DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

Bangladesh University of Business and Technology

Lab Manual

Department of EEE
BUBT

Program	**: B.Sc. Engineering in EEE**
Course Code	**: PHY-104**
Course Title	**: Physics Lab**
Course Credit	**: 1.50**
Contact Hours	**: 3_{hrs}**

Introduction

This course will mainly focus on Electricity (Specific resistance of a wire, emf of one cell and compare e.m.f. of two cell, verify the laws of resistance by P.O. Box), Heat & Thermodynamics (Mechanical equivalent of heat 'J'), Physical Optics (Newton's ring, Specific rotation of sugar solution, wavelength of various spectral lines), Sound (Frequency of a tuning fork).

1. Course Objectives

This course will provide practical knowledge by applying the experimental methods to correlate with the Physics theory and the ideas of different measuring devices and meters to record the data with precision.

2. Course Outcomes

Upon completion of this course, students will be able to:

CO1: To apply the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results;

CO2: To develop intellectual communication skills through working in groups in performing the laboratory experiments and by interpreting the experimental results;

CO3: Select and use modern hardware and software tools and devices

CO4: Assess societal, health, safety, legal and cultural issues involved with the mini project

CO5: Realize the impact of societal, environmental and sustainable development issues for the design solution of mini project.

CO6: Apply professional ethics and responsibilities in the implementation of mini project.

CO7: Work individually and in a team

CO8: Communicate and share knowledge, data, information, results etc. with others

CO9: Apply engineering project management knowledge and skill to implement the mini project.

CO10: Gather and apply knowledge, data and information from various multidisciplinary sources to analyze, design and implement the mini project

3. Course Outcomes (COs), Program Outcomes (POs) and Assessment:

CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
Upon completion this experiment, students will be able to: **CO1: To apply** the various procedures and techniques for the experiments, mathematical equations and graphical analysis to the experimental data to obtain quantitative results	**PO1– Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☑ Project show & project presentation
CO2: To develop intellectual communication skills through working in groups in performing the laboratory experiments and by interpreting the experimental results;	**PO9–- Team Work**	**Psychomotor**		
CO3: Select and use modern hardware and software tools and devices	**PO10- Communication**	**Affective domain/ Psychomotor**		
CO4: Assess societal, health, safety, legal and cultural issues involved with the mini project	**PO6- The engineer and society**	**Affective domain/ Psychomotor**		☐ Lab tests

				☐ Lab reports ☐ Final lab test ☐ Open ended lab ☑ Project show & project presentation ☑ Continuous lab performance
CO5: Realize the impact of societal, environmental and sustainable development issues for the design solution of mini project.	**PO7- Environment and Sustainability**	**Affective domain/ Psychomotor**		
CO6: Apply professional ethics and responsibilities in the implementation of mini project.	**PO8- Ethics**	**Psychomotor**		
CO7: Work individually and in a team	**PO9- Individual work and teamwork**	**Affective domain**		
CO8: Communicate and share knowledge, data, information, results etc. with others	**PO10- Communication**	**Affective domain**		☑ Project show & project presentation
CO9: Apply engineering project management knowledge and skill to implement the mini project.	**PO11-Project management and finance**	**Affective domain/ Psychomotor**		☑ Project show & project presentation
CO10: Gather and apply knowledge, data and information from various multidisciplinary sources to analyze, design and implement the mini project	**PO12-Life-long learning**	**Affective domain/ Psychomotor**		☑ Project show & project presentation

4. Text Book

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin.

5. Reference

1. 1. Physics II Lab Manual Sheets, EEE Department, BUBT

2. Practical Physics, R.K. Shukla and Anchal Srivastava

6. Weekly Schedule

Exp. No	Name of the Experiment	No. of Week
Exp. 01	To determine the radius of curvature of a lens by Newton’s rings.	Week1
Exp. 02	To calibrate a polarimeter and hence to determine the specific rotation of a sugar solution by means of a polarimeter.	Week2
Exp. 03	To determine the moment of inertia of a fly-wheel about its axis of rotation.	Week3
Exp. 04	To determine the specific resistance of a wire by using a meter bridge.	Week4
Exp. 05	To determine the e.m.f of a cell with a potentiometer of known resistance.	Week5
Exp. 06	To compare the e.m.f of two cells with a potentiometer	Week6
	Mid Examination	Week7
Exp. 07	To determine the wavelength of various spectral lines by a spectrometer using a plane diffraction grating.	Week8
Exp. 08	To determine the mechanical equivalent of heat ‘J’ by electrical method.	Week9
Exp. 09	To determine the value of unknown resistance and verify the laws of series and parallel resistance by Post Office Box.	Week10
Exp. 10	To verify the laws of transverse vibration of springs and to determine the frequency of a tuning fork by Melde’s experiment.	Week11
Exp. 11	To determine the stopping potential from the photocurrent versus applied potential graph.	Week12
Exp. 12	To find the temperature coefficient of resistance of a given coil.	Week13
	Final Examination	Week 14

Experiment Number: 1

Name of The Experiment: Determination of the radius of curvature of a lens by Newton's rings.

