray end' of the box should be left uncovered and the under side of the box should permit the free passage of air.

For use with 12V.AC/DC power source at 2 to 3 amps.

CAUTION: WHEN UNIT IS OPERATING, THE LAMP IS VERY HOT. DO NOT TOUCH.

REPLACEMENT LAMP: Axial Filament, Halogen, type 'G4', 2 pin, 12V. 30W.

When replacing the lamp, do not remove the lamp socket. Allow the globe to cool, reach through the openings and pull lamp firmly from the small socket. Hold the new lamp in a plastic covering so that fingers do not touch the glass, align the two small pins with the holes in the socket and press firmly into place.

TO CONVERT OLD LAMP SYSTEM TO NEW LAMP SYSTEM: Twist old model lamp socket to release it from the Light Box and remove the lamp from the socket. Fit the new style 2 pin globe into the new lamp socket and position the socket in the hole. Rotate it until the two lugs engage and lock the socket from turning. Invert the box while holding the socket in place and, on the inside of the box and through the end opening, slide the "keeper plate" into the groove provided in the socket. The small "pips" on the "keeper plate" should be pressing against the Light Box body. When the "keeper plate" is fully engaged into the groove of the lamp socket, the socket is fully secure.

REMOVAL OF LAMP SOCKET: The lamp socket can be removed from the box by sliding the "keeper plate" away from the groove in the socket and extracting it through the open end of the box.

UPGRADES: Low cost upgrade kits are available to change your old style Light Box into the new style lamp socket, lamp and sliding collimating lens. Ask you equipment supplier for more details.

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CONTENTS

Printwize:: Follow the chapters and colours as listed below.

Always start a new page for a new chapter.

Front / rear covers: not sure yet about this. Might go fo full colour for the covers showing a light box emanating coloured light. The possible jpg pic for the front cover is emailed with this word file.

Introduction pages: (mid brown or fawn)

Chapter 1: Reflection (red)

Chapter 2: Refraction (blue)

Chapter 3: Colour Observations (green)

Chapter 4: Optical Bench (mid brown or fawn)

Colours to be used in a band across top of page, for names of experiments and for italics questions asked throughout the book. Use you imagination - whatever looks nice.

Printwize: Follow the Light Box book in the way it lists the index of experiments.

Page numbers for experiments to go in at the end.

The Light Box and Optical Set

Introduction and general description

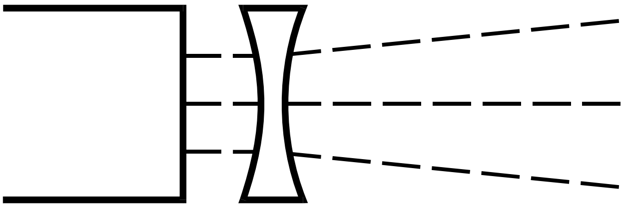
Power requirements - 12V.AC/DC. at 2 to 3 Amp.

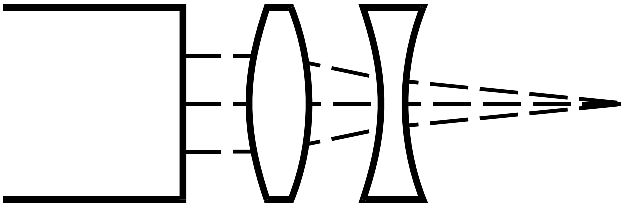
The optical set consists of a source of light rays and a set of devices which reflect, refract and colour blend light so that measurements and observations may be easily obtained.

The light source is housed in a specially designed Light Box complete with an adjustable collimating lens. The opposite end of the box is fitted with two hinged mirrors which are used to reflect the light emerging from the side apertures. With various colour filters in place, the two side beams may be swung back and forth to overlap and blend with the fixed centre beam. The effect is evident on a screen placed about 200 mm from the box.

The collimated light beam that emerges from the front of the box may be broken into one narrow beam (for the production of spectra) or alternatively one, two, three or four narrow slit rays, by fitting the appropriate slit former into the groove provided. These rays or beams may be coloured by placing a colour filter into the wider groove provided at the front of the box.

The beam may be made slightly converging or diverging by sliding the collimating lens with the adjustment button provided. This change can be clearly observed when using a multiple slit former. If greater convergence or divergence is required for a particular experiment use the lenses as shown below.





SETTING UP FOR AN EXPERIMENT.

Place the Light Box on a table top with the light socket on top. The three point base contact ensures stability during operation. Connect the lamp cable to a 12V 3A supply. The lamp (see spares) will run at higher voltages (up to 14 volts) but this is not recommended because lamp life will be reduced.

Insert one of the multiple slit former into the front groove. Slide the collimating lens to obtain a set of parallel rays.

Place the block lenses, prisms and mirrors on a plain sheet of paper in the various positions as indicated in the experiments. Always handle them by their finger grips to protect their optical faces from smears and scratches. The base of each lens and prism is specially finished to cause the light rays to reflect so that the path of each ray through the device is visible. Of course the best visual results are obtained in semi or full darkness.

As devices are placed very close to the Light Box, bright internally reflected rays may become evident inside the blocks. These are due to rays entering the block through the top face and internally reflecting off the vertical faces. In addition, rays passing over the blocks may be evident some distance beyond the block. These can be eliminated by:-

- *moving the prisms and blocks further from the Light Box;*
- *by raising the sheet of paper from the table by placing it on a thin book, or*
- *by blanking off the upper ends of the slits to shorten the ray height.*

RECORDING RAY PATHS

To record ray paths, mark the position of the lens, prism or mirror being used by running a sharp pencil around the perimeter. Then mark the centre of the ray being observed in two positions, one dot close to the lens surface and one as far away as possible. If the ray pattern is complicated with rays crossing each other, number the dots representing each ray so that they can be easily followed.

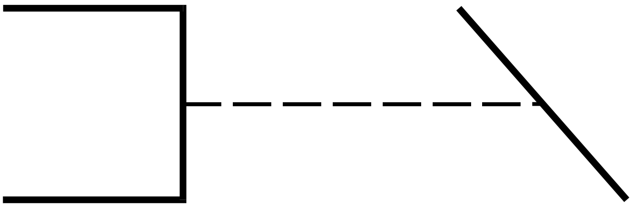
Remove the lens or prism and carefully rule lines through the numbered points to show the ray paths to and from the device and also the path taken through the device. Mark arrow heads on the lines to indicate their direction of propagation.

If in doubt as to the continuity of any line, replace the device in exactly the same position and retrace the ray.

Chapter 1 REFLECTION

Experiment 1
REFLECTION
- Single Ray

Project a single ray along the paper and mark its two ends. Place the plane mirror halfway along this path, crossing it at an angle.



Mark the position of:-

- *The glass front face of the mirror.*
- *The reflecting rear face of the mirror.*
- *The reflected ray (or rays). Explain the second fainter reflected ray.*

Draw a line perpendicular to the mirror at the point where the incident and reflected rays meet the mirror face. Such a perpendicular is called the NORMAL to the mirror at this point.

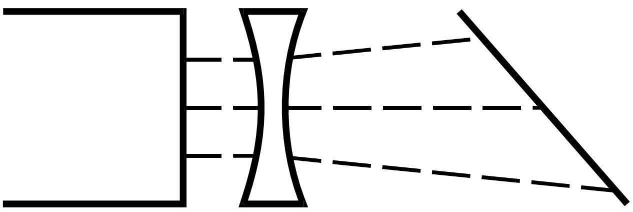
Measure the angle between the INCIDENT RAY and the NORMAL. This angle is called the ANGLE OF INCIDENCE.

Measure the angle between the REFLECTED RAY and the NORMAL. This angle is called the ANGLE OF REFLECTION.

These angles are measured from the NORMAL because in later experiments you will be reflecting rays from curved mirrors. Since you cannot measure the angle between the ray and the curved surface of the mirror, you must draw a normal to the curved surface and from this straight line measure the angles of incidence and reflection.

Experiment 2
REFLECTION
- Divergent Rays

Place a triple slit former in the narrow front groove of the Light Box. Project a set of diverging rays along a sheet of paper and mark the ray paths. Place a plane mirror so that the rays meet it at angles that are not 90^o. Mark the reflecting surface of the mirror and the paths of the reflected rays.



Draw normals to the mirror surface at each point of the reflection.

Measure the angle of incidence and angle of reflection at each point of reflection.

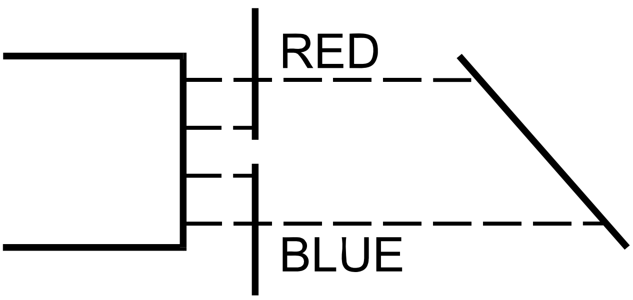
Tabulate your results as follows:

RAY	ANGLE OF INCIDENCE	ANGLE OF REFLECTION
A		
B		
C		

- *Is the angle of incidence greater than, less than, or equal to the angle of reflection?*
- *You have discovered one of the laws of reflection – what is it?*
- *Did the diverging rays remain diverging after reflection?*
- *Do parallel rays remain parallel after reflection? Try it and see.*
- *Do converging rays remain converging after reflection? Try it and see.*

Experiment 3
REFLECTION
- Lateral and Vertical Inversion

Set the ray box to project two parallel rays. Place a colour filter (blue) over the left hand beam (as viewed from the front or slit end of the box) and colour the right hand beam red. Reflect the two beams from the plane mirror as previously.



