BOROUGH OF MANHATTAN COMMUNITY COLLEGE
SCIENCE DEPARTMENT. GENERAL PHYSICS (PHY 110).

Laboratory Experiment 10.

OHM'S LAW

OBJECTIVES

To study the relationship among potential difference (voltage), current and resistance in a simple electric circuit with an ammeter and a voltmeter.

APPARATUS

A variable resistor, voltmeter, ammeter, tap key direct current (DC) power source and wires.

THEORY

When a potential difference ΔV is applied at the endpoints of a resistor, it results in the flow of a current I through the resistor. The resistance R of the resistor is defined as

$$R = \frac{\Delta V}{I} \tag{1}$$

or equivalently

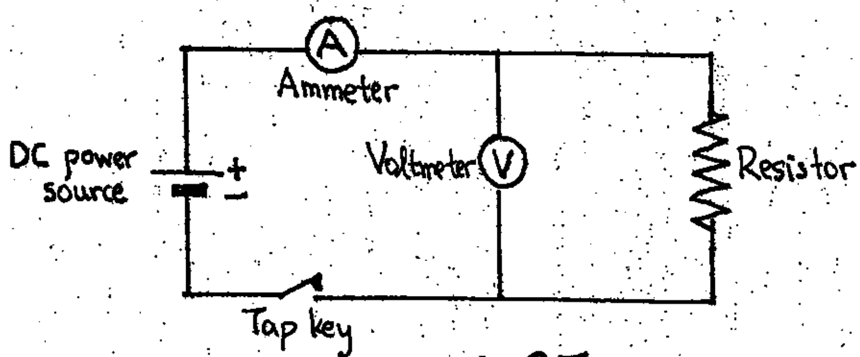
$$\Delta V = RI \tag{2}$$

Ohm's law states that in a large class of resistors, R is independent of ΔV or I. In such a case, because of (2), the graph ΔV versus I is a straight line passing through the origin of the coordinate system. The slope of this line is, by definition, equal to R.

PROCEDURE

Before you start this experiment, make certain that you know how to read the indications of the voltmeter and of the ammeter in the appropriate scales. All measurements are taken with these two instruments. Disregard the numbers on the instruments of the DC power source.

1. Set the moving part of the variable resistor somewhere in the middle (between its two ends).
2. Set up the circuit as in the figure below. *Ask your Instructor to check the circuit after you have completed it. Then, plug the DC source to the power outlet and turn it on.*



STUDENT NAME : ______________________________ SECTION: _____
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3. Turn the knob of the power source gradually. Record the potential difference reading of the voltmeter and the electric current reading of the ammeter, after each small turn of the knob. Repeat five more times. Report your measurements in Table 1 below.

TABLE 1.

Potential Difference ΔV (V)	Electric current I (A)

4. Move the moving part of the variable resistor to another location (away from the ends). Repeat Step 3 for this value of the resistor. Report your measurements in Table 2 below.

TABLE 2.

Potential Difference ΔV (V)	Electric current I (A)

5. Construct a graph of the potential difference (in the vertical axis) versus the electric current (in the horizontal axis), for each Table (separately).

6. Draw the "best fit line" in each of these two graphs.

7. Calculate the slope of each line. The slope is equal to the value of the resistance in each case.

Resistance (from Table 1) = _______ Ω   Resistance (from Table 2) = _______ Ω

QUESTION

Do these resistors satisfy Ohm's law ? Explain your answer.

BOROUGH OF MANHATTAN COMMUNITY COLLEGE
SCIENCE DEPARTMENT. GENERAL PHYSICS (PHY 110)

Laboratory Experiment 8.

SERIES AND PARALLEL CONNECTIONS OF RESISTORS

OBJECTIVES

Becoming familiar with the reduction of a complicated electric circuit to a simpler one, by combining groups of resistors connected in series and in parallel.

APPARATUS

Direct current source (DC battery), wires, switch, resistors, voltmeter, ammeter.

