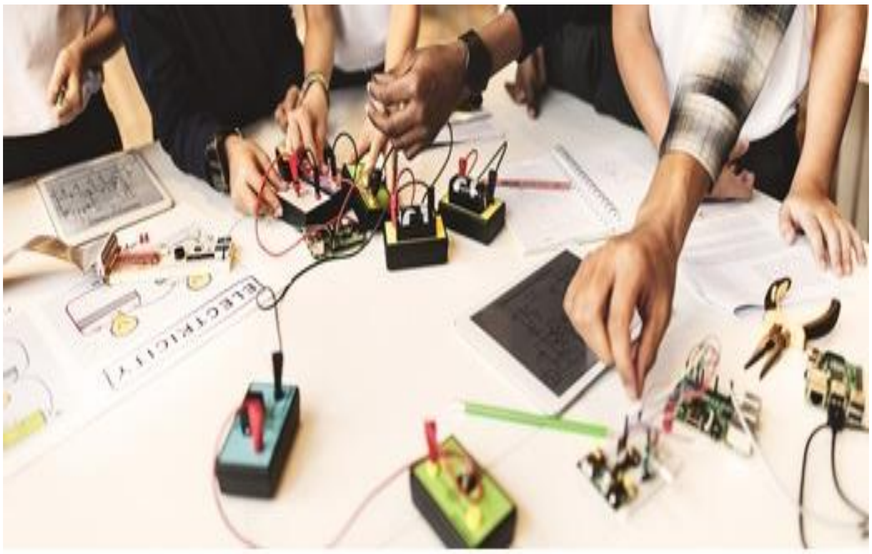
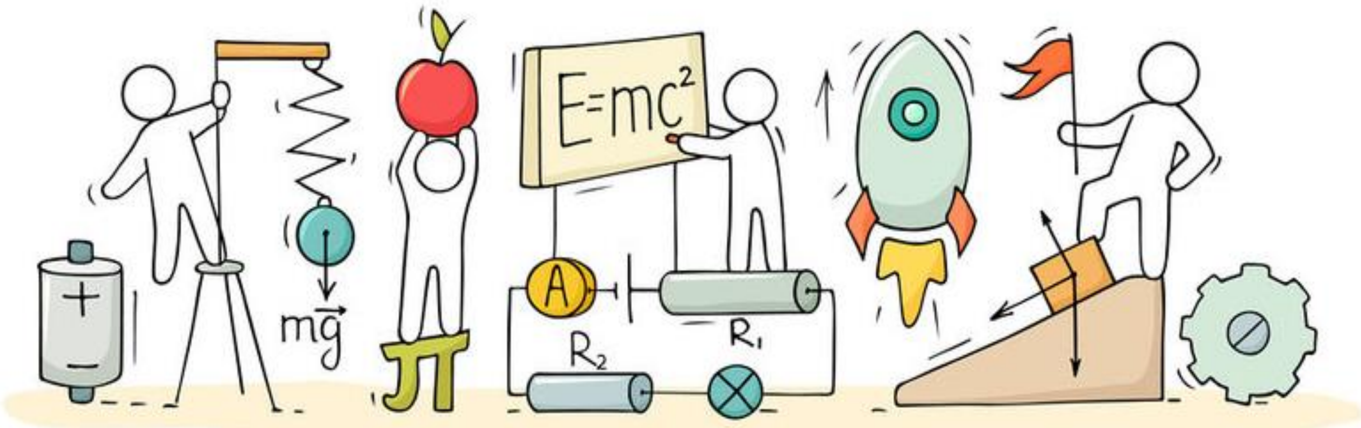


Physics for Engineers Laboratory Manual

B. Tech Semester - I



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Lab and exam Instructions:

To be updated…… (as on 23/01/2024)

7. **Cell phones, smartphones, microphones, earbuds, headsets, and smartwatches, among other electronic devices, are strictly always forbidden within the laboratory premises. If a mobile phone is discovered, it will be confiscated and reported to the dean's office.**

COMPOUND PENDULUM

Aim: - Determination of the acceleration due to gravity, g via the time period of an oscillating compound pendulum.

Apparatus: -A bar pendulum, stopwatch, meter scale and a stand for hanging pendulum.

Theory: - In lower classes you might be familiar with simple pendulum experiment for the determination of acceleration due to gravity, hence before to do this experiment one has to know the difference between simple pendulum, and compound pendulum experiment, both of them were meant for determination of 'g' value. They are

1. Simple pendulum is an ideal case, because it require a point mass object
2. It requires torsion less string.

The above mentioned two conditions are not practically possible, hence it is only a mathematical ideal case, and whereas compound pendulum is a physical pendulum.

A rigid body of any shape which is free to oscillate without any friction on a vertical plane is called compound pendulum. It swings harmonically back and forth about a vertical z-axis (Passing through point "O" as shown in Fig), when compound pendulum is displaced from its equilibrium position by an angle. In the equilibrium position, the centre of gravity of the body is vertically below at a distance of OG. Let the mass of the body is m, In this experiment you are going to measure the acceleration due to gravity, g by observing the motion of a compound pendulum. Let us consider a compound pendulum shown in figure 1.
Pull the compound pendulum through an angle and release it, then it makes angular oscillations due to torque acting on it, given by

$$\boldsymbol{\tau = r\ X\ F}$$
$$\boldsymbol{\tau = OG\ X\ mg\ \sin\theta}$$

$$\tau = -mgD\sin\theta - - - - - - (1)$$

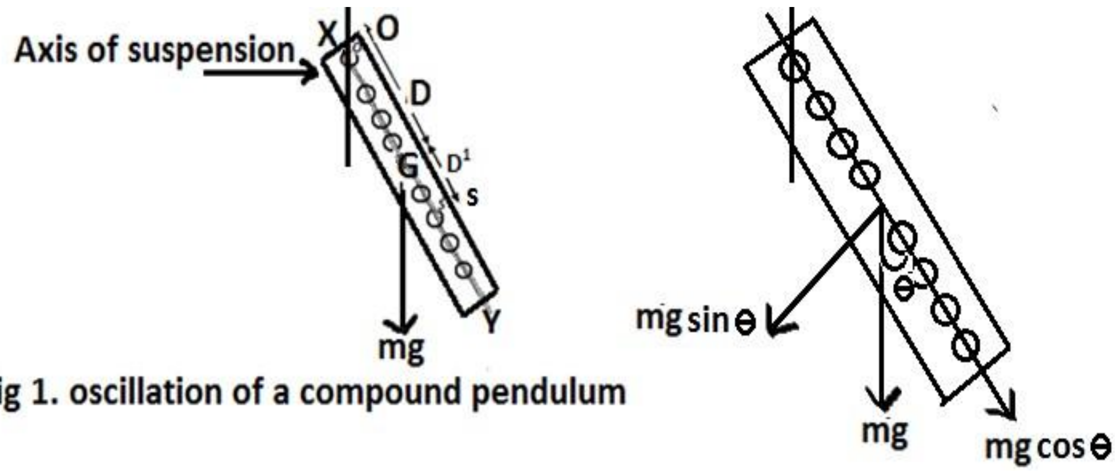


Fig 1. oscillation of a compound pendulum

Here –ve sign is because of force and displacement is opposite to each other.

For Small amplitudes $\sin\theta \approx \theta$

Now expression (1) becomes $\tau = -mgD\,\theta$

We know that Torque (τ) = **[Moment of Inertia (I)] [Angular acceleration (α)}]**

$$\tau = I\frac{d^2\theta}{dt^2}$$

$$=> I\frac{d^2\theta}{dt^2} = -mgD\,\theta$$

$$\frac{d^2\theta}{dt^2} + \left(\frac{mgD}{I}\right)\theta = 0 - - - - - - (2)$$

Here I is the moment of inertia of pendulum, about an axis passing through point "O".

