

Date:

1. PHOTO CELL

Aim : To draw the characteristic curves of a photo cell and determine the stopping potential.

Apparatus : Photo cell, volt meter, micro ammeter, supply, and a source of radiation.

Description:

A photo cell is a device which makes use of photo electric effect for converting light energy into electric energy. According to their construction Photo electric cells are three types.

1) Photo-emissive cell 2) Photo Voltaic cell 3) Photo Conductive cell

Photo-emissive cells are of two types i) Vacuum and ii) Gas filled.

Vacuum type photo emissive cell consists of two electrodes, cathode and anode. The cathode is either V-shaped or semi cylindrical and is made of metal coated with emissive material like potassium or cesium i.e. alkaline metals. The anode is in the form of nickel or platinum wire facing the cathode. The two electrodes are sealed in a glass or quartz bulb .When light of frequency greater than the threshold frequency is incident on cathode, electrons are emitted which are attracted by anode. Thus a current flows in the external circuit. This current depends on (a) intensity of incident radiation and (b) anode to cathode voltage. As the anode potential is increased, the current increases until saturation occurs.

In Vacuum photoelectric cells, the current is very small. In order to increase this current the cell is filled with a suitable inter gas like helium, neon etc at a Pressure of 0.1 to 1 mm of mercury. The photo electron ionize the gas and thus the current magnified. The drawback of gas filled photo electric cell is that the photo electric current does not vary linearly with the intensity of light. In our experiment we are using gas filled photo emissive cell.

Theory : According to Planck's quantum theory a photon of frequency ν has an energy

$$E = h\nu.$$

When such a photon of the incident radiation strikes the metal surface of the photo-cell, electrons are released or emitted by the cathodes (metal surface) which are accelerated towards the anode. The energies of these electrons, according to Einstein is given by the equation

$$K.E = h\nu - w$$

Where w is the work function of the metal surface, and is equal to $h\nu_0$, where ν_0 is the threshold frequency.

The maximum energy of the emitted electrons is

$$\frac{1}{2} mv^2 = h\nu - h\nu_0$$

The maximum energy of the emitted electrons $\frac{1}{2} mv^2 = eV_s$

Where V_s is the stopping potential.

Definitions:

Stopping potential (v_s): The stopping potential is the negative anode potential required to stop the most energetic electrons emitted by the cathode and reaching the anode.

Work function (w): It is the minimum energy required to remove the electrons from the surface of the metal.

Threshold frequency (ν_0): It is the minimum frequency of the incident radiation to start the photoelectric effect.

Circuit Diagram:

Positive anode potential :

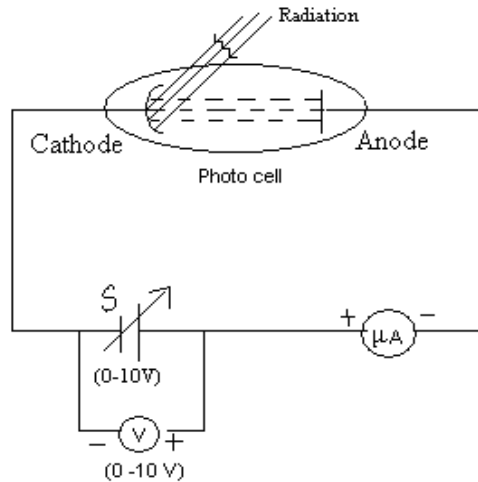


Fig. (1)

Procedure:

Connect the circuit as shown in the fig.(1). Keep the source as close as possible facing the cathode. Note the distance between the source and the photo cell. Keep the anode potential at zero and note the current in the ammeter. Now increasing the anode potential in convenient steps, note down the ammeter reading till the potential reaches the maximum value.

Stopping potential is the -ve anode potential that is required to stop the most energetic electron, emitted by the cathode in reaching the anode.

Circuit Diagram:

Negative anode potential :

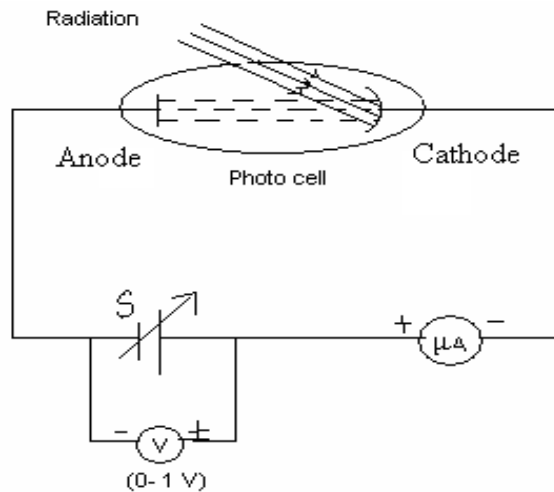
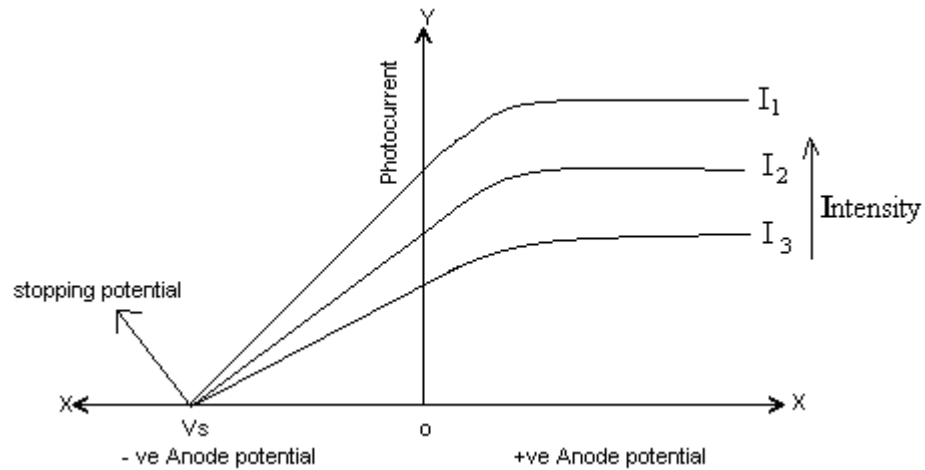


Fig. (2)

Procedure: Connect the circuit as shown in the fig. (2). Keep the source at the same distance from the photo cell as in the case of positive anode potential and note the reading of the ammeter at zero potential. This should be the same as in the positive anode potential circuit. Now increase the negative anode potential in small steps till the reading in the ammeter becomes zero. Note the potential and ammeter reading at every step till the zero current value is reached.

Graph:

Plot a graph with +ve anode potential on the +ve X-axis and -ve anode potential on the -ve X-axis with the current on the +ve Y-axis.



From the graph note down the value of the stopping potential.

Precautions: The distance of the incandescent lamp from the photocell (cathode) should not be altered while taking the readings for a particular intensity.

Result:

Lecturer signature with date:

Observations:

+ ve anode potential:

	For Intensity I_1 (d= cm)		For Intensity I_2 (d= cm)		For Intensity I_3 (d= cm)	
S.No	+ ve anode potential (Volts)	Photo current (μA)	+ ve anode potential (Volts)	Photo current (μA)	+ ve anode potential (Volts)	Photo current (μA)

- ve anode potential:

	For Intensity I_1 (d= cm)		For Intensity I_2 (d= cm)		For Intensity I_3 (d= cm)	
S.No	- ve anode potential (Volts)	Photo current (μ A)	- ve anode potential (Volts)	Photo current (μ A)	- ve anode potential (Volts)	Photo current (μ A)

Possible Viva Questions:

- 1) What is photoelectric effect?
- 2) Who discovered the photoelectric effect?
- 3) What is a photocell and what are the types of photoelectric cells?
- 4) How the electrons released from the metal?
- 5) Are all the metals useful for photoelectric effect?
- 6) Does the work function depend on the incident light and the cathode metal?
- 7) What is the stopping potential?
- 8) Does the stopping potential depend on the incident light and the cathode metal?
- 9) What is the significance of photoelectric effect?
- 10) What is the main source of error here and how will it effect the result?
- 11) What are the types of photo emissive cells?
- 12) What is the advantage of gas filled photo emissive cell over vacuum photo emissive cell?
- 13) What is the drawback of gas filled photo electric cell?
- 14) In this experiment which type of photo cell is used?
- 15) How is the energy converted here?
- 16) What voltmeter is used in the circuit, whether ac or dc?
- 17) What is the range of the current in this experiment?
- 18) What is the value of planks constant ($6.6 \times 10^{-34} \text{JS}$)

Date:

2. Determination of Planck's constant 'h'

Aim: To determine the value of Planck's constant(h) with the help of a photo cell.

Apparatus : Photo cell, volt meter, micro ammeter, supply, different colours of filters and a source of radiation.