THEORY

Consider a complicated electric circuit containing several resistors. It can be reduced to a simpler one by combining the resistors in groups and substituting one resistor for each group. The basic groups of resistors that are used in such a reduction contain resistors connected in:

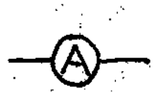
- **Series.** Resistors $R_1, R_2, R_3, \ldots$ are connected in series when the same current passes through each one of them. A group of resistors connected in series can be substituted for one equivalent resistor R_{eq} given by

$$R_{eq} = R_1 + R_2 + R_3 + \ldots \tag{1}$$

- **Parallel.** Resistors $R_1, R_2, R_3, \ldots$ are connected in parallel when the potential difference between the ends of each one of them is the same. A group of resistors connected in parallel can be substituted for one equivalent resistor R_{eq} given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \tag{2}$$

The symbols of some elements encountered in electric circuits are:

Voltmeter:		Resistor:	
Ammeter:		DC Source:	

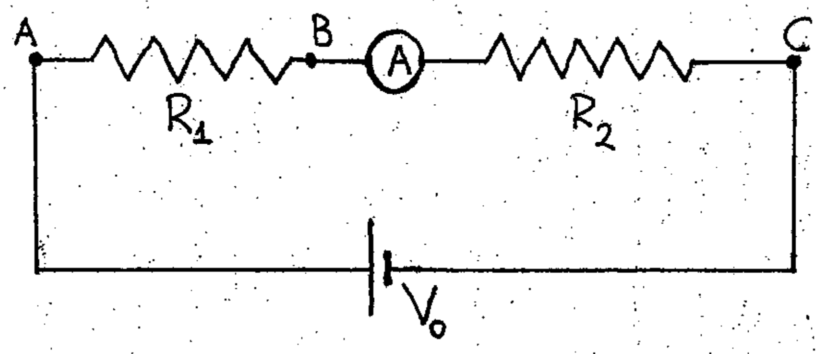
STUDENT NAME : ______________________ SECTION: ____
(PLEASE PRINT) LAST FIRST

CIRCUIT SET UP AND MEASUREMENTS

I. Set up the following circuit and measure (using the Ammeter) the current i passing through resistors R_1 and R_2. This current is theoretically predicted to be $i = \frac{V_o}{R_1+R_2}$

Measured $i =$ ________ Calculated $i =$ ________ % Error of measured $i =$ ________

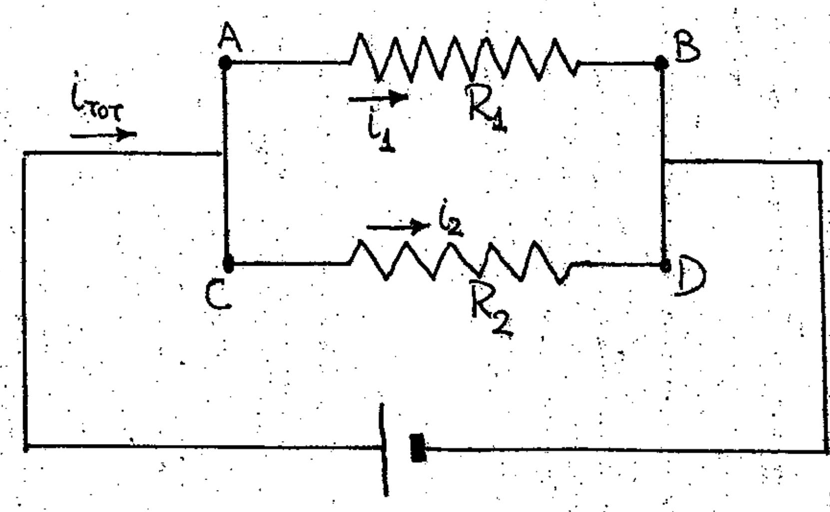
Using the Voltmeter, measure $V_{AB} =$ ______ and $V_{BC} =$ ______. Is $V_{AB} + V_{BC} = V_o$? YES NO



II. Set up the following circuit and measure (using the Ammeter) the currents i_1, i_2 flowing through resistors R_1, R_2, respectively. Measure also the total current i_{tot} flowing through the circuit.