Equation (2) represents simple harmonic equation of the form, i.e.

$$\frac{d^2\theta}{dt^2} + \omega^2\theta = 0$$

Here ω is angular frequency of simple pendulum. From comparison with Eq (2), we can write

$$\omega = \sqrt{\frac{mgD}{I}}$$

$$\omega = \frac{2\pi}{T} = \sqrt{\frac{mgD}{I}}$$

$$T = 2\pi\sqrt{\frac{I}{mgD}} - - - - - - -(3)$$

According to parallel axes theorem, the rotational moment of inertia, about any axis parallel to the one passing the centre of gravity is given by

$$I = \ I_G + mD^2 - - - - - - (4)$$

We know that moment of inertia about an axis passing through centre of gravity “G”, given by

$$I_G = mk^2$$

Here “K” is radius of gyration of the body about an axis passing through “G”.

Thus $T = 2\pi\sqrt{\frac{mk^2+mD^2}{mgD}} = 2\pi\sqrt{\frac{D+\frac{K^2}{D}}{g}} - - - - - - -(5)$

Comparing expression (5) with expression for time period of simple pendulum i.e.

$$T = 2\pi\sqrt{\frac{L}{g}}$$

This suggests that $L = \ D + \frac{K^2}{D} = D + D^1 - - - - - - - - - -(6)$

The term **“L”** is called length of **“equivalent simple pendulum”.**

This is because simple pendulum of length “L” is having a time period, same as that of time period of compound pendulum. Also it seems that all the mass of the body were concentrated at point “S”, along “OG” produced such that

$$OS = \ D + \frac{K^2}{D} = D + D^1$$

The point "S" is called centre of oscillation. In analogy with simple pendulum we may suppose that, the entire mass is concentrated at that point.

From expression (6), the extra distance $\mathbf{D^1}$ is below the centre of gravity "G", at a point "S", and is shown in Figure (1).

From expression (6) we can write $\boldsymbol{D^2 - LD + K^2 = 0}$

The above equation is a quadratic equation in "D" and it's two roots are given by

$$\boldsymbol{D_1 = \frac{L + \sqrt{L^2 - 4k^2}}{2} \qquad and \qquad D_2 = \frac{L - \sqrt{L^2 - 4k^2}}{2}}$$

That is for each half of pendulum, there are two different points of oscillation (do not get confusion with centre of oscillation) i.e. which are at $\mathbf{D_1}$ **&** $\mathbf{D_2}$ distance away from centre of gravity "G", for which the value of **"L"** is same. Since **"L"** is same for $\mathbf{D_1}$ **&** $\mathbf{D_2}$, then, the time period is also same. When we perform this experiment on both sides of centre of gravity "G" we have a total of 4 points (2 points on one side) having same time period "T", as shown in Figure 2. The points **D** and $\mathbf{D^1}$ are clearly shown in Graph.

Formula: -

Time period of oscillation of a physical pendulum or compound pendulum is given by

$$T = 2\pi\sqrt{\frac{K^2 + D^2}{gD}} \quad \text{Sec}$$

Compare the above formula with time period of oscillation of a simple pendulum. i.e.

$$T = 2\pi\sqrt{\frac{L}{g}} \quad \text{Sec}$$

Here $\mathbf{L= K^2+D^2/D}$ is called length of equivalent simple pendulum. K is radius of gyration; 'D' is distance of the point of suspension from centre of gravity. The value of " L " is estimated from a graph drawn between distance of point of suspension (l) verses time period of oscillation (T) From the above formula acceleration due to gravity is given by

$$g = 4\pi^2\left(\frac{L}{T^2}\right) \text{Cm}/_{\text{Sec}^2}$$

Procedure: -

1. Observe the centre of gravity G of the bar by counting the number of holes.

2. Insert the metal wedge in the first hole in the bar towards A and place the wedge on the support S1S2 so that the bar can turn round S (figure-2).

3. Set the bar to oscillate taking care to see that the amplitude of oscillations is not more than 50. Note the time for 20 oscillations.

4. Measure the length from the point of suspension to the centre of gravity G of the bar.

5. In the same way suspend the bar at holes 2,3,…….. and each time note times for 20oscillations. Also measure distances from the centre of gravity G for each hole.

6. When the middle point of the bar is passed, it will turn round so that the end B is now on the top. But continue measuring distances from the point of suspension to the centre of gravity G.

7. Now calculate the time period T from the time recorded for 20 oscillations.

8. Plot a curve in excel with length as abscissa and period as ordinate with the centre of gravity of the bar at the origin at the middle of the paper along the abscissa.

9. Put the length measured towards the end A to the left and that measured towards the end B to the right of the origin. A line ABCD drawn parallel to the abscissa

intersects the two curves at A B C and D. Here also the length AC or BD is the length of the equivalent simple pendulum.

Precautions:

1. Angular displacement of the pendulum should be confined to below 10^o.
2. Pendulum should oscillate only in vertical plane, without wobbling.
3. Knife edge should rest on horizontal surface only. The sharp angular edge side of the axial of the pendulum should face towards the resting surface, ensuring lowest surface induced friction as possible.

Observations:

Table -1: Observation for the time period and the distance of the point of suspension from CG for End- A.

Hole. No	Distance from CG L (cm)	Time for 20 Oscillations (Sec)	Mean Time (t) Sec	Period $T = \frac{t}{20}$ Sec
9	45			
8	40			
7	35			
6	30			
5	25			
4	20			
3	15			

2	**10**			
1	**5**			

Table -2: Observation for the time period and the distance of the point of suspension from CG for End- B.

Hole. No	**Distance from CG L (cm)**	**Time for 20 Oscillations (Sec)**	**Mean Time (t) Sec**	**Period $T = \frac{t}{20}$ Sec**
9	**45**			
8	**40**			
7	**35**			
6	**30**			
5	**25**			
4	**20**			
3	**15**			
2	**10**			
1	**5**			

Table 3:

S. No	**T**	**T^2**	**Length of bar pendulum**			**L/T^2**
			AC	**BD**	**L= (AC+BD)/2**	

Graph:

Draw a graph between "D" values on x-axis and corresponding "T" values on Y- axis, then we get the following nature of graph.(Fig 1). Draw a straight line, at one particular "T" value, then it intersect the graph at four points and mark them as A,B,C,& D

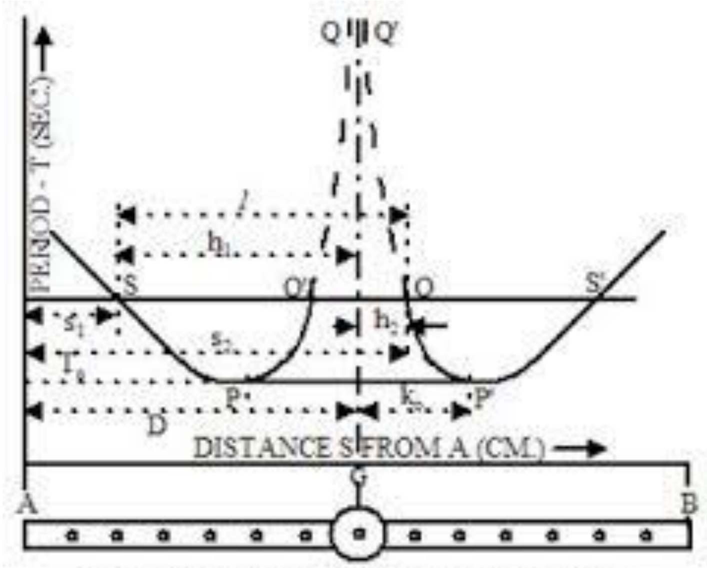


Fig. 2. Graphical analysis of the compound pendulum

Result: - Acceleration due to gravity using compound pendulum = **………… cm /s^2**

Error estimation:

The actual value of the earth's acceleration (g) = 9.8 m/sec^2 or 980 cm/ sec^2

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}\,|}{\text{Actual value}} X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

References:

1. Texla scientific instruments Lab Manual.
2. https://www.studocu.com/row/document/american-international-university-bangladesh/physics-2/experiment-4compound-pendulum/48583615
3. http://www.becbapatla.ac.in:8080/physics/JAN-18%20MODIFIED%20BT_LAB.pdf

e/m THOMSON METHOD

Aim: - Determination of the specific charge (e/m) of an electron by Thomson method.

Apparatus: -

1. Cathode Ray Tube (CRT) is mounted on wooden stand.
2. Power supply fitted with a voltmeter to measure the deflecting voltage.
3. Bar Magnets (Permanent) one pair.
4. Compass box one set.
5. Wooden stand having two arms fitted with scales to measure the distance of the poles of the magnets. The stand can accommodate Cathode Ray Tube in its middle.
6. Another wooden stand also provided to place the compass box in the centre. This wooden stand also be mounted in the middle of the armed stand.