Objectives:

a) To observe the interference of light and learn how this pattern helps to determine the radius of curvature of a Plano-convex lens.

b) To determine the wavelength of monochromatic light by Newton's rings.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

<table>
<tr><th>Expt. No.</th><th>CO Statement</th><th>Correspon ding PO</th><th>Domain / level of learning taxonomy</th><th>Delivery methods and activities</th><th>Assessment tools</th></tr>
<tr><td rowspan="2">01</td><td>Upon completion this experiment, students will be able to:
CO1: use the various procedures and techniques for determination Newton's ring.</td><td>PO1– Engineering knowledge</td><td>Affective domain/ analyzing level</td><td rowspan="2">☑ Simulation
☑ Experiment
☑ Practice lab
☑ Group discussion
☐ Tutorial</td><td rowspan="2">☑ Lab tests
☑ Lab reports
☑ Final lab test
☐ Open ended lab
☐ Project show & project presentation</td></tr>
<tr><td>CO3: learn the writing techniques of lab report in a systematic way.</td><td>PO10- Communication</td><td>Affective domain</td></tr>
</table>

Theory:

If a convex lens and a plane plate of glass are placed in contact with each other, Newton's ring are formed as a result of interference between two reflected rays from the bottom and top of air film between glass plates and lens. Near the point of contact, the thickness of the air film will be very small in comparison with the wavelength of light. Consequently, a circular black spot, when viewed by a transmitted light will surround the point of contact of lens and the plate. As the surface of the lens is a portion of a sphere, the thickness of the air film will be increasing from the point of contact towards the periphery of the lens and will be uniform for all points on a circle, concentric with the point of contact. Thus the central black spot shown by reflected light will be surrounded by a concentric bright rings separated by dark rings.

In Fig.1 *COD* represents a lens the convex surface of which is in contact with the plane glass *AB* at *O*, Fig.1 when viewed normally by reflected light. The points *C* and *D* equidistant from *O* will lie on a bright or a dark ring according as twice the distance *DB* (or *CA*) is equal to an odd or even number of half wave-length of incident light. From *O* draw the diameter *OF* of the circle of which the curved section of the lens is *COD*. Join *CD* cutting *OF* in *E* let *DB* = *CA* = x_1 and let D_n denote the diameter *CD* of the *n*th ring under observation. If *R* is the radius of curvature of the lower surface of the lens, then we have

OE . EF = CF . ED

or, $x_1(2R - x_1) = \left(\frac{D_n}{2}\right)^2$

$\Rightarrow 2R\,x_1 - x_1^2 = \left(\frac{D_n}{2}\right)^2$

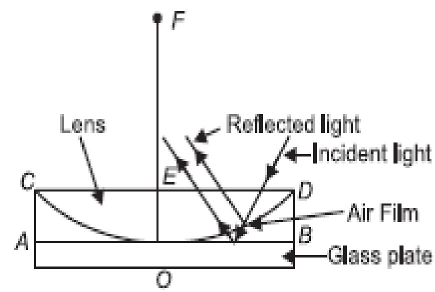

Fig.1: Newton's rings

Since x_1 is very small as compared to *R*, we have

$x_1^2 << 2Rx_1$

$\Rightarrow 2R\,x_1 = \left(\frac{D_n}{2}\right)^2$

$\Rightarrow x_1 = \frac{D_n^2}{8R}$

For *C* and *D* to be situated on a bright ring, we have

$2\mu x_1 = (n + \frac{1}{2})\,\lambda$

$\Rightarrow 2\,\frac{D_n^2}{8R} = (n + \frac{1}{2})\,\lambda$ [μ = 1 for air]

$\Rightarrow \frac{D_n^2}{4R} = (n + \frac{1}{2})\,\lambda$ ……….. (1)

When *n* has values 1, 2, 3, ... etc., for the first, second, third, fourth etc rings respectively.

The above formula is sufficient to give the value of R, if *a traveling microscope measures D* and λ is given.

From the formula (1) we see that *R* and λ (For a particular set up) are constant, thus

$D_n^2 = 4R\,(n + \frac{1}{2})\,\lambda$ ………… (2)

$D_{n+p}^2 = 4R\,(n+p + \frac{1}{2})\,\lambda$ ………. (3)

Hence if we draw curve with the square of the diameter as ordinate and the number of rings as abscissa, the graph will be a straight line.

Subtract equation (2) from equation (3), we have

$D_{n+p}^2 - D_n^2 = 4Rp\lambda$

$\therefore R = \frac{D_{n+p}^2 - D_n^2}{4p\lambda}$ ………….(4)

Thus the diameter of the $(n+p)^{th}$ and n^{th} rings are to be found and substituted in the above formula to get R.