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Face the mirror and look at the reflection of the rays

- *Is the left beam red or blue?*

Record the rays in coloured pencil showing the red and blue beams.

- *What happens to an image on reflection in a plane mirror?*
- *Is the image you see of yourself in a mirror the same as the image your friends see of you?*
- *If your face is reversed from left to right in reflection why is it not reversed from top to bottom?*

If you turn your head sideways, so that it is horizontal, your reflection will be reversed vertically. Try it and see.

- *What is meant by "LATERAL INVERSION ON REFLECTION?"*

If you hold a card labelled L $\rightarrow$ R so that it is reflected in a mirror, which one of the following examples should be the reflection?

L ► R	R ► L	Я ◄ ⅃	R ► ⅃	⅃ ◄ Я	R ► ⅃
L ◄ R	R ◄ L	Я ► ⅃	Я ◄ ⅃	Я ► L	Я ◄ L

Do not try it until you have predicted the result. When scientists believe they know the rules of how things behave, they say that they have a theory and they predict what should happen under certain circumstances. Then they experiment to test their prediction. Depending on the result of their experiments they either accept, reject or modify their theory.

- *Did your experiment lead you to accept, reject or modify your theory?*

Try another prediction.

- *What should the reflection of the following capital letter word look like if a plane mirror is placed vertically along the dotted line and the reflection is observed in the mirror from a position at the bottom of the page?*

....

CARBON-DI-OXIDE

Write down the expected image before you actually try the experiment.

- *Was your prediction correct?*
- *Was this LATERAL INVERSION?*
- *If you were told to hold the word, CARBON-DI- OXIDE and observe its reflection in a mirror, how would you hold it?*
- *Is this the way it was presented to the mirror in the previous experiment?*
- *If the word is written on transparent paper and presented to the mirror in the two manners described, how would it look to you if you viewed the mirror through the paper? Try it and see.*
- *Is this last inversion due to the mirror, or due to the way the word is presented to the mirror?*
- *Why do some of the letters show reversal while others do not?*

If both halves of an object or image are mirror images of each other about a central line, they are called SYMMETRICAL.

- *Is your face symmetrical?*

Place a large plane mirror so that it stands out vertically from your face, straight down the centre of your nose, then look at yourself in another mirror

- *Do you look normal with a perfectly symmetrical mirror image type of face?*
- *Which half reflected do you like best?*

Move the mirror to the other side of your nose.

- *Is having two noses an improvement?*

Move the mirror to the other side of your nose.

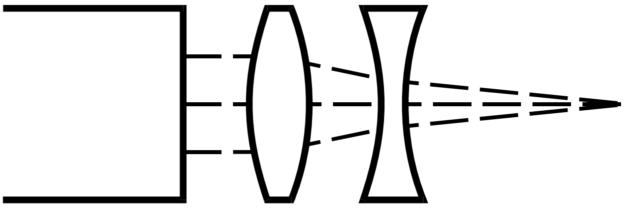
- *Do you like yourself with no nose and two eyes close together?*

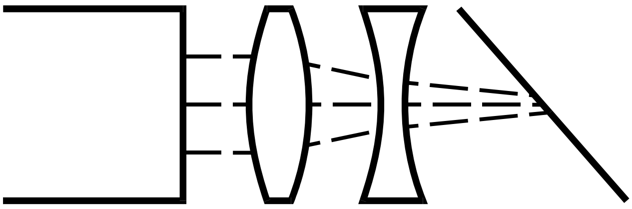
Experiment 4

REFLECTION
- Position in a Plane Mirror

When looking into a mirror, your reflected image appears to be somewhere behind the mirror. If you move backwards half a metre, the reflection also moves away from you. The following experiment will help you to locate the image position.

Project a set of converging rays across your sheet of paper and record their positions and focal point. Use the lens combination shown and move them relative to one another to adjust your focal length.





Place a plane mirror across the rays at an angle and record the paths of the reflected rays.

While looking in the mirror at the reflection of the converging rays, lift the mirror and observe the real converging rays. Remove and replace the mirror several times vertically, noting the similarity of the real and reflected rays.

- *Would you say the point where the real rays meet is the reflection of the point where the reflected rays meet?*

Record these two points of convergence and the position of the reflecting surface of the mirror.

Draw a line joining the two points of convergence.

- *What angle does the line make with the mirror?*
- *What is the distance of the real convergence point and of the reflection convergence point from the mirror?*

Repeat the experiment with another piece of paper, another set of converging rays and the mirror closer to or further from the point of convergence.

Locate the convergence points and the mirror position, then draw lines and measure angles as before. Stand a pin vertically in the paper (using cardboard beneath it) exactly at the two convergence points.

You now have a pin in front of the mirror and another pin hidden behind the mirror.

Lift the mirror vertically until you can see the hidden pin, then replace it and lift it several times.

- *Is the hidden pin located at the position of the reflected image of the front pin?*
- *Does any shift in your (the observer's) position affect the location of the image position?*

Leave the front pin and the mirror unaltered. Try it and see.

Experiment 5a
REFLECTION
- Multiple Reflections

Reflect a single ray from the plane mirror at an angle of incidence of 45^o to 50^o.

Examine the reflections closely.

- *How many reflections are there?*
- *Which is the brightest?*

Look carefully down on the mirror from above and then make an enlarged drawing to show how the three reflected rays occur.

- *Is there something special in the angle of incidence being 90^o?*

Experiment to discover if all three reflections occur at other angles of incidence, e.g. 10^o, 20^o and so on to 90^o.

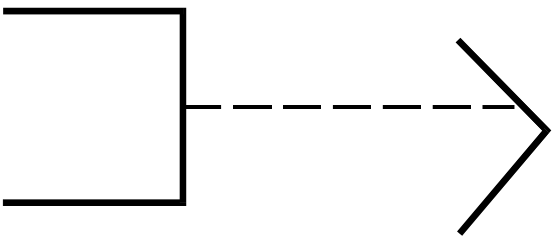
- *Which reflected ray disappears and at which angle does this occur?*
- *Why is this reflection the faintest of the three?*

Place the rectangular block in front of the mirror and repeat the experiment and observations.

Experiment 5b
REFLECTION
- Multiple Reflections

Place two mirrors at an angle of 90^o to each other.

Aim a single ray to strike one mirror at an angle, at a point about 25 mm from the corner where the two mirrors meet.



Observe the principal reflected ray (not the fainter secondary reflections), as it is reflected from both mirrors. Record this position.

- *What do you notice about the directions of the original ray and the emergent ray?*
- *Does this result occur at whatever angle you send the ray into the right angled mirror?*

Look into the corner of the mirrors.

- *What do you see?*
- *If you shift your position does the same thing occur?*

If there is a larger plane mirror available, place it horizontally on the desk and stand the other two plane mirrors on it at right angles to each other, so that the three mirrors are mutually perpendicular.

A set of reflectors like this was placed on the moon by the astronauts.

Move aside and up and down, looking into the triple corner from all directions.

- *What do you see in the corner?*

Aim a beam of light into the corner.

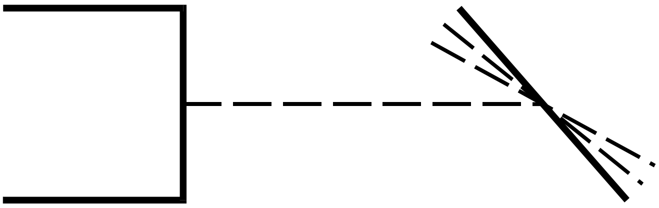
- *What do you notice about the reflection?*
- *Suggest why the reflector placed on the moon was a triple right angled reflector.*
- *What type of light beam was aimed at it and with what result?*
- *Since scientists know this type of reflection occurs on Earth, what have they gained by placing the reflector on the moon?*
- *Examine the reflectors on the back of a car or bicycle. What is the shape of the dimples in the glass or plastic?*

Experiment 6

REFLECTION

- Rotation of a Plane Mirror

Aim a single ray of light at a plane mirror. Record the incident ray, the mirror reflecting surface position (label it M1) and the reflected ray (label it R1).



Now rotate the mirror about 5^o around the incident point, so that the incident ray strikes the mirror in the same position, but at a slightly different angle.

Record the new mirror position as M2 and the new reflected ray as R2.

Using a protractor, measure the angle through which the mirror was rotated (the angle between lines M1 and M2).

Similarly measure the angle through which the reflected ray was rotated (the angle between lines R1 and R2).

Compare the two angles.

- *Predict what will happen to R2 if the mirror is rotated from M2 by a further 10^o.*

Check if your prediction is correct.

This technique is often used by scientists to exaggerate or amplify slight movements within measuring equipment such as electrical meters. Place the mirror in such a position that the reflected beam falls on a wall or a sheet of card about two metres from the mirror.

Move the mirror fractionally by about 0.5^o.

- *What is observed at the distant image?*

Ask your teacher to show you a spot galvanometer and discover how it uses a mirror and a light ray as a long pointer.

Experiment 7

REFLECTION

- Images in a Plane Mirror

- Parallax

Stand a pin vertically in a sheet of paper using cardboard beneath it.

Place the plane mirror about 40 mm behind the pin and observe the reflection of the pin in the mirror. The reflection appears to be behind the mirror.

To locate the image position, aim a single ray of light to hit the mirror and reflect back to the pin.

- *Does the reflection of the ray seen in the mirror go to the reflection of the pin?*
- *If you look above the pin and along the ray towards the mirror, is the ray bent or is it straight?*

Mark the mirror position and incident ray only.

Move the Light Box to a different position, aiming the reflected ray at the pin as before. Record the incident ray.