Theory: -

Cathode Ray Tube consists of three basic components:

1. Electron Gun : This consists of a cathode and an anode. It produces, accelerates, and focuses the electrons into a fine beam.

2. The Screen : The screen is coated with fluorescent material like zinc sulphide (ZnS) so that a visible spot is observed when electron beam strikes the screen.

3. Deflecting System. : Two plates are fitted in the tube symmetrically on either side of the electron beam so that electric field perpendicular to the plane of the paper can be applied. A magnetic field can also be applied at the same place in a direction perpendicular to the direction of the electric field i.e., in the plane of the paper. Thus, the deflection of the cathode rays due to the electric as well as the magnetic field takes place in a direction perpendicular to the plane of the paper.

Formula:

$$\frac{e}{m} = \frac{V.y}{lLH^2d} X\ 10^7\ {emu}/{gm}$$

Where H = H_e Tanθ (Where H_e is horizontal components of earth magnetic field of the place where experiment is performed, usually we take its value as 0.345)

Where Various parameters are:

l = Length of horizontal pair of plate.

L = Distance of the screen from the edges of the plates.

V = Voltage applied to the plates.

Y = Total deflection in the spot.

H= Intensity of the applied field.

d = Separation between two plates.

Procedure: -

1. Mount Cathode Ray Tube (CRT) in armed wooden stand such that the CRT faces towards North & South direction while arms of the stand towards East and West Direction.(set the direction with the help of compass box.)
2. Connect the CRT Plug to the power supply socket mounted on the front panel.
3. Switch on the instrument using ON/OFF toggle switch provided on the front panel.
4. Set the deflection voltage to 0 volt & x shift Control potentiometer to middle position. Adjust the intensity & focus of the spot (clear as small as a point) on screen of CRT. Throw the deflection selector switch towards forward position.
5. Read the initial reading of spot on the scale attached to the screen of the CRT, say it is- 0.2 cm. Now give a deflection to the spot in the upward direction by applying deflecting voltage such that the final reading is +0.8 cm. so the total deflection on the screen of the spot is (0.2+0.8)= 1.0 cm. Note down this applied voltage (V) & deflection of the spot (/) in observation table.

6. Now place Bar magnets on both sides of the woodenstand arms such that their opposite poles face each other and their common axis is perpendicular to the axis of Cathode Ray Tube. The magnets should be kept in such a manner that these may be made to slide along the scales.

7 Adjust distances and polarity of the magnets so that the spot traces back to its initial position (which was -0.2 cms).

8. Remove Cathode Ray Tube from stand and place a magnet meter compass box mounted in a stand in centre of the armed wooden stand. Adjust the pointer of the compass box to read 0-0 without disturbing the direction of armed wooden stand.

9. Note down the deflection angle (q) through compass box & note down it in the observation table. Calculate the value of magnetic field (H) by using formula:

$$\mathbf{H = He \tan \theta}$$

(Where He is the horizontal components of earth magnetic field of the place where experiment is performed, usually we take its value = 0.345.) Note down the value of magnetic field (H2) in observation table.

10. Calculate the value of e/m by using formula given.

11. Repeat steps 5 to 10 for other values of spot deflection.

12. Calculate mean value of e/m for different set of readings.

NOTE: For better accuracy apply deflection voltage only up to 20 volts.

Constant of the Cathode Ray Tubes:-

DESCRIPTION

a) Separation between the plates (d) = 10 mm
b) Length of horizontal pair of plate (l) = 25 mm
c) Distance of the screen from the edges of the plates (L) = 130 mm

Precautions:

1. The cathode ray tube should be handled carefully.
2. There should not be any other disturbing magnetic field near the apparatus.
3. Rotate magnet(s) on these axes if spot does not come back to its original position

Observation Table:-

Table 1: Detrmination of deflection for different voltage V

S. No	Applied Voltage (V)	Initial Position (Cm)	Final Position (Cm)	Deflection (Y) (Cm)	Distance of Magnets (Cm)			
					'a' pole	'b' pole	'c' pole	'd' pole

Table 2: Detrmination of the magnetic field

S. No	Applied Voltage (V)	Reading of Pointer				Mean θ	Tan θ	H= H_e Tan θ
		θ_1	θ_2	θ_3	θ_4			

Result: -

The specific charge (e/m) of an electron = ... **emu/gram**

Error estimation:

The actual value of the specific charge (e/m) of an electron = 1.756 x 10^7 emu/gm

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}|}{\text{Actual value}} X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

ENERGY GAP OF A SEMICONDUCTOR

Aim: - Determination of Energy band gap of a given semiconductor.

Apparatus: - D.C Power Supply, Semi-conductor diode (Germanium or Silicon), thermometer, heating arrangement to heat the diode, Voltmeter, Microammeter and connecting wires.

Theory & Formula: - The Energy gap (Eg) of a material is defined as the minimum amount of energy required for an electron to get excited from the top of the valance band to the bottom of the conduction band. The energy gap for metals is zero since the valance band and conduction band overlap each other, whereas the energy gap for the insulators is very high. The energy gap for the semiconductors lies between the values for metals and the insulators.

The resistance of a semiconductor varies with the temperature as

$$R = R_o e^{\frac{E_g}{2KT}}$$

Apply Log on both sides, then

$$\log_e R = \log_e R_o + \frac{E_g}{2KT} ------Equ(1)$$

Where R_0 is the resistance of the semiconductor at absolute zero.

K = 1.381×10^{-23} J/K is the Boltzmann constant and

T is the temperature of the material

Equation (1) is a linear equation between $\log_e R$ and 1/T, and its slope is obtained from:

$$Slope = \frac{E_g}{2KT}$$

Therefore, The formula for Energy band gap is

E_g = 2 x $1.381\text{x}10^{-23}$ x Slope = in Joules.

$$E_g = \frac{2 \text{ x } 1.381\text{x}10^{-23} \text{ x Slope}}{1.601 \ X \ 10^{-19}} \quad \text{in eV}$$

Procedure: -

The experimental arrangement comprises an oil bath with sockets at its mouth. The sockets are used to insert the thermometer and the semiconductor diode. A heating element is fixed inside, which is used to raise the temperature by connecting to the Heater Coil. The reverse biasing voltage can be adjusted using the voltmeter, and the reverse saturation current can be measured with the help of a micro ammeter.

Connecting the two terminals of the given semiconductor diode (Germanium or Silicon) to the DC Power supply and microammeter so that the diode is reverse biased. Immerse the diode in the oil bath. Insert the thermometer at the same level as that of the diode.

Switch on the DC Power supply and adjust the reverse bias voltage to 5 Volts. Switch on the AC main supply, and then the temperature gradually increases. Consequently, the current through the diode also increases. Note the current value of every 5oc increase in the temperature. When the temperature reaches about 65oc, then switch off the Heater. Then, the temperature will rise and stabilizes at about 70oc. Note the temperature and the current through the diode. After a few minutes, the temperature will begin to fall, and the current through the diode decreases. Note the value of the current of every 5oc decrease of the temperature till the temperature falls to room temperature.

Tabulate the values of current and temperature. Repeat the experiment for two or three different voltages.

Precautions:

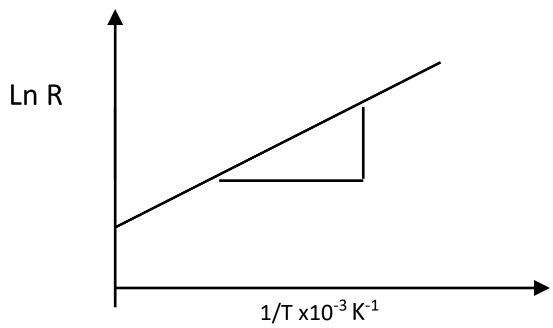
1. Circuit Connections should be done properly as per the circuit diagram.
2. The oven should not be over heated. The maximum temperature should not exceed 75^{O}C.
3. The bulk of the thermometer and the diode should be inserted well in the oven.

