THE LIGHT BOX AND OPTICAL SET

Introduction and General Description

This optical set consists of a source of light rays and a set of devices which reflect, refract and manipulate color light so that measurements and observations may be easily made.

The light source in housed in a specially designed light box complete with an adjustable collimating lens. It can be moved by loosing the screw on the top. 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 color filters in place, the two side beams may be swung back and forth to overlap and blend with the fixed beam. The effect is evident on a screen placed about 20 cm from the box.

The collimated light beam, emerging from the front of the box, may be broken into one narrow beam or alternately into one, three or four narrow slit rays, by the fitting of the appropriate black slit former into the slide on the end of the ray box at the end with the collimating lens. These rays or beams may be colored by placing a color filter into another slide on the end of the box.

The beam may be made slightly converging or diverging by adjustment of the collimating lens. This is clearly observed with a multiple slit former in place. If great convergence or divergence is required for a particular experiment use the devices as shown in Figure 1.

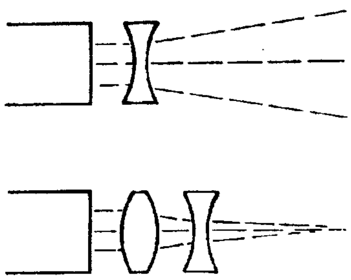

Figure 1

Setting Up For An Experiment

Place the light box on a table top with the light socket uppermost. Connect the lamp leads to the red and black outlets of a power source. The red light of the power source should be off. Insert the multiple slit former into the narrow front slide. Turn on the power source.

Place the slab lenses, prisms and mirrors an a plain sheet of paper in the various positions as indicated in the experiments that are to follow. 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 in visible. The best visual results are obtained in darkness.

Sometimes faint secondary rays may be visible emerging from the ray box. These may not be parallel to the main rays and may be a nuisance. They are caused by reflections from the support wire holding the filament inside the bulb. They can usually be eliminated or reduced by rotating the lamp holder on the top of the light box so that the support wire is directly behind the filament.

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 device through the top face and internally reflecting off the vertical faces. In addition, rays passing over the device may be evident some distance beyond the device. These can be eliminated by:

- moving the blocks further from the light box
- raising the sheet of paper using a piece of cardboard
- blanking off the top of the slits to shorten the rays.

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 center of the ray being observed in two positions, one close to the lens surface arid one as far away as possible. If the ray pattern is complicated with crossing taking place, number the dots representing each ray so that they can be 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 arrows heads on the lines to indicate their direction of propagation. If in doubt as to the continuity of any lines replace the device in exactly the same place and retrace the ray. Some students say it helps to alternately block out different rays to see the path of a particular ray. Others have placed different colored filters over different rays.

INVESTIGATION: REFLECTION FROM PLANE MIRRORS

1. Reflection - Single Ray

Project a single narrow ray along a sheet of paper and mark its two ends. Place a plane mirror midway along the path crossing it at an angle as shown in Figure 2. Mark the position of:

- the glass front of the mirror
- the reflecting rear surface of the mirror
- the reflected ray (or rays)

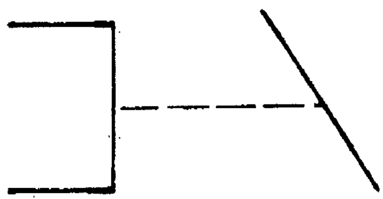

Figure 2

Draw a line perpendicular to the mirror at the point where the incident and reflected rays meet the reflecting surface of the mirror. (Remember that the reflecting surface in on the bacl of the glass.) Such a perpendicular is called the NORMAL to the mirror at this point.

Measure the angle of incidence, (the angle between the INCIDENT RAY and the NORMAL). Measure the angle of reflection, (the angle between the REFLECTED RAY and the NORMAL). How do they compare?

These angles are measured from the NORMAL because in later experiments we 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 angle of incidence and reflection.

If you got a second ray, explain its existence.