Description: Same as in photo cell experiment.

Theory: Same as in photo cell experiment.

Circuit Diagram:

Negative anode potential :

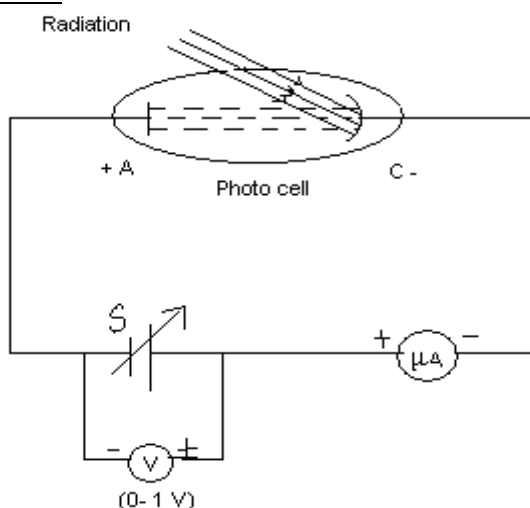


Fig. (1)

Procedure:

1. Connect the circuit as shown in fig(1) i.e. negative anode potential connection.
2. Keep the source as close as possible to the photocell
3. Using white light as source determine the stopping potential (i.e. the negative anode potential where the current becomes zero)
4. Now without changing the distance between the source and the photocell, insert a filter (say green) of known wavelength in the path of the light (in the slit provided)
5. Repeat the step(4) and (5) or other filters also.

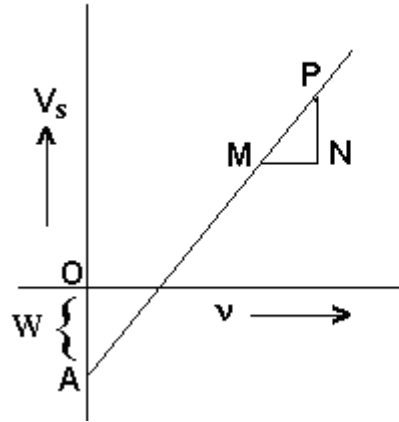
Graph:

1. Draw a graph with the frequency of the light corresponding to the filters on the X-axis and the corresponding stopping potential on the Y-axis.

The slope of the graph is given by h/e

Where e is the charge of the electron whose value is 1.6×10^{-19} Coloumb
 OA gives the work function.

From OA we get the work function (W)



$$OA = \frac{h\nu_0}{e}$$

$$w = h\nu_0 = OA \times e$$

Now calculate plancks constant

$h = e \times$ slope of the graph

2. The intercept on the negative Y-axis gives the work function.

Work function = intercept $\times e$

3. Planck's constant can also be calculated from the formula

$$h = e (\nu_2 - \nu_1) \lambda_1 \lambda_2 / c (\lambda_1 - \lambda_2)$$

where C is the velocity of light = $3 \times 10^8 \text{ ms}^{-1}$

Red filter $\lambda_1 = 6143 \times 10^{-10} \text{ m}$

Note: wave length of mean colour of white light i.e. yellow colour

$\lambda_2 = 5890 \times 10^{-10} \text{ m}$

Green filter $\lambda_3 = 5645 \times 10^{-10} \text{ m}$

Blue filter $\lambda_4 = 5265 \times 10^{-10} \text{ m}$

Precautions:

1. Care should be taken to see that the filters chosen are monochromatic as far as possible.
2. Filters can't be exposed for long duration, otherwise it will be spoiled.

Result:

Lecturer Signature:

Observations:

-ve anode potential:

For Intensity I_1

For Intensity I_2

For Intensity I_3

S.No	- ve anode potential (Volts)	Photo current (μA)	- ve anode potential (Volts)	Photo current (μA)	- ve anode potential (Volts)	Photo current (μA)

Observations:

S.No	Colour	Frequency of incident light $\nu = c/\lambda$ (Hz)	Stopping potential V_s corresponding to zero photo current (volts)

Date:

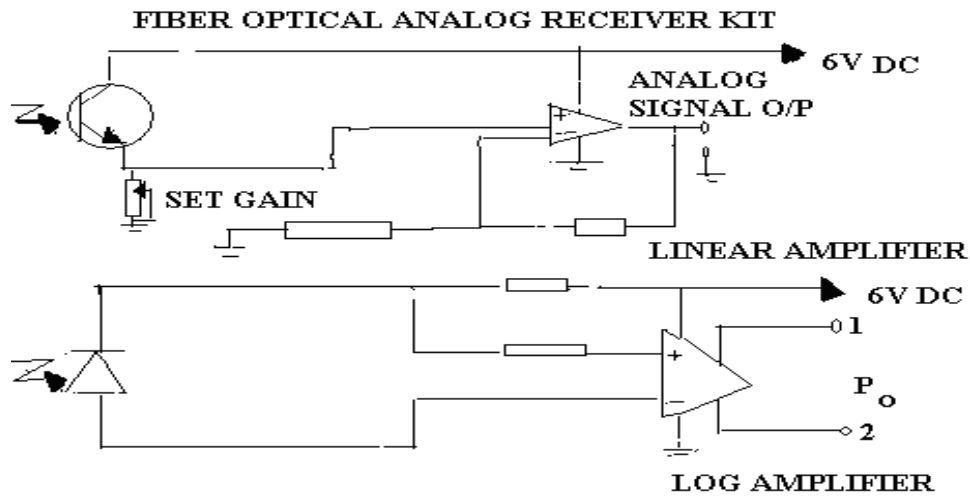
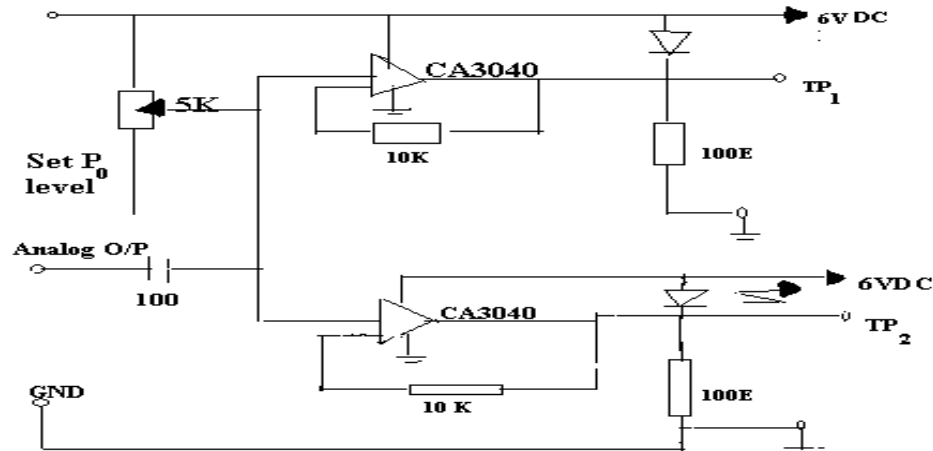
3.Experiments with Fibre-optic kit

Aim: - Using the fibre-optic kit to determine

- A) Loss in fibres at 660nm and 850nm
- b) Numerical aperture of optical fibres

Brief Description of the kit:

Fibre-optic analog Transmitter kit



The transmitter unit converts input electrical signals to optical signals for transmission through an optical fibre at 660nm (FO LED1) as well as 850nm (FO LED2), simultaneously. The electrical signal is converted to optical output, by driving the FO LEDS linearly, using negative feedback operational amplifier circuits. DC LED current setting is done by rotating the knob marked set P_0 . The optical power is coupled to the optical fibre through the SMA connectors.

Set P_0 sets up dc currents through the LEDs. The LED currents can be measured by monitoring the voltages V_{01} and V_{02} with a Digital multimeter (DMM) respectively. $V_{01}/100$ gives the FO LED1 current; $V_{02}/50$ gives the FO LED2 current. (V_{01} , V_{02} is the voltage across 100Ω resistor in the Transmitter kit for 660nm, 850nm).

Fibre optic Receiver unit: The receiver unit accepts the input optical power at the SMA connectors from the optical fibre and provides linear or logarithmic outputs. When the optical signal is given to Fibre optic PT, it is demodulated linearly to give an output voltage, V_{out} . This is directly proportional to the optical input power. For DC measurements, an oscilloscope is required. When the optical signal is given to the FO PIN the resulting photocurrent is converted to a logarithmic voltage P_0 .

