1. Newton's Rings

Aim:

To determine the Radius of curvature of a plano convex lens by forming Newton's rings.

Apparatus :

A plano convex lens, two glass plates, sodium vapour lamp, travelling microscope, magnifier and black paper.

Formula:

Radius of curvature, $R = \frac{D_m^2 - D_n^2}{4\lambda(m-n)}$ cm

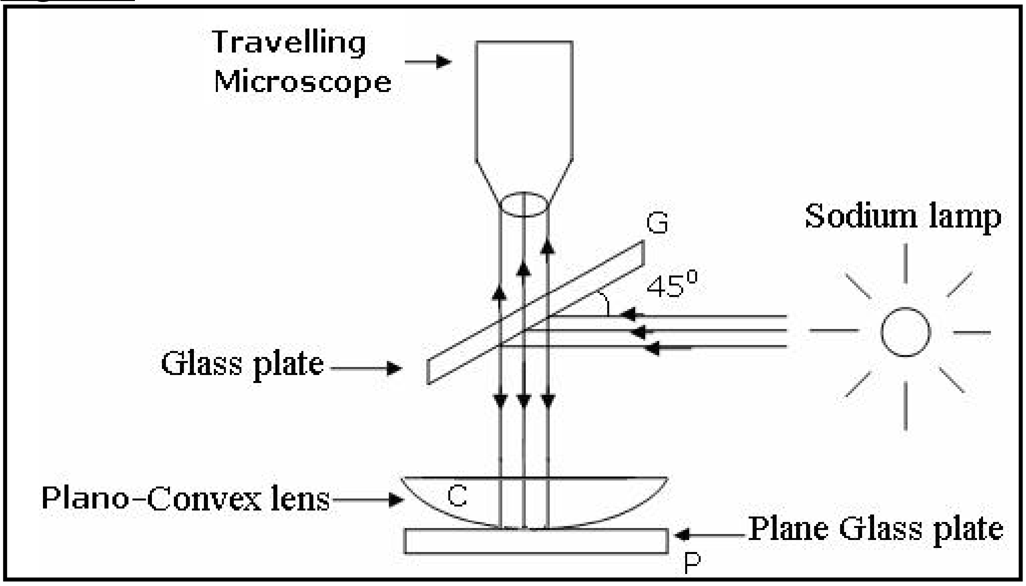
D_m : Diameter of the m^{th} ring.

D_n : Diameter of the n^{th} ring.

R : Radius of curvature of the lens (cm).

λ : Wavelength of monochromatic (Sodium) light (5893×10^{-8} cm)

Figure 1



Theory:

The experimental setup consists of a plano convex lens(C) of large radius of curvature placed on a plane optically flat glass plate (P) with the curved surface of plano convex lens facing the plane glass plate. A thin air film of varying thickness is formed between the plano convex lens and glass plate. Another glass plate (beam splitter) is arranged above the plano-convex lens making an angle of 45^0 with the horizontal. The light from a monochromatic light source (sodium vapour lamp) is allowed to incident on the glass plate G at 45^0 as shown in the figure 1. The light reflected from glass plate G is incident on the the plano convex lens in perpendicular direction. By division of amplitude, the light reflected from top and bottom surface of the air film interferes and produces concentric alternate dark and bright rings as shown in figure 2, called Newton’s rings. A travelling microscope is arranged vertically on the top of the glass plate G to view the Newton’s rings.

Procedure:

1. The source of monochromatic light is switched on and adjusted to illuminate the glass plate G horizontally.
2. Due to interference of light concentric rings are formed as shown in the diagram. These rings are clearly visible through the travelling microscope.
3. The microscope is then adjusted until the rings are in sharp focus.
4. The point of intersection of the cross wires is brought to the centre of the rings system. Starting from the centre of the ring system the microscope is moved to the left across the field of view counting the number of rings.
5. Then the cross wires of the microscope may be set tangential to the rings. Now the readings on the horizontal scale are noted for 15^{th}, 10^{th} and 5^{th} fringes. Similarly, the microscope is moved in the opposite direction say right and corresponding readings for the 5^{th},10^{th} and 15^{th} and fringes are noted.
6. Finally, the diameters of the fringes are calculated.

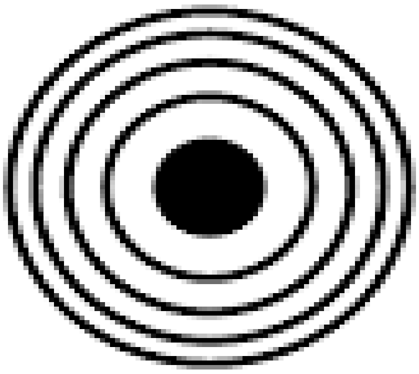


Figure 2 : Newton’s Rings

Observation Table:

Least count of travelling microscope (LC) = __________cm.

Fringe number I	Microscope reading (cm)						Diameter of the i^{th} ring D_i= (a~b)	D_i^2 (cm^2)
	Left side			Right side				
	MSR	VC	Total(**a**)= MSR+(VC*LC)	MSR	VC	Total(**b**)= MSR+(VC*LC)		

Precautions:

1. Electric connections of the light source should be carefully handled.
2. Travelling microscope cross-wires should be properly adjusted.
3. Vernier coincidence should be found without parallax error.
4. Travelling microscope must be moved in one direction only to avoid backlash error.

Result:

The radius of curvature of the given plano convex lens is found as _______________.

2.DIFFRACTION GRATING

Aim:

To determine the wavelength of given monochromatic source by using diffraction grating.

Apparatus:

Plane diffraction grating, spectrometer, Sodium vapour lamp and magnifier.

Principle:

$$\text{Wavelength, } \lambda = \frac{Sin\theta}{Nn}$$

Where θ =Angle of diffraction
N=Number of lines per **cm** on the grating = (15000/2.54)
n=Order of the spectrum

Description:

A plane diffraction grating (G) consists of a glass plate with equidistant parallel lines drawn very closely on it by means of diamond tip. The number of lines/inch on the grating will vary from grating to grating and will be mentioned on it. Other types of gratings are replica of the original grating on a plane celluloid film. The celluloid film is fixed on an optical plane glass. Care should be taken while handling the grating to avoid any scratches on the grating.

Theory:

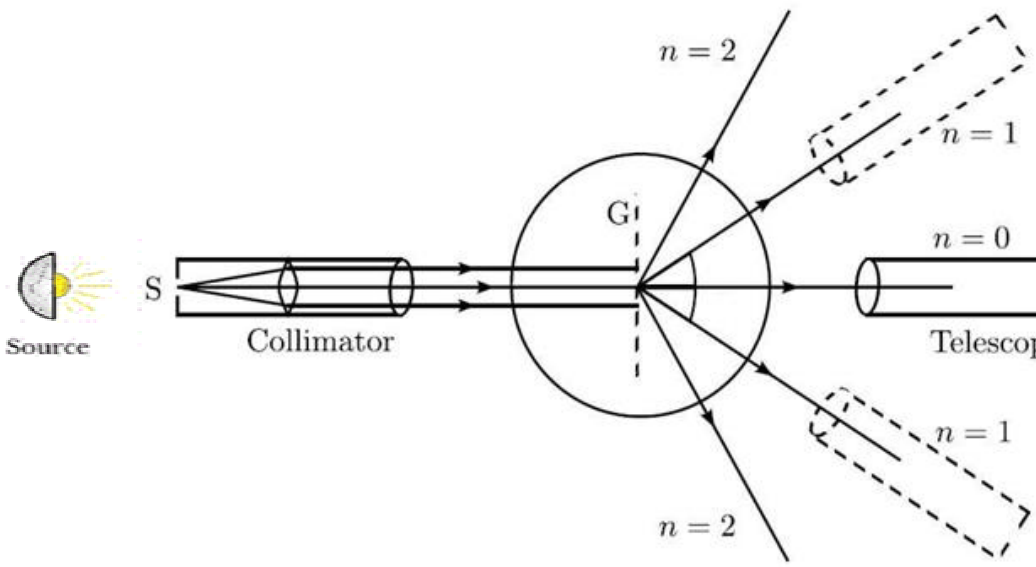
When a parallel beam of monochromatic light from the collimator of a spectrometer is made to pass normally through a plane diffraction grating mounted on the prism table, diffraction pattern will be formed which can be observed through the telescope. The diffraction pattern consists of a central sharp line with other symmetric lines pertaining to first, second, third..….orders on either side of the central line. If N is the number of lines on the grating per cm, n, the order of spectrum (1,2,3,…), λ the wavelength of light source and θ, the angle of diffraction then

$$\lambda = \frac{Sin\theta}{Nn}.$$

Procedure:

1. Preliminary adjustments of the spectrometer like
   a) Focusing the telescope to a distant object to get a clear image.
   b) Adjusting the collimator (illuminated by the given monochromatic light) to produce narrow beam of light rays.
   c) Levelling of grating table using spirit level is done.