Diagram: The optical arrangement for Newton's ring is shown in Fig.2.Light from a monochromatic source (sodium light) is allowed to fall on a convex lens through a broad slit, which renders it into a nearly parallel beam. Now it falls on a glass plate inclined at an angle 45° to the vertical, thus the parallel beam is reflected from the lower surface. Due to the air film formed by a glass plate and a plane-convex lens of large radius of curvature, interference fringes are formed which are observed directly through a travelling microscope. The rings are concentric circles.

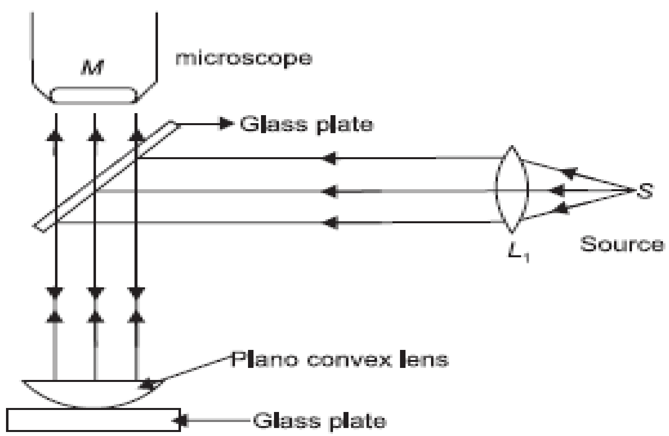

Fig.2: Experimental set up of Newton's ring

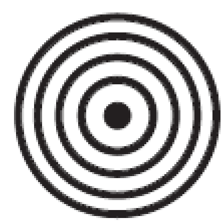

Fig.3: Newton's ring

Required Equipment and Devices:

1. Travelling microscope
2. Plano-convex lens,

3. Sodium lamp set, etc.

Procedures:

(i) Arrange your apparatus as shown in figure. Level the microscope so that the scale along which it sides is horizontal and the axis of the microscope is vertical. Focus the eye-piece on the cross-wires. Determine the Vernier constant of the micrometer screw of the microscope.

(ii) Carefully clean the surface of the lens L and the glass plate P by means of cotton moisted with alcohol. Place the glass plate P and lens L vertically below the microscope objective.

(iii) Place the glass plate G in its position, as shown in figure, in such a way that light from the source S, after passing through the lens C, is incident on it at an angle of approximately 45^0. If you now look into the microscope, you will probably see a system of alternate dark and bright rings. Adjust the glass plate G by rotating it about a horizontal axis until a large number of evenly illuminated bright and dark rings appear on both sides.

(iv) After completing these preliminary adjustments, focus the microscope to view the rings as distinctly as possible and set one of the cross-wires perpendicular to the direction along which the microscope slides. The cross-wire should pass through the middle of the ring and should be tangential to it. Note the reading of the microscope. Turn the screw always in the same direction to avoid any error due to back-lash. Set the cross-wire carefully on the centre of each successive bright ring and observe the microscope reading. Go on moving the microscope in the same direction. Repeat the operation for dark ring also. Considering a particular ring, the difference between the left side and right side readings, gives the diameter of the ring.

(v) Draw a graph with the square of the diameter as ordinate and number of the ring as abscissa. The graph should ne straight line.

(vi) From the graph determine the difference between the squares of the diameters of any two rings. Now calculate R with help of the equation (4)

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. When heating anything.
    2. When using any type of projectile.
    3. When instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Collection:

Table 1: Determination of diameter of the rings

Ring number	Readings of the microscope										Diameter, D= L~R (cm)	D^2 $(cm)^2$
	Left side					Right side						
	MSR (cm)	VSD	VC (cm)	VSR (cm)	Total (cm)	MSR (cm)	VSD	VC (cm)	VSR (cm)	Total (cm)		
1												
2												

3												
4												
5												
6												
7												
8												
9												
10												

Data analysis and demonstration:

1. Graph of the square of diameter vs ring number

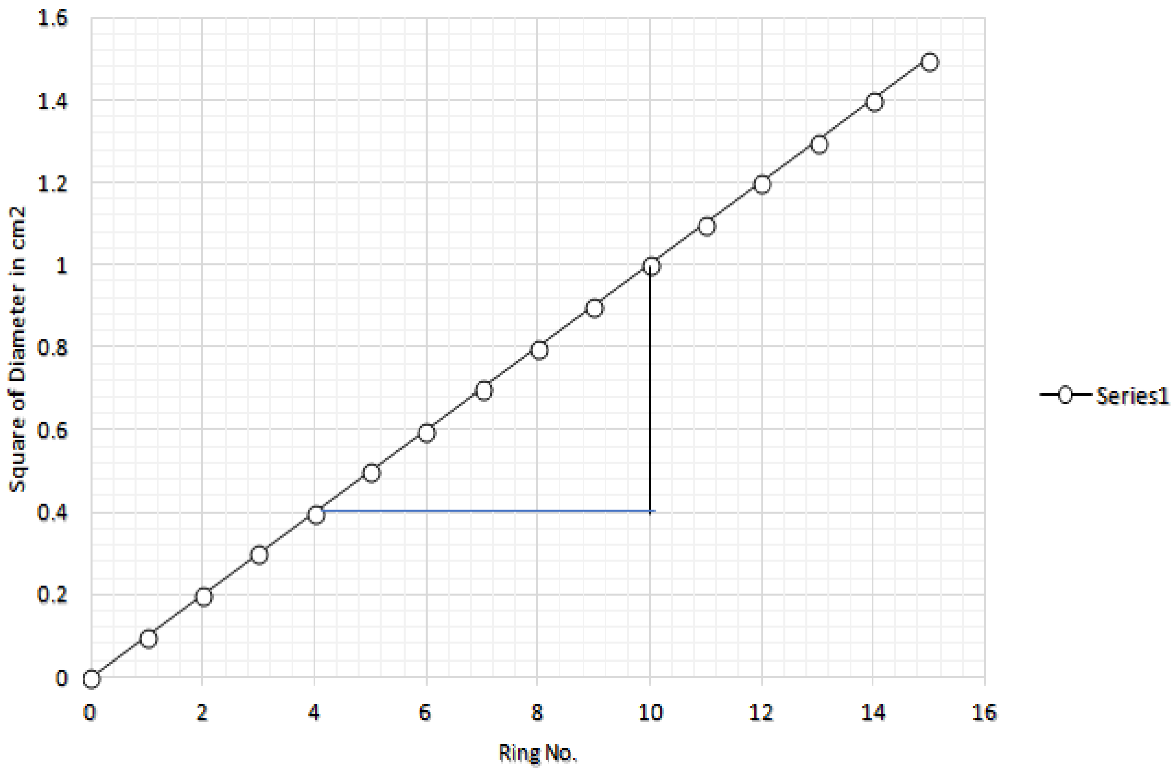

Fig.3: Graph of the square of diameter vs ring number

From the graph,

$$\text{slope} = \frac{D_{n+p}^2 - D_n^2}{(n+p) - n}$$

$$\Rightarrow \text{slope} = \frac{1.0 - 0.4}{6}$$

$$\Rightarrow \text{slope} = \ldots\ldots\ldots$$

∴ The radius of curvature of the lens,

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

$$\Rightarrow R = \frac{\text{Slope}}{4\lambda}$$

$$\Rightarrow R = \ldots\ldots\ldots\ldots$$

Results and Discussion:

The radius of curvature of the Plano-convex lens is ……………….. cm.

1. **……………………………………………………**
2. **……………………………………………………**
3. **……………………………………………………**
4. **……………………………………………………**
5. **……………………………………………………**

Conclusion:

In this experiment the diameter of the rings are measured and radius of curvature is calculated

Reference:

2. Practical Physics", Dr. Giasudin Ahmed and Md.Shahabuddin
3. http://vlab.amrita.edu/?sub=1&brch=189&sim=335&cnt=4

Knowledge Test

Pre-lab viva sample Question

1. What is interference of light?
2. What is the condition of interference?

Post-lab viva sample question

1. Why central point of Newton's ring is dark?
2. What is radius of curvature of a lens?
3. What is focal length of a lens?

Experiment Number: 02

Name of the Experiment: To calibrate a Polarimeter and hence to determine the specific rotation of a sugar solution by means of a Polarimeter.

Objectives:

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
02	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using ammeter voltmeter for finding the specific resistance.	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-Communication**	**Affective domain**		

Theory:

The angle of rotation produced to the plane of vibration by an optically active substance, in solution is proportional to

(i) The thickness of the medium (solution)
(ii) The concentration of the solution or the density of the active substance in the solvent and
(iii) The nature of the substance.

Thus, $\theta \infty l.c$ or, $\theta = slc$, or, $s = \frac{\theta}{lc}$

Where θ is the angle of rotation produced, l is the length of the substance in decimeters, c is the concentration in gm/cm^3 of the solution and s is a constant called specific rotation and depends upon the nature of the substance.

If l = 1 decimeter and c = 1 gm/cm^3 then specific rotation may be defined as the rotation produced while traversing a path of one decimeter (10 cm) length in the solution containing 1 gm of the optically active substance per cm^3 of the solution. Then, Specific rotation = $\frac{Rotation\ produced\ by\ 1\ decimetre\ length\ of\ the\ solution}{density\ of\ the\ solution\ in\ gm\ per\ c.c.} = \frac{\theta}{l/10} \div c = \frac{10\theta}{lc}$

Where the length *l* is expressed in centimeters.