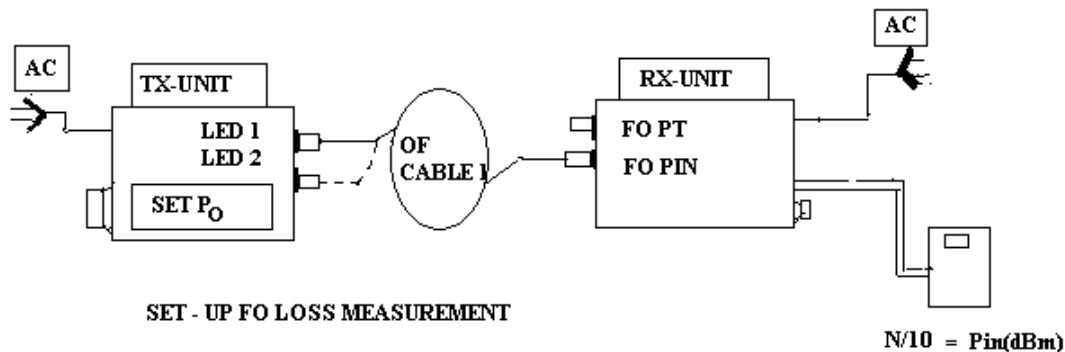
The optical power, is given by (DMM Reading)/10 in decibels referred to 1mw. As an example, if the meter reading is -193, then the optical power P_0 is -193/10 dBm or -19.3dBm.

The DMM may be used in 0-200mV range for higher sensitivity. The reading in this range when divided by 10 again gives optical power P_0 . The optical power meter has been designed to read in decibels (dB) referred to 1mw (dBm), directly as this is the standard practice. The optical power meter has been calibrated at 660nm. (e.g.: 0dBm = 1mw, 10dBm = 0.1mw or 100 μ w; -20dBm = 0.01mw or 10 μ w; -3dBm = 0.5mw)

The P_0 readings have to be corrected for when measuring optical power at 850nm, in the case of the 850nm LED.

a) Losses in optical fibres at 660nm and 850nm

Aim: To study various types of losses that occur in optical fibres and measure losses in dB of two optical fibre patch cords at two wavelengths, namely, 660nm and 850nm. The co-efficient of attenuation per meter at these wavelengths are to be computed from the results.



Definitions: Attenuation in an optical fibre is a result of a number of effects. The optical power at a distance L , in an optical fibre is given by $P_L = P_0 10^{-\alpha L/10}$, where P_0 is the Launched power and α is the attenuation co-efficient in decibel per unit length. The typical attenuation co-efficient value for the fibre under consideration is 0.3dB per meter at a wavelength of 660nm. Loss in fibres is expressed in decibels as $-10\log P_0/P_F$, where P_0 is the launched power and P_F is power at the far end of the fibre. Losses at the connector junctions may vary from 0.3dB to 0.6dB.

Losses in fibres occur at fibre - fibre joints or splices due to axial displacement, angular displacement separation, mismatch of cores diameters, mismatch of numerical apertures, improper cleaving and cleaning at the ends.

The loss equation for a simple fiber optic link is given by

$$P_{in}(dBm) - P_{out}(dBm) = L_{J1} + L_{F1B1} + L_{J2} + L_{F1B2} + L_{J3}(dB)$$

Where $L_{J1}(dB)$ is the loss at the LED - connector junction, L_{F1B1} is the loss in Cable 1, L_{J2} is the insertion loss at a splice or in-line adaptor.

L_{F1B2} is the loss in cable 2.

L_{J3} is the loss at the connector-detector junction.

Procedure:

Block-diagram:

Step1:- Connect one end of cable(1) of length 1m of the TX unit and the other end to the FOPIN Port(power meter)of RX unit.

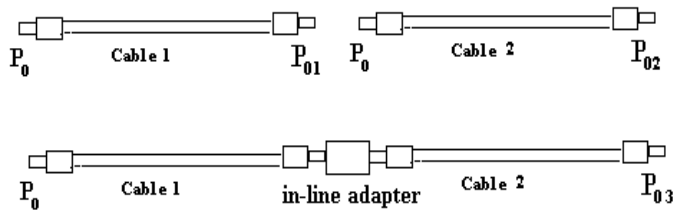
Keep the DMM between the terminals 1 & 2.

Step 2:-Set the digital multi meter to the 2000mV range and switch on the multi meter.

Step 3:-Set the P_0 knob to set power of LED1 to a suitable value, say -15.0dBm (the multi meter will show 150mV). Note this as P_{01}

Step 4:-Wind one turn of the fibre on the mandrel and note the new reading in power meter P_{02} . Now the loss due to bending and strain on the plastic fibre is $P_{01}-P_{01}^1$ dB. For more accurate values set the DMM to 200.0mV and take the measurement. Typically the loss due to strain and bending the fibre is 0.3 to 0.8 dB.

Step 5:- Remove the mandrel and relieve the cable1 of all twists and strains and measure P_{01} . Repeat the measurement with cable2 of length 5m and note the reading P_{02} . Use the in-line SMA adaptor and connect the two cables in series. Note the measurement P_{03} .



$$\text{Loss in cable 1} = P_{03} - P_{02} - L_{ila}$$

$$\text{Loss in cable 2} = P_{03} - P_{01} - L_{ila}$$

Assuming a loss of 1.0 dB in the in-line adapter ($L_{ila} = 1.0\text{dB}$) we obtain the loss in each cable. The difference in the losses in the two cables will be equal to the loss in 1m of fibre (assuming that the losses at connector junctions are the same for both the cables). The experiment also may be repeated for other P_0 settings such as -15dBm, -20dBm, -25dBm etc.

Observations: Loss in the cable1 (1m cable) due to strain and bending = $(P_{01} - P_{01}^1)$ dB

b) To determine the Numerical aperture of the optical fibres:

PMMA fibre – Polymethyl methacrylate

Numerical aperture of any optical system is a measure of how much light can be collected by the optical system. It is the product of the refractive index of the incident medium and the sine of the maximum ray angle.

$$\text{Numerical aperture NA} = n_i \sin\theta_{\max}$$

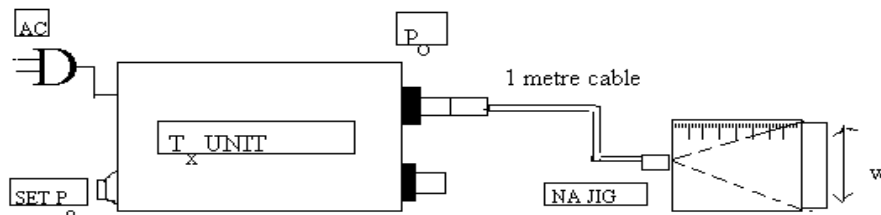
n_i for air is 1, hence $\text{NA} = \sin\theta_{\max}$

For a step-index fibre, as in the present case, the numerical aperture is given by

$$N = \sqrt{n_{\text{core}}^2 - n_{\text{cladding}}^2}$$

For very small differences in refractive indices the equation reduce to $\text{NA} = n_{\text{core}}\sqrt{2\Delta}$, where Δ is the fractional difference in refractive indices.

Procedure:



SET UP FO NA MEASUREMENT

Step1: connect one end of the 1m FO cable to P_0 of T_x unit and the other end to the NA jig.

Step2: Switch on the unit. Light will appear at the end of the fibre on the NA jig. Turn the set P_0 knob clockwise to set to maximum P_0 . The light intensity should increase.

Step3: Hold the white screen with the 4concentric circles (10, 15, 20 and 25mm diameter)

Vertically at a suitable distance to make the red spot from the fibre coincide with the 10mm circle. Note that the circumference of the spot (outermost) must coincide with the circle. Record L , the distance of the screen from the fibre and note the diameter (W) of the spot.

Step4: Compute the Numerical aperture NA from the formula

$\text{NA} = \sin\theta_{\max} = W / (4L^2 + W^2)^{1/2}$. Tabulate the reading and repeat the experiment for 15mm, 20mm and 25mm diameters.

Step5: Incase the fibre is under filled, the intensity with in the spot may not be evenly distributed. To ensure even distribution of light in the fibre, remove the twists on the fibre and then wind 5 turns of the fibre on to the mandrel using adhesive tape and now view the spot. The intensity will be more evenly distributed.

Specifications of the fibre.

PMMA – Polymethyl methacrylate

Fibre structure – step index type

Cladding material – Fluorinated polymer

Cladding refractive index – 1.405 to 1.417

Core refractive index – 1.492

Numerical aperture - 0.5 (typical)

Connector – SMA

Acceptance angle – 55 to 60 degrees.

Precautions:

1) Be careful while using the fibres, do not bend and cut them

2) while measuring the numerical aperture make sure that the corresponding circle is field with maximum intensity.