2. The Plane diffraction grating (G) is mounted vertically on the grating table normal to the incident light from the source as shown in the experimental arrangement.
3. Observe the narrow beam of light coming from the slit (S) directly, which is the zero order diffraction.
4. Move the telescope to the right until the image of the slit is observed, which is the first order diffraction.
5. The vertical crosswire of the telescope is made to coincide with this image of the slit and the spectrometer readings on both scales viz., vernier 1 and vernier 2 are noted.
6. Then the telescope is further moved away to observe the second order slit. The spectrometer readings on both scales viz., vernier 1 and vernier 2 are noted.
7. This procedure is repeated by moving the telescope to the other side (Left side position). The readings are tabulated.



Experimental arrangement

Observation Table

Least Count of the spectrometer =

Order of spectrum (n)	Left side readings		Right side readings		$\theta_1 = (a \sim c)$	$\theta_2 = (b \sim d)$	$\theta = \left\{\frac{\theta_1 + \theta_2}{4}\right\}$	$\lambda = \frac{Sin\theta}{Nn}$
	Vernier1	Vernier2	Vernier1	Vernier2				
1	MSR= VC= **Total(a)**= (MSR+(VC*LC))	MSR= VC= **Total(b)**= (MSR+(VC*LC))	MSR= VC= **Total(c)**= (MSR+(VC*LC))	MSR= VC= **Total(d)**= (MSR+(VC*LC))				
2	MSR= VC= **Total(a)**= (MSR+(VC*LC))	MSR= VC= **Total(b)**= (MSR+(VC*LC))	MSR= VC= **Total(c)**= (MSR+(VC*LC))	MSR= VC= **Total(d)**= (MSR+(VC*LC))				

Precautions:

1. Care should be taken while handling the power supply.
2. Experiment should be conducted in absence of any other light.
3. Spectrometer telescope and collimator should be properly adjusted to produce and receive parallel beam of light rays.
4. Readings should be taken without parallax error.

Result:

The wavelength of given monochromatic source is ____________________.

3. Dispersive Power

Aim:

To determine the dispersive power of the material of given prism.

Apparatus:

Spectrometer, prism, mercury vapour lamp and magnifier.

Principle:

The dispersive power is given by, $\omega = \frac{\mu_V - \mu_R}{\mu - 1}$

Here $\mu = \frac{\mu_V + \mu_R}{2}$

μ_V : Refractive index for violet colour.

μ_R : Refractive index for red colour.

The refractive index of the prism, $\mu = \frac{\sin\left\{\frac{A+D_M}{2}\right\}}{\sin\frac{A}{2}}$

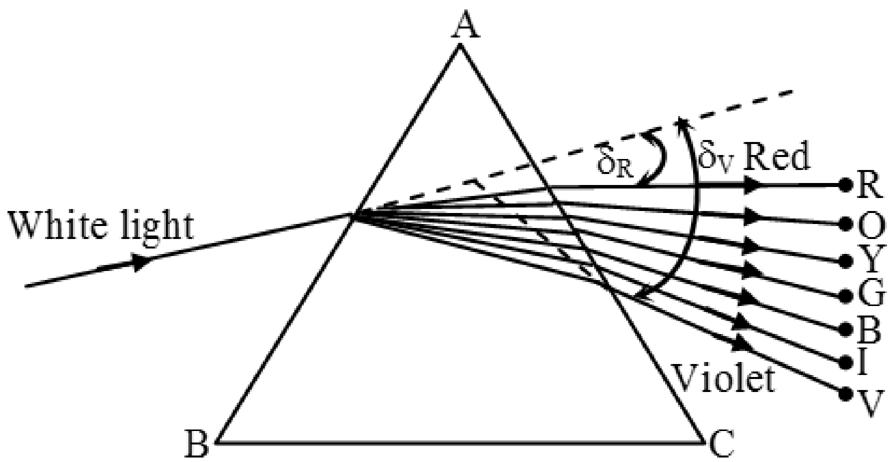
A: Angle of the prism (60°).

D_M: Angle of minimum deviation.

Theory:

When white light is passed through a glass prism it splits into its spectrum of colours (in order violet, indigo, blue, green, yellow, orange and red) and this process of splitting of white light into its constituent colours is termed as dispersion. When light travels from one medium to another, the speed of its propagation changes, as a result, it ‘bends’ or is ‘refracted’. Now when light passes through a prism, it is refracted towards the base of the triangle.

The refraction of light through the prism is well illustrated in the diagram given below. The different colours in the spectrum of light have different wavelengths. Therefore, the speed with which they all bend varies depending on their wavelength, where violet bends the most, having the shortest wavelength and red bends the least, having the longest wavelength. Because of this, the dispersion of white light into its spectrum of colours takes place when refracted through a prism.



Dispersion of white light by a glass prism

Procedure:

1. Preliminary adjustments of the spectrometer like
    a) Focusing the telescope to a distant object to get a clear image.
    b) Adjusting the collimator (illuminated by the given monochromatic light) to produce narrow beam of light rays.
    c) Levelling of grating table using spirit level is done.
    d) Make the vertical cross wire to coincide with narrow beam of light and fix the direct readings as 0° and 180° by rotating the circular scale.
2. The prism table is released and the vernier table is clamped. The prism is placed on the prism table with the rough surface of the prism on the left or right side of collimator.
3. The ray of light passing through collimator strikes one of the surface of prism and undergoes deviation and emerges out of the prism from the other side.
4. Looking at the spectrum through the telescope the prism table is turned slowly in such a direction that the spectrum moves towards direct path of the beam.
5. The process is continued until the spectrum changes its direction of motion, even though the prism table is turned in the same direction as before.
6. In this limiting position of the spectrum, deviation of the beam is minimum.
7. Now the telescope is fixed on violet colour and the readings on Vernier-1 and Vernier-2 are taken. Similarly, the readings for red colour are also taken.
8. The refractive index and dispersive power are calculated as per the formulae given.

ObservationTable:

Colour	Direct ray position		Minimum deviation Position		V_1	V_2	Angle of minimum deviation(D_M)= $(V_1+V_2)/2$	Refractive Index(μ) $= \dfrac{\sin\left\{\dfrac{A+D_M}{2}\right\}}{\sin\dfrac{A}{2}}$
	Vernier1 (**a**)	Vernier2 (**b**)	Vernier1 **(c)**	Vernier2 **(d)**	a~c	b~d		
Violet	0°/ (360°)	180°	MSR= VC= Total(**c**)= (MSR+(VC*LC))	MSR= VC= Total(**d**)= (MSR+(VC*LC))				
Red	0°/ (360°)	180°	MSR= VC= Total(**c**)= (MSR+(VC*LC))	MSR= VC= Total(**d**)= (MSR+(VC*LC))				

Precautions:

1. Care should be taken while handling the electrical connections of the source.
2. Spectrometer telescope and collimator should be properly adjusted to produce and receive parallel beam of light rays.
3. The slit width shoud be sufficiently narrow.
4. Prism should be placed exactly at the center of prism table.

Result:

The dispersive power of the given material is found as ______________________________.

4. SINGLE SLIT DIFFRACTION USING LASER

Aim:

To determine the wavelength of given LASER by single slit diffraction.