Graph:-

Draw a graph between ln R and 1/T

Take 1/T (in kelvins) on the X – axis and ln R on the Y –axis. One should get a straight line which does not pass through the origin. Find the slope of the straight line.

Model Graph



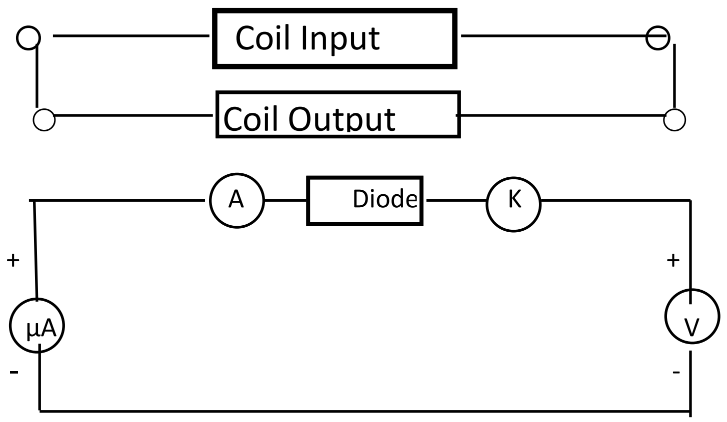
Tabular form: -

S. No	Temperature		Current (µA)		Mean µA	R= (V/I)x10^6 in ohms	Ln R	1/T x 10^{-3} in K^{-1}
	^oC	K	Increasing Temperature	Decreasing Temperature				

Result: -

The Energy band gap of the given semiconductor = ______________________________ **eV**

Circuit Diagram:



Error estimation:

The actual value of the energy band gap of the given semiconductor (Ge) = 0.7 eV

$$\text{Error percentage (\%)} = \frac{|\text{Actual value} - \text{Experimental value}|}{\text{Actual value}} X100$$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

MOMENT OF INERTIA OF FLY WHEEL

Aim: - Determination of the moment of inertia (i) of a fly wheel about its axis of rotation.

Apparatus: - Fly wheel, stop clock, slotted weights, strings, meter scale vernier calliper & screw gauge.

Descriptions: - The flywheel, as shown in fig.1, is a heavy disc usually, made of iron having a large diameter and fitted with an axle having comparatively small diameter. The ends of the axle are mounted on ball bearings, which are rigidly supported against the wall. For counting the rotations made by the flywheel a counter is generally used otherwise it is manually.

Principle: - The moment of inertia (i) of flywheel can be determined using the principle of conservation of energy. According to law of conservation of energy the potential energy gained by the flywheel on winding it is converted into linear kinetic energy of the mass attached, rotational kinetic energy of flywheel and work done against friction. If F is the work done against friction per turn, then:

Formula: -

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}i\omega^2 + n_1 f$$

The moment of inertia (i) of flywheel is given by the formula.

$$\mathbf{i = \frac{M}{n_1 + n_2}\left(\frac{ght^2}{8\pi^2 n_2} - n_2 r^2\right) \ gm - cm^2}$$

here g is acceleration due to gravity = 980 cm - sec $^{-2}$, M is mass, h is height of the weight from ground, t is time and n_1, n_2 are number of turns.

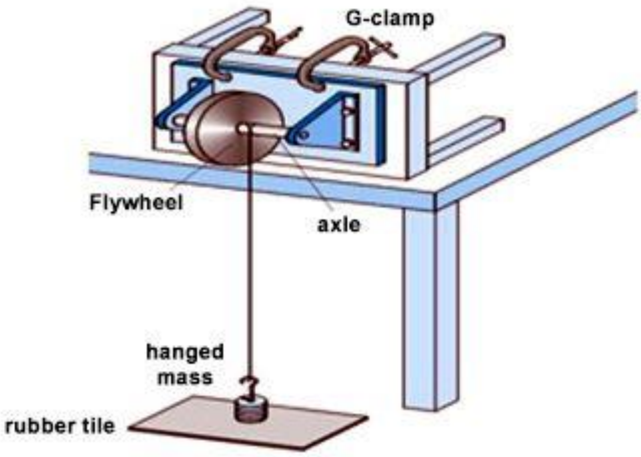


Fig. 1: Fly Wheel

Procedure: -

1. One end of the string is connected to the axle of the flywheel with a pin while the other end is attached with a hanger such that it just touches the ground.
2. The flywheel is turned so that string is wrapped round the axle and count the number of turns n_1 made by the string without overlapping.
3. The height h between the ground and bottom of the load is measured with a scale.
4. Release the wheel and when the load touches the ground, start the stop clock, and measure the time (t) till the flywheel comes to rest. At the same time the number of turns n_2 made by the flywheel is also noted.
5. Measure the radius of the axle r_1 using vernier callipers and measure the diameter of the string (a) using screw guage. The effective radius of the axle r is then given as $r_1+\frac{a}{2}$
6. The experiment is repeated for different values of n_1 and different loads. The results are posted in the tabular form.
7. The moment of inertia of the flywheel about its axis of rotation is calculated using above equation.

Precautions:

1. The load should not rest on the ground, it should hang freely.
2. There should be least friction in flywheel.
3. There should be no kink in string.
4. The stopwatch should be started just after detaching the loaded string.

Tabular form: -

Radius of the Axle: ……………… Cm   Least count= ………………….. Cm

S. No	M.S. R (Cm)	V.C	V.C X L.C (Cm)	M.S.R + (V.C X L.C) (Cm)

Table 2:

S. No	Load (M) In gm	Height (h) In cm	No. of turns (n_1)	No. of Complete Revolutions (n_2)			Time (t) in Sec			i
				Trail 1	Trail 2	Mean	Trail 1	Trail 2	Mean	

Result: - The moment of inertia of flywheel is I = ……………………………… **Kg – m^2**

Error estimation:

The actual value of the moment of inertia of flywheel (in our laboratory) = 0.00021325 kg-m^2

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}|}{\text{Actual value}} X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

References:

4. Texla scientific instruments Lab Manual.
5. https://www.studocu.com/in/document/panjab-university/engineering-mechanics-lab/experiment-03-moment-of-inertia-of-flywheel/17445242.
6. https://youtu.be/9MBE5t1Sv_w (YouTube Video Link)

HALL EFFECT

Aim: - Determination of hall coefficient, charge carrier concentration and mobility of charge carriers in the given sample by using hall apparatus

Apparatus: - Electromagnets and its Constant Current Power Supply Digital Gauss meter, hall Effect Set-up having a milli Voltmeter and a constant current Power Supply (mA) and an n- (or p-) type lightly doped Hall probe Germanium crystal.

Theory: - When an electrical current passes through a sample placed in a magnetic field, a voltage develops across the sample in a direction perpendicular to both the current and the magnetic field. This is known as Hall effect. A rectangular slab of a semiconducting sample with its width (w) along y-direction and thickness (z) along z-direction is placed in a magnetic field of strength B directed along the z-direction. Now an electric current, I_H is made to pass through the sample along its length by maintaining a potential difference along x-direction.

Formula:-

I) The value of Hall coefficient is calculated applying the formula,

- $R_H = \frac{V_H.Z}{I_H}$

Where V_H is hall voltage, Z is the thickness of the sample and I_H is the hall current produced.

II) The value of Carrier Density is calculated applying the formula, $R_H = \frac{1}{nq}$

$$n = \frac{1}{R_H.q}$$

Where n is the carrier density, R_H is the hall coefficient and q is the electron charge.

III) The value of Carrier Mobility is calculated applying the formula,

$$\mu = R_H.\sigma$$

Where σ is the conductivity, R_H is the hall coefficient

Procedure: -

1. Connect the width wise contacts of the Hall probe to the terminals marked 'voltage' and Length wise contacts to terminals marked 'current'.

2. Switch 'ON' the Hall effect setup and adjustment current (say few mA).

3. Switch over the display to voltage side. There may be some voltage reading even outside the magnetic field. This is due to imperfect alignment of the four contacts of the Hall probe and is generally known as the 'Zero field potential'. In case its value is comparable to the Hall voltage it should be adjusted to a minimum possible (for Hall probe (Ge) only). In all cases the error should be subtracted from the Hall voltage reading.

4. Switch on the constant current power supply at any desired value.

5. Measure the magnetic field between the pole pieces of the electromagnet using digital Gaussmeter and also measure the distance between two pole pieces.