$i_1 =$ ________ $i_2 =$ ________ $i_{tot} =$ ________. Is $i_1 + i_2 = i_{tot}$? YES NO

Using the Voltmeter, measure $V_{AB} =$ ________ $V_{CD} =$ ________. Is $V_{AB} = V_{CD}$? YES NO



LABORATORY EXERCISE - AIR COLUMN RESONANCE

NAME____

OBJECTIVES: 1. To investigate the phenomenon of resonance in a column of air closed at one end.
2. To measure the speed of sound in air using the resonance phenomenon.

EQUIPMENT NEEDED: Resonance tube apparatus, rubber mallet, various tuning forks, room thermometer

THEORY: In order to have resonance in a pipe one must have a ***standing*** wave. With a pipe closed at one end the requirement for a standing wave is a ***(vibration or displacement) node*** at the closed end and an ***antinode*** near (but not exactly on) the open end. If you can change the length of the pipe while sounding a tone of a single frequency the first resonance will occur when the pipe is (approximately) one quarter wavelength long. The next resonance occurs when the pipe has a length of about three quarters of a wavelength. In general, resonance will occur when the length of the pipe is equal to an ***odd number of quarter wavelengths!*** The first two resonances are illustrated in Figure 1. Although the antinode is not exactly at the open end of the pipe, ***the distance between successive nodes is exactly equal to one half wavelength.*** Since the wave speed is equal to frequency times wavelength ($v = f\lambda$) we can calculate the speed of sound in air once the distance between nodes (one half wavelength) is measured; multiplication of the wavelength by the (known) frequency gives us the wave speed.

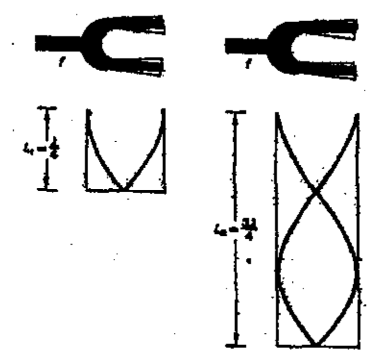


Figure 1
Resonance occurs when the length of the pipe is about one quarter of a wavelength and when it is about three quarters of a wavelength.

There is an alternative way to determine the speed of sound in air that makes use of the fact that the speed of sound increases with increasing temperature. The equation that describes this relationship is: $v = 331.5 + 0.6T_c$ where T_c is the air temperature in Celsius degrees. This equation gives us the speed of sound in meters per second.

PROCEDURE: The length of the air column in the resonance tube apparatus is changed by sliding the aluminum cup up or down. This changes the height of the water column in the glass tube. One student strikes a tuning fork with a rubber mallet and holds it right above the top of the glass tube. Another student lowers the aluminum cup lengthening the air column in the tube. When resonance occurs the sound of the tuning fork will get considerably louder. The top of the water column has then reached a node. The position of this node is noted in the data table as L_1. The water level is the lowered more with the fork having been struck again. The location of the next node is entered as L_2 (L_2 is about three times L_1). The frequency of the tuning fork is also entered in the data table You may be able to find a third resonance at a point L_3 that is about five times L_1. Now $L_2 - L_1 = \lambda/2$. This value is ***doubled*** in order to get the wavelength λ. Now multiply this by the frequency in order to find the wave speed. Repeat these steps with a tuning fork of a different frequency. Finally, look at the room thermometer to determine the air temperature and calculate the speed of sound using the temperature-dependence equation $v = 331.5 + 0.6T_c$. This speed can be compared with the average of the speeds found using the resonance tube.