Appartus:

Laser source, single slit, meter scale, traveling microscope.

Formula: Wavelength of the source (λ) = (a sinθ)/n.

Where n = the order of diffraction.

a =slit width

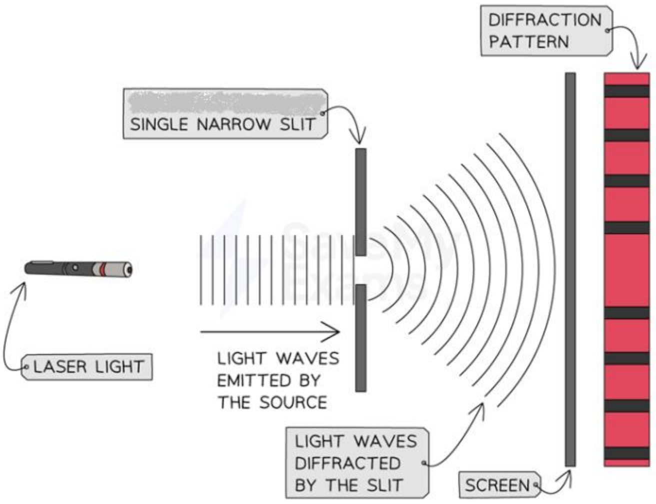
θ = the angle of diffraction

Theory:

The single slit may be treated as a large number of equally spaced point sources and each point on the slit is source of Huygen's secondary wavelets, which interfere with the wavelets emanating from the other points. The secondary wavelets traveling in the direction parallel to the slit comes to focus on the screen at a point. Since all rays are in phase, diffraction pattern is point of maximum intensity. The secondary waves traveling in a direction making an angle θ converge to some other point on the screen. The intensity of this point will be maximum are minimum depending upon the path difference between the secondary waves orienting from the corresponding wave fronts. The path difference for minima is given by

$$a \sin\theta = n\lambda$$

Where n= 1,2,3……….



Diffraction pattern of LASER by single slit

Procedure:

1. Place the single slit parallel to the laser source such that the rays are incident on slit.
2. Adjust the slit width such that we see clear diffraction pattern on screen/ wall.
3. Measure the distance from slit to screen (say L=100 cm).
4. Mark the diffraction minima (say five orders) on the graph.
5. Note down the distance between centre of the zero maxima and 1st order minima on both sides as y_1, y_2. Calculate the mean as y.
6. Continue the same measurement for remaining minima.
7. sin θ can be calculated by using small approximation, $\sin\theta \approx \frac{y}{L}$
8. Using travelling microscope measure the slit width (a).
9. Finally, the wavelength can be calculated using the formula.

Observation:

Slit width by travelling microscope

Least count of travelling microscope =

Microscope reading (cm)						Slit width a= (b~c) cm
Left side			Right side			
MSR	VC	Total(**b**)= MSR+(VC*LC)	MSR	VC	Total(**c**)= MSR+(VC*LC)	

Wavelength calculation from diffraction pattern:

Order of minima 'n'	L (cm)	y (cm)			$\sin\theta \approx \frac{y}{L}$	$\lambda = \frac{a\sin\theta}{n}$
		Left (y_1)	Right (y_2)	Mean $y = \frac{y_1+y_2}{2}$		
1						
2						
3						
4						
5						

Precautions:

1. Care should be taken while handling the power supply.
2. Experiment should be conducted in absence of any other light.
3. Readings should be taken without parallax error.

Result:

The wavelength of the given LASER source is______________

5.Energy gap of a P-N junction Diode

Aim:

To determine the energy gap of semiconductor using given PN junction diode.

Apparatus:

Germanium diode, thermometer, copper vessel, regulated power supply, micro ammeter, heater and Bakelite lid.

Formula:

$$\text{Energy gap, } E_g = \left\{\frac{2.303\times K}{1.6\times10^{-19}} \times slope\right\} \text{eV.}$$

Where K= Boltzmann constant (1.38×10^{-23} J.K^{-1})

Theory:

The energy gap (E_g) of a material is defined as the minimum amount of energy required for an electron to get excited from the top of valence band to the bottom of the conduction band .The energy gap for the metals is zero since the valence band and conduction band overlap each other where as the energy gap for the insulators is very high .The energy gap for the semiconductors lies between the values for metals and insulators.

Energy gap can also be taken as the amount of energy required to break the covalent bond .In a junction diode hoes are majority carriers in 'p' side and electrons in 'n' side .Apart from these majority carriers they have electrons and holes as minority carriers respectively. Minority carriers are purely because of covalent bond breaking due to thermal energy. In Reverse bias the majority carriers, which are due to doping are arrested from contributing towards the current and only thermal excited minority carriers contribute to the reverse saturation current. When a diode is heated the covalent bonds break and contribute more charge carriers for conduction.

Reverse saturation current in a diode is given as

$$I_0 = C\, e^{\frac{-E_g}{KT}}$$

As R=V/I

We have resistance of a semiconductor varying with the temperature as

$$R = R_0\, e^{\frac{E_g}{KT}} \text{-------------------------------(i)}$$

Where R_0 is the constant resistance of the semiconductor at absolute zero,

k is Boltzmann constant and

T is the temperature of the material.

By applying the logarithms on both side of the equation (i) we get

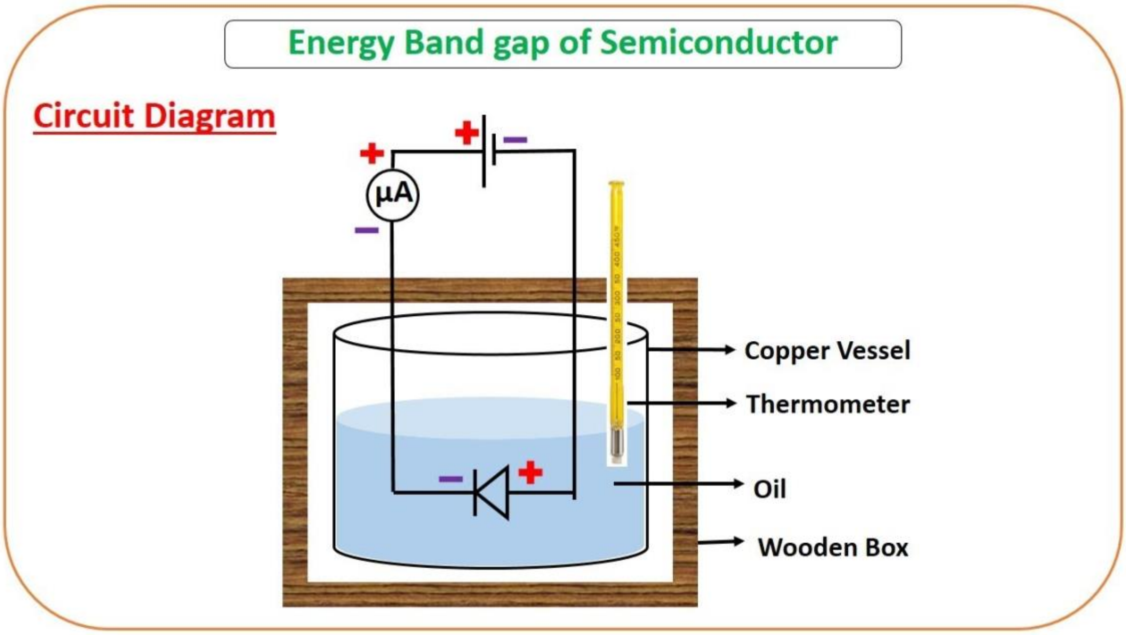
$$\text{Log}(R) = \text{Log}(R_0) + (E_g/kT)\log(e) \text{-----------------(ii)}$$

This is a linear equation between Log(R) and $(\frac{1}{T})$ and its slope is obtained from

Slope = E_g (log(e))/K ; (e = 2.71)

E_g = (Slope)K/ log(e)

$$E_g = \left\{\frac{2.303\times K}{1.6\times 10^{-19}} \times slope\right\} \text{eV}$$