3) keep the digital multimeter either 150mv or 200mv

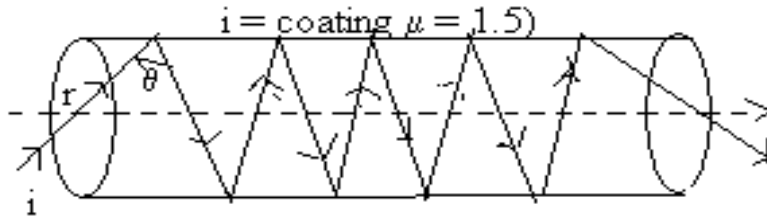
Result:

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OPTICAL FIBRES

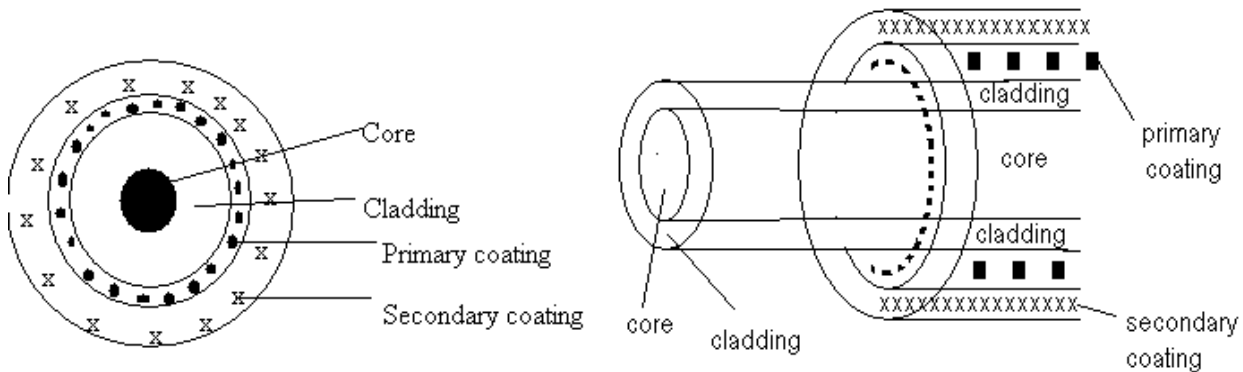
Fibre optics is a technology related to transportation of optical energy(light energy) in guiding media specifically glass fibres.

Principle of optical fibre: The optical fibres are based on the Principle of total internal reflection.(Total internal reflection means when incidence ray angle is greater than critical angle, the light ray does not undergo refraction and travels back into the same medium.)



Structure of optical fibres: An optical fibre is a hair thin cylindrical fibre of glass or any transparent dielectric medium. In practical applications, they consist of many thousands of very long fine quality glass/quartz fibres. The fibres are coated with a of lower refractive index.

An optical fibre consists of an inner cylinder which is made of glass, called the ‘CORE’. The core carries light. The core is surrounded by another cylindrical shell of lower refractive index called ‘CLADDING’. The cladding helps to keep the light within the core through the phenomenon of total internal reflection. The core diameter can vary from about 5µm to about 100µm. the cladding diameter is usually 125µm. for greater strength and protection of the fibre, a soft plastic coating (primary coating) is done whose diameter is about 250µm. This is often followed by another layer of coating known as secondary coating.



Types of optical fibres: The optical fibres are classified into two categories based on a)The number of modes
b)The refractive index

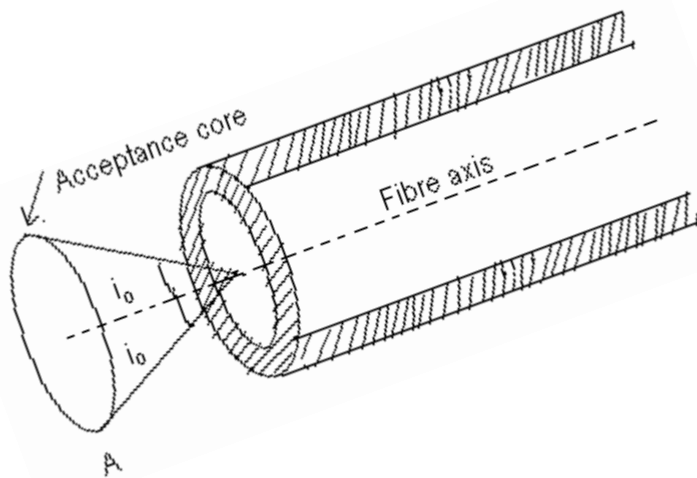
Acceptance Angle and Numerical Aperture:

- a) **Acceptance angle:** The maximum angle that a light ray can have relative to the axis of the fibre so that it may propagate down the fibre. In other words, the maximum angle from the fibre axis at which light may enter the fibre so that it will propagate in the core by total internal reflection.

$$i_0 = \text{Sin}^{-1}\sqrt{(n_1^2 - n_2^2)}$$

where i_0 – Acceptance angle; n_1 – Refractive index of inner core

n_2 – Refractive index of an outer cladding



b) **Numerical Aperture:** It is defined as sine of acceptance angle. In other words, it is a measure of how much light can be collected by the optical system.

$$NA = \sqrt{(n_1^2 - n_2^2)}$$

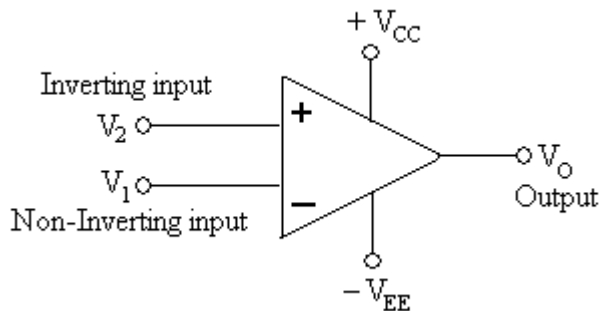
Numerical aperture = 0.4 to 0.5 in short distance communications
 = 0.1 to 0.3 in long distance communications

Operational amplifier:

The operational amplifier is a special type of direct-coupled high gain amplifier with a very large input impedance and a very low output impedance. The unique features of the op-amp makes it suitable for performing a variety of linear functions and hence is often referred to as the basic linear integrated circuit. A negative voltage-shunt feedback is normally employed to the amplifier to control the over all characteristics of the op-amp.

Operational amplifiers can be used to perform arithmetic operations with signals. Op-amp can also be used to integrate and differentiate signals.

Symbol:



If $V_1 > V_2$, the differential input signal produces a positive output voltage V_0 .

If $V_2 > V_1$, the differential input signal produces a negative output voltage V_0 .

The power supply terminals are not normally shown for the simplicity of circuit schematic of an op-amp.

Operational amplifier can be used as a sign changer or inverter, scale changer, phase shifter and buffer. Operational amplifier can also be used to perform mathematical operations such as the addition, subtraction, differentiation, integration and logarithmic operations.

Table of readings for 660nm:

S.No	P_{01} (dBm) (1m cable)	P_{02} (dBm) (5 m cable)	P_{03} (dBm) (1m+5 m) Cable	Loss in cable1 dB $P_{03} - P_{02}$	Loss in cable2 dB $P_{03} - P_{01}$	Loss in 4 meters difference in losses of cable2 and cable1	Loss per meter (dB) at 660nm
1	-15.0						
2	-20.0						
3	-25.0						
4	-30.0						

Repeat the experiments with LED2 at 850nm and tabulate.

Note: The power meter has been calibrated internally to read. Power in dBm at 660nm. To calibrate the power meter at 850nm, deduct 2.2dB from the measured reading

Table of readings for 850nm

S.No	P_{01} (dBm) (1m cable)	P_{02} (dBm) (5 m cable)	P_{03} (dBm) (1m + 5 m cable)	Loss in cable1 dB $P_{03} - P_{02}$	Loss in cable2 dB $P_{03} - P_{01}$	Loss in 4 meters difference in losses of cable2 and cable1	Loss per meter (dB) at 850nm
1	-15.0						
2	-20.0						
3	-25.0						
4	-30.0						

Table of readings:

S.No	L (mm)	W (mm)	Numerical Aperture NA	$\theta = \sin^{-1}NA$
1		10		
2		15		
3		20		
4		25		
5				

Date:

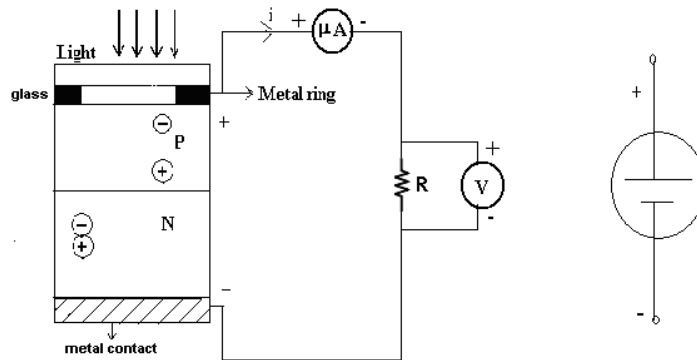
4. The Solar Cell

Aim: To draw the characteristics of a given solar cell.