Repeat the procedure, moving the ray source to several other positions on both sides of the pin. Record the incident rays only.

Remove the mirror and draw the incident rays, continuing them until they meet.

- *Do they all meet at one point?*

Replace the mirror.

- *Do the lines you have drawn in front of and behind the mirror lead to where you see the reflection of the pin?*

If you are in doubt, stand a tall pin or knitting needle vertically at the point where the lines meet behind the mirror so that you can see the top of the needle and the reflection of the pin at the same time.

- *Do they appear to be in line?*

Move your head to one side and then the other. Do the needle and pin reflections remain in line? This is a phenomenon known as PARALLAX.

PARALLAX is the apparent sideways motion of a distant object, relative to a near object, in the same direction as the movement of the observer.

Astronomers use parallax to show which are near and which are distant stars. As the Earth moves along its orbit path, distant stars appear to move, relative to the nearest stars, in the same direction as the Earth. Join the pin position to its image position.

- *Does this line cut the mirror line at right angles?*
- *Is the image position as far behind the mirror as the object is in front of it?*

Move the pin to another position and predict where its image will be. Repeat the earlier part of this experiment to check if your prediction is correct.

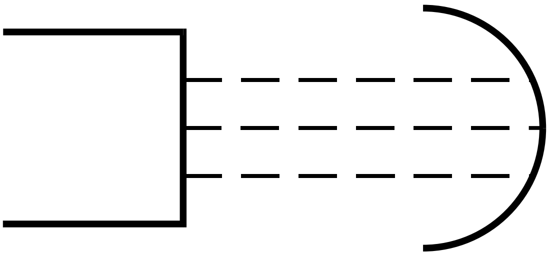
Experiment 8

REFLECTION

- In a Circular, Concave Mirror.

Select the semi-circular curved mirror.

Aim a set of parallel rays into the centre of the inside curve of the mirror so that the rays are parallel to the axis of symmetry of the mirror.



Record the incident and reflected rays and note where they meet. This point is called the FOCUS of the mirror.

- *How far is the focus (or FOCAL POINT) from the mirror?*

This distance is called the FOCAL LENGTH of the mirror.

If the focal point appears blurred and broad, with too many rays overlapping through it, block the outer rays as they leave the Light Box and use only the central ones.

Experiment 9

REFLECTION

- Centre of Curvature

- Radius of Curvature

- Focal Length of a Circular Mirror

Set up as in the last experiment and, on paper, trace the inside reflecting surface of the concave mirror. Move the mirror around the curve and continue tracing until you have a complete circle.

Measure the diameter of this circle in several directions and calculate an average diameter.

- *What is the radius of the circle?*

Find the centre of curvature, i.e. the centre of the circle.

- *How does the radius compare with the focal length you found in the last experiment?*

Another method of finding the centre of curvature is to aim a single ray at the inside curve of the mirror so that it reflects straight back on itself. To do this, the ray must be meeting the surface along its ”normal” or must be perpendicular to the surface at that point and must be reflected back along this radius position through the centre of curvature. Record this ray position and without moving the mirror, move the ray box to another position where the ray again reflects back on itself and record the new ray position. Repeat this procedure a third time.

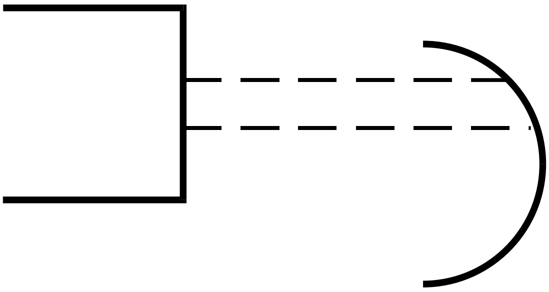
The point where the rays meet is the CENTRE OF CURVATURE and the distance from this point to the curve of the mirror is the RADIUS OF CURVATURE.

Experiment 10.

REFLECTION

- Circular Aberration.

- *What happens when parallel rays are directed at a circular mirror PARALLEL to the axis of symmetry but displaced sideways?*



Use only two rays from the Light Box.

Record six positions of the focal point as you move the ray box to different positions, keeping the rays parallel to the axis of symmetry.

- *Do the various focal points lie on a curve or on a straight line?*
- *When four rays which are parallel to the axis of symmetry of the mirror are focused do they really focus at one point?*

Using a four slit former, block the inner two rays and record the position of the outer two rays and their focal point. Mark the mirror position.

Block the outer two rays and record the inner two rays and their focal point.

- *Which rays focus nearer to the mirror - the inner rays or the outer rays?*

Using another sheet of paper, repeat the outer and inner ray tracing, with four rays PARALLEL to the axis of symmetry but displaced sideways.

- *Is the circular aberration (i.e. failure for all rays to focus at one point) increased or decreased by shifting the rays to one side of the axis of symmetry?*

Remove the slit-former from the Light Box and adjust the collimating lens to project a diverging beam. Hold the Light Box above the table and move it about one metre away. Project this wide beam into the mirror at a slight downward angle and observe the brightly illuminated area. Outline this area.

This shape is called a CAUSTIC CURVE. Caustic means burning.

- *Why is a magnifying glass often called a burning glass?*
- *What causes the shape of this caustic curve?*

Slide the single slit-former sideways across the face of the Light Box so that the wide beam is gradually cut off

Determine to where each part of the beam is reflected.

A shape like the caustic curve, which is the outline of the limiting positions of a movable or flexible line, is sometimes called an ”envelope”. You will meet more envelopes in higher mathematics and find the equations that generate them.

On one of your records of reflections, draw lines from the centre of curvature to the points of reflection. Each of these new lines is a radius and is normal to the mirror curve.

For each reflection, mark the angle of incidence (between the incident ray and the normal) and the angle of reflection (between the reflected ray and the normal).

Does each angle of incidence equal the accompanying angle of reflection?

Experiment 11
REFLECTION
- Convex Mirror

Project a number of parallel rays to strike the OUTSIDE surface of the semi circular mirror, parallel to its axis.

Record the mirror position and ray paths and indicate the ray directions with arrow heads.

- *Where do the diverging rays appear to come from?*

Locate this point by drawing the diverging rays backwards through the mirror position. The point they come from is called the VIRTUAL FOCUS and the distance of this point from the mirror is called the VIRTUAL FOCAL LENGTH.

- *How does this focal length compare with the focal length of the concave side of the mirror?*
- *How does it compare with the radius of curvature of the mirror found previously?*
- *By how much do the results differ?*
- *Can this amount be related to the mirror construction?*
- *Suggest why slightly convex mirrors are used as rear vision mirrors in cars.*

If a line is drawn from the centre of curvature through the point where a ray strikes the mirror, this line is normal to the surface. Draw several of these normals.

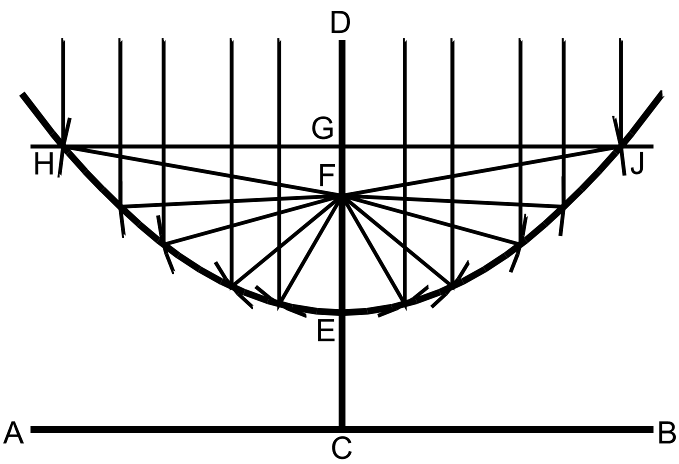
For each reflection, measure the angle of incidence (between the incident ray and the normal) and the angle of reflection (between the reflected ray and the normal)

- *For each reflection, does the angle of incidence equal the accompanying angle of reflection?*

Experiment 12
REFLECTION
- Parabolic Reflector

A parabola is an unusually shaped curve which is found by one of the following methods -

- *Plot a graph of $y = x^2$ or some other quadratic algebraic function.*
- *Record the flight of a projectile through the air.*
- *Move a point P so that it is always a relative distance from a fixed point F (called the FOCUS) and a straight line AB. This line is called the DIRECTRIX because it directs which way the parabola will face.*



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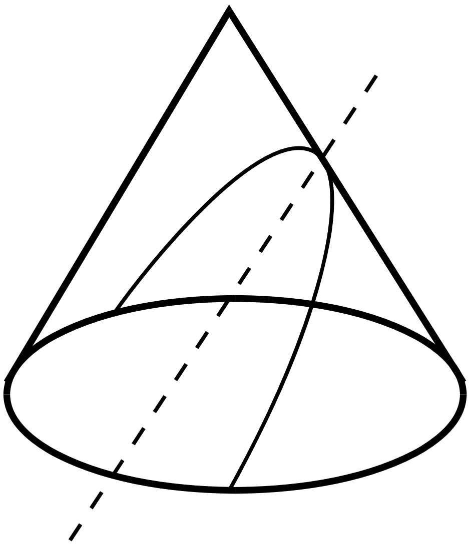
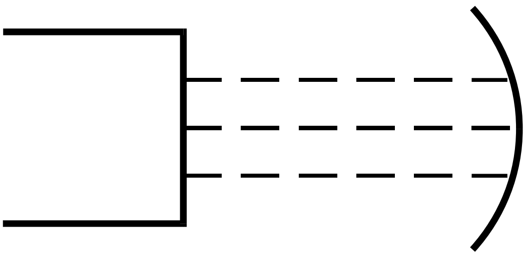
- *Cut a cone in a plane parallel to the sloping side. This is called making a CONIC SECTION. Other conic sections are circles, ellipses, or hyperbolas.*
- *How are these made?*



Aim a set of parallel rays into a parabolic reflector along paths parallel to the axis of symmetry of the mirror.