Procedure:

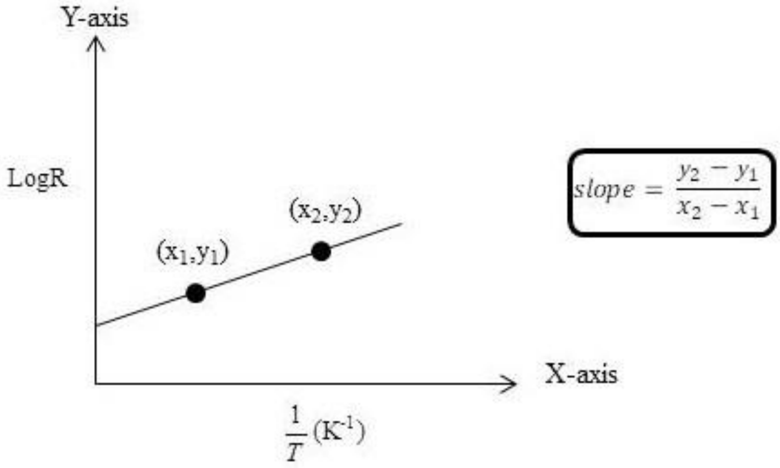
1. Connections are made as per the circuit diagram. 2.
2. Pour some oil in the copper vessel.
3. Fix the diode to the Bakelite lid such that it is reversed biased, a hole is provided on the lid through which the thermometer is inserted into the vessel.
4. With the help of heater, heat the copper vessel till the temperature reaches up to 80^0C.
5. Note the current reading at 80^0C by applying suitable voltage say 1.5V (which is kept constant) and note the corresponding current with every 5^0C fall of temperature, till the room temperature.
6. Tabulate the values and draw a graph by taking ($\frac{1}{T}$) on x-axis and LogR on y-axis.
7. Calculate the slope from the graph and substitute in the formula to get the energy gap value of given semiconductor.

Observation Table:

V=1.5V

Temp (t in ^{0}C)	T= (t+273) °K	Current (I in µA)	R= $\frac{V}{I}$ in Ω	LogR	$\frac{1}{T}$ (K^{-1})

Model graph:



Precautions:

(1.) Do not allow the temperature to rise near 100^0C. If you can switch off the heater at 80^0C it will keep on rising for few minutes and may go up to 90 degrees before stabilizing/falling.

(2.) The oil in the container will be hot and hence must be handled carefully.

Result :

The energy gap of semiconductor is found to be _________eV.

6. LED CHARACTERISTICS

Aim:

To study and plot Voltage-Current (V-I) and Current-Luminous Intensity (I-P) characteristics of given LED.

Apparatus:

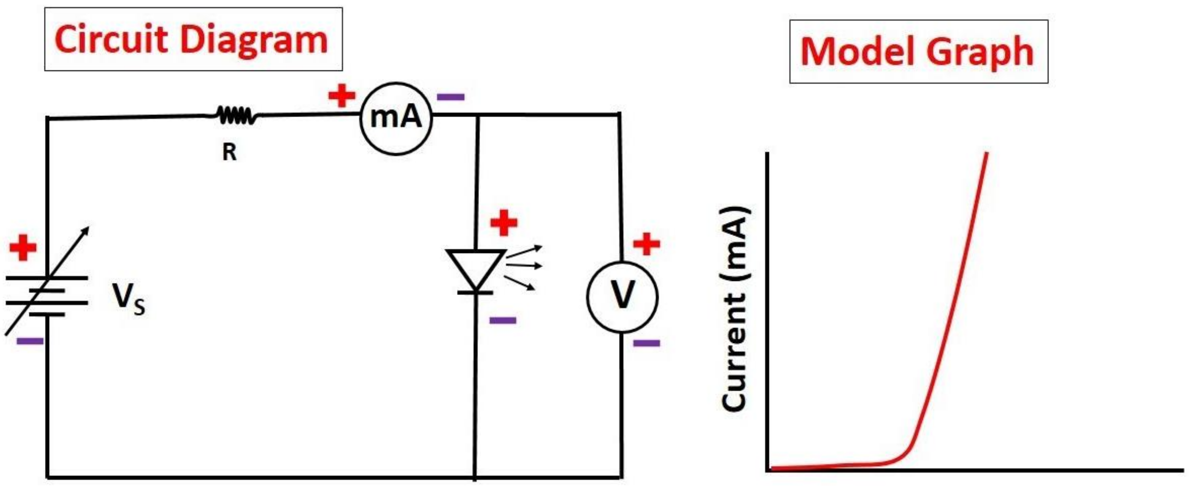
LED trainer kit with voltmeter, milli ammeter and optical power meter; connecting wires.

Theory:

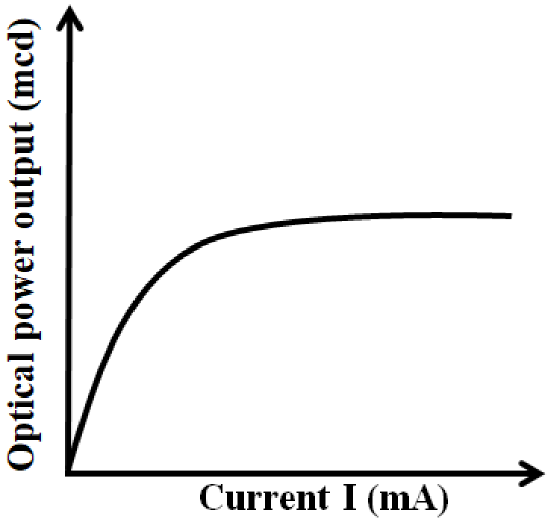
The light emitting diodes (LEDs) are popular electronic devices which work on the principle of injection luminescence, the process that converts electric input into light output. This device basically consists of a direct band gap semiconductor material doped with impurities to create a structure called PN junction which can be thought of as a border region between P type and N type blocks.

Under forward bias the positive voltage is applied to P region and negative to the region. The holes and electrons are pushed towards the junction. The charge carriers diffuse through PN junction recombine with the majority carriers on the other side and emit photons. Depending on the band gap different wavelength of light may be produced.

Circuit Diagram and Graph:



Forward Biasing condition of LED



Characteristics of LED:

The schematic arrangement of the experiment is shown in the fig. The diode V-I Characteristics are measured by applying a sweep voltage by source V to the diode and monitoring the current by ammeter A. The general V-I characteristics curve is shown in the fig. It shows the relation between the output current (I) and the driving voltage (V).

Procedure:

1. The circuit is connected as shown in fig. The DC power supply is connected to LED.
2. A milli-voltmeter is connected across the terminals of LED.
3. The power is switched on and varied slowly.
4. The reading in the milli ammeter and the reading in the voltmeter is noted.
5. The procedure is repeated by varying the voltage.
6. At each step the reading of milli ammeter and voltmeter are noted.
7. A graph is drawn between voltage (x-axis) and current (y-axis).
8. Again the experiment is conducted with the switch on the board changed to L-I (P-I) characteristics mode.
9. By varying the current, note down light power output from the optical power meter.
10. Draw a graph by taking current on x-axis and optical power output on y-axis.

Observation Tables:

V-I Characteristics:

S.no	V-Voltage(Volts)	I-Current(mA)

I-L Characteristics:

S.no	I-Current(mA)	L- Luminance/ P-Optical power output (in milli-candela)

Precautions:

1. Higher voltages should be avoided to safeguard the LED.
2. Reading should be taken without parallax error.
3. Loose contacts are avoided.

Result:

V-I and P-I characteristics of given LED have been plotted and studied.