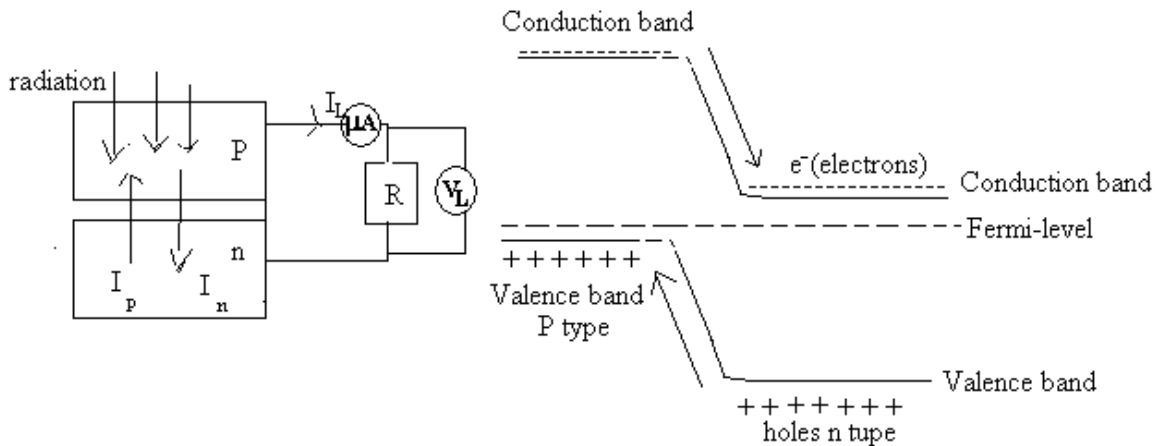
Apparatus: Solar cell, source of light, micro ammeter, variable resistance, voltmeter and connecting wires.

Theory: The Solar Cell is basically a P-N junction diode which converts solar energy into electrical energy. In principle, a solar cell is nothing but a light emitting diode (LED) operating in reverse.

Common materials for solar cells include silicon, gallium Arsenide (GaAs), indium arsenide (InAs) and cadmium Arsenide (CdAs). The most common is silicon. For silicon, the band gap (the energy necessary to transfer an electron from the upper valence level to the conduction band) is 1.12eV. The maximum theoretical efficiency of a solar cell depends on this band gap. For silicon the maximum efficiency is only 22%.



When photons fall on a p-n junction, electrons are lifted from the valence band to the conduction band provided the photon energy exceeds E_g , the energy gap. Thus additional carriers, both electrons and holes are provided by the photons.



Few of the additional electrons in the n-region have enough energy to diffuse to the p-region, but electric field to the n-side. Similarly holes are swept to the p-side. Thus photons increase the minority carrier densities substantially in both p and n-region and an appreciably greater minority carrier transfer is produced across the junction.

When no external potential difference is applied to an illuminated p-n junction. The photon induced charge transfer results in producing a photo voltage V_p across the barrier layer with the n-region negative and the p-region positive. Once equilibrium is established in the crystal in the absence of an external circuit, the forward current due to V_p just balances induced current I_p .

When a solar cell is used to supply power to a load the photon-generated current I_p is equal to the load current I_L plus the forward junction current due to the induced potential difference V .

$$I_p = I_L + I_0(e^{VC/KT} - 1) \text{ -----(1)}$$

The voltage V_L appearing across the load is the generated potential difference minus the potential drop $I_L R_C$, where R_C is the solar cell resistance, due almost entirely to the very thin p layer.

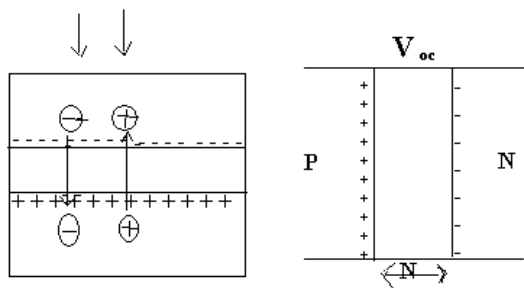
Combining $V_L = V - I_L R_C$ with (1) leads to

$$V_L = \frac{KT}{e} \log\left(\frac{I_p - I_L}{I_0} + 1\right) - I_L R_C$$

A good silica solar cell may have an efficiency of about 15%.

Construction: A solar cell consists of P-N junction diode made of silicon. The inward arrow in the symbol indicates the incoming light. The P-N diode is packed in a can with glass window on top so that light may fall upon P and N type materials. The thickness of the P-region is kept very small so that electrons generated in this region can diffuse to the junction before recombination takes place. Thickness of N-region is also kept small to allow holes generated near the surface to diffuse to the junction before they recombine. A heavy doping of P and N regions is done to obtain a large photo voltage. A nickel plated ring is provided around the P-layer. This acts as the positive output terminal. A metal contact at the bottom serves as the negative output terminal.

Working:



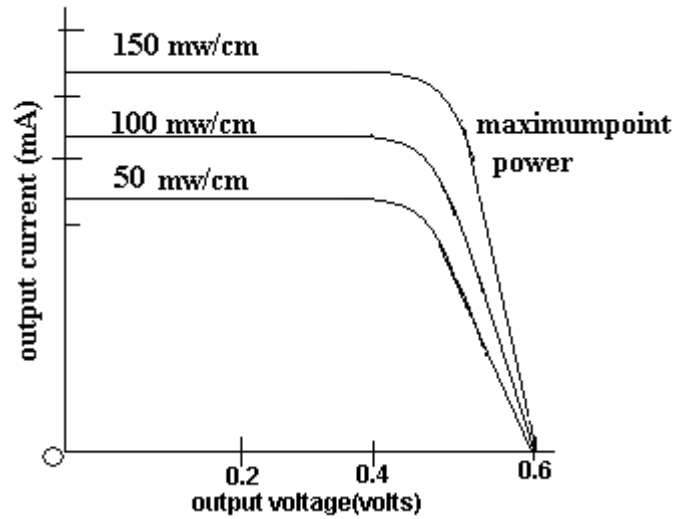
When light radiation falls on a P-N junction diode, photons collide with valence electrons and impart them sufficient energy enabling them to leave their parent atoms. Thus electron hole pairs are generated in both the P and N sides of the junction. These electrons and holes reach the depletion by diffusion and are then separated by the strong barrier field existing there.

There are some minority carriers in both P and N regions which reach the opposite side in spite of the barrier potential. Their flow constitutes the minority current which is directly proportional to the illumination and also depends on the surface area being exposed to light.

The accumulation of electrons and holes on the two sides of the junction gives rise to an open circuit voltage V_{oc} which is a function of illumination. The open-circuit voltage produced for a silicon solar cell is typically 0.6V and the short circuit current is about 40mA/cm^2 in bright light.

Procedure: Study the circuit configuration given on the front panel of the trainer. Connect 47E resistor between the (-) and (+) terminals of the solar cell. Focus bright light on the solar cell. Measure the voltage between the (-) and (+) terminals of the solar cell and also the current through the resistance. Repeat steps 3 and 4 for different values of the resistors provided on the trainer. Note the effect of increased resistance in series with the solar cell. Connect 10K potentiometer, between the (-) and (+) terminals of the solar cell. Vary the potentiometer. You will notice that as the resistance changes, the current and voltage output of the solar cell changes.

Characteristics: Typical (VI) characteristics of a solar cell, corresponding to different levels of illumination are as shown below. Maximum power output is obtained when the cell is operated at the knee of the curve.



Uses:

1. Solar cells are used extensively in satellites and space vehicles to supply power to electronic and other equipments or to charge storage batteries.
2. Solar cells are used to power calculators and watches.
3. Solar cells are used to provide commercial electricity.

Precautions:

1. When you're not taking the readings switch off the source so that the solar cell is not damaged.
2. Check the maximum and minimum intensity of the source before you start the experiment, so that you can choose three convenient intensities for tabulation.

Result:

Lecturer signature with date:

Observations

S.No	Voltage (V)	Current (μ A)

Date:
5.
Temperature
characteristic
s of a
Thermistor

Aim : To draw the temperature characteristics of a thermistor

and to evaluate the constants.

Apparatus : Thermistor, three resistance boxes (1 – 1000 Ohms), 2 V battery, table galvanometer, 0 - 110° c thermometer, water bath, test tube with oil, two plug keys and connecting wires.