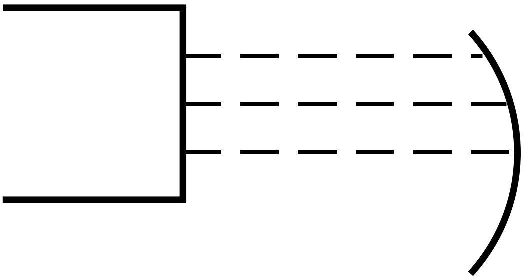
Record the mirror position and ray paths.

Record the focal length.



Move the Light Box sideways keeping the rays parallel to the axis of symmetry. Graph paper is useful to align the mirror and ray paths to ensure the rays are parallel to the axis.

- *What do you notice about the position of the focal point?*



Aim a broad parallel sided beam of light into the parabolic mirror and observe the effect.

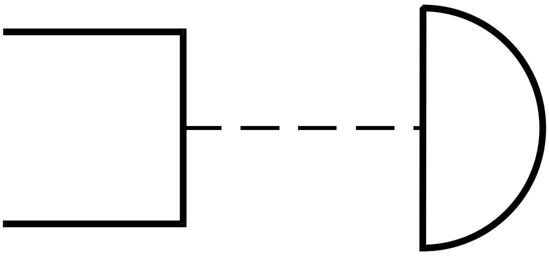
- *What shaped mirror would be used to produce sharp images of stars scattered in all directions over the field of view?*
- *What would happen if a point source of light (a torch globe) is placed at the focal point of a parabolic mirror? Try it and see.*
- *Why do radar antennae, radio-telescopes, car head lamp reflectors and radiator reflectors, have a parabolic shape rather than a spherical or circular shape?*
- *In the examples given, where in relation to the reflector, would the receiving, transmitting or radiating device be placed?*

Suggest why this is so.

Chapter 2 REFRACTION

Experiment 13
REFRACTION
- Semi Circular Block

Aim a single beam at an angle of 90^o at the centre point of the flat side of the semi circular block.

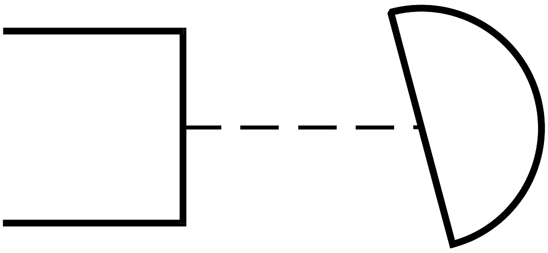


Record the block position and the ray path.

- *Is there any deflection in the beam?*

If there is, the angle is not 90^o.

Move the Light Box so that the ray strikes the same central point on the flat side of the block, but at an angle of 10^o to the normal.



Record the ray path into and out of the block, so that when the block is removed the ray path through it can be clearly seen.

Move the Light Box several times and using coloured pencils record with different colours the new ray paths (all entering the same place on the block).

What happens when a light ray:-

- *Passes from one medium (air) to another medium (acrylic plastic) at an angle of 90^o?*
- *Passes as before, but at an angle of not 90^o? (i.e. the angle of incidence is not zero).*
- *Passes from the acrylic plastic back into the air?*
- *Why does no bending (refraction) occur as the ray passes through the semi circular face while it does bend (refract) passing through the flat face?*

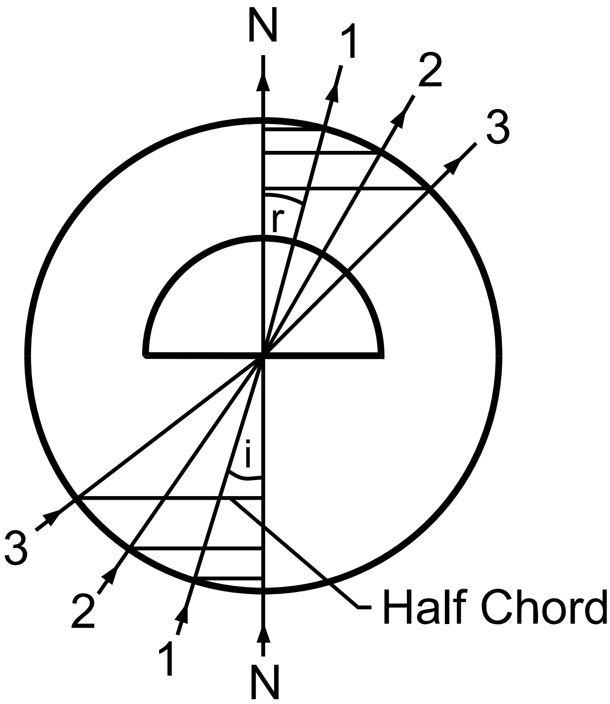
Remove the block after making about six rays and mark the position of the flat side of the block. (Rays can be used on both sides of the normal to the flat surface.)

Carefully draw all the rays meeting at the mid point of the flat side and their subsequent paths.

Draw a 100 mm diameter circle where the centre is the point of incidence. Carefully extend the incident and refracted rays to intersect the circle. Draw the normal N to the incident surface, through the point of incidence.

Draw perpendiculars to the normal line from where the rays and circle intercept.

Your diagram should look like this:-



These last perpendiculars are called HALF CHORDS.

Compile a table of observations as follows:

RAY #	ANGLE OF INCIDENCE **i**	ANGLE OF REFRACTION **r**	DIFFERENCE BETWEEN ANGLES **i-r**	RATIO OF $\frac{i}{r}$	LENGTH OF HALF CHORD **i**	LENGTH OF HALF CORD **r**
1.						
2.						
3.						
4.						
5.						
6.						

RAY #	RATIO OF: $\frac{\text{HALF CHORD } i}{\text{HALF CHORD } r}$	SIN **i**	SIN **r**	RATIO OF: $\frac{\text{SIN } i}{\text{SIN } r}$
1.				
2.				
3.				
4.				
5.				
6.				

If you have not studied TRIGONOMETRY or LOGARITHMS, you may not know how to fill in the last three columns, but this does not matter. They are simply a more accurate way of checking the answers obtained in the fourth last column.

- *Is the difference between angle i and angle r always the same?*
- *Is the ratio of:* $\frac{\text{angle } i}{\text{angle } r}$ *always the same?*
- *Is the ratio of:* $\frac{\text{half chord } i}{\text{half chord } r}$ *always approximately the same?*
- *Is the ratio of:* $\frac{\sin i}{\sin r}$ *always the same?*

The man who discovered this phenomenon was named Snell. Snell's Law states:-

* When a light ray passes from one medium (material) to another medium at an angle (not perpendicular to their interface), it undergoes bending (REFRACTION)

and the ratio of: $\frac{\sin i}{\sin r}$ (or the ratio of the half chords) is a constant for these two particular media.

* The incident ray, the normal to the interface and the refracted ray, lie on one plane (i.e. they are called CO-PLANAR).

The ratio of: $\frac{\sin i}{\sin r}$ (or the ratio of the half chords) is a called

the REFRACTIVE INDEX for the two materials.

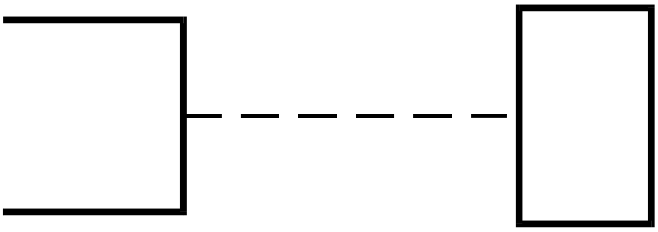
- *What is the refractive index for an AIR-ACRYLIC Plastic interface?*

To observe and record the different bending properties (different REFRACTIVE INDICES) of materials other than acrylic, use either a glass block in place of the acrylic block, or use a shallow semi circular plastic tray partly filled with water, kerosene, paraffin, or other clear liquid.

Disregard what eventually happens to the rays but record only the first interface bending.

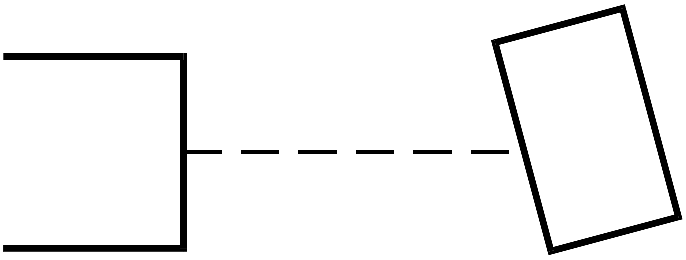
Experiment 14
REFRACTION
- Parallel Sided Block

Place the rectangular block with the long side perpendicular to a single beam.



- *Is there any refraction at either incident or emergent faces? If not, why not?*
- *The ray passes from one medium (air) into a second medium (acrylic plastic) at the first interface and vice versa at the second interface. Therefore what other condition, besides a ray passing from one medium to another, must be present for refraction to occur?*

Move the Light Box until the ray hits the centre of the long side of the block at an angle of incidence of 10^o.



This is at 80^o to the surface. Record the incident and emergent paths. Remove the block and draw:

(a) The ray path through the block.

(b) The theoretical ray path which would have been followed if no block had been in position.