Figure 2
Students using the resonance tube apparatus

LABORATORY EXERCISE - AIR COLUMN RESONANCE

NAME____

Tuning fork 1 **FREQUENCY =** ________________ **hertz**

NODE LOCATION (meters)	$\lambda/2$ (meters)
$L_1 =$	
$L_2 =$	$L_2 - L_1 =$

$\lambda/2 = L_2 - L_1 =$ ________

$v_1 = f\lambda =$ ________ meters per second

Tuning fork 2 **FREQUENCY =** ________________ **hertz**

NODE LOCATION (meters)	$\lambda/2$ (meters)
$L_1 =$	
$L_2 =$	$L_2 - L_1 =$

$\lambda/2 = L_2 - L_1 =$ ______

$v_2 = f\lambda =$ ________ meters per second

SPEED OF SOUND FROM TEMPERATURE EQUATION

ROOM TEMPERATURE (T_c) = ______ °C

$v_T = 331.5 + 0.6T_c =$ __________ meters per second

$$V_{AVE} = \left[\frac{V_1 + V_2}{2}\right] = \_\_\_\_\_\_\_\_\_\_ \text{ meters per second}$$

$$\%ERROR = \frac{|V_{AVE} - V_T|}{V_T} * 100\% =$$

BOROUGH OF MANHATTAN COMMUNITY COLLEGE
SCIENCE DEPARTMENT
GENERAL PHYSICS (PHY 110).

Laboratory experiment

LIGHT REFLECTION AND REFRACTION

OBJECTIVES:

To test the validity of the laws of reflection and refraction of light.

APPARATUS:

Sheets of white paper, plane glass mirror, straight pin, semicircular transparent plastic box, ruler, protractor and pencil.

EXPERIMENT # 1: REFLECTION

THEORY:

When a light ray strikes a reflecting surface the incident ray makes an angle i with a line perpendicular to the surface (called a normal line). After reflection, the reflected ray makes an angle r with the normal line. The law of reflection simply states that the two rays and the normal are contained in the same plane and that $i = r$. This is illustrated below.

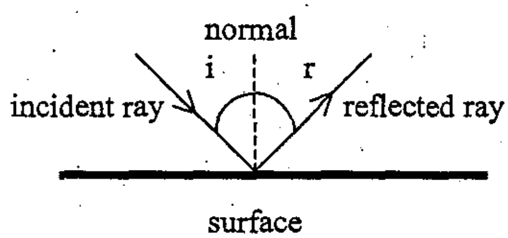


Figure # 1

PROCEDURE:

1- Draw a long straight line across a sheet of white paper. This line should be roughly at the center of the paper and will represent the reflecting surface.
2- Mark with the pencil a point P_1 on the paper about 5 cm from the drawn line.
3- Draw an arrow-headed straight line from P_1 until it intersects the reflecting surface line. This second line will represent the incident ray. These two lines should not be perpendicular to each other. Mark the intersection point and call it P_2.
3- Place the plane mirror on the paper with its **back** carefully aligned with the reflecting surface line (note that the reflecting surface of a glass mirror is in the back rather than the front of the glass).
4- Put your eyes at the level of the sheet of paper, close one of your eyes and with the open eye look at the reflection of the line coming from P_1.
5- Take the pin and hold it vertically over the paper. Adjust its position until you observe that the pin perfectly overlaps the reflection of the line coming from P_1. When this

condition is achieved, puncture the paper with the pin, mark this point with the pencil and call it P_3.

6- Remove the mirror and draw an arrow-headed line from P_2 to P_3. This line will represent the reflected ray.
7- From P_2 draw a broken line perpendicular to the reflecting surface line. This will represent the normal line.

MEASUREMENTS:

Measure the incident and reflection angles.

Angle of incidence i_1 = _____ degrees, Angle of reflection r_1 = _____ degrees

OPTIONAL MEASUREMENTS AND PROCESSING:

8- Repeat steps 3 to 7 for a new incident ray coming from the same point P_1 but striking the reflecting surface at a different point P_2' and originating a new reflected ray leading to a different point P_3'.

Angle of incidence i_2 = _____ degrees, Angle of reflection r_2 = _____ degrees

9- Apply ray tracing to find the image of point P_1.