The amount of rotation also depends upon (a) the *temperature* and (b) the wavelength of the light used. So for a given temperature and a given wavelength

$(s_\lambda^t) = \frac{10\theta}{lc}$…………..(1)

The specific rotation of dextro-rotatory substance is taken as positive while that of a laevo-rotatory substance is considered negative.

Now, the angles of rotation (θ) for different values of known concentrations (c) of a solution can be measured with the help of a polarimeter. If a graph is plotted with θ against c, then the graph will be a straight line. The polarimeter is thus calibrated. Taking then the solution of an unknown concentration, the rotation of the plane of polarization produced by the solution can be measured and from the graphs, its concentration can be determined.

Again, using eqn (1), the value of the specific rotation of the solution can also be determined.

Required equipment and devices:

1. A polarimeter or saccharimeter,
2. sodium lamp,
3. sugar,
4. balance,
5. Graduated cylinder and thermometer.

Procedures:

(i) Examine the circular scale in contact with the analyzer and find its Vernier constant. Obtain the zero reading of the instrument.

(ii) Carefully weigh out 20 gm of sugar in a water glass; dissolve it in about 50 or 60 cc of distilled water. Make up the solution up to 100 cc so that you may have a 20 percent solution. During dissolving, do not apply heat; just pour the solution from one vessel to another so that the solution has a uniform concentration.

(iii) Carefully measure the length of the tube. Clean the tube as well as the glass plates used to close its ends. Filter some distilled water so that it becomes free from dust and fill the tube with it. Take care so that no air bubble is introduced. Close the tube.

(iv) Place the tube with its contents horizontally on two V supports between the analyzer and polarizer so that it is coaxial with the telescope. Focus the eye-piece of the telescope so that on the field of view of the polarizer any line dividing it may be seen clearly. Rotate the analyzer so that the field of view is completely and uniformly dark i.e. both halves are equally dark. Read the position of the analyzer on the circular scale. Use the Vernier. Repeat the operations for at least three times ad take the mean of these three readings. Call this reading P.

(v) Remove the tube, empty it and rinse it with a little of the prepared solution. Carefully fill the tube completely with the solution. Take care not to have any air bubble inside the tube. Clean the ends, replace the tube in position and allow it to stand there for sometime so that the temperature becomes uniform. Note the temperature by placing a thermometer by its side. See through the telescope, the two halves are no longer completely and equally dark. Rotate the analyzer till the two halves get equally and completely dark as before. Take the reading. Repeat the operation for at least three times and take the mean of these three readings. Call it Q. (Q~P) is the angle through which the plane of polarization has been rotated. Calculate the specific rotation.

(vi) Next repeat the operation described in (v) with 10 percent, 5 percent and 2.5 percent solution. Find out (Q~P) in each case. Always take care that the temperature remains constant. Calculate specific rotation in each case.

(vii) Repeat the entire experiment with different tubes having different lengths.

(viii) Draw a graph between the percentages of the solution and the corresponding angle of rotations. This should be a straight line. Take a point P on the graph and find the values of θ and c corresponding to this point. Calculate the specific rotation of the solution using equation (1)

Precautions:

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:

    1. when heating anything.
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    3. when instructed to do so.

6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.

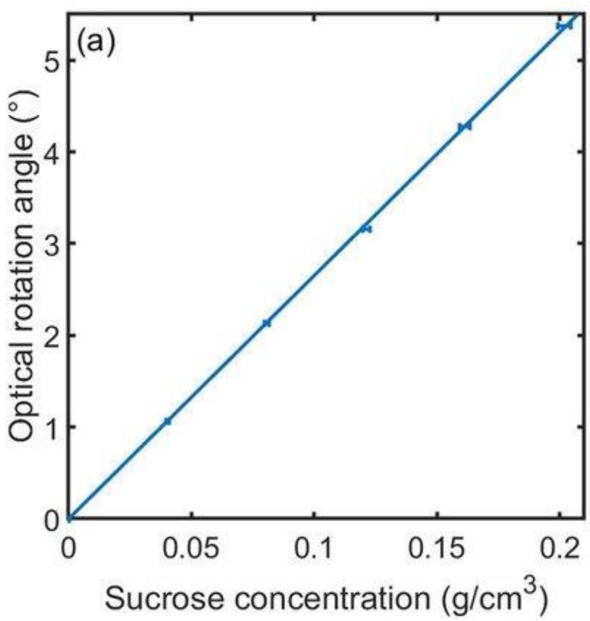
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