6. The Hall probe is placed in between the pole pieces of the electromagnet and rotate the Hall probe till it becomes perpendicular to the magnetic field so that the Hall voltage will be minimum in this adjustment.

7. Measure the Hall voltage as a function of current in the Hall effect setup keeping the magnetic field constant and plot a graph.

8. The slopes (V1 / I1) &(V2 / I2) is to be calculated from the graph.

Precautions:

1. The current through the sample should not be large enough to cause heating.

2. The pressure contacts should be clean and firm to avoid noise.

Observations:-

S.No	Constant Magnetic Field B_1 = ... Gauss		Constant Magnetic Field B_1 = ... Gauss	
	Current I_1 (mA)	Voltage V_1 (mV)	Current I_2 (mA)	Voltage V_2 (mV)

Result: -

1. The value of Hall coefficient (R_H) is = ________________________

2. The value of Carrier Density (n) is. = ________________________

3. The value of Carrier Mobility (μ) is. = ________________________

Model Graph:

A graph is plotted between Hall current (I_H) and Hall voltage (V_H) for two constant magnetic fields.

Error estimation:

The Actual values of

The value of Hall coefficient (R_H) is = 19.28 x 10^3 cm^3/coulomb

The value of Carrier Density (n) is. = 3.24 x 10^{14} cm^{-3}

The value of Carrier Mobility (μ) is. = 1.928 x 10^3 V^{-1} sec^{-1}

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}|}{\text{Actual value}} X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

References:

1. https://lecturenotes-classroom-assignment-and-submission.s3.ap-south-1.amazonaws.com/3-b095c39ddc-eng-phy-lab-ref-material-expt-10-hall-effect.pdf

LASER DIFFRACTION EXPERIMENT

Aim: - Determination the wavelength of a given laser source by using diffraction grating.

Apparatus: - Laser diode module, grating, scale and screen etc.

Theory: - The word "diffraction" refers to the spreading out of waves after passing through a small opening. Diffraction effects are important when the size of the opening is comparable to or less than the wavelength.

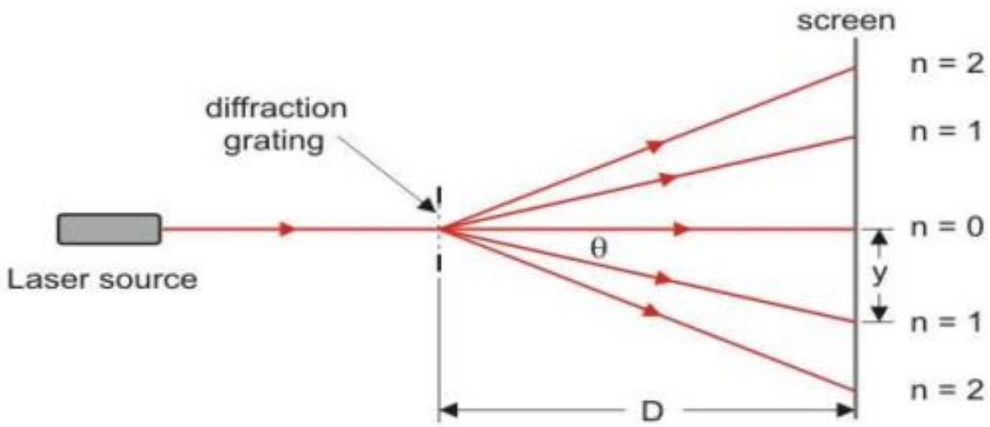
To measure wavelengths, we need a device that can split a beam of light up into different wavelengths. Such a device is a diffraction grating. A transmission diffraction grating consists of a very large number of equally spaced parallel lines scratched on a transparent surface. The diffraction gratings used in this experiment are plastic replicas of a master grating, made by pressing the plastic against the master grating, which acts as a Mold. A diffraction grating behaves as if it were a series of slits in an opaque screen.

Formula: -

$$\lambda = \frac{\sin\theta}{n \cdot N}\, cm\ (or)\ A^0$$

Where λ is the wavelength of light; θ is angle of diffraction. n is order of maximum. N is grating element, i.e., **N** = No. of lines per inch / 2.54 = number of lines/cm on a grating

Diagram:



Procedure: -

The laser diode module is mounted horizontally. A diffraction grating (2500LPI) is placed on a stand at the same height and adjusted for normal incidence. When laser is switched on, we get diffraction maxima on a scale placed at about 0.3 m distance (D) with respect to grating. The distances between different orders on left and right side (2x) are measured and tabulate.

This procedure is repeated for different values of D and the results are tabulated as follows.

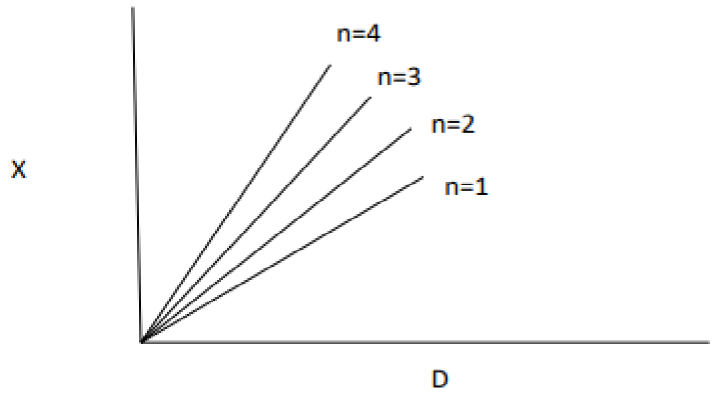
Precautions:

1. The Laser diode should not be disturbed throughout the experiment.
2. Be careful while measuring the distance of order of maxima.
3. Experiment should be performed in the dark room.

Observation Table:-

S. No	Distance between grating and screen (D)	Order of diffraction (n)	Distance Between corresponding order (2X) Cm	Distance between centre and maximum (X) Cm	θ = $\tan^{-1}$ (X/D)	sin θ	λ = Sin θ /n. N
1	30 cm	1 2 3					
2	40 cm	1 2 3					
3	50 cm	1 2 3					

MODEL GRAPH:



Result: -

The wavelength of the given laser beam is λ = …………………………… **cm**

Error estimation:

The actual wavelength of the given laser beam is λ = 6500 A°

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}|}{\text{Actual value}} X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

NEWTON'S RINGS

Aim: - Determination of the Radius of curvature of the plano-convex lens by source forming Newton's rings.

Apparatus: -

Traveling microscope, sodium vapour lamp, plano-convex lens, plane glass plate, magnifying lens.

Theory: -

When a Plano-convex lens with its convex surface is placed on a plane glass plate, an air film of gradually increasing thickness is formed between the two.

If a monochromatic light is allowed to fall normally on this combination and the combination is viewed in fig., then a pattern of alternate light and dark circular rings can be observed.

These circular fringes are called Newton's rings. The fringes are circular because the air film has a circular symmetry. They are formed because of interference between waves reflected from the top bottom surfaces of the air film formed between the plates.

1. To observe sustained interference in light during an optical experiment two conditions must be satisfied.
   a) The sources must be coherent that is they must maintain a constant phase difference.
   b) They must be monochromatic
2. In young's double slit experiment and Fresnel's biprism the condition for dark fringes is $d \sin\theta = (m+\frac{1}{2})\lambda$ (m=0,1,2....)