2. Reflection - Divergent Rays

Place a triple slit former in the narrow front side of the light box. Project a set of diverging rays along a sheet of paper and mark the ray paths as shown in Figure 3. Place a plain mirror so that no ray meets it at 90 degrees. Mark the reflecting surface of the mirror and the paths of the reflected rays.

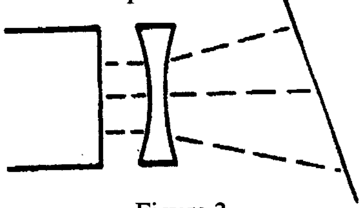

Figure 3

Draw normals to the mirror surface at each point of the reflection. How does the angle of reflection compare to the angle of incidence? 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. What about converging rays?

3. Images in a Plane Mirror -1-

When you looks into a mirror you see a reflected image of yourself. Where is this image? As you move forward or backwards relative to the mirror, what happens to the image? This investigation will help you find the location of the image.

Project a set of converging rays across a sheet of paper as shown in Figure 4 so that they focus at the far end of the paper. Use the lens combination shown and move them relative to one another to adjust the focal length so that the point where they focus (focal point) is on the sheet of paper. (Trouble, see instruct6or.) Record the location of the rays and the focal point.

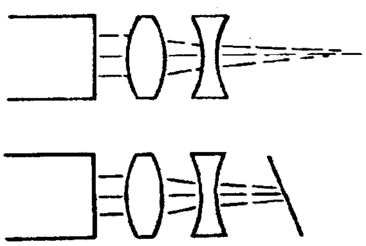

Figure 4

Place a plane mirror across the rays at an angle and mark the path 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. Lift and lower the mirror several times vertically. What do you note about the real and reflected rays?

What would you say about the point where the real rays meet and the point where the reflected rays appear to come from?

Locate these two points of convergence and the position of the reflecting surface of the mirror. Draw a line connecting the two points of convergence. What angle does this line make with the mirror? What is the position of the mirror at the point where this line crosses the reflecting surface relative to the two convergence points?

Have your partner repeat the experiment with a different set of converging rays and with the mirror at a different distance from the point of convergence. Record all information and make all measurements as before.

Place a piece of cardboard under the paper. Place one pin, vertically into the cardboard esactly at the two convergence points. Replace the mirror at its previous location. Place your eyes such that you can see a reflection of the front pin in the mirror and the top of the back pin above the mirror. What is the location of the top of the pin seen above the mirror and the image of the pin seen in the mirror? Do they appear in line? Move your head to one side and then the other. Does the pin and pin-reflection remain in line?

Move one of the pins to a different location and observe the relative position of the pin seen above the mirror and the image of the pin seen in the mirror. Does any shift in your position alter their relative positions?

This is a phenomenon known as PARALLAX. Parallax is the apparent side ways motion of a distance objects relative to a near object in the same direction as the movement of the observer.

Please ask your instructor for additional information at this time.

INVESTIGATION: REFLECTION FROM PLANE MIRRORS -2-

4. Images In a Plane Mirror - 2 -

Stick a pin vertically, centered on a sheet of paper, placed on some cardboard 8 cm from one end of the paper. Place the plane mirror about 12 cm from the same end of the paper or 4 cm behind the pin. Observe the reflection of the pin in the mirror. Where is the image?

To locate the image position move the ray box such that a single ray of light hits the mirror, at an angle, 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? Straight?

Mark the mirror position and incident ray only.

Move the ray box to a different position with the reflected ray hitting the pin at a different angle relative to the mirror. Mark the incident ray. Move the ray source to several other positions on both sides of the pin. Again mark only the incident ray.

Remove the mirror and continue the incident rays until they meet. What do you observe?

Replace the mirror. Do the lines drawn in front of and behind the mirror lead to where you see the reflection of the pin?