7. PHOTO DIODE

Aim:

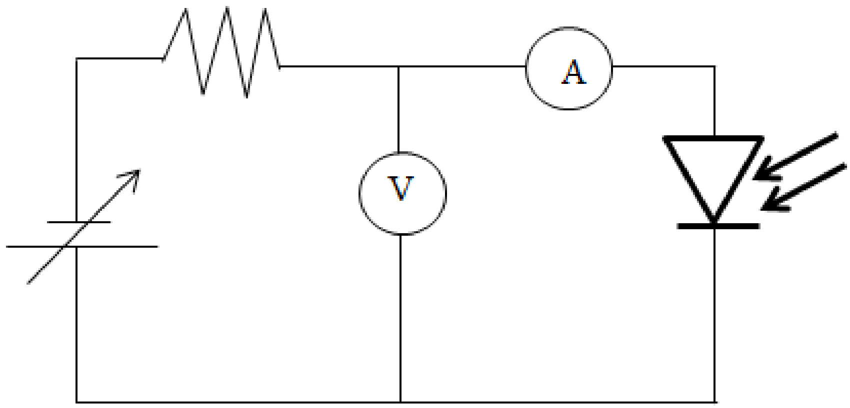
To study the V-I characteristics of photo diode at different intensities.

Apparatus:

Photo Diode kit consisting of Photo Diode, light source, ammeter, voltmeter, D.C. source; connecting wires.

Theory:

The semiconductor photodiode is a light detector device which detects presence of light. It is used to convert optical power into electrical current. PN junction Photo diode have P type and N type semiconductor forms junction. Thin P type layer is deposited on N type substrate. P-N junction has a space charge region at the interface of the P and N type material. Light enters through P-layer as shown in the following figure. This diode has relatively thin depletion region around the junction. It is reverse biased to increase width of the depletion region. Photons of light entering in P-layer ionize electron-hole pair. Photon generates electron-hole pair in the depletion region that moves rapidly with the drift velocity by the electric field.



Circuit diagram

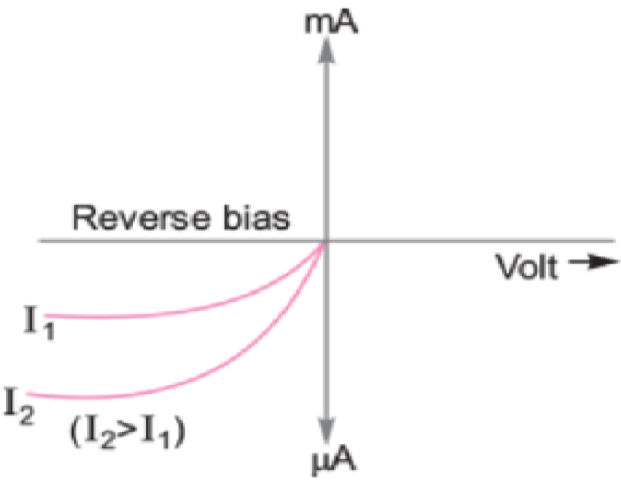
Responsivity is important technical term related to the photodiode. It is ratio of photocurrent to incident optical power. Responsivity of the photodiode is proportional to width of the junction. Photo diode is used in fiber optic communication at receiver side. It detects incoming light from the fiber end and convert it into electrical signal. It can be also used in remote control receiver.

Procedure:

1. Connect the power supply, voltmeter, ammeter with the photodiode as shown on the kit.
2. Apply 10V from the DC power supply.
3. Place the photo diode facing towards the lamp.
4. Measure photo current of photodiode by varying voltage in regular intervals.
5. Increase AC power given to lamp to increase intensity and note down voltage vs current values.
6. Draw a graph of voltage (x-axis) versus photocurrent (y-axis) at two different intensities.

Observation Table:

S. No.	V-Voltage	**I-Photocurrent** (At different Lamp intensities)	
		I_1 (Low Intensity)	I_2 (High Intensity)



Model Graph

Precautions:

1. Higher voltages should be avoided to safeguard the Photo diode.
2. Reading should be taken without parallax error.
3. Loose contacts are avoided.

Result:

V-I characteristics of the given Photo diode has been plotted and studied.

8. SOLAR CELL

Aim:

To study and plot the V-I Characteristics of the solar cell.

Apparatus:

Solar cell trainer kit with a solar cell, optical source, volt meter and ammeter; connecting wires.

Theory:

The solar cell is a semiconductor device, which converts the solar energy into electrical energy. It is also called a photovoltaic cell. A solar panel consists of numbers of solar cells connected in series or parallel. The number of solar cell connected in a series generates the desired output voltage and connected in parallel generates the desired output current. The conversion of sunlight (Solar Energy) into electric energy takes place only when the light is falling on the cells of the solar panel. Therefore in most practical applications, the solar panels are used to charge the lead acid or Nickel-Cadmium batteries. In the sunlight, the solar panel charges the battery and also supplies the power to the load directly. When there is no sunlight, the charged battery supplies the required power to the load.

V-I Characteristics

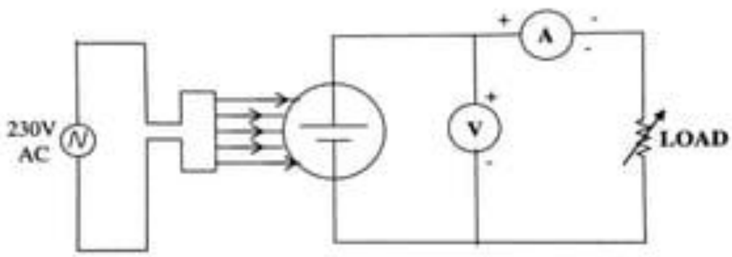


Fig. 1 Circuit Diagram

A solar cell operates in somewhat the same manner as other junction photo detectors. A built-in depletion region is generated in that without an applied reverse bias and photons of adequate energy create hole-electrons pairs. In the solar cell, as shown in Fig. 1a, the pair must diffuse a considerable distance to reach the narrow depletion region to be drawn out as useful current. Hence, there is higher probability of recombination. The current generated by separated pairs increases the depletion region voltage (Photovoltaic effect). When a load is connected across the cell, the potential causes the photocurrent to flow through the load.

The e.m.f. generated by the photo-voltaic cell in the open circuit, i.e. when no current is drawn from it is denoted by V_{OC} (V-open circuit). This is the maximum value of e.m.f.. When a high resistance is introduced in the external circuit a small current flows through it and the voltage decreases. The voltage goes on falling and the current goes on increasing as the resistance in the external circuit is reduced. When the resistance is reduced to zero the current rises to its maximum value known as saturation current and is denoted as I_{SC}, the voltage becomes zero. A V-I characteristic of a photovoltaic cell is shown in Fig. 2.

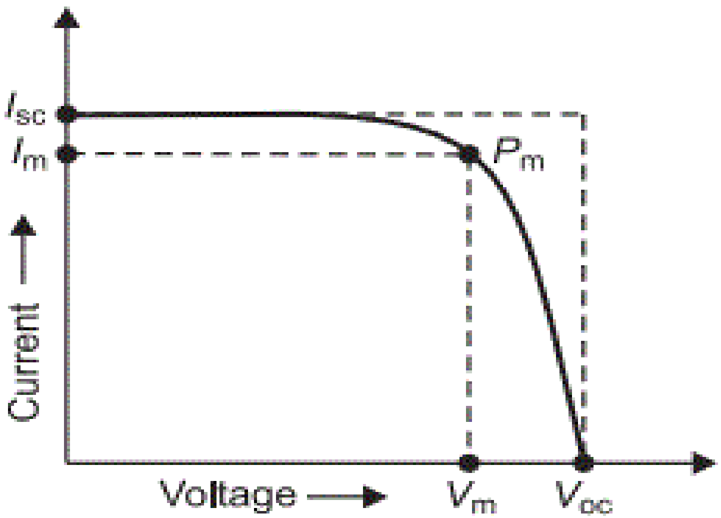


Fig. 2 V-I Characteristics Graph

Procedure:

1. Place the solar cell and the light source (100 watt lamp) opposite to each other on a wooden plank.
2. Connect the circuit as shown by dotted lines (Fig. 1) through patch chords.
3. Select the voltmeter range to 2V, current meter range to 250µA and load resistance (R_L) to 1000 Ω.
4. Switch ON the lamp to expose the light on Solar Cell.
5. Vary the load resistance through band switch and note down the current and voltage readings every time in table.
7. Plot a graph between output voltage vs. output current by taking voltage along X-axis and current along Y-axis.