- *Is the emergent ray parallel to the incident ray and its extension?*

Now draw the normals to the interface where the rays entered and emerged from the block.

Measure the angles of incidence and refraction (from the normals) at both interfaces. Draw arrows on the ray if you have doubt as to which is the incident ray at the second interface.

Using a protractor, measure and label the angles of incidence and the angles of refraction of the two refractions.

- *Is the amount of refraction at the first interface reversed at the second face?*

Draw circles, as in EXPERIMENT 13, around each point of refraction and draw and measure half chords to the normals at these points.

Using the formula: Refractive index = $\frac{\sin i}{\sin r}$ or $\frac{\text{half chord i}}{\text{half chord r}}$ find the refractive index from air to acrylic and the refractive index from acrylic to air.

- *Which is greater than 1? Which is less than 1?*
- *Is one the inverse of the other?*
- *If the refractive index from air to glass is 1.5, (i.e. 3/2), what is the refractive index from glass to air?*
- *If the refractive index from air to water is 1.33, (i.e. 4/3), what is the refractive index from water to air?*

Only one angle of incidence (about 10^o) has been used to find the refractive index.

- *Is there any need to use any other angle of incidence? If not, why not?*

Experiment 15

REFRACTION

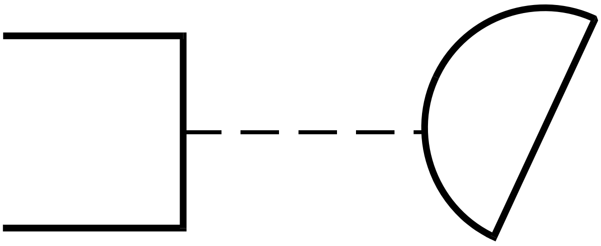
- Total Internal Reflection

Using the Semi-Circular Block

Arrange the semi circular block so that a single light ray strikes the curved surface at its normal mid-point and passes through the Centre of the flat side.

- *Is there any refraction at either interface?* *If not, why not?*

Mark the position of the centre of the straight side of block and rotate the block slightly about this point until the ray inside the block meets the flat side at an angle.



- *Is the ray at this flat face refracted towards or away from the normal at the point of incidence?*

Again rotate the block about the centre point of the flat side and observe and record the emergent ray at the new position.

Continue this rotation of the block until no refracted ray emerges from the flat face.

- *What is the angle of incidence at the flat face when this occurs?*

Rotate the block a little further.

- *What happens to the ray that was previously refracted? Rotate it back again until the ray ceases to be internally reflected and is again refracted.*

Once again find the angle of incidence at which refraction ceases and INTERNAL REFLECTION commences.

Measure this angle of incidence which is called the CRITICAL ANGLE for this material.

The definition is: The critical angle for a material is the angle of incidence beyond which a light ray, passing from a dense to a light medium is no longer refracted out of the medium but is totally internally reflected.

Draw a circle of approximately 100 mm radius about the incident point and record the half chords of the critical angle (called ic).

Calculate the ratio of: $\frac{\text{half chord of ic}}{\text{radius}}$ or find sin ic from a book of mathematical tables.

Using your previous experimental results,

calculate: $\frac{1}{\text{refractive index for acrylic to air}}$.

What do you notice about:

$$\frac{\text{half chord of ic}}{\text{radius}} \quad : \quad \sin ic \quad :: \quad \frac{1}{\text{refractive index for acrylic to air}} \,.$$

- *If the refractive index from air to glass is 1.5, (i.e. 3/2), what is its inverse?*
- *What then does sin ic equal from glass to air?*
- *What then is the critical angle from glass to air?*
- *If the refractive index from air to water is 1.33, (i.e. 4/3), what is its inverse?*
- *What then is the critical angle from water to air?*

If possible, take a block of glass and a shallow tray of water and project a single ray through them in turn. Find and check the critical angles for glass to air and water to air.

- *If a glass block is placed in water and the glass to water interface observed, should the critical angle occur when the ray passes from water to glass, or glass to water?*

Check your answer experimentally.

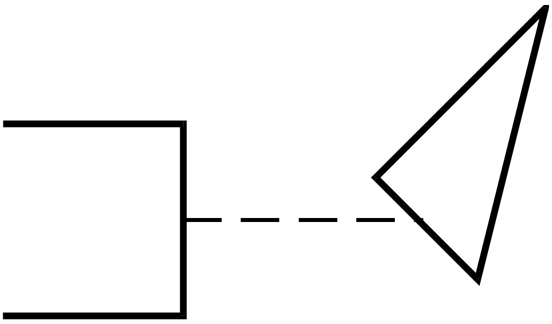
- *How is the critical angle of a piece of acrylic plastic used to find its refractive index?*

Experiment 1 6
REFRACTION
- Total Internal Reflection

Using Triangular Prisms

(a) Aim a single beam of light at the shortest side of the 30^o-60^o-90^o acrylic prism, so that the refracted beam inside the prism strikes the hypotenuse.

Adjust the Light Box and prism positions until total internal reflection occurs and the ray emerges through the third side.



Record the first position at which this occurs and measure the angle of incidence from the normal to the hypotenuse.

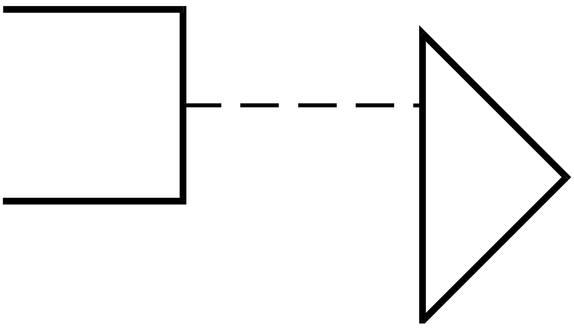
- *Is it the same as the critical angle in the last experiment?*

(b) Aim the single beam perpendicularly into the shorter side of the 45^o-45^o-90^o acrylic prism so that the ray strikes the hypotenuse internally.

- *Is it reflected?*

Record the entrant and emergent rays and the prism position.

Aim a single ray perpendicular to the hypotenuse of the 45^o prism at about a quarter the distance from one end.



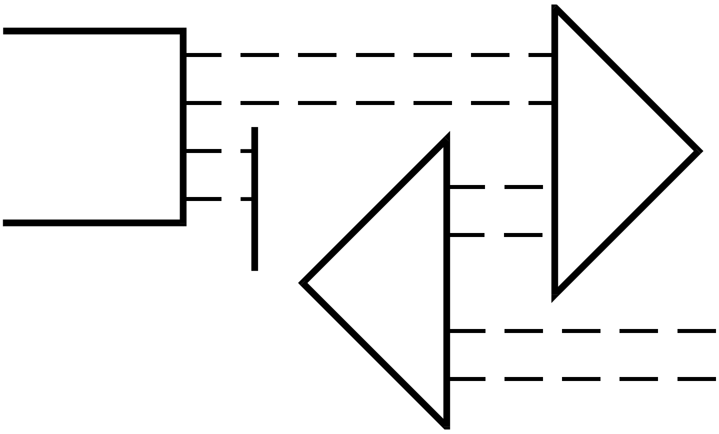
This time the ray is totally reflected internally in the prism twice and returns on a path that is parallel to its original one but reversed in direction.

Trace the prism position and the ray path through it.

(c) Aim four parallel rays into the 45^o prism hypotenuse near one end, colour the rays in turn (by placing a colour filter over them) and trace the path of each ray in different colours.

- *Are the ray positions reversed by the double reflections?*

(d) Aim two parallel beams into two 45^o prisms, placed as in the diagram.



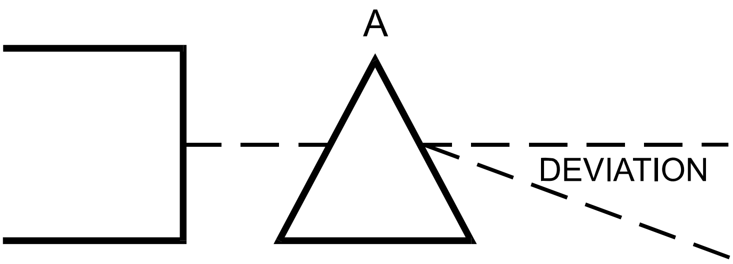
Colour each beam in turn and trace its path.

- *Does the quadruple reflection (twice in each prism) restore the beams to their original relationship, or are they still reversed?*

Pairs of prisms arranged in such a manner are used in prismatic binoculars, to shorten the overall length of what would otherwise be a 0.5 metre to 0.75 metre long telescope.

Experiment 17
REFRACTION
- Double Refraction Angle of Minimum Deviation

Aim a single ray of light into one face of the equilateral triangular prism (60^o-60^o-60^o) so that the beam is approximately parallel to an adjacent side and the ray emerges from the third side after being refracted twice.



Record the prism position and the light ray paths.

Aim the ray at the same spot on the prism face and alter the angle of incidence. Observe the alteration in the direction of the emergent ray.

Find the position of the prism and light ray which produces the minimum deviation of the beam from its original to its final direction.

Repeat this experiment using the 45^o angle at position A and find the angle of minimum deviation.

Repeat this experiment using the 90^o angle at position A and find the angle of minimum deviation

Repeat this experiment using a 30^o angle at position A and find the angle of minimum deviation.

Tabulate your observations as follows:

RAY	ANGLE OF INCIDENCE	ANGLE OF MINIMUM DEVIATION
A		
B		
C		

- *How does the angle of the prism affect the angle of minimum deviation?*
- *What happens when the 90' angle is used in position A?*

Experiment 18
REFRACTION
- Double Refraction Using Parallel Rays

(a) As in the previous experiment, aim a single ray through a triangular prism. Regard the apex angle of the prism as angle A and the side opposite A as its base.