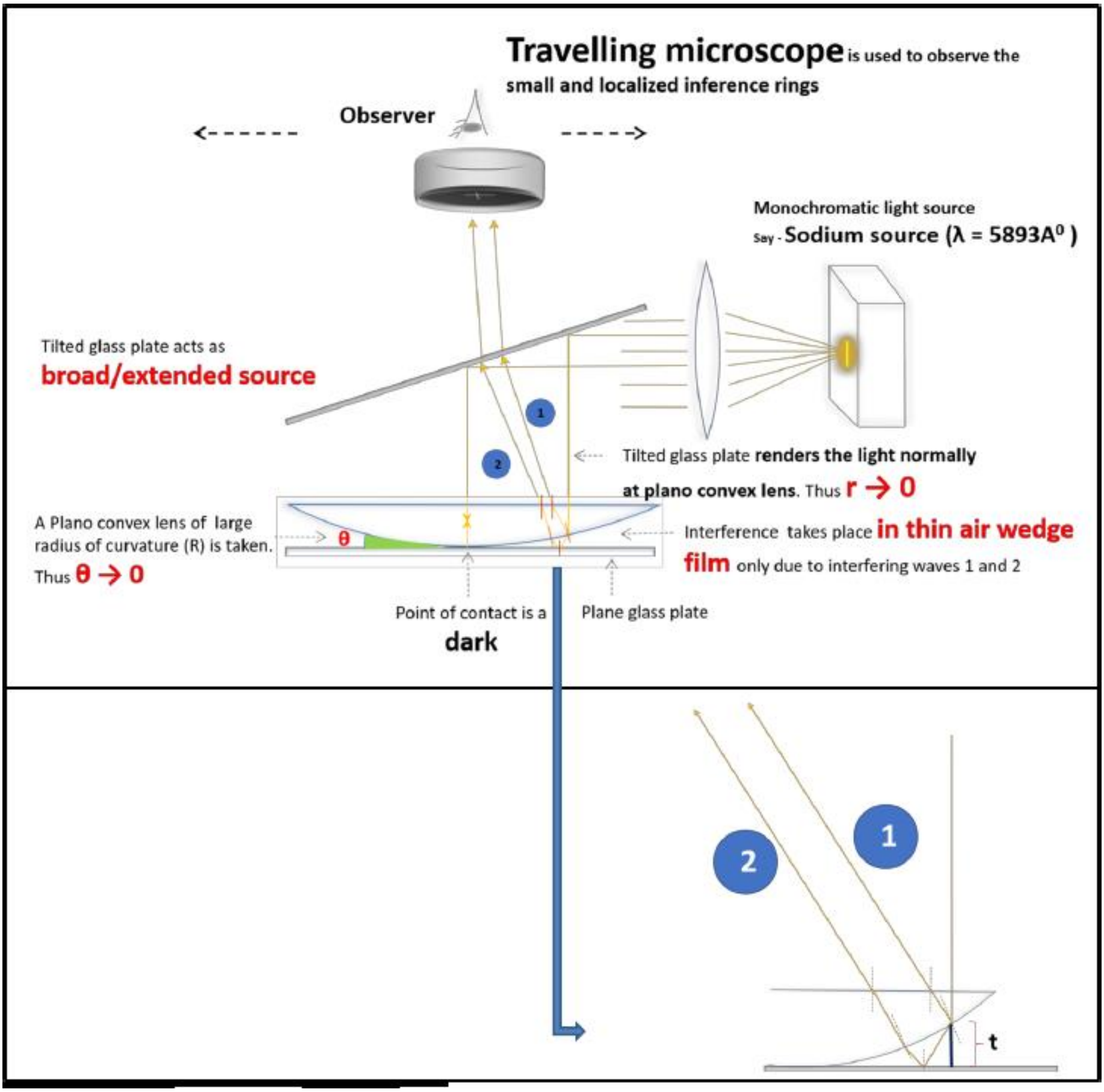
   Here the interference is due to the division of wave front.

3. Interference is possible by the division of amplitude. Interference effects are commonly observed in thin films. Consider a film of uniform thickness t and refractive index n.

Let us assume that light rays in air are nearly normal to the surfaces of the film. In this case interference occurs when light rays reflected from upper and lower surfaces of the film combine.

The equation for destructive interference is $2\mu t=m\lambda$ (m=0, 1, 2…..) where μ is the refractive index of the medium and $\mu=1$ for air.

A similar situation exists in the Newton's rings set up. On looking through the microscope alternate yellow and dark rings will be seen. Definition of the rings can be improved small adjustments reflecting glass plate and source. The innermost rings are avoided as they are not quite circular.



Formula: -

Diameter $(D_n)^2$ of n^{th} dark ring is given by $(D_n)^2 = 4n\lambda R$ where λ is wavelength of the given light source.

Similarly diameter for the $(n+p)^{th}$ dark ring is $(D_{n+p})^2 = 4(n+p)\lambda R$

$$(D_{n+p})^2 - (D_n)^2 = 4\,PR\lambda$$

$$R = \frac{(D_{n+p})^2 - (D_n)^2}{4P\lambda}\ cm$$

Procedure: -

Set the point of intersection of the cross wires at the centre of the ring system. Rotate the microscope about its axis, so that one cross wire is at right angles to the direction of motion of the microscope and the other parallel to it. This will enable us to make the vertical cross wire tangential to any of the rings.

Set the cross wire tangential to say the 15th dark ring on ONE side (say the left hand side) of the central dark. Spot counting the central dark spot as zero. Read the microscope position. The main scale has 90 millimetres engrave on it. The least count is 1mm/100=0.01mm. Because when the micrometre head is turned through 1 complete revolution it means a distance of 1mm. on the main scale. To take any reading the procedure is to record it as follows

(M.S.R in mm + x (0.01mm)) where x is the number indicated on micrometre head.

Repeat the procedure till the 5th dark ring on the left appears in the field of view. Move on, turning the screw in the same direction till the vertical cross wire is successively tangential to 5th dark ring on right, 6th dark ring on right and so on till the 15th dark ring is reached. [Direction of rotation of screw must be the same throughout]. The results are tabulated as follows.

Precautions:

1. The glass plate surface and the lens surface must be thoroughly cleaned otherwise the fringes will not be bright and sharp.
2. The microscope's eyepiece must be properly focused on its crosswire. The microscope should be given motion only along one direction to avoid backlash error.
3. The planoconvex lens should be of large radius of curvature.

Observations:-

No. of Ring	Micrometre Reading		Difference D	D^2
	On the Left	On the Right		
10				
9				
8				
7				
6				
5				

Result: -

The Radius of curvature of the given Plano-convex lens is = …………… **Cm**

Error estimation:

The actual value of the radius of curvature of the given plano-convex lens = 100 cm

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}\,|}{\text{Actual value}}\, X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

Photo electric effect - PLANCK'S CONSTANT

Aim: - Determination the value of Plank's constant 'h' and the Work function (w) of a given Photocell by using Phot electric effect.

Apparatus: - Photo emissive cell mounted in a box provided with a wide slit, D.C. Power Supply, set of filters, filter stand, light source.

Theory: - The phenomenon of emission of electrons from the surface of a material when light falls on it, is known as the photoelectric effect. The emitted electrons are called photoelectrons. Light falls on a target metal plate T enclosed in a vacuum tube and as a result electrons are ejected from the surface of the plate. When the ejected electrons reach the collector electrode C placed opposite to T, an electric current, called photocurrent flows through the circuit. This photocurrent can be measured by an ammeter connected to the circuit. The kinetic energies of the emitted electrons can be estimated by applying a negative potential to the collector C and tuning the potential such that it is just enough to prevent the electrons from reaching the collector. This negative potential, V_0 to C at which the photo current becomes zero, is called the stopping potential.

Formula: -

The photoelectric equation can be written as follows.

$$h\nu = h\nu_0 + E_{max} \text{ -------------------- } (1)$$

$$h\nu = W_0 + eV_s$$

If V_s is the applied stopping potential, $eV_s = h\nu - W_0$

$$\textbf{Work function } (W_0) = h\nu - eV_s$$

$$V_s = [h/e]\,\nu - [W_0/e] \text{ ------------- } (2)$$

Equ (2) is in the form of Y=mx + c. Therefore, the slope = h/e

$h = e \times slope$ in Joules. sec

Procedure: -

For Plank's Constant:

1. Make the circuit connections as per the circuit diagram provided after that before switching on the light source adjust the ammeter and voltmeter readings to zero.

2. A light source is arranged. The light is allowed to fall on the tube. The distance between tube and light source is adjusted such that there is a deflection in between 40 to 80 uA. Now a suitable filter of known wavelength is placed in the path of light (in the slit provided) say it is with wavelength λ_1.

3. A deflection is observed in the micro-ammeter. This deflection corresponds to the zero-anode potential.

4. Now vary the DC voltage slowly by knob and see the value of current. It should decrease as the voltage is increased.

5. When the current becomes zero, note the value of applied voltage by DC voltmeter. This is the stopping potential V_1 for the given colour. Switch off the DC voltage source.