Observation Table:

Voltmeter reading for open cicuit, V_{OC} = ______Volts

Milli ammeter reading with zero resistance, I_{SC} = ______mA.

S. No.	V-Voltage (mV)	I-Current(mA)	R_L-Load Resistance (kΩ)

Precautions:

1. The solar cell should be exposed to sun light before using it in the experiment.
2. Light from the lamp should fall normally on the cell.
3. A resistance in the cell circuit should be introduced so that the current does not exceed the safe operating limit.

Result: V-I characteristics of the given solar cell have been studied and plotted.

9. LCR Circuit

Aim:

To draw the characteristics of LCR series and parallel resonant circuits and to determine the resonance frequency.

Apparatus :

LCR kit with Inductors, capacitors, resistors and ammeter; function generator and connecting wires.

Formulae:

Resonant frequency (Theoretical) $f_O = \frac{1}{2\pi\sqrt{LC}}$

L – Inductance

C- Capacitance

Description:

The circuit containing a capacitance C, Inductance L and resistance R, connected in series and parallel as shown in fig.1 and fig.3 respectively when an alternating emf is applied to the circuit an alternate current flows in the circuit. The impedance of the circuit is given by

$$|Z| = \sqrt{R^2 + (X_L - X_C)^2}$$

The effective reactance is inductive or capacitive depends upon the $x_L > x_C$ or $x_L < x_C$. The inductive reactance is proportional to the frequency and increases as the frequency increases from zero onwards. The capacitive reactance is inversely proportional to the frequency, decreases from infinity value downwards. At certain frequency both reactances become equal and this frequency is called the resonant frequency. At resonance the impedance is minimum and is equal to the resistance. Under these conditions, the current I = V/R and cosΦ = 1 or Φ = 0. That is, the current and the voltage are in phase. Such a circuit is called an acceptor circuit.

In parallel resonant circuit, at resonance, the circuit does not allow the current to flow and works as a perfect choke for AC. Such a circuit is called Rejecter circuit.

Theory:

In a series LCR circuit (Resonant), the impedance of an inductance and a capacitor are equal in magnitude and are in opposite directions, hence, the impedance of the circuit is only the resistance. Therefore, the current is maximum at the resonant frequency. The resonant frequency is given by

$$f_O = \frac{1}{2\pi\sqrt{LC}}$$

In a parallel LCR circuit, the impedence is maximum at the resonant frequency and the current is minimum.

The resonant frequency for parallel circuit is given by

$$f_O = \frac{1}{2\pi\sqrt{LC}}$$

The bandwidth of the circuit is defined as the difference in half power frequencies. These can be determined by drawing a half power line on the characteristic curve at 70.7% of the resonant or the maximum value on the curve.

Procedure:

1. Series Resonance:

The circuit is connected as shown in fig 1. Fixed amplitude of voltage at all frequencies is applied to the circuit through a function generator. By changing the frequency, the current in the circuit is noted. The readings are tabulated in table 1. A graph is drawn between frequency (x-axis) and the current (y-axis). The shape of the curve is shown in fig.2

$$\text{Band width } \Delta f = \left(f_2 - f_1\right) \text{ Hz}$$

$$\text{Resonant frequency } f_O = \frac{1}{2\pi\sqrt{LC}}$$

2. Parallel Resonance:

The circuit for the parallel resonance is shown in fig.3. A constant amplitude of voltage at all frequencies is to be applied to the circuit through the function generator. By changing the frequency in steps, the current in the circuit is noted. The readings are tabulated in table 2 and a graph is drawn between frequency on (x-axis) and the current on (y-axis). The nature of the curve is shown in figure 4. In the graph i is the magnitude of current.

$$\text{Resonant frequency } f_O = \frac{1}{2\pi\sqrt{LC}}$$

The resonant frequency in series and parallel circuit are compared with theoretical calculations and from graph.

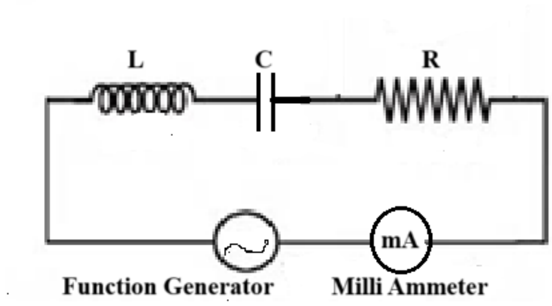


Fig.1. LCR series circuit diagram

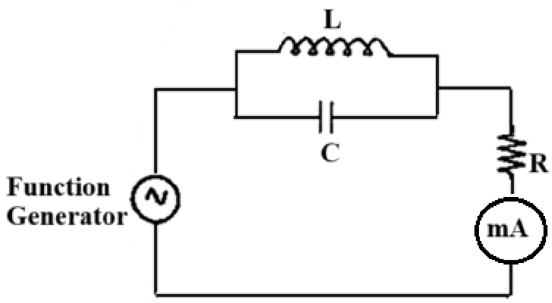


Fig.3. LCR parallel circuit diagram

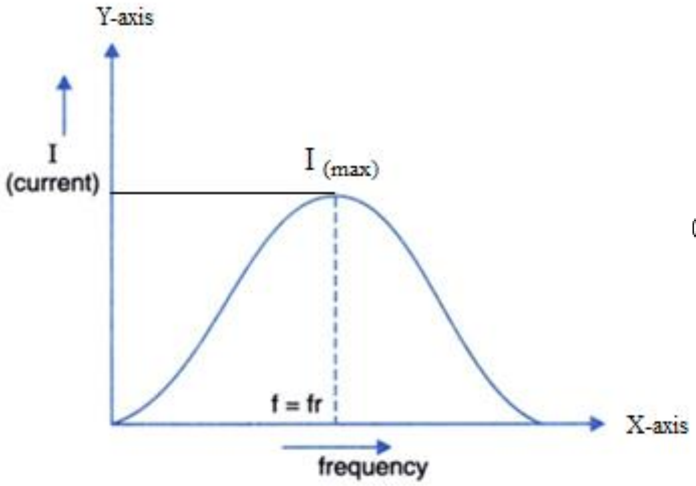


Fig.2. LCR series model graph

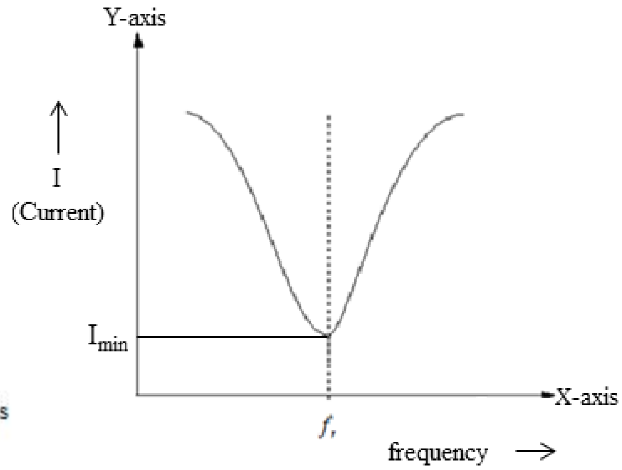


Fig.4. LCR parallel model graph

Observation Tables:

Series Resonance:

S.No	Frequency (Hz)	Current (mA)

Parallel Resonance:

S.No	Frequency (Hz)	Current (mA)

Precautions:

1. Readings should to be taken carefully to avoid parallax error.
2. Amplitude, once fixed, should not be changed in midst of the experiment.
3. Apparatus should be handled carefully as they are sophisticated appliances.

Result:

Series Resonant frequency

Experimental value =

Theoretical value =

Parallel Resonant frequency

Experimental value =

Theoretical value =

10. R-C Circuit

Aim:

To study the exponential growth and decay of charge in R-C circuit and to determine RC time constant.

Apparatus:

RC circuit board with Resistors, capacitors, switch and voltmeter; fixed power supply, stop clock and Connecting wires.