Stand a tall pin vertically at the point where the lines meet behind the mirror so that you can see the top of this pin and the reflection of the pin, placed in front of the mirror, at the same time. Do they appear in line? Move your head to one side and then the other. Does the pin and pin-reflection remain in line?

Join the pin position to its image position with a straight line. What is the orientation of this line to the mirrors reflecting surface? How far in the image behind the mirror? the object in front?

What is the value of knowing where the image is located?

5. Multiple Reflections

Reflect a single ray from a quarter inch thick mirror, obtained from your instructor, at an angle of incidence of 45 to 50 degrees. Examine the reflection closely. How many reflections are there? Which is the brightest? Look down carefully from above and then make an enlarged drawing to show all the reflected rays and how they occur. If unable to see anything, contact your instructor.

Is there something special in the angle of incidence being 90 degrees?

Experiment to discover if all three reflections occur at other angles of incidence. Which reflected rays disappear and at what angle does this occur?

Can one account for the intensity of each reflected ray?

Place the rectangular plastic block in front of the mirror and repeat the above investigation and observations.

6. More Multiple Reflections

Place two mirrors at an angle of 90 degrees relative to each other. Aim a single ray to strike one mirror at an angle at a point approximately 2 cm from the corner where the two mirrors meet. Observe the principle reflected ray as it is reflected from both mirrors. Record the rays and the position of the reflecting surfaces. What do you notice about the direction of the incident and final reflected ray. Does this result occur at other angles of incidence?

Look into the corner of the mirrors. What do you see? Shift your position. Does the same thing occur?

Ask for the large, corner cube, demonstration mirror which has two mirrors oriented at right angles to each other. Move right-left, up-down, looking into the corner from all directions. What do you observe?

Place two small mirrors located at right angles to each other on a piece of paper. Aim a thin ray of light so that it reflects off both mirrors. What do you notice about the double reflected ray?

Return to the corner cube, remove the cardboard from the bottom. Orient the mirror so that you are looking into the corner of the three mirrors. What do you see?

A set of reflectors like this, but much smaller, was placed on the moon by the first astronauts to land there. Why was a reflector of this type placed there? What typo of "light" was aimed at it? What was learned from this data?

Examine the reflectors on the back of a car or bicycle. What in the shape of the dimples in the glass or plastic? Your instructor has a plastic bicycle reflector that you may investigate if you ask to see it.

7. Rotation of a Plane Mirror

Aim a single ray of light at a plane mirror. Record the incident ray, reflected ray and mirror reflecting surface. Your instructor will provide you with a piece of polar graph paper which makes this part of the investigation simpler..

Now rotate the mirror approximately 10 degrees so that the incident ray strikes the mirror at the same point as before. Record the new reflected ray and new mirror position. How does the angle through which the mirror was rotated compare to the angle through which the reflected ray rotated?

What would happen to the reflected ray if the mirror were rotated a further 15 degrees?

This technique is often used by scientists to exaggerate or amplify slight movements of measuring equipment. To see the effect, place the mirror in such a position that the reflected beam falls on a wall about 3 meters from the mirror. Now move the mirror a very small amount. What is observed on the wall?

INVESTIGATION: REFLECTIONS FROM CURVED MIRRORS -1-

1. Reflection - Circular Concave Mirror

Shine three parallel rays into the center of the concave side (inside circle) of the mirror in Figure 5 so that the center ray reflects back upon itself.

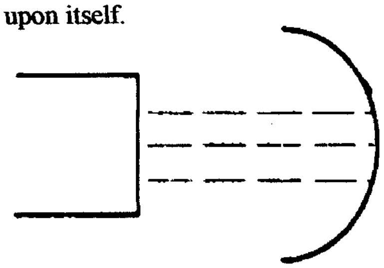

Figure 5

Mark the incident and reflected ray and the reflecting surface of the mirror. Note where the reflected rays meet. This point in called the FOCAL POINT of the mirror. A line drawn along the ray on which the point lies is called the PRINCIPLE AXIS. The point where the principle axis hits the mirror is called the VERTEX of the mirror. How far is the focal point from the mirror?