EXPERIMENT # 2: REFRACTION

THEORY:

When light passes from one medium into another its speed changes. The greatest speed light can attain is its speed in vacuum. When light passes into a different medium it slows down. The denser the medium, the slower the speed of light within the medium. A quantity called the index of refraction (n) of a medium is used to compare the speed of light in the medium to the speed in vacuum. It is defined as:

$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in the medium}} \qquad (1)$$

The change of the speed of light as it passes from one medium to another causes its direction of propagation to change. If we draw a line perpendicular (normal) to the surface separating the two media, then a light ray is seen to bend toward the normal line when it slows down and away from the normal when it speeds up. This is illustrated below for the case when the speed of light in medium 2 is smaller than in medium 1 so that θ_2 is smaller than θ_1.

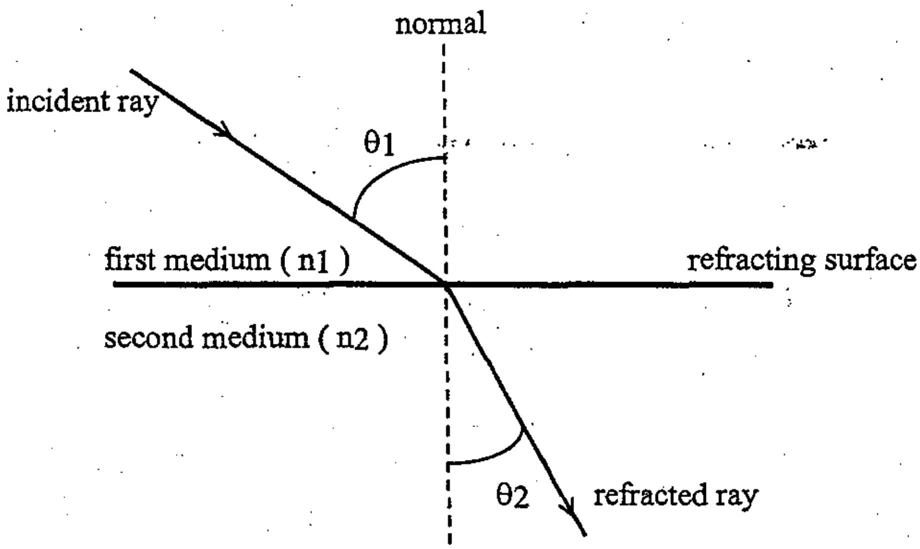


Figure # 2

Light refraction is described by the law of refraction or Snell's Law which states that:

1- The incident ray, refracted ray and normal are all contained in the same plane.
2- The indexes of refraction n1 and n2 of the two media and the angles of incidence θ_1 and refraction θ_2 are related by the expression:

$$n1 \sin \theta_1 = n2 \sin \theta_2 \qquad (2)$$

PROCEDURE:

1- Draw a long straight line across a sheet of white paper. This line should roughly be at the center of the paper and will represent the refracting surface.
2- Mark with the pencil a point P_1 on the paper about 5 cm from the drawn line.
3- Draw an arrow-headed straight line from P_1 until it intersects the refracting surface line. Mark the intersection point and call it P_2. This second line will represent the incident ray. These two lines should not be perpendicular to each other.
4- Half fill the semi-circular plastic box with water. Put the box over the paper with the straight side along the refracting surface line and opposite to the incident ray line.
5- **Adjust the position of the box until the middle point of its straight side is exactly over point P_2.**
6- Put your eyes at or slightly above the level of the sheet of paper, close one of your eyes and with the open eye look through the water at the image of the incident ray line coming from P_1.
7- Take the pin and hold it vertically over the paper. Adjust its position until you observe that the pin perfectly overlaps the image of the incident ray line coming from P_1. When this condition is achieved, puncture the paper with the pin, mark this point with the

pencil and call it P3. **Be sure to look through the water all the time rather than through the air inside the box above the water!!.**

8- Remove the plastic box and draw and arrow headed straight line from P2 to P3. This line will represent the refracted ray.

9- Draw a broken line through P2 perpendicular to the refracting surface line as shown in figure 2. This will represent the normal line.

MEASUREMENTS:

1- Measure the angles of incidence θ_1 and refraction θ_2.