6. The experiment is repeated after replacing the green filter with blue and red filters. Say with wavelength λ_2 and λ_3 respectively and stopping potential V_2 and V_3 are noted.

7. Taking frequency on x-axis and stopping potential on y-axis, graphs are plotted.

8. By using above values Plank's Constant 'h' is calculated by the formula given. Standard values of e, c and wavelength of standard filters are given below.

$e = 1.6 \times 10^{-19}$ coulombs $\qquad$ $C = 3 \times 10^{8}$ m/sec. $= 3 \times 10^{10}$ cm/sec

Wavelength of green filter $\lambda_1 = 5645 \times 10^{-10} \pm 2\%$ meter.

Wavelength of orange filter $\lambda_2 = 6125 \times 10^{-10} \pm 2\%$ meter.

Wavelength of blue filter $\lambda_3 = 5265 \times 10^{-10} \pm 2\%$ meter.

Precautions:

1. Fix the incident light source and filter positions exactly with suitable distance.

2. Stopping potential should be note down exactly at zero ammeter reading.

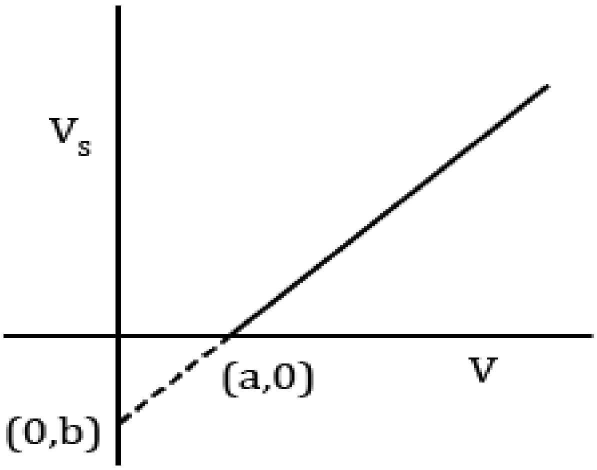
3. The negative potential must be applied very slowly until zero current value is reached.

Observations:

S. No	Colour of the filter	Frequency (ν)	Stopping Potential (V_s)

Graph:

Plot a graph between frequency on x-axis and stopping potential on y-axis from data in Table .

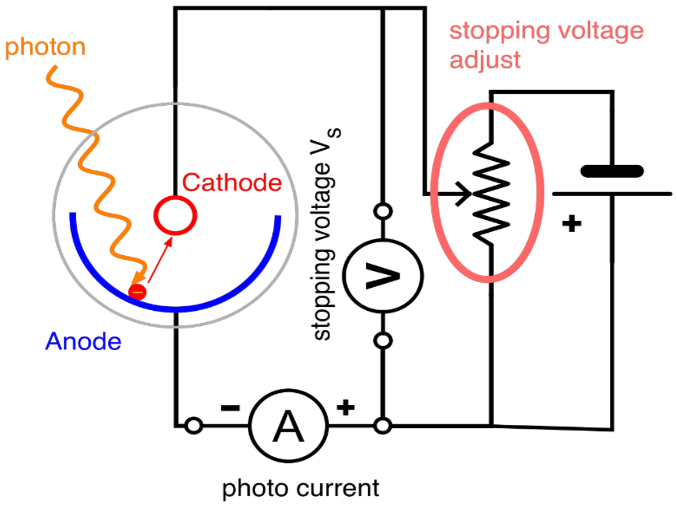


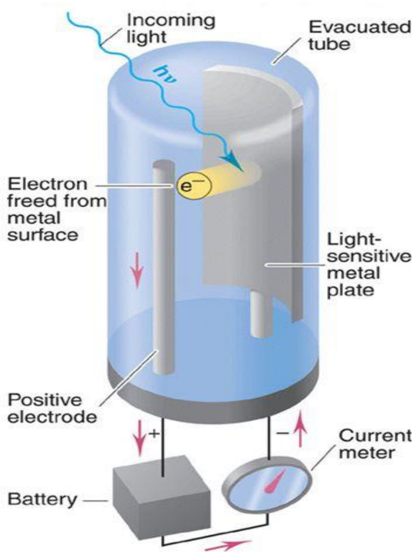
Result: -

1. The value of Planck's constant (h) = ____________________________ **J-S**

2. The value of Work function (W_0) = _____________________________**eV**

Circuit Diagram:





Error estimation:

The actual value of the value of Planck's constant (h) = 6.626×10^{-34} Joule-sec.

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}|}{\text{Actual value}} X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

SOLAR CELL CHARACTERISTICS

Aim: - To Obtain the characteristics of a given solar cell.

Apparatus: - Trainer board consists of Voltmeter, Ammeter and Two variable resistance, Solar cell, Source of light and connecting wires.

Theory: - Solar cell is basically a two terminal p-n junction device designed to absorb photon absorption through the electrical signal or power in the external circuits. Therefore it is necessary to discuss the physics of semiconductor p-n junction diode, which converts the optical energy into electrical signals. It is well known that doped semiconductors are of two types, p and n- types semiconductors depending upon the nature of the charge carriers. In n-type semiconductor the free carriers are electrons and in p- type semiconductor, the positive charge carriers are holes. Since the semiconductors are electrically neutral, in a doped semiconductor the number of free carriers is equal to the lattice ions present in the semiconductor

A solar cell is illuminated by light having photon energy greater than the band gap energy of the solar cell. Then, using a proper circuit, the open circuit voltage, short circuit current and power drawn from the solar cell are measured.

Formula: - The Characteristics of the Solar cell we are going to observer in this experiment are

$$\text{Fill Factor} = \frac{P_{Max}}{I_{sc}V_{oc}}$$

$$\text{Series Resistance } (R_s) = \frac{\Delta V}{\Delta I}$$

Procedure: -

1. Complete the circuit as shown in circuit diagram
2. Illuminate the solar cell. Adjust the Rh position for resistance so that the volt meter reads zero & ammeter reads a value of max value. This is the short circuit connection. Note down the value of the current as short circuited current, I_{sc}

3. Increase the resistance by varying the Rh slowly and note down the readings of current and voltage till a maximum voltage is read. Ensure to take at least 5 – 10 readings in this region

4. Disconnect the Rh and note down the voltage. This is the open circuit voltage, Voc.

5. Repeat the experiment for another intensity of the illumination

6. Tabulate all readings in Table 1. Calculate the power using the relation, P = V x I

7. Plot I vs. V with Isc on the current axis at the zero volt position and Voc on the voltage axis at the zero current

8. Identify the maximum power point Pm on each plot. Calculate the series resistance of the solar cell using the formula as follows : RS = [$\Delta V/\Delta I$].

9. To see the performance of the cell calculate fill factor (FF) of the cell, which can be expressed by the formula, FF = [Pm/Isc Voc].

10. Repeat the experiment with distance varying from source to solar cell for example say 50cms

11. Note the reading of Voltmeter , Ammeter & also Rh Load resistance value by varying provided on Board. Tabulate all readings in Table 2

Precautions:

1. The circuit should be connected properly as per circuit diagram.
2. The light from source should fall normally on the cell.
3. Light exposure time should be optimum as over exposure of light will heat the cell, which subsequently degrade the cell performance.

Observations: -

Table 1

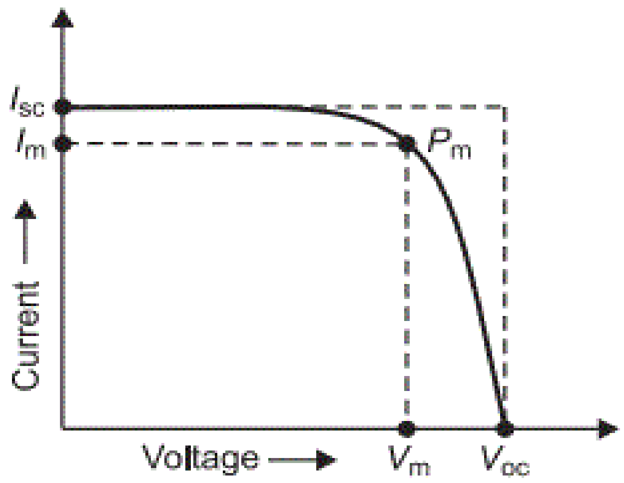
Voltage (V)	Current (mA/μA)	Power (P) = V x I

Table 2

Voltage (V)	Current (mA/μA)	Power (P) = V x I

Graph:

Graph is taken between voltage and current. Voltage is taken on X-axis and output current is taken on y- axis.