Formula:

Theoretical Time Constant (τ) =RC

Where R= Resistance

C= Capacitance

Theory:

When a battery is connected to a circuit consisting of elements like resistor and capacitors, voltages can develop across these elements and current can flow through them. Capacitors store charge and develop a voltage drop (V) across them proportional to the amount of charge (Q) that they have stored, such that $V=\frac{Q}{C}$.The constant of proportionality (C) is called capacitance (measured in Farad=$\frac{coulomb}{volt}$).

(i) Charging: The voltage across the capacitor, during the charging phase,

$$V = V_0\left(1-e^{\frac{-t}{RC}}\right)$$

Where (V_0) is the peak voltage to which the capacitor is charged and (t) is the time.

At time t = RC,

$$V = V_0\,(1-\frac{1}{e})$$

$$V = 0.63V_0$$

(ii) Discharging: The voltage across the capacitor, during the discharging phase,

$$V = V_0\,(e^{\frac{-t}{RC}})$$

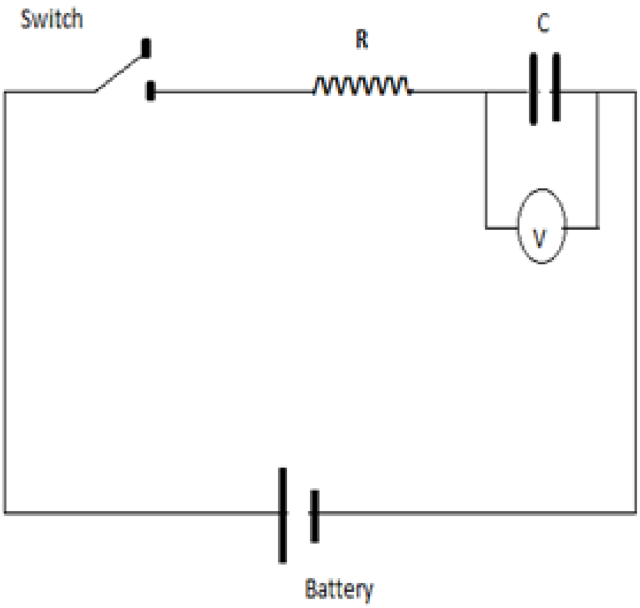
Where (V_0) is the peak Voltage to which the capacitors is charged and (t) is the time.

At time t=RC

$$V = V_0\left(\frac{1}{e}\right)$$

or $$V = 0.37V_0.$$

Circuit diagram:



Procedure:

1. By taking one set of resistor and capacitor the circuit is connected as per circuit diagram.
2. On the switch 'S' and start the clock simultaneously. The interval of time can be selected according to convenience from 5 sec to 10 sec.
3. Note the voltmeter reading at regular intervals of time and also note the maximum voltage V_o (at which voltage becomes constant).
4. Off the switch 'S' after attaining V_o. Start the stop clock and note the voltmeter readings at the same regular intervals of time till it reaches minimum voltage.
5. Plot the graph by taking time (t) on x-axis and voltage (v) on y-axis for charging and discharging.
6. From the charging graph, identify the time constant, the time corresponding to $0.67V_o$ voltage
7. From the discharge graph identify the time constant, the time corresponding to $0.37V_o$ voltage value.
8. These graphical time constant values are compared with the theoretical time constant i.e $\tau =$ RC
9. The Experiment is repeated for the different values of R and C.
10. The observations are tabulated and the time constant is calculated theoretically from the values of R and C used and also from the graph.

Observation Table:

<table>
<tr><td colspan="3">Set-1</td><td colspan="3">Set-2</td></tr>
<tr><td colspan="3">R=__________Ω
C=__________Farads</td><td colspan="3">R=__________Ω
C=__________Farads</td></tr>
<tr><td rowspan="2">Time(sec)</td><td colspan="2">Voltage(volt)</td><td rowspan="2">Time(sec)</td><td colspan="2">Voltage(volt)</td></tr>
<tr><td>Growth (Charging)</td><td>Decay (Discharging)</td><td>Growth (Charging)</td><td>Decay (Discharging)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Calculation of time constant:

Theoretical Value:

Time constant =RC

Experimental Value:

The time corresponding to the decrease of Voltage to $0.368V_0$ is time constant

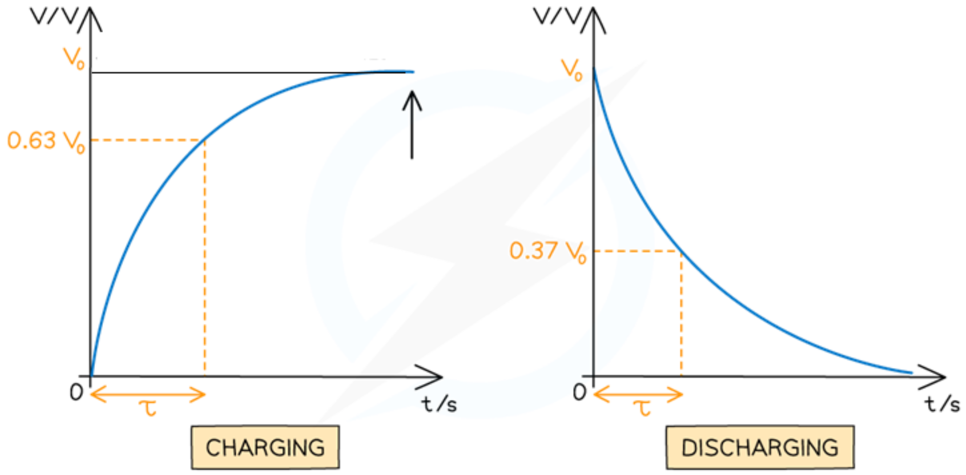
$$V = V_0\,(e^{\frac{-t}{RC}})$$

t=RC

$$V=V_0 e^{\left(\frac{-RC}{RC}\right)}$$

$$V=0.368\ V_0$$

Graph:



Precautions:

1. Readings should be taken without parallax error.

2. Loose contacts are to be avoided.

Result:

The time constant of RC circuit is found as follows

	Theoretical Value(Sec)	Graphical Value(Sec)	
		Charging	Discharging
Set-1			
Set-2			

11. OPTICAL FIBRE

Aim:

a) To determine the numerical aperture and acceptance angle of the given optical fiber.
b) To estimate attenuation due to transmission in optical fibers.

Apparatus:

Fiber optic kits, optical fibre cables of different lengths and numerical aperture jig.

Formulae: Numerical aperture (NA) = $\frac{W}{\left(4L^2 + W^2\right)^{1/2}}$,

Acceptance angle (θ_{max}) = Sin^{-1}(NA).

Where W= The diameter of the spot on the screen.
L=Distance between the fiber end and screen.

Theory:

The light collecting capacity of optical fiber is called as Numerical aperture. It is defined as the product of refractive index of surrounding medium and sine of maximum acceptance angle.

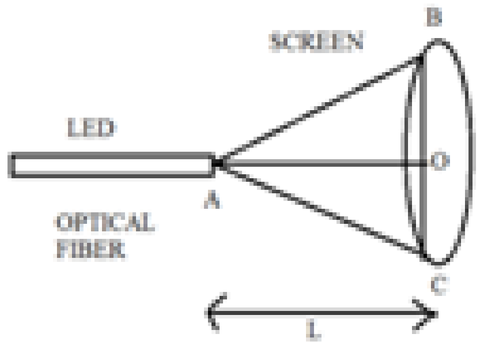
Numerical aperture (NA) = $n_0 \sin\theta_{max}$ -------------------------(1)

For air as surrounding medium n_0=1 and

NA=$\sin\theta_{max}$-----------------------(2)

For step index Fiber, NA is given by NA=$(n_1-n_2)^{½}$-----------------(3)

Where n_1 and n_2 are refractive indices of core and cladding materials.