Measured angle of incidence θ_1 = ______ degrees
Measured angle of refraction θ_2 = ______ degrees

OPTIONAL CALCULATIONS:

The index of refraction of water n2 can be obtained from the Snell's Law as follows:

$$n2 = \frac{n1 \sin(\theta_1)}{\sin(\theta_2)} \qquad (3)$$

1- Use a scientific calculator to find $\sin(\theta_1)$ and $\sin(\theta_2)$, then set the index of refraction of air(n1) equal to 1 in equation (3) and calculate the index of refraction of water n2.

n2 calculated = ________

2- Calculate the % relative error between your experimental value for n_2 and the accepted value. The accepted value of the index of refraction for pure water is 1.33.

% relative error = _________ %

3- Use the definition of the index of refraction given in equation (1) to calculate the speed of light in water from your calculated value of n knowing that the speed of light in vacuum is approximately $3x10^8$ m/s.

v in water = _________ m/s

QUESTIONS:

1- Do your results support the validity of the law of reflection?. Explain.
2- Is the speed of light in water smaller, equal or larger than in air?
3- Is the index of refraction for water smaller, equal or larger than the one for air?
4- If a light ray passes from air to water, does it bend toward or away from the normal?

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SCIENCE DEPARTMENT
GENERAL PHYSICS (PHY 110)

Laboratory Experiment

FOCAL LENGTH OF A CONVERGING LENS. SIMPLE TELESCOPE

OBJECTIVES:

1- To determine the focal length of a double convex lens.
2- To study the characteristics of the images that are produced by the lens.
3- To construct a simple refractor telescope.

APPARATUS:

Double convex lenses mounted on holders, optical bench, white cardboard screen, illuminated object and meter stick.

EXPERIMENT # 1: FOCAL LENGTH OF A CONVERGING LENS

THEORY:

If a beam of parallel rays falls upon a converging lens, refraction causes the light to converge toward a point called the focal point F of the lens. The distance from the center of the lens to F is called the focal length f of the lens (figure 1).

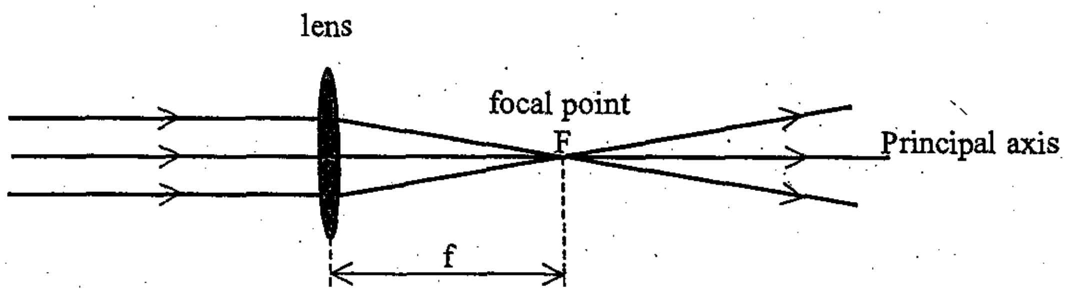

Figure # 1

To determine the focal length of a lens, one makes use of the lens equation (see figure 2):

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}$$

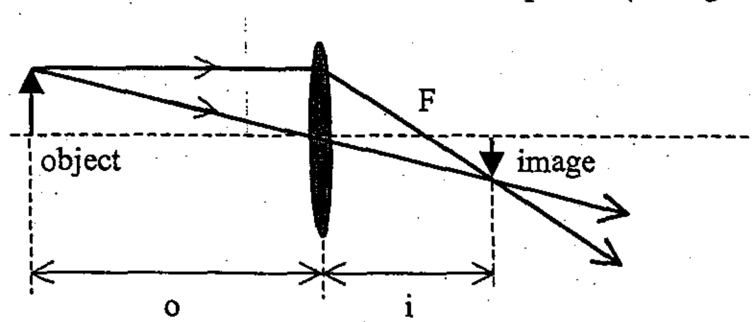

Figure # 2

where:
o is the object distance
i is the image distance
f is the focal distance

PROCEDURE:

1- Set up the apparatus shown in figure 3 by mounting a double convex lens and the cardboard screen on the optical bench. Place the illuminated object mounted as shown in the figure. The illuminated arrows will be used as an object.
2- Turn on the illuminated object. Move the screen to a position where the image of the arrows are in sharp focus. If you do not obtain a sharp image you might also have to move the position of the lens farther away from the object.
3- Measure the distance between the illuminated object and the center of the lens (object distance o) and the distance from the lens to the screen (image distance i).
4- Using the lens equation, calculate the focal length of the lens.
5- Use the value of the focal length calculated for your lens to put the lens at a distance from the illuminated object as indicated in (a) through (d) below. For each case, after putting the lens at the desired position, move the screen until a sharp image is formed (if any) on the screen and describe the characteristics of the image (larger or smaller than the object, erect or inverted, real or virtual).
   (a) at 2.5 times the value of the focal length.
   (b) at exactly twice the value of the focal length.
   (c) at 1.5 times the value of the focal length.
   (d) at one-half the value of the focal length.

MEASUREMENTS:

Object distance o = ________ cm.
Image distance i = ________ cm.

CALCULATIONS:

Focal distance: f = ________ cm.

Object distance (cm)	Size (larger/equal/smaller)	Orientation (erect/inverted)	type (real/virtual)

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EXPERIMENT # 2: SIMPLE ASTRONOMICAL TELESCOPE

THEORY:

A simple astronomical refractor telescope consists of two lenses, the objective lens and the eyepiece. The objective is a converging lens of long focal length which forms a real image of a distant object in its focal plane. The eyepiece is a converging lens of short focal length which uses the image formed by the objective lens as the object and produces an enlarged virtual image. The eye looks directly at the enlarged virtual image produced by the eyepiece (figure 4).

PROCEDURE:

1- Pick up a converging lens (with the longest possible focal length) as the objective and another converging lens (with the shortest possible focal lens) as the eyepiece. Initially mount the two lenses on the optical bench separated by a distance approximately equal to the sum of the two focal lengths with the eyepiece near one end of the optical bench.
2- Aim the optical bench with the lenses on it at a distant object on the New Jersey's waterfront. Look through the eyepiece and adjust its position until a sharp inverted image of the object is formed.

QUESTIONS:

1- Under what condition will a convex lens produce a virtual image from a real object?