- *Does the doubly refracted ray bend towards or away from the base?*

Repeat this experiment, using each angle of each prism at angle A in turn.

- *Is the direction of bending towards the base the same for any angle at position A?*

(b) Aim a pair of parallel beams through each of the triangular prisms in turn and observe the emergent rays.

- *Do the parallel rays emerge parallel to each other for each of the three prism angles of 30^o, 45^o and 60^o?*

Experiment 19
REFRACTION
- Double Refraction

Using Colour Dispersion

Fit the slit former that gives the wide beam. Aim single wide beam through the equilateral prism and adjust the prism so that the maximum deflection of the ray is obtained. Place a white card in the path of the ray.

- *Is the original beam from the Light Box white or coloured?*
- *Does the emergent beam have any indication of colour?*
- *Which edge of the beam is red and which is blue?*

If more colours than red and blue are present, make a list of the order in which they appear.

Such a spread of colours, caused by the dispersion of white light is called a SPECTRUM. It is caused because each colour bends a slightly different amount during diffraction. All colours together make white light and a prism can separate them again because of this amazing phenomenon.

Experiment 20
REFRACTION
- Colour Absorption by Filters

With the apparatus set up as in the previous experiment, place a red filter in the wide groove of the Light Box in front of the wide beam slit former plate.

- *What effect has this on the emergent spectrum?*

Remove the filter from between the light source and the dispersing prism. Now place the filter so that the colour dispersed beam emerging from the prism passes through the filter.

- *What happens to the colours which are NOT red?*

Repeat this procedure, using the other filters in the kit. Firstly do this one by one then try various pairs.

Copy and complete the following table by placing ticks and crosses in the appropriate boxes.

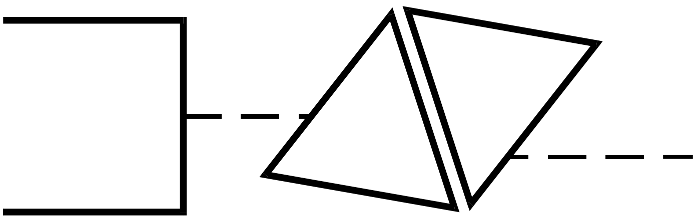
WHITE LIGHT CONTAINS THESE COLOURS

		RED						VIOLET
RED FILTER	TRANSMITS							
	ABSORBS							
BLUE FILTER	TRANSMITS							
	ABSORBS							
YELLOW FILTER	TRANSMITS							
	ABSORBS							
? FILTER	TRANSMITS							
	ABSORBS							

ETC.

Experiment 21
REFRACTION
- Newton's Experiment with Spectra

Produce a clear spectrum using the colour dispersion caused by double refraction through a single prism of 60' included angle set at the position of minimum deviation. Use a narrow ray.



Perform Sir Isaac Newton's experiment by placing a second 60^o prism in the path of the colour dispersed beam. Be sure that the faces of the two prisms are parallel and very close together.

This refracts the beam again in the opposite direction and recombines the colours of the spectrum to make white light.

When a disc on which a set of all the spectrum colours is painted is spun rapidly, the eye sees only a blur of all the colours and the disc appears to be white.
Ask your teacher to demonstrate a "Newton's Colour Disc".

Experiment 22

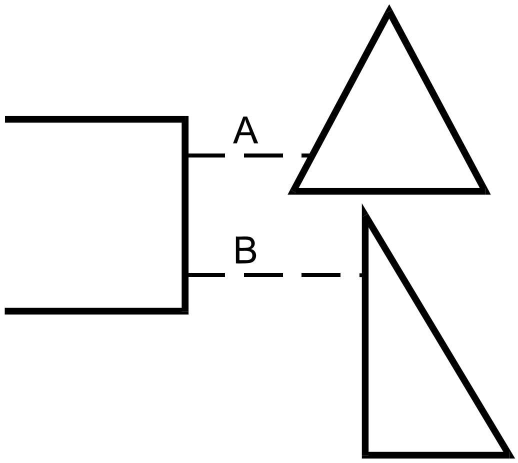
REFRACTION

- Double Refraction Using Bi-Convex Lens

EXPERIMENT 18 demonstrated that a single prism will not bring parallel rays to a focus - they remain parallel after refraction, although showing a little colour dispersion.

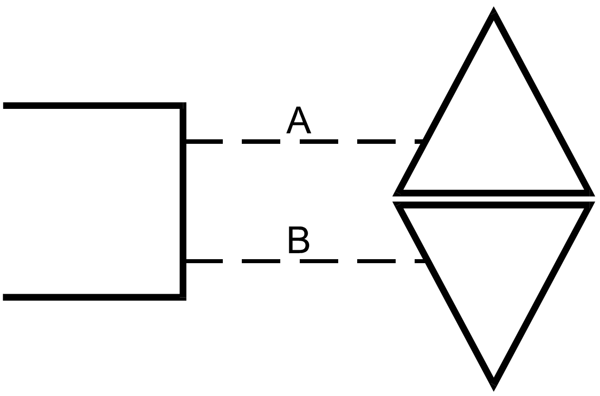
Sets of prisms, however, can be used to focus what were parallel rays, to meet at a point.

Set the Light Box to produce two parallel rays as widely spaced as possible.



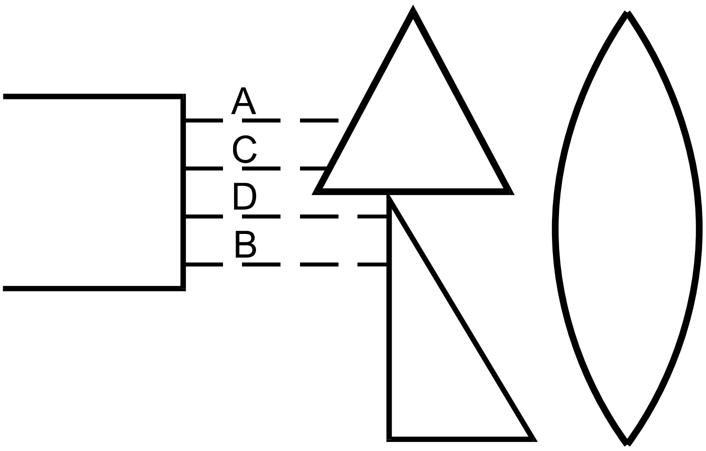
Place prisms with 60^o and 30^o angles as shown in the diagram, and trace the path of the emergent rays. Rearrange the prisms as shown in the diagram below, this time using two identical prisms. (Borrow one from another set.)

This method of placement focuses two parallel beams A and B to the one point.



- *If another beam parallel to beam A and one parallel to beam B are added, do they also focus at the same spot?   Try it and see.*
-

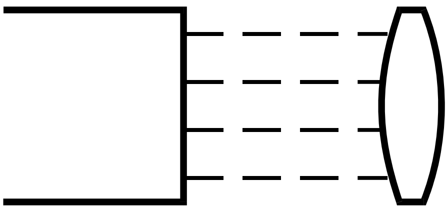
To bring ALL rays to a focus at one point, another prism with a different angle for ray C and yet another with different angle for ray D is required. This means that a prism is needed where the angle is continuously changing from a small angle to a large angle. Such an object is called a LENS.



Aim four parallel rays into one face of the thinner of the two lenses of the kit as shown in the diagram below. Record the lens position, the ray paths and the focal point.

- *If the FOCAL LENGTH of a lens is the distance from the LENS-CENTRE to the FOCAL POINT, what is the focal length of this lens?*

On a separate piece of paper, find the focal length of the thicker lens of similar shape in the kit.



Lenses of this shape are called BI-CONVEX because both sides bulge outwards.

Experiment 23
REFRACTION
- Radius of Curvature

Trace the curve of one side of the thinner lens surface on your sheet of paper.

Move the curved surface along this tracing and extend the tracing a number of times until it forms a circle.

Measure the diameter of the circle and calculate the radius.

Repeat the experiment, using the thicker bi-convex lens.

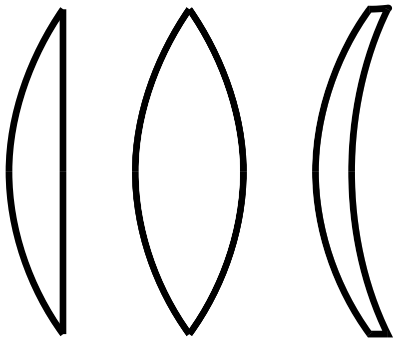
- *What is the radius of the second circle?*

Each of the radius of the circles is called the RADIUS OF CURVATURE of the particular lens used to draw the circle.

Using the results obtained in EXPERIMENT 22, compare the radius of curvature of each lens with its focal length.

- *How does radius of curvature affect focal length?*
- *If a lens with a focal length of 20 mm is required, what radius of curvature should be used.*

The curvature of a lens does not necessarily need to be the same for both sides.



A lens may be the same shape as those in the kit, although many are shaped in a similar manner to those shown in the diagram above. The curvature on one side may not be the same on the other side and one side can be convex (bulging out) while the other side is concave (bulging inwards).

The following formula shows the relationship between refractive index, focal length and radius of curvature:

$$\frac{1}{f} = (n - 1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

Where:-
t - focal length of lens
n - refractive index of the material
R_1 - radius of curvature of one face
R_2 - radius of curvature of the other face

- *What are the Values of R_1 and R_2 for the two bi-convex lenses in the kit?*
  Use one of these sets of values in the above formula and calculate the value of 'n' for the plastic material in the lenses.