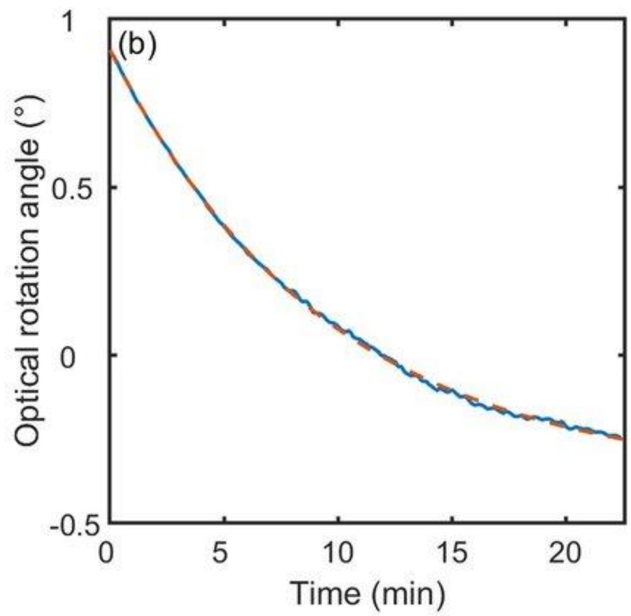
Data Collection:

Table for angular rotation

Strength of sugar solution (%)	No. of obs	First reading with water (P)	Second reading with solution (Q)	Angular rotation (Q~P)	Mean angular rotation	Specific rotation (s)
20	1.					
	2.					
	3					
10						

Data analysis and demonstration:





Weight of empty glass, m_1= …….gm

Weight of watch glass + sugar, m_2= ……..gm

Weight of sugar = m_2- m_1= ………gm

Length of the tube = …………..cm

Vernier constant of the circular scale =

Calculation:

So for 20% solution, specific rotation (s)= $\frac{10\theta\times100}{l\times20}$= …….

From graph, angle of rotation at point P, θ = …..

Concentration of the solution, c = ……… mass/cc

specific rotation (s)= $\frac{10\theta\times100}{l\times c}$= …….

Results and Discussion:

The specific rotation of sugar solution, s= …………

Conclusion:

In this experiment the specific rotation of sugar solution is calculated

Reference:

4. Practical Physics", Dr. Giasudin Ahmed and Md.Shahabuddin
5. http://vlab.amrita.edu/?sub=1&brch=189&sim=335&cnt=4

Knowledge Test

Pre-lab viva sample Question

15. Are light waves of transverse nature?
16. Do you believe electromagnetic waves are light waves?
17. What do you mean by plane of polarization?

Post-lab viva sample question

4. What are polaroids?
5. What are the uses of Nicol prism?
6. If two prisms are placed co-axially, can you see the polarized light from the second one?

Experiment No: 03

Experiment Name: Determination of moment of inertia of a flywheel about its axis of rotation.

Objectives:

a) To measure the angular velocity of a flywheel and conservation of energy for calculate its moment of inertia.
b) To determine intrinsic property of material.
c) To learn the use of rotation to measure moment of inertia.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
09	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques to determine moment of inertia of fly wheel.	**PO1– Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10- Team Work**	**Psychomotor**		

Theory:

Fig.1 (a) shows a mass M, attached by means of a string to the axle, radius r, of a fly-wheel the moment of inertia of which about its axis of rotation is I. The length of the string is such that it becomes detached from the axle when the mass strikes the floor. In falling a distance h, the potential energy of the mass has been converted into kinetic rotational and transnational energy. If ω be the maximum angular velocity of the Wheel and F be the amount of work done against friction per revolution and n_1 be the revolutions made while the mass falls the distance h,

Then, the loss in P.E. of M= Gain in K.E. of M + Gain in K. E of fly-wheel + work done against friction

So, $Mgh = \frac{1}{2} Mr^{2\omega^2} + \frac{1}{2} I\omega^2 + n_1F$……………………………………………….. (1)

After the mass strikes the ground the wheel executes a further n_2 revolutions and the angular velocity gradually decreases to zero.

The rotational kinetic energy $\frac{1}{2}$ Iω^2 have been used up in overcoming frictional forces, hence

$Fn_2 = \frac{1}{2}$ Iω^2 ……………………………………………………..….. (2)

If n_2 revolutions take a time t, then the average angular velocity $\omega_a = \frac{2\pi n_2}{t}$

Since the angular velocity decreases uniformly from a maximum ω to a minimum of zero, the average angular velocity is also given by, $\omega_a = \frac{\omega+0}{2} = \frac{\omega}{2}$

Also the motion is uniform. Hence $\frac{\omega}{2} = \frac{2\pi n_2}{t}$

i.e. $\omega = \frac{4\pi n_2}{t}$ ………………………………………………………… (3)

From equations (1) (2) and (3) it follows that

$I = \frac{2mgh - m\ \omega^2 r^2}{\omega^2(1+\frac{n_1}{n_2})}$ ……………………………………………..….(4)