Theory : A thermistor is a thermally sensitive resistor. It is a semiconductor made up of mixtures of oxides of cobalt, magnesium, manganese, nickel or uranium. In many respects a thermistor resembles a conventional resistor. It is a two terminal device having resistance as the fundamental property and is operated in the same way as a resistor. A thermistor is available in many shapes such as a rod, disc or bead. Most of the thermistors have a negative temperature coefficient of resistance $R = A e^{B/T}$. The resistance of a resistor varies linearly with temperature. A thermistor, on the other hand, has a non-linear variation of resistance with increase of temperature given by the relation,

$$R = A e^{B/T} \text{ -----(1)}$$

Here A and B are constants and T is the temperature in degrees absolutely. The constants A and B are characteristic of the thermistor used. It is our aim to determine R as a function of T and to evaluate the two constants A and B.

$$\text{Then } \text{Log}_e R = \text{Log}_e A + B/T$$

Principle of wheat stone’s bridge:

A wheat stone’s bridge consists of four resistors P,Q,R,S in the four arms connected in series to form a bridge. Two opposite corners are connected to a battery through a plug key.

The bridge is said to be balanced when there is no flow of current in the galvanometer arm. Under this condition the ratio of resistance P, Q will be equal to the ratio of resistance R, S i.e. $P/Q = R/S$. This is called the balancing condition of the wheat stone's bridge. Using this we can determine any unknown resistance.

Circuit Diagram:

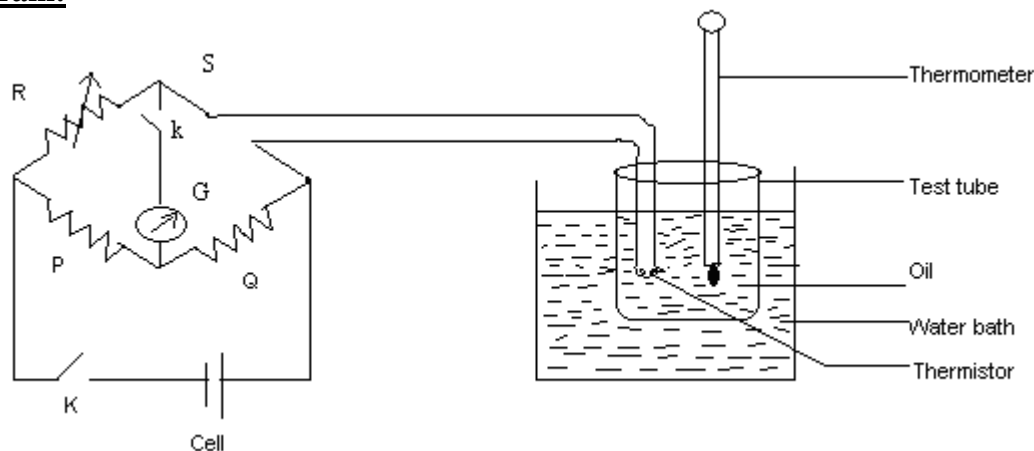


Fig (1)

Procedure : Make the connections as shown in the figure 1. The thermistor is connected in the fourth arm of the bridge while P, Q, R form the other three arms. P and Q represent the ratio arms. Take $P = Q = 100 \Omega$ and balance the bridge with the thermistor in the test tube containing transformer oil or sweet oil and the test tube maintained at the cold water temperature of the water- bath.

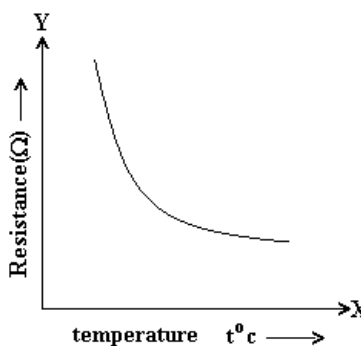
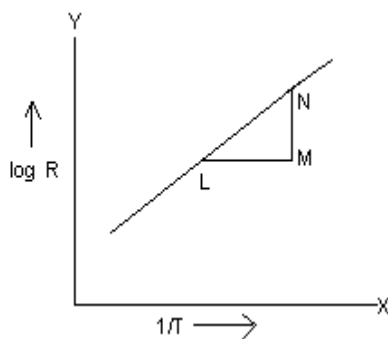
The value of R which is obtained for balancing the bridge gives the resistance of the thermistor at cold water temperature.

Heat the water – bath till the water boils and now again determine the resistance of the thermistor at regular intervals of 10°C each, only while cooling as the temperature is steady. Tabulate the results as follows.

Note: we keep the thermistor in the test tube containing oil for heating. Because direct heating of the thermistor in water will spoil the specimen, due to large heat capacity of water. Secondly since the density of oil is less than that of water. The specimen will get heated slowly and reach the steady temperature.

Graph:

Draw a graph with $\text{Log}_{10} R$ on Y-axis and $1/T$ on X-axis. Draw another graph with resistance (R) on y-axis and temperature $t^\circ\text{C}$ on x-axis.



Slope of the straight line gives

$$B = \frac{MN}{LM} \times 2.303 K$$

The intercept of the Y-axis gives $\log A$, but it is easier to calculate A from the equation

$$\log_{10} A = \log_{10} R - B \frac{\log_{10} e}{T} \quad (\log_{10} e = 0.4343) \quad \text{-----(2)}$$

Substituting the values of R , B and T in equation (2) A can be calculated.

Specimen calculation of A:

$$\text{Let } R = 120 \Omega \text{ at } T = 333^\circ\text{K} \text{ and } B = 3000^\circ\text{K}$$

$$\text{Then } \log_{10} A = -1.8295 = -2 + 0.1705 \text{ (by adding and subtracting '1' on both sides)}$$

$$= 2.1705$$

$$A = 0.015 \Omega$$

Precautions:

1. Remove the plug key from the galvanometer circuit while heating.
2. Tighten all the keys in the resistance boxes before you start experiment and also see that keys are replaced tightly after using them while doing the experiment.
3. Do not operate above 90°C .
4. Values of resistance should be picked up to get a exact null deflection in the galvanometer.

Result :

Lecturer Signature:

Possible Viva Questions

- 1) What is a thermistor?
- 2) How are thermistors made?
- 3) What are ohmic and non-ohmic resistances?
- 4) Why do we have to take readings while cooling only and not during heating?
- 5) What are the shapes of thermistor?
- 6) Why galvanometer should show zero deflection while finding the unknown resistance?
- 7) what is wheat stone's bridge?
- 8) what is the balancing condition for wheat stone bridge?
- 9) How is the thermistor's resistance found by using the balancing condition of wheat stone's bridge?
- 10) why is the thermometer placed in oil instead of water?
- 11) why a semiconductor has got a negative temperature coefficient of resistance?
- 12) which materials have got positive temperature co-efficient of resistance?
- 13) in a semiconductor at absolute zero how will the valence band be?
- 14) what is a semiconductor? what are the types of semiconductors?
- 15) what are intrinsic and extrinsic semiconductor?
- 16) why much care is needed while using thermistor?
- 17) why are all keys tightened in the resistance box while doing the experiment?

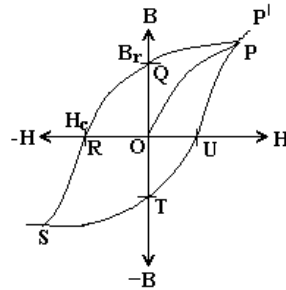
Date:

6. HYSTERESIS CURVE OF TRANSFORMER CORE

Aim: To trace the hysteresis curve of a transformer core using a Cathode Ray Oscilloscope, find the energy loss per unit volume per cycle the corecivity and retentivity of the material of the core.

Apparatus: Given transformer core with primary(N_p) and secondary (N_s) windings, a step down transformer(T_r) (having an output of 3V to 6V and 100mA) low loss capacitor C_s of $4\mu F$ capacitance, Resistors R_1 and R_2 ac mains supply (220V-50Hz) and cathode ray oscilloscope.

Formula: The phenomenon by which the magnetic induction (B) lags behind the magnetizing field (H) is called hysteresis.



The hysteresis curve-graph with H on x axis and corresponding B (of the material) on y - axis will be as shown in Fig-1

The area under the B - H curve gives the hysteresis loss per cycle, that is the work done per unit volume per cycle ----- (1)

OQ gives the value of the retentivity (B_r), that is the remanent induction even when the field H is removed ----- (2)

OR gives the value of the coercivity (H_c), that is the negative field to be applied to demagnetize the specimen completely. -----(3)

Circuit Diagram:

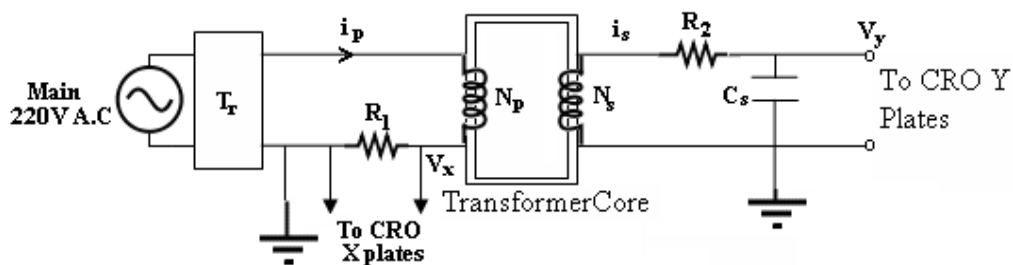
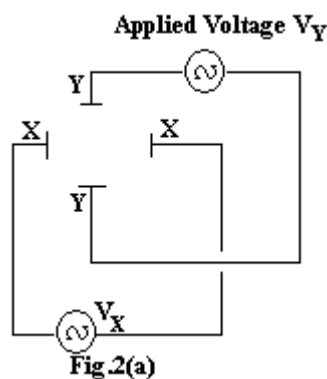


Fig.2 Hysteresis curve on CRO-Experimental arrangement



Theory: Ferromagnetic materials like iron, cobalt and nickel are having certain specific magnetic properties. They will be having a large number of small regions in which magnetization will be already saturated spontaneously. These regions are called “Domains”. Different domains will be having their magnetization in different directions and the overall magnetization with no applied magnetic field will be zero.