Let W be the diameter of one such concentric ring and the distance between fiber and screen AO = L (from the triangle AOB)

$$\text{Sin}\theta_{max} = \frac{OB}{AB} \ ;$$

$$\text{Sin}\theta_{max} = \frac{W}{\left(4L^2 + W^2\right)^{1/2}}$$

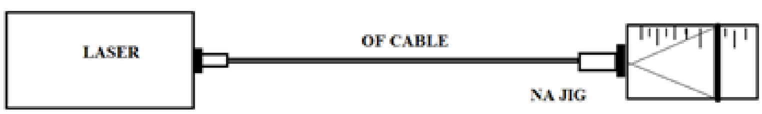
$$\text{Sin}\theta_{max} = \frac{\left(\frac{W}{2}\right)}{\left(L^2 + \frac{W^2}{4}\right)^{1/2}} \ ;$$

$$\text{NA} = \text{Sin}\theta_{max} = \frac{W}{\left(4L^2 + W^2\right)^{1/2}} \quad \text{------------------------------------} \ (4)$$

$$\text{NA} = \text{Sin}\theta_{max} = \frac{W}{\left(4L^2 + W^2\right)^{1/2}}$$

Knowing W and L , the NA can be calculated and substituting this NA value in eq(2) the acceptance angle can be calculated.

Figure



Attenuation is the loss of optical power as a result of absorption, scattering, bending, and other loss mechanisms as the light travels through the fiber. The total attenuation is a function of the wavelength λ of the light. The total attenuation A between two arbitrary points X and Y on the fiber is A(dB) = 10 $\log_{10}(P_x/P_y)$. P_x is the power output at point X. P_y is the power output at point Y. Point X is assumed to be closer to the optical source than point Y.

Procedure to determine numerical aperture :

(1.) Connect one end of the optical fiber cable to po and another end to the NA jig.
(2.) Plug the AC mains , red light should appear at the end of the fiber on the NA jig .To set maximum out put turn the set po knob clockwise . The red light intensity should increase.
(3.) Hold the acrylic white screen which has printed scale at a distance of 5mm (L) from the emitting fiber end and you will view the red spot on the screen .Measure the diameter W of the spot .

Substitute the measured values of L and W in the formula

$$NA= \sin\theta_{max}= \frac{W}{\left(4L^2+W^2\right)^{1/2}}$$

and calculate the value of the NA of the given fiber.

Repeat the experiment for the various distances .

Observation table:

S.no	L in mm	W in mm	$NA= \frac{W}{\left(4L^2+W^2\right)^{1/2}}$	Acceptance angle, (θ_{max}) = $\sin^{-1}$(NA)

Procedure to estimate attenuation:

To estimate transmission loss,

1. Connect one end of the 1m length OFC to the output of the transmission kit and the other end to the receiver kit.
2. Note down the output power of 1m cable as P_x.
3. Remove 1m OFC and connect 5m OFC. Now note down the output as P_y.
4. The attenuation A between 5m and 1m OFC is $A= 10 \log_{10} (P_x/P_y)$ in dB

Precautions :

1. Surroundings should be perfectly dark.
2. Fiber should be coupled smoothly to the connector.

Result:

a) The Numerical aperture of a given optical fiber is found to be ___________.

b) The attenuation due to transmission in optical fibers is found as ___________.

12. Method of least squares: Torsional Pendulum

Aim:

To find best fitted line of L-T^2 for Torsional pendulum by the method of least squares and to estimate rigidity modulus.

Apparatus required:

Wire, metal disc, screw gauge, vernier caliper, stop clock, meter scale.

Formula:

Slope of line, $m = \frac{n\Sigma xy - \Sigma y \Sigma x}{n\Sigma x^2 - (\Sigma x)^2}$

Y-Intercept of line, $c = \frac{\Sigma y - m\Sigma x}{n}$

Rigidity modulus, $\eta = \frac{8\pi I}{a^4}\frac{l}{T^2}$ Dynes/cm^2

Where n is the number of data points.
l: length of the wire between the chucks.
T: Time period of oscillation.
I: Moment of inertia of the disc. I=(MR$^{2)}$/2
M: mass of the disc
R: radius of the disc
a: Radius of the wire.

Method of least squares:

The least-squares method is a statistical method used to find the line of best fit of the form of an equation such as y = mx + b to the given data. The curve of the equation is called the regression line. Our main objective in this method is to reduce the sum of the squares of errors as much as possible. This is the reason this method is called the least-squares method. This method is often used in data fitting where the best fit result is assumed to reduce the sum of squared errors that is considered to be the difference between the observed values and corresponding fitted value. The sum of squared errors helps in finding the variation in observed data.

Least-square method is the curve that best fits a set of observations with a minimum sum of squared residuals or errors. Let us assume that the given points of data are (x_1, y_1), (x_2, y_2), (x_3, y_3), …, (x_n, y_n) in which all x's are independent variables, while all y's are dependent ones. This method is used to find a linear line of the form y = mx + c, where y and x are variables, m is the slope, and c is the y-intercept. The formula to calculate slope m and the value of c is given by:

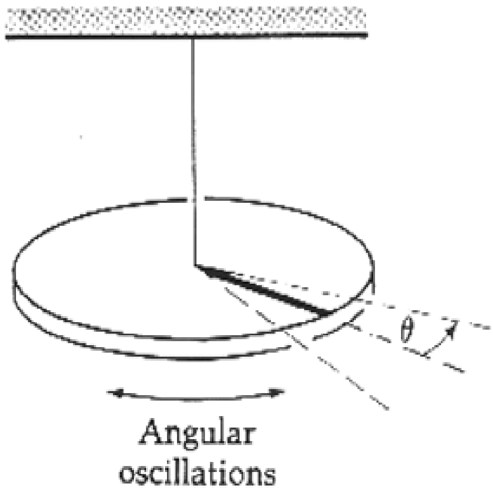
$$m = \frac{n\Sigma xy - \Sigma y\Sigma x}{n\Sigma x^2 - (\Sigma x)^2}$$

$$c = \frac{\Sigma y - m\Sigma x}{n}$$

Here, n is the number of data points.

Procedure:

1. A circular metal disc is suspended by means of the given wire using a clamp as shown in the figure.
2. The length of the wire between the chucks is measured using a meter scale and adjusted to maximum length.
3. The disc is **slightly** displaced angularly (rotated) about its axis.
4. This produces restoring force in the wire thus establishing angular oscillations of the disc about the axis.
5. A small angular displacement about the axis is produced to the disc.
6. A small mark is made on the edge of the disc, which helps to note the number of oscillations made by the disc.
7. The disc is set to oscillate slowly by turning it through a small angle when the disc is oscillating the time taken for 5 oscillations is noted with the help of stop clock and the observations are tabulated.
8. The procedure is repeated by decreasing the length of wire in steps of 10 cm.
9. With the noted data, Slope of the line and y-intercept of the line should be calculated.
10. From this slope, the rigidity modulus of the material of given wire can be calculated as $\frac{1}{m} = \frac{l}{T^2}$



Observation tables:

Diameter of wire using screw gauge:

L.C = Error: Correction:

S.no	Pitch Scale reading (a) mm	Head scale reading	Corrected head scale reading	L.C X Corrected head scale reading (b) mm	Diameter {(a) + (b)} mm
1					
2					
3					

Diameter of the disc using vernier caliper:

L.C =

S.no	Main scale reading (a) cm	Vernier coincidence	L.C X Vernier coincidence (b) cm	Diameter {(a) + (b)} cm
1				
2				
3				

Table for line fitting:

S.no (Data Points)	Length of wire (l cm) **X**	Time for 5 oscillations			Time for one oscillation T=(t/5) sec	(T^2) **Y**	XY	$\mathbf{X^2}$
		Trail 1	Trail 2	Mean (t)				
1								
2								
3								
4								
5								

Σ **X**= Σ **Y** Σ **XY** Σ $\mathbf{X^2}$

Graph: A graph is drawn with the calculated slope and y-intercept to get a straight line.

Precautions:

1. The amplitude of oscillations should be small.
2. The wire should be firmly fitted to the support.
3. Time period of oscillation should to note accurately.

Result:

The best fitted line of L-T^2 of torsional pendulum is drawn and Rigidity modulus of the given wire is identified as ____________________.