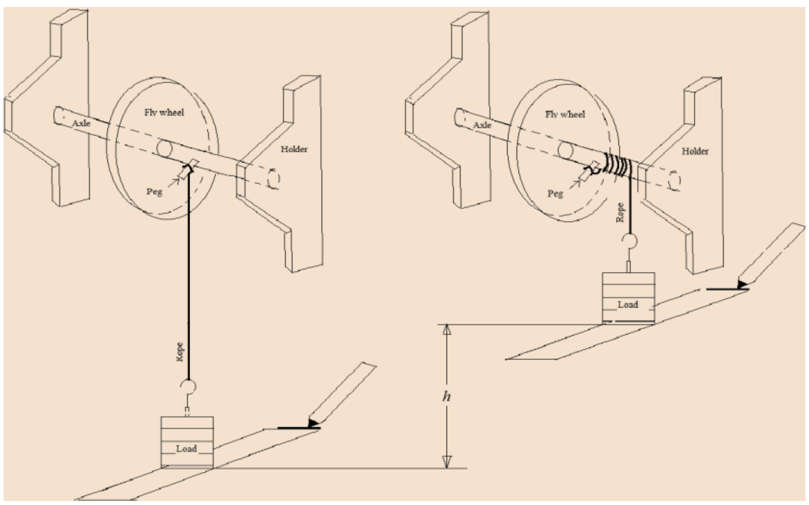


Fig.: 1(a) Flywheel when the rope and load is about to be detached from the axle. (b) The same flywheel after rotating it for n_1 number of times. There is a small peg on the axle, as shown in figure. We make a loop on one end of a rope round this peg. A load of mass, M, is connected to the other end of the rope. hold the flywheel in such a way that the load is about to be detached from the axle.

Required equipment and devices:

1. Fly-wheel,
2. weights,
3. cord,
4. stop-watch,
5. setsquare,

6. meter scale
7. calipers

Procedures:

1. The length of the cord is carefully adjusted, so that when the weight-hanger just touches the ground, the loop slips off the peg.
2. A suitable weight is placed in the weight hanger
3. A chalk mark is made on the rim so that it is against the pointer when the weight hanger just touches the ground.
4. The other end of the cord is loosely looped around the peg keeping the weight hanger just touching the ground.
5. The flywheel is given a suitable number (n) of rotation so that the cord is wound round the axle without overlapping.
6. The height (h) of the weight hanger from the ground is measured.
7. The flywheel is released.
8. The weight hanger descends and the flywheel rotates.
9. The cord slips off from the peg when the weight hanger just touches the ground. By this time the flywheel would have made n rotations.
10. A stop clock is started just when the weight hanger touches the ground.
11. The time taken by the flywheel to come to a stop is determined as t seconds.
12. The number of rotations (N) made by the flywheel during this interval is counted.
13. The experiment is repeated by changing the value of n and m.
14. From these values the moment of inertia of the flywheel is calculated using equation $I = \frac{Nm}{N+n}\left[\frac{2gh}{\omega^2} - r^2\right]$.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.

8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Collection:

Table 1: Determination of n_1, n_2 and t:

Mass M Gm	Height h Cm	No. of Revolutions n_1	No. of Revolutions n_2	Average n_2	Time t in sec	Average t Sec
200	4	3	61.40	61.40	72	72
			61.40		72	
			61.40		72	

Table 2**:** Determination of the radius of the axle: We got from simulator software **r= 1 cm.**

LSR (X) (cm)	VSD	VC (cm)	VSR Y =(VSD×VC) (cm)	Total Reading = X+Y Cm	Average Diameter cm	Radius r cm

Data analysis and demonstration:

- For the mass of 200.gm

$\omega = \frac{4\pi n_2}{t}$ = 10.71

Formula for determination of moment of inertia:

For the mass of 200.gm

I = $\frac{2mgh-m\ \omega^2 r^2}{\omega^2(1+\frac{n_1}{n_2})}$ = 1.28×10^4 $gmcm^2$

- For the mass of 400.gm

$\omega = \frac{4\pi n_2}{t}$ = 10.71

Formula for determination of moment of inertia:

For the mass of 600.gm

I = $\frac{2mgh-m\ \omega^2 r^2}{\omega^2(1+\frac{n_1}{n_2})}$ = 1.28×10^4 $gmcm^2$

- For the mass of 600.gm

$\omega = \frac{4\pi n_2}{t}$ = 10.71

Formula for determination of moment of inertia:

For the mass of 200.gm

I = $\frac{2mgh-m\ \omega^2 r^2}{\omega^2(1+\frac{n_1}{n_2})}$ = 1.28×10^4 $gmcm^2$

Results and Discussions:

The moment of inertia of the given fly-wheel is

1. ………………………………………

Conclusion:

The angular velocity of a flywheel can be measured and the moment of inertia of fly wheel for different mass can be determined.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin

2. http://phy-sc22-au.vlabs.ac.in/mechanics/Moment_of_Inertia_of_Flywheel/

Knowledge Test

Pre-lab viva sample Question

1. What is a fly-wheel? Why is its mass mostly concentrated in its rim?
2. What is moment inertia of a body? Is it a constant for a body?
3. What is the physical significance of the moment of inertia? What is the unit of moment of inertia?
4. What is the radius of gyration?