When an external magnetic field H is applied, the domains having their magnetization parallel to the field grow at the expense of other domains. Thus, initially the magnetization increases. This is shown by the curve OP . As and when all the domains get magnetized, there is no further scope for increase in magnetization and the magnetization is saturated as can be seen from PP^1 .

Now let us gradually decrease the magnetizing field H . instead of coming back along PO , the curve retraces along PQ . At Q , even though the applied field H is completely removed, there still remains certain magnetic induction B_r ($=OQ$). This is because, the domain boundaries do not move completely back to their original position. This B_r is called the retentivity of the material.

Now, when the applied field is reversed in direction ($-H$), the remanent magnetization decreases and becomes zero at $-H=OR$. $OR=H_c$ is called the coercivity. As we further increase H in reverse direction, the specimen gets magnetized now in an opposite direction and this process continues up to saturation at S . when the negative field is gradually decreased the curve follows the path ST where there is still magnetization (now is negative direction) even when $H=0$. B becomes zero when $+H$ is increased up to U . With further increase of $+H$ the curve follows UP . The closed curve $PQRSTUP$ is called the hysteresis curve of the given ferromagnetic material. The phase lag between B and H is the cause of hysteresis loop.

The tendency of the magnetic domains to turn around (both during magnetization and demagnetization as well) gives rise to mechanical stresses inside the material. This gives rise to heating. The energy wasted due to the cyclic magnetization is called the hysteresis loss and is given by the area under the hysteresis curve.

When we apply an alternating current, the material gets magnetized during one half cycle and demagnetized during the second half cycle. Thus we get the hysteresis curve in a simple fashion. The curve can be visualized on the CRO screen by feeding V_x of primary to ‘X’ plates and V_y of secondary to Y plates.

Procedure:

The electrical connections are made as shown in Fig-2 and Fig.2 (a). The primary of the transformer core is connected via the resistor R_1 to the step down transformer (T_r) which in turn is connected to the 220V-50Hz mains. The secondary of the transformer core is connected in series with the resistor R_2 and capacitor C_s . The voltage V_x across R_1 is fed to the horizontal input (XX plates) of the CRO. The voltage V_y across C_s is fed to the vertical input (YY plates) of the CRO.

The horizontal and vertical gain control of the CRO are adjusted to get a convenient size of the hysteresis curve of the material of the transformer core.

Here V_x corresponds to H while V_y corresponds to B .

On a graph sheet, trace the B - H curve appearing on the CRO screen by plotting point by point wise.

Observations and Calculations:

By adjusting the horizontal and vertical gain controls of CRO a hysteresis loop of convenient size is obtained on the screen of CRO.

The same is plotted on a graph sheet.

The area of the hysteresis loop PQRSTUP is counted. This gives hysteresis loss.

1) $OQ = B_r = \text{retentivity} = \text{_____ tesla (Wb/m}^2\text{)}$

2) $OR = H_c = \text{corecivity} = \text{_____ ampere/meter.}$

3) Hysteresis loss = _____joules/cycle/unit volume.

Precautions:

1. Do not touch the transformer while doing the experiment.
2. Use graph paper while measuring the area of the hysteresis loop.

Result:

Lecturer signature with date:

Possible viva Questions

1. What is hysteresis?
2. In what materials do you find this behaviour?
3. What is the root cause for hysteresis?
4. What are magnetic domains?
5. How is the curie law modified due to these domain?
6. What happens to a ferromagnetic material above the curie temperature θ_C .
7. What is the cause of hysteresis?
8. What is the cause of hysteresis losses?
9. How can you estimate the hysteresis loss of a given specimen?
10. What are the practical uses of hysteresis curves.
11. What are the differences between soft iron and steel as far as retentivity and coercivity are concerned?
12. What are the characteristics of a transformer core?
13. Can we use an electrolyte capacitor for C_s in this experiment?
14. What are the units of B and H?
15. Out of soft iron and steel which has got smaller hysteresis loop?

Date:

7. STEFAN-BOLTZMAN LAW

AIM: To verify Stefan – Boltzman’s fourth – power radiation law using an electrically heated filament.

APPARATUS : A sealed bulb with tungsten filament , a variable D.C source, a milli ammeter of 0-200 mA range, three resistance boxes, galvanometer, plug key and connecting wires.

THEORY : STEFAN – BOLTZMAN LAW : A black body at absolute temperature T surrounded by another black body at absolute temperature (T_0) not only losses an amount of energy σT^4 but also gains σT_0^4 . Thus the amount of heat lost by the former per unit area per unit time .
$$E = \sigma(T^4 - T_0^4)$$

Where σ is known as the Stefan’s constant .

When $T \gg T_0$, T_0 can be neglected in comparison with T .

Hence $E = \sigma T^4$.

If the body is not perfectly black and its emissivity is ‘e’ then Stefan’s law may be written as $E = e \sigma T^4$.

According to this law the energy radiated by the tungsten filament of area ‘A’ is given by $E = eA \sigma T^4$.

The experiment consists of measuring the resistance of the filament of the bulb for different currents and equating the rate at which electrical energy is supplied to the filament to the rate at which energy is radiated by it.

$$i^2R = eA \sigma T^4 \text{ -----(1)}$$

Here we are neglecting energy lost by heat convection.

Taking log of equation(1) ,

$$\text{Log}(i^2R) = \text{log}(eA \sigma) + 4 \text{log} T \text{ -----(2)}$$

If a graph is plotted with $\text{log}(i^2R)$ on the y-axis and $\text{log} T$ on the x-axis , a straight line is obtained whose slope should be equal to 4 verifying Stefan–boltzman law .

The temperature of the filament is calculated using the formula

$$R = R_0 [1 + \alpha (T - T_0)] \text{ -----(3)}$$

Where, R is resistance at temperature T .

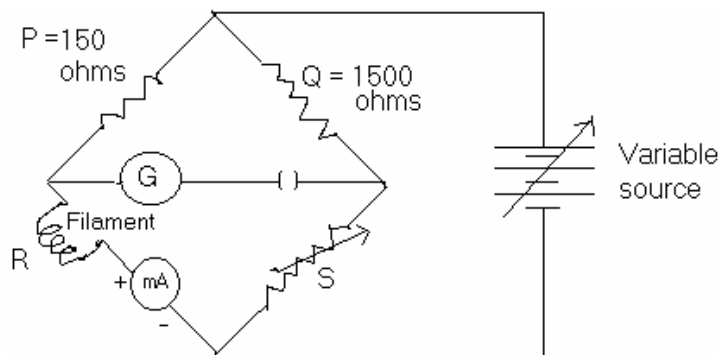
R_0 is resistance at room temperature T_0 .

α is the mean temperature coefficient of resistance.

$\alpha = 0.0053 \text{ k}^{-1}$ for tungsten

solving eq (3) for T , $T = [(R - R_0) / \alpha R_0] + T_0 \text{ -----(4)}$

Circuit diagram:



Fig(1)

PROCEDURE :

- 1) A wheat-stone bridge is constructed with the tungsten filament and a milli-ammeter in one arm and its resistance is measured for different currents.