- *Use the second set of values to verify the value of 'n' for this material. (Both lenses are made of the same material).*
  How does the value of 'n' you have calculated compare with the value you obtained in EXPERIMENT 13?

Experiment 24

REFRACTION

- Focal Line or Focal Plane of a Bi-Convex Lens

Place one of the bi-convex lenses on a sheet of paper and trace its outline.

Without altering the lens position, arrange the Light Box to project two parallel rays and move it so that it –

(a) Projects the rays parallel to the axis of symmetry of the lens.

(b) Projects the rays at a small angle to the axis but aimed at the centre of the lens; first from the left hand side and then from the right hand side.

(c) Projects the rays at larger angles from the axis, but still aimed at the lens centre.

Draw a line through this series of focal points (FOCI).

- *Do the points form a straight or curved line?*
- *If we assume that the pairs of parallel rays are coming from distant stars and passing through the lens, where should a photographic film be placed so that the star images are in focus?*

The position at which parallel rays from any angle come to a focus is called the FOCAL PLANE of the lens.

Some cameras have a shutter which opens and closes near the lens. Others (which have removable or interchangeable lenses) have a shutter like a roller-blind which covers the film, except for the instant when the blind rolls up to make the exposure. Such a shutter is called a FOCAL PLANE shutter.

Experiment 25

REFRACTION

- Chromatic Aberration by Bi-Convex Lens

Pass rays through the outer edges of a bi-convex lens.

Observe that they have coloured edges after refraction.

- *Which edge is red and which blue?*

Pass two parallel rays through the outer edges of the lens so that they come to a focus.

Place a vertical white card near the point of focus and move it to and from the lens.

- *In what position from the lens is the card placed when the image on the card has a reddish centre and blue edges?*

Suggest why cheap toy telescopes and binoculars have colour fringes around the images they produce. Makers of lenses for cameras, telescopes, etc. go to great trouble using combinations of lenses of different curvatures and made from glasses of different refractive indices, to ensure that all colours come to a focus at the same point. A lens combination which has elements designed to do this is called an ACHROMATIC LENS.

Experiment 26
REFRACTION
- Bi-Concave Lens

Select the lens which has two hollow sides curving in towards each other, making it thinner at the centre than at the sides. This is called a BI-CONCAVE lens.

Aim four parallel rays of light at the lens, parallel to its axis of symmetry.

Trace the lens position and both the entrant and emergent rays.

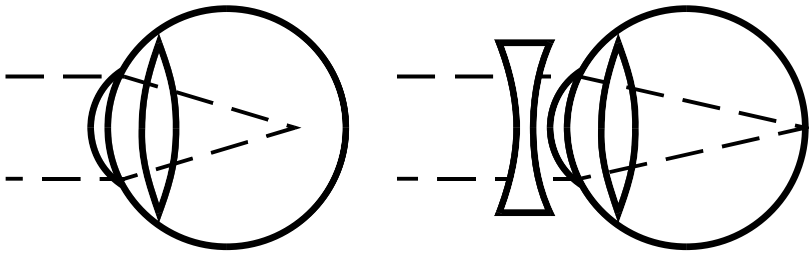
Remove the lens and extend the emergent rays back through the lens position towards the Light Box.

- *Do they appear to radiate from one point, or from several?*

A bi-concave lens is a DIVERGING LENS and is said to have a NEGATIVE FOCAL LENGTH because the point from which the rays appear to emerge is not beyond the lens but between the light source and the lens.

- *What is the focal length of the lens used?*

Such lenses are useful in correcting short-sightedness. This is a condition in which the image formed by the lens of the eye falls short of the light sensitive retina.



They are also used to increase the focal length of converging lenses.

Try to remember the method that was suggested at the beginning of this manual to give a long converging beam from the Light Box?

Chapter 3 COLOUR OBSERVATIONS

Experiment 27

COLOUR OBSERVATION

- Colours of Objects

In CHAPTER 2, EXPERIMENT 20, white light was dispersed into a rainbow coloured spectrum by passing it through a prism. Various filters are placed in the beam to see which of the rainbow colours are transmitted by the filters and which are absorbed.

The rear end of the Light Box has swinging mirrors and is designed to carry colour filters in 3 positions. Using the rear end of the Light Box (not the mirrors) direct a beam of white light on to each of the eight coloured plates in the kit. Colour the incident beam by sliding filters into the grooves provided and record the observed colours of the plated when illuminated by different coloured beams. Copy and complete the table shown below.

The colour of an object is explained by stating that white light is composed of many colours and that a white object reflects all these colours.

A red object absorbs all the colours except red, which it reflects, making the object appear red.

If however, the red is completely filtered from the incident light by using a blue-green (or cyan) filter, then the red object should absorb the incident cyan colour and should reflect nothing. Check your tabulated observations against this theory.

Familiarise yourself with the coloured filters and plates and predict how the following colours should appear –

A blue object, illuminated by red and seen with the naked eye.

A red object, illuminated by orange and seen through a yellow filter.

A blue object, illuminated by red and seen through a yellow filter.

A red object, illuminated by orange and seen with the naked eye.

A red object, illuminated by orange and seen through a blue filter, etc., etc.

COLOUR OF OBJECT IN WHITE LIGHT	COLOUR OF OBJECT WHEN INCIDENT LIGHT ON OBJECT IS:					
	RED	ORANGE	YELLOW	GREEN	BLUE	VIOLET
RED						
ORANGE						
YELLOW						
GREEN						
BLUE						
VIOLET						

Illuminate the various plates with white light, and holding the filter close to your eye, observe the plates. Copy and complete the following table.

COLOUR OF OBJECT IN WHITE LIGHT	COLOUR OF OBJECT WHEN VIEWED THROUGH A FILTER OF COLOUR					
	RED	ORANGE	YELLOW	GREEN	BLUE	VIOLET
RED						
ORANGE						
YELLOW						
GREEN						
BLUE						
VIOLET						

Experiment 28
COLOUR OBSERVATIONS
- Addition of Colours

Using the 2 side positions with mirrors and also the end position of the Light Box, project three coloured beams on to a white card. Make the first set of colours red, blue and yellow.

NOTE: Place the weakest colour in the end position of the Light Box and the stronger colours at the sides. This compensates for the small loss of intensity during reflection from the side mirrors. To blank off one of the openings, use the blank slit former (the end without slits).

Move the mirrors to use the beams to overlap and record your observations in tabulated form as follows:

RED + BLUE gives....
RED + YELLOW gives....
YELLOW + BLUE gives....
RED + BLUE + YELLOW gives....

Use the other filters from the set and work out all the other possible combinations.

Find a combination that gives white light, or close to it, when mixed. Combinations that do this are called COMPLEMENTARY COLOURS.

Complementary colours are two colours that add together to make WHITE LIGHT.

Add three colours to make white, then remove any one of them by moving its mirror. The colour left on the screen is the COMPLEMENT to that removed.

List the three colours, then list each colour and its complement.

The three colours used are: 1 ....2.......and 3..........

The complementary colour for 1 is: ....
The complementary colour for 2 is: ....
The complementary colour for 3 is: ....

NOTE: Remove the colour filters from the Light Box after use, as prolonged exposure to heat from the lamp may damage the filter.

Experiment 29
COLOUR OBSERVATIONS
- Colour Shadows

Blend three colours to make white.

Place a pencil about 80 mm in front of the screen so that it is illuminated by all three beams.

Observe and record the colours of the shadows and the colours of their background. Explain these coloured shadows.

To assist your explanation, draw a sketch of the experimental arrangement, including the direction and colours of the three light beams.

Experiment 30
COLOUR OBSERVATIONS
- Shadows

Remove the colour filters and close the side mirrors. Aim the light emerging from the rear aperture at a white screen about 300-450 mm from the box. Hold a pencil about 50 mm in front of the screen and observe the sharp shadow.

This sharp shadow is called the "UMBRA".

Repeat the experiment this time diffusing the light through tracing paper. Observe the two intensities of shadow.

The diffuse shadow is called the PENUMBRA and the UMBRA is seen within it.

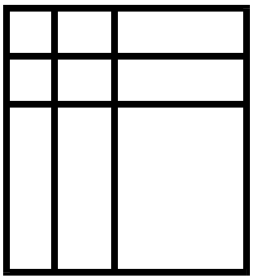
Chapter 4 OPTICAL BENCH

OPTICAL BENCH

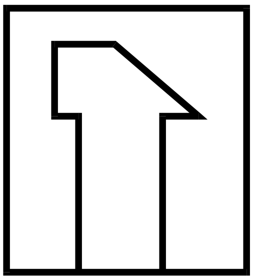
INTRODUCTION

IEC manufactures a low cost Optical Bench suitable for using the Light Box as the light source. It is complete with many lenses and components for many experiments. Ask for Cat.No: HL2240-001 (including Light Box) or Cat.No: HL2241-001 (not including a Light Box)

The Light Box may be used as a light source for many experiments with lenses and mirrors. To do this, cover the rear aperture with a piece of tracing paper held in place by rubber bands or adhesive tape. Use a fine black marker to draw a grid or cross pattern on the tracing paper. Make the end of the Light Box appear as in the diagrams.



OR



It is best if the pattern is NOT symmetrical, for then it is obvious if the resultant image is reversed or inverted.

If you do not have an IEC Optical Bench, using plasticene, carefully mount a bi-convex glass lens on a small cardboard or coin mount. Ensure that it is quite vertical and that its centre is the same height above the bench top, as the centre of the illuminated screen on the Light Box.

To make a screen on which to focus the pictures, tape a piece of white card vertically to a wood block. A better device is a 100 mm square of tracing paper pasted to a 100 mm square of cardboard. Cut the centre from the cardboard, leaving a 12 mm wide picture frame to support the tracing paper. Pin or tack this vertically to a block of wood.