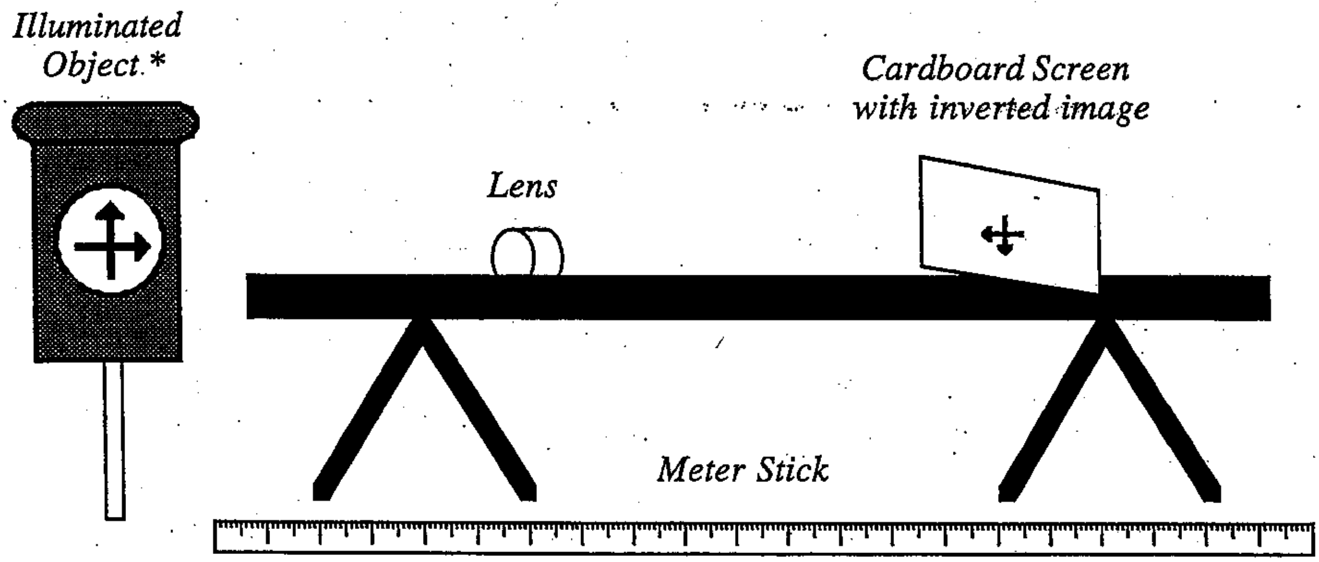

Figure 3. Determination of the Focal Length of a Lens

* *Note: Do not use Illuminated Object in the horizontal (sideways) position. This causes a harmful buildup of heat. Always use it upright, as in the illustration above.*

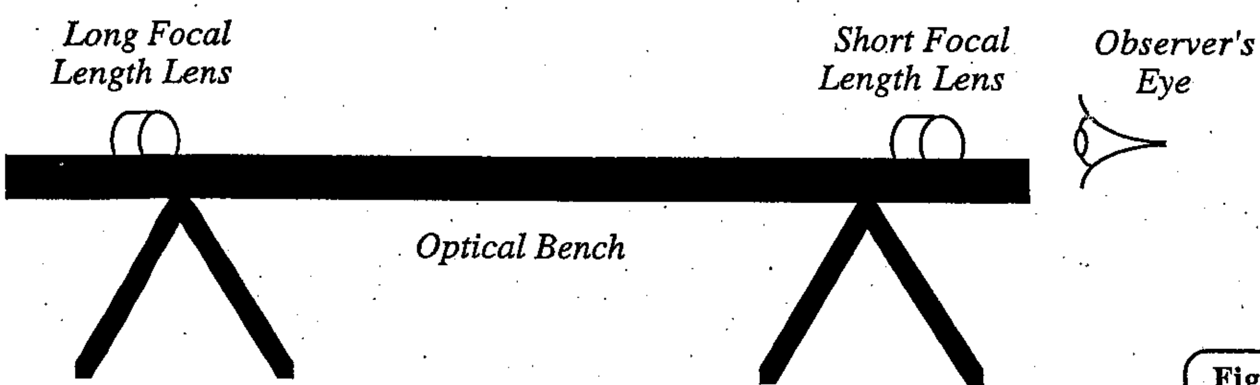

Figure 4. Refracting Telescope

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PROCEDURE:

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QUESTIONS:

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Laboratory Experiment

SPECTRA

OBJECTIVES:

To study the characteristics of an emission spectrum using a spectroscope to get an idea of how scientists know what elements are present in the stars and other materials.

APPARATUS:

Diffraction grating spectroscope, hydrogen, neon, helium and mercury lamps, incandescent and fluorescent light bulbs.

THEORY:

The spectrum in a diffraction grating spectroscope is obtained by diffraction which separates the light from any source into its component colors and projects them in different directions. The spectrum can contain a first, second, third and more orders of diffraction. Gases produce discrete line spectra which means that several colors will be observed separated from each other by dark spaces. Solids produce continuous spectra in which all colors appear continuously without any dark space separation among them.

PROCEDURE:

1- Using the spectroscope, observe the spectrum of the incandescent light bulb.
2- Make a careful drawing of the observed colors listing them in order.
3- Repeat steps 1 and 2 for all other light sources.

MEASUREMENTS:

Incandescent	
Fluorescent	
Hydrogen	
Neon	
Helium	
Mercury	

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QUESTIONS:

1- What is the gas contained in the fluorescent lamp which produces the line spectra component on the observed spectrum from the fluorescent lamp?
2- How does a study of spectra aid us in identifying elements ?
3- How is this used by astronomers in their study of the stars ?