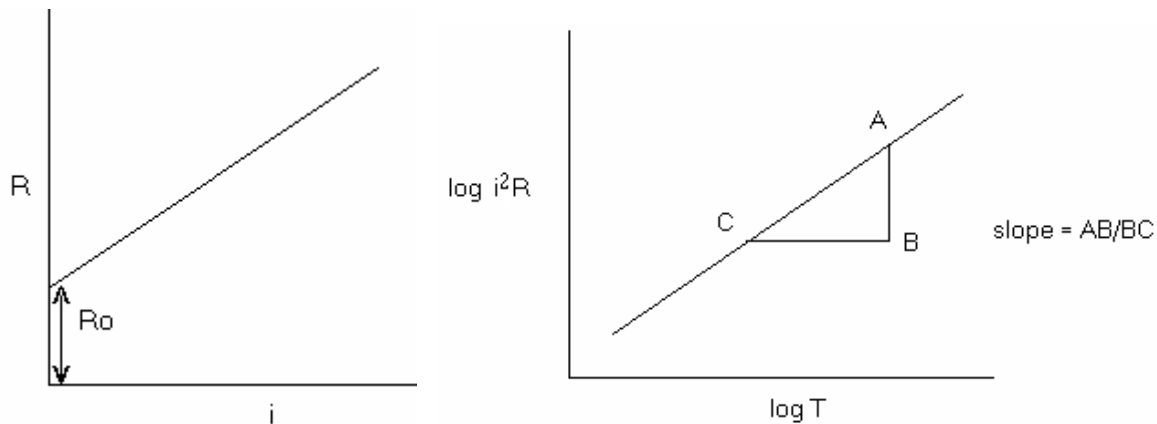
$$R = S \times 150/1500 \Omega$$

- 2) A graph is plotted with current I on the x -axis and resistance R on the y -axis . The intercept on the y -axis gives R_0 the resistance of the filament at room temperature.

- 3) Temperature of the filament for different currents is calculated by substituting the values of R , R_0 , T_0 and α in the eq (4).

- 4) A graph is plotted by taking $\log(i^2R)$ on the y -axis and $\log T$ on the x -axis .

Graph:



- Precautions:**
- 1) All the precautions for using the wheat stone's bridge must be taken.
 - 2) Note the ammeter reading only after keeping the key.

Result:

Lecturer Signature with date:

Possible viva questions

1. What is Stefan-Boltzman fourth-power radiation law.
2. What is temperature co-efficient of resistance.
3. What is an ammeter? What are the types
4. Why the current in galvanometer should show zero.
5. What is a black body and perfectly black body. Give an example?
6. Why the slope should be equal to 4 from the graph.
7. What is a table galvanometer.
8. What is a wheat stone's bridge.

OBSERVATIONS :

P = 150Ω

Q = 1500Ω

Room temperature T_o =

Resistance at room temperature (from the graph) R_o =

Temperature Co-efficient α = 0.0053 k⁻¹

S.No	Current i (mA)	Resistance R = S/10Ω	Temperature T = [(R-R _o)/R _o α]+T _o	i ² R	Log i ² R	Log T

Date:

8. CONSTANT OF A BALLISTIC GALVANOMETER

Aim : To determine the constant of a B.G by steady deflection method or half deflection method.

Apparatus : Three resistance boxes of range 1 to 10,000 Ω , ballistic galvanometer, two plug keys, commutator, stop watch and connecting wires.

Circuit Diagram :

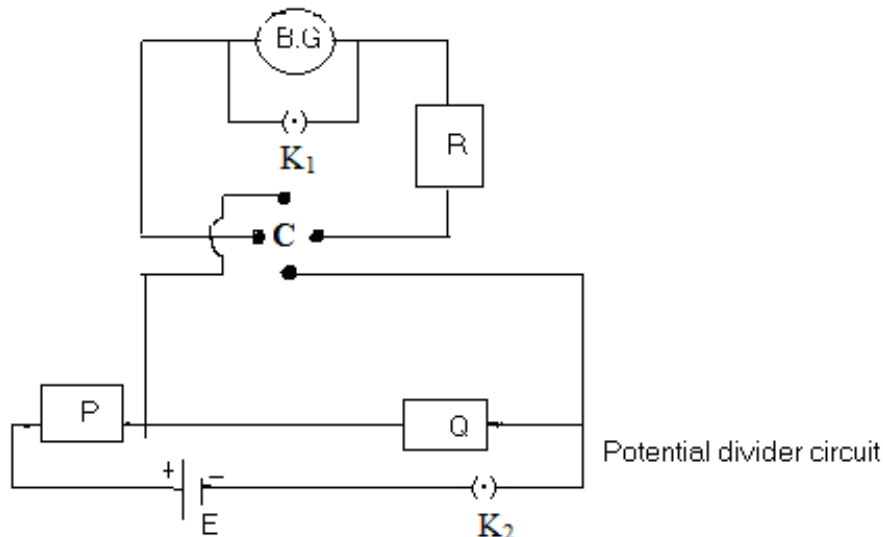


Fig (1)

Theory : The moving coil ballistic galvanometer is a specially designed galvanometer suitable for measuring charge. It performs angular oscillations and the maximum deflection is proportional to the total charge passed through it.

The moving coil galvanometer is said to be dead beat when the coil returns to the initial position quickly without making any oscillation. The steady deflection produced is proportional to the current.

When a coil of “n” turns and area” A” is suspended in a magnetic field of strength “H” and a charge “q” passes through it, the coil will oscillate. If “C” is the restoring couple per unit twist of the suspension fiber, “T” is the time period of oscillation and “ θ ” the ballistic deflection then

$$q = \{C/nAH\} \{T/2\pi\} \cdot \{\Phi\} \quad \text{that is } q = K \Phi$$

$$\text{The ballistic constant } K = \{C/nAH\} \cdot \{T/2\pi\} = q/\Phi$$

For a galvanometer in the dead beat mode if ‘i’ is the current and ‘ Φ ’ the steady deflection then

$$i = \{C/nAH\} \Phi \quad \text{that is } i = k \Phi$$

The galvanometer constant

$$k = C/nAH = i/\phi$$

Therefore the ballistic constant $K = k T/2\pi$

Potential Divider Circuit :

Since a moving coil galvanometer is very sensitive instrument, a potential divider circuit is used to send a small current through the galvanometer.

Current in the circuit $I = E / (P+Q)$ current is kept constant throughout the experiment by keeping $P+Q$ constant.

The potential difference across $Q = EQ / (P+Q)$ is varied by changing Q (but keeping $P+Q$ constant) to

send different currents through the galvanometer.

Half Deflection Method :

To Find The Resistance Of The Galvanometer G :

Let ϕ be the deflection in the galvanometer when a current i passes through it and the series resistance $R = 0$ (in the dead beat mode)

$$i = [EQ / (P+Q)] \cdot 1/G = K \phi \text{ ----- (1)}$$

Let R be the resistance to be included in series with the galvanometer to reduce the deflection to half. Then the changed current i' is

$$i' = [EQ / (P+Q)] \cdot 1/(G+R) = K \phi /2 \text{ -----(2)}$$

Dividing eqn (1) by eqn(2) we get $(G+R)/G = 2$ or $G = R$

Procedure :Connect the circuit as shown in the figure (1). Adopting the potential divider method, unplug 1 ohm from Q , keeping $R=0$ close the circuit. Adjust Q keeping $(P+Q)$ at 10,000 ohm until a decent steady deflection is obtained in ballistic galvanometer. At this stage note the value of Q unplugged and the steady deflection noted. Reverse the current with the help of a commutator and note the deflection in other side. Let the average deflection be ϕ .

Now to determine the resistance of galvanometer by half deflection method, unplug resistance from R till the deflection is reduced to half of its previous value ϕ . The resistance unplugged is equal to the resistance G of the galvanometer. Take six set of readings and tabulate the results and do the calculations. Write the results.

Time Period Of Oscillation :

Change the galvanometer to ballistic mode and make the deflection maximum by passing current . Now disconnect any one wire going to the galvanometer from the commutator and note the time for 20 oscillations.

Precautions :

1. Do the necessary adjustments of galvanometer.
2. The deflector must be same for left and right while steady current is flowing.
3. While determining the period of oscillation, detach the galvanometer from the circuit.
4. Connections should be very tight and make sure that there is no insulator around the copper wire near the connections.
5. Remove the plug from key 2 while the experiment is not being done.

Result :

Lecturer Signature with date :

Observations :

Table

Time for 20 oscillations				Time period $T=t/20\text{sec}$
Trial 1	Trial 2	Trial 3	Mean t	

E.M.F of the battery $E = \underline{\hspace{2cm}}$ volts.

$P+Q = \underline{\hspace{2cm}}$ ohms

S.no	P Ω	Q Ω	Deflection ϕ			Resistance R for half deflection = G Ω			$k = [EQ / (P+Q)G] \cdot 1 / \phi$
			Left	Right	mean	Left	right	mean G	

Average galvanometer constant $K = \hspace{2cm}$ amps / def

The ballistic constant $K = K T / 2\pi = \hspace{2cm}$ coulombs / def.

Possible Viva Questions

1. What is a potential divider circuit?
2. What is the action of a commutator?
3. What is the action of plug key K_1 ?
4. What is the time period of oscillations?
5. What is the use of moving coil ballistic galvanometer?
6. What is an oscillation?
7. What is magnetic field strength?
8. What is a Restoring force?
9. What is the relation between produced steady deflection and the current?