Experiment 31
OPTICAL BENCH
- Bi-Convex Lens

Run a piece of streamer or paper tape along the centre of the bench and tape it in position. Using sunlight, or the light from a distant window, focus a sharp image through the lens to the screen and carefully measure the distance from lens to screen. This dimension is its FOCAL LENGTH. The focal length of a lens is the distance from the lens at which parallel rays come to a focus. The sun's rays may be considered to be parallel.

Stand the lens vertically in the middle of the tape and mark the tape on either side of it at the distance of its focal length. Mark these points with the letter F, then double the distance F on both sides of the lens and mark these two points as 2F.

Place the Light Box (with the marked image attached to the front) on the tape somewhere beyond 2F. On the other side of the lens, place the focusing screen. Move the screen to and from the lens until a sharp image of the light source image is obtained. Mark the positions of the light source and its image on the tape.

- *If the source is outside 2F on one side of the lens, where in relation to 2F on the other side, does the image lie?*

Step by step move the source in towards the lens whilst recording at each step, the position of the source and its image (AA, BB, CC, etc.).

- *As the source moves closer to the point 2F what happens to its image on the other side?*

NOTE: It may prove necessary to slightly tilt the lens vertically or twist it horizontally to align the source. lens and image, along the tape.

- *When the source is outside 2F, does the image appear to be longer or shorter than the source?*

Move the source into a position between 2F and F.

- *What happens to the image position?*

Record several of these positions between 2F and F and label them with matching letters as before.

- *What happens to the image when the source is at F?*
- *Where was the "sun source" when its image was at F?*

When scientists observe regular behaviour, they look for mathematical connections to account for the observed behaviour.

From the tape, use a metre ruler to measure each of the distances from the marks A, B, C, etc., to the focal point **F**, on that side of the lens. **Si** is distance from image to **F** and **So** is distance from source to **F**.

Tabulate your observations as shown on the next page. Now square the focal length and compare the product **Si x So** with **F**^{2}. If the experiment is carefully performed and if the focal length is correctly found, then **Si x So** should equal **F**^{2}.

POS.	DISTANCE **So** SOURCE TO **F**	DISTANCE **Si** IMAGE TO **F**	PRODUCT **So x Si**
A			
B			
C			
D			
E			
F			
G			
H			

If instead of measuring distances from the focal point, source and image distances are measured from the lens (i.e. u and v respectively), another formula may be checked. The formula is:

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ where **f** is the focal length

Move the source to a position between **F** and the lens.

The image no longer focuses on the screen, but by moving the light source a little to one side and putting your head down fairly close to the lens on the opposite side, you should observe an ERECT ENLARGED IMAGE which appears to be somewhere behind the light source, just as when a magnifying glass is used.

- *When the source is outside F, are the images: (a) ERECT (b) INVERTED (c) REDUCED or (d) ENLARGED?*

Experiment 32
OPTICAL BENCH
- Ray Tracing with Bi-Convex Lens

Ray tracing is one method of finding the location of image positions. To do this, three principal rays are used. They are:-
(a) The ray from the source, parallel to the axis of symmetry.
(b) The ray from the source through the focal point.
(c) The ray from the source through the centre of the lens.

Set the Light Box to make a single narrow ray.

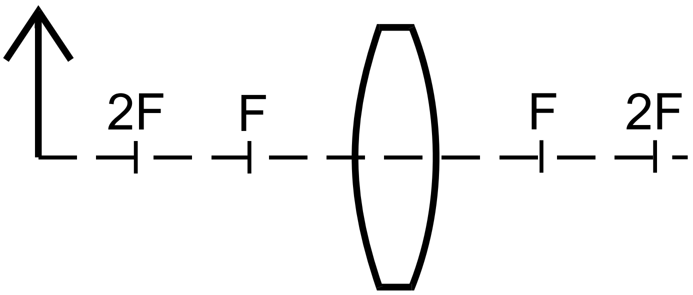
Place the bi-convex block lens on a sheet of paper, with a line ruled to mark the axis of symmetry.

Mark a spot to indicate the focal point F. (If in doubt, aim parallel rays parallel to the axis of symmetry, from the other side of the lens to find point F.)

Mark the point 2F at twice the focal length on both sides of the lens.

Draw a bold arrow, about 40 mm high, perpendicular to the axis of symmetry, somewhere beyond 2F.

The set up should appear as follows:



Aim the first principal ray through the point of the arrow, parallel to the axis of symmetry. Trace its subsequent path after refraction which should be through F on the other side.

Direct the second principal ray through the point of the arrow and through the nearest focal point F. Trace its subsequent path through the lens. If it misses the lens, the arrow is too long. If necessary, shorten the arrow and re-trace the first ray.

This second ray should emerge parallel to the axis after passing through the focal point F and the lens.

Aim the third principal ray through both the arrow point and the lens centre and trace its subsequent path.

This ray should pass through the point on the other side of the lens where rays one and two meet.

This is the image position for an object placed at the arrow point. Aim rays in various directions through the arrow point, ensuring that they meet the lens.

- *Do they all pass through the image point where rays one, two and three met?*

Draw a line from this point, perpendicular to the axis of symmetry and mark an arrow head on it at the end where the rays met.

- *If this new arrow is the projected image of the original arrow, is it REDUCED or ENLARGED?*
- *Is it ERECT or INVERTED?*

Copy and complete the following table:-

POS .	DISTANCE **So** OF LIGHT SOURCE FROM **F**	DISTANCE **Si** OF IMAGE POSITION FROM **F**	NATURE OF IMAGE		PRODUCT **So x Si**
			ERECT OR INVERTED	ENLARGED OR REDUCED	
A					
B					
C					
D					

Repeat this procedure several times for different positions of the original arrow beyond 2F, at 2F and between 2F and F.

Check the formula:

Si x So = F^2 for any of these positions where

So is the distance of the original arrow from F on that side of the lens.

Si is the distance of the image position from F on that side of the lens.

F is the focal length.

- *What happens if the arrow is placed at F or between F and the lens?*
- *Does the product, So x Si bear any relationship to F*^{2} *where F is the focal length?*

Experiment 33
OPTICAL BENCH
- Ray Tracing with a Parabolic Mirror

Using the parabolic mirror and a single light ray, find the convergence point for the three principal rays passing through the point of an arrow drawn perpendicular to the axis of symmetry.

Repeat all the steps of EXPERIMENT 32 and copy and complete the following:-

- *The first principal ray from an object, parallel to the axis of a parabolic mirror, reflects back through ....*
- *The second principal ray from an object, passing through the focal point of a parabolic mirror, reflects back from the mirror .... to the axis.*
- *The third principal ray from an object to the centre of a parabolic mirror, reflects back from the mirror so that the angle of incidence .... the angle of reflection*

Experiment 34
OPTICAL BENCH
- Concaved Spherical Parabolic Mirror

Magnification by a lens is defined as the ratio of the

$$\frac{\text{HEIGHT of its IMAGE}}{\text{HEIGHT of the OBJECT}}$$

Sometimes the ratio is greater than 1 and sometimes less than 1.

Using a concave parabolic mirror, state for which positions of the original arrow (that is, beyond 2F, at 2F and between 2F and F) the magnification ratio is greater than 1, equal to 1, or less than 1

Two other ratios may be used to obtain the magnification

For several recorded observations check if -

MAGNIFICATION =

$$\frac{\text{HEIGHT OF IMAGE}}{\text{HEIGHT OF OBJECT}} = \frac{\mathbf{F}}{\mathbf{So}} = \frac{\mathbf{Si}}{\mathbf{F}}$$

Experiment 35
OPTICAL BENCH
- Magnification - Spherical Parabolic Mirror

Arrange the Light Box as a light source with a non-symmetrical pattern on it. (See the method as described in the introduction to CHAPTER 4).

Place the edge of a parabolic reflector at the end of a long piece of paper tape which is fixed to the bench as the axis of symmetry.

Mark the mirror position and its focal point F. If in doubt, aim four parallel beams parallel to the axis of symmetry and record on the tape the point at which they meet. This point can be seen on a focusing screen.

Mark the position 2F at twice the focal length from the mirror.

Place the light source beyond 2F and a little to one side of the centre line, at exactly the same height as the mirror centre from the bench.

Use the focusing screen to locate a sharp reflected image somewhere between F and 2F, on the opposite side of the centre line.

On the tape, record the position of the light source and its image. (Use letters AA.)

Move the light source to several different positions closer to 2F, at 2F and to positions between 2F and F. At each position, record the position of the light source and thus the obtained image (Use letters BB-CC etc.)

Copy the table in EXPERIMENT 32 and complete it from the marked paper tape.

Experiment 36
OPTICAL BENCH
- Magnification Factor of a Spherical Parabolic Mirror

The same mathematical ratios used in EXPERIMENT 34 for a convex lens apply also to a spherical parabolic mirror.

From the results on the paper tape used in EXPERIMENT 35, check the following relationships:-

MAGNIFICATION =

$$\frac{\text{HEIGHT OF IMAGE}}{\text{HEIGHT OF OBJECT}} = \frac{\mathbf{F}}{\mathbf{So}} = \frac{\mathbf{Si}}{\mathbf{F}}$$

Spare Globe: Use only Axial Filament, Halogen, 2 pin, 12V.30W. globe.

All spare components and parts for the "Hodson" Light Box and Optical Set are available from your equipment supplier.

This Light Box and Optical Set was
proudly designed and manufactured by:

Industrial Equipment and Control Pty. Ltd.
Melbourne. Australia
iec@iecpl.com.au