Repeat the above using 4 rays making sure that the incident rays are parallel to the principle axis. What do you observe?

2. Center of Curvature - Radius of Curvature

Shine a single ray at the concave side of the mirror so that it reflects straight back on itself. Record the position of the reflecting surface and the ray. Without moving the mirror, move the ray box to another position where the ray again reflects back on itself. Record the new ray position. Repeat for two more rays. The point where the rays cross is called the CENTER OF CURVATURE and the distance from this point to the mirror is the RADIUS OF CURVATURE. How does the radius of curvature compare to the focal length found earlier?

Now ask your instructor for some enlightenment.

3. CIRCULAR ABERRATION

Mask the 2 outer rays of the 4 slit-former leaving the two central rays to strike the concave side of the mirror. Record the position of the focal point as you move the ray box to different positions. Make sure that all incident rays are parallel to the principle axis. Do this for 8 to 12 rays. What do you notice about the relative position of the focal points?

Using the 4 ray-former, shine the rays on the mirror making sure the rays are parallel to the principle axis. Where do the 2 inner reflected rays focus? The outer 2 rays? Which rays focus nearer to the mirror? Mark the position of the incident and reflected rays and reflecting surface of the mirror. Carefully move the 4 incident rays sideways being careful to keep them parallel to the first rays. Does the CIRCULAR ABERRATION (the failure for all rays to focus at one point) increase or decrease as the incident ray distance from the principle axis increase?

On two of the reflected rays draw lines from the center of curvature to the points of reflection. Each of these lines is a radius and thus is normal (perpendicular) to the mirror surface. Mark and measure the angle of incidence and the angle of reflection. Now do they compare?

4. Reflection - Convex Mirror

Using the 4 slit-former, shine rays parallel to the principle axis that hit the convex surface of the circular mirror. Record the position of the reflecting surface and the ray paths. Indicate the ray direction with arrow heads. Where do the diverging rays appear to come from? Draw the diverging rays backward through the mirror. The point where the rays appear to originate is called the VIRTUAL FOCUS and the distance of this point to the mirror (reflecting surface) Is called the VIRTUAL FOCAL LENGTH.

How does this focal, length compare with the focal length of the concave side of the mirror? If they differ, by how much? What might be the reason for the difference?

5. Reflection - Parabolic Reflector

A parabola is an unusual shaped curve, which is found by one of the following methods:

a. Plot a graph of y a x^2 or some other quadratic algebraic function,
b. Record the flight of a projectile.
c. Move a point P so that it is always a relative distance from a fixed point F (called the FOCAL POINT) and a straight line AB (called the DIRECTRIX because it directs which way the parabola will face). See Figure 6.
d. Cut a cone in a plane parallel to the sloping side. This is called a CONIC SECTION. Other conic sections are circles, ellipse, or hyperbolas.

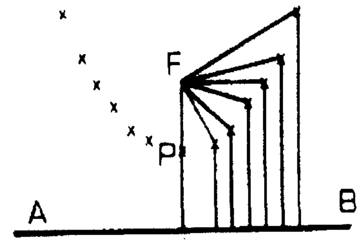

Figure 6

Aim a set of parallel rays onto the concave side of a parabolic reflector along paths parallel to the principle axis of the mirror. Record the location of the mirror and ray paths. Record the focal length. Move the light box sideways keeping the rays parallel to the principle axis. What do you notice about the position of the focal point?

Shine a broad parallel sided beam of light at the parabolic mirror and observe the effect.

What would happen if a point source of light is placed at the focal point of a parabolic mirror? Try it and see.

What is the advantage of using a parabolic shaped reflector rather than a spherical shaped reflector or radar antennas, radio telescopes, car headlight reflectors, etc. ? Where Is the receiving transmitting or radiator device relative to the reflecting surface?