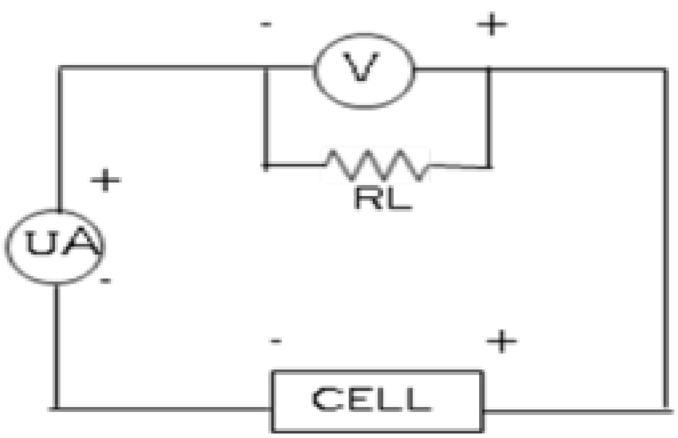
Result: -

The Characteristics of the solar cell is obtained practically

1. Fill Factor (FF) = ______________________________

2. Series Resistance (R_S) = _______________________________ **Ohms**

Circuit Diagram:



Error estimation:

The actual value of the Fill Factor (FF) = 1

The actual value of the Series Resistance (R_S) = 100 K Ohms /10 K Ohms

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}|}{\text{Actual value}} X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

STEFAN'S LAW

Aim: - To verify Stefan's law by electrical method.

Apparatus: - Battery, D.C. Voltmeter, D.C. ammeter, Electric bulb (having tungsten filament) of 6V, Resistance, Connecting wires.

Theory & Formula: - According to Stefan's –Boltzmann's law the heat energy E Radiated per unit area per second by a body at temperature T surrounded by another body at temperature To then by Stefan's law

$$E = \alpha T^4 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where, α = Stefan's constant. (5.67 x 10-8 W/m2k4)

For the bodies other than black bodies, the similar relation for the power emitted by a body at temperature T surrounded by another body at temperature T_0 is given as

$$P = C\,(T^4 - T_0^4) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

Where C is some constant which depends on the material and area of the body and α is a power very close to 4. Further

$$P = CT^{\alpha}(1 - T_0{}^{\alpha}/T^{\alpha}),\ \text{If } T >> T0,$$

then the above relation reduces to

$$P = CT^{\alpha} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Taking logarithm on both sides, we get

$$Log_{10}P = \alpha Log_{10}T + Log_{10}C \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (4)$$

Eq. (4) gives the straight line graph. Therefore a graph between $\log_{10}P$ & $\log_{10}T$ should be straight line whose slope gives α. The value of α is equal to 4, then Stefan's law is verified.

Procedure: -

Step 1: Determination of the filament resistance (R_0) at filament temperature $t = 0^0C$

To determine the value of R_0, first find out the filament glow resistance (Rg) at temperature (t) Now to obtain this value of Rg, let allow the minimum current to flow through the filament so that just glow is seen, and corresponding voltage is measured as per table 1.

$$R_g = \frac{V_g}{I_g}$$

Table 1:

V_g	I_g

Now when R_g is known, R_0 can be determined using the relation $R_0 = R_g / 3.9$

Step 2: Now increase the current I regularly with increase and corresponding V is measured.

Table 2: Determination of power dissipated, P for different temperature T

S. No	Filament Voltage V_f (Volt)	Filament Current I_f (mA)	Resistance $R_f = V_f/I_f$	R_f/R_o	Temp (K)	Power (P) = $V_f \cdot I_f$ watt	Log_{10} P	Log_{10} T

Precautions:

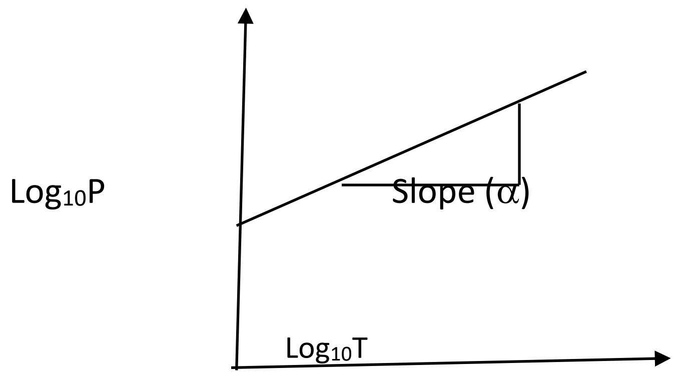
1. The body you consider must at least approximate to a blackbody.
2. The connection should be tight.
3. Temperature Calculations should be done carefully.
4. The slope of straight line should be determined as accurate as possible.

Result: -

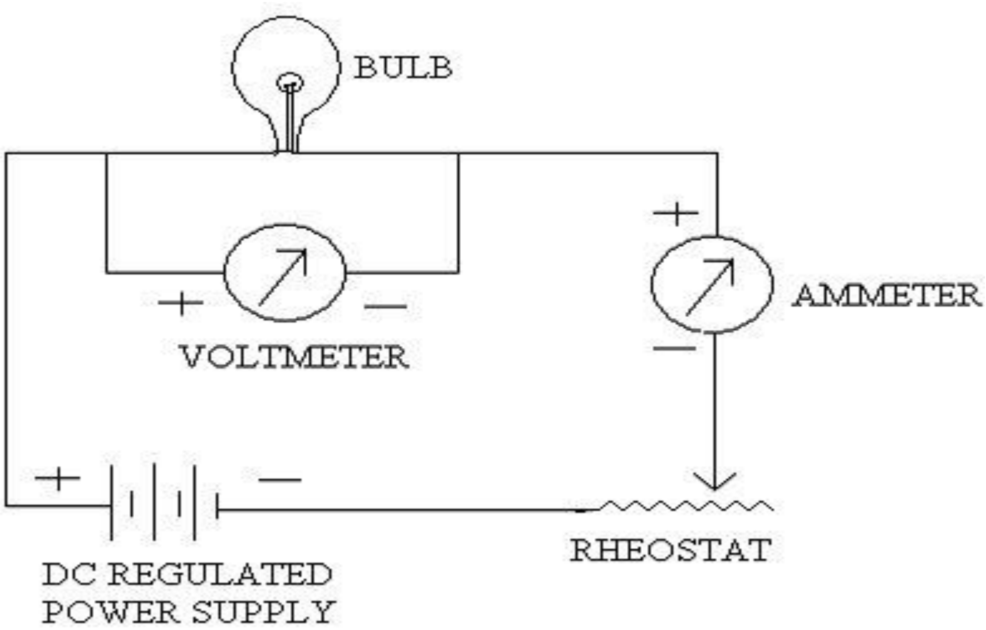
The graph between $Log_{10}P$ and $Log_{10}T$ is a straight line with a slope of the line α = ………. Which is almost equal to 4. Hence, Stefan's law is verified within the experimental error.

Model Graph:

The graph is plotted by taking log T on X-axis & log P on Y-axis. The graph will be a straight line. Find the slop which would be 4.



Circuit Diagram:



Error estimation:

The actual value of the Stefan's law = 4

Error percentage (%) = $\frac{|\text{Actual value} - \text{Experimental value}|}{\text{Actual value}} X100$

Assignments for the student:

1. List the possible factors for the error:

2. Provide maximum three (at least one) applications of this experiment/result:

Temperature Calculation Table:

Temp. in ^{o}C	R_T/R_0	Temp. in ^{o}C	R_T/R_0
0	1.00	1100	7.60
100	1.53	1200	8.26
200	2.07	1300	8.90
300	2.13	1400	9.70
400	3.22	1500	10.43
500	3.80	1600	11.17
600	4.40	1700	11.42
700	5.00	1800	12.67
800	5.64	1900	13.50
900	6.37	2000	14.30
1000	6.94		