Post-lab viva sample question

1. What type of difficulties did you face while counting the number of revolutions of the flywheel? Please mention.
2. What will happen if the rope were too thick? [hint: could you write v= ωr]
3. Name the forces acting on the descending in the mass.
4. What happens to the potential energy lost by the mass?
5. Describe a practical application of Fly wheel.

Experiment Number: 04

Name of the Experiment: To determine the Specific resistance of a wire using a Meter Bridge

Objectives:
To find the resistance of a given wire using a meter bridge and hence determine the specific resistance of its materials.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
02	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using ammeter voltmeter for finding the specific resistance.	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-Communication**	**Affective domain**		

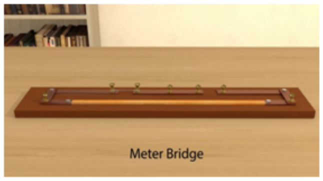
Theory:

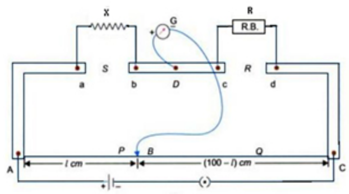
The metre bridge is operates under Wheatstone's principle. Here, four resistors P, Q, R, and S are connected to form the network ABCD. The terminals A and C are connected to a battery, and the terminals C and D are connected to a galvanometer through keys K1 and K2 respectively. In the balancing condition, there is no deflection on the galvanometer. Then,

$$\frac{P}{Q} = \frac{R}{S}$$

Metre Bridge apparatus

The metre bridge, also known as the slide wire bridge consists of a one metre long wire of uniform cross sectional area, fixed on a wooden block. A scale is attached to the block. Two gaps are formed on it by using thick metal strips in order to make the Wheat stone's bridge. The terminal B between the gaps is used to connect galvanometer and jockey.





A resistance wire is introduced in gap S and the resistance box is in gap R. One end of the galvanometer is connected to terminal D and its other end is connected to a jockey. As the jockey slides over the wire AC, it shows zero deflection at the balancing point (null point).

If the length AB is l , then the length BC is (100-l).

Then, according to Wheatstone's principle;

$$\frac{X}{R} = \frac{l}{(100 - l)}$$

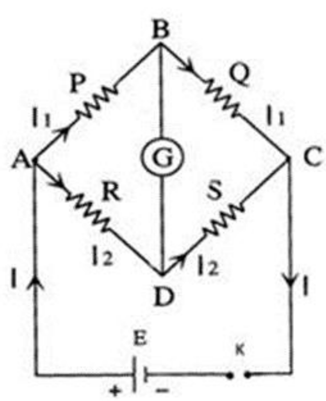
Now, the unknown resistance can be calculated as,

$$X = R\frac{l}{(100 - l)}$$

The specific resistance or resistivity of the material of the wire can be then calculated by using the relation,

$$\rho = \frac{\pi r^2 X}{L}$$; Where L be the length of the wire and r be its radius.

Circuit Diagram:



Required equipment and devices:

1. Metre bridge (slide wire bridge)
2. Leclanche cell or Battery eliminator
3. Galvanometer
4. Resistance box
5. Jockey
6. One way key
7. A resistance wire
8. Screw gauge
9. Metre scale
10. Connecting wires

Procedures:

(i) Make connections as shown in figure. Before putting in, fold one cm of the specimen wire at each end at right angles to the rest of it and put the folded portion within the binding screws of the left gap. Insert 1 ohm resistance in the right gap. With 100 ohms or higher in the rheostat, move the sliding contact first to the left end and then to the right end of the bridge wire. If the deflections are on the opposite directions, the connections have been correctly made.

(ii) Move the sliding contact along the bridge wire until the galvanometer deflection is almost zero. Null point is being approached.

(iii) If the balance point seems to be far from the middle of the bridge wire, change the value of the resistance ® in the right gap until the null point is brought very near the middle of the wire. Remove the galvanometer shunt by unplugging the key K' and find the null point accurately and note it. Reverse the current by changing the commutator plug and note the null point again. Take the mean of the two readings, thus eliminating thermo-electric effects. Now interchanging the positins of X and R with R in the left gap. Find out the null point. Reverse the current and gain find out the null point.Then

- You can calculate the unknown resistance of the resistance wire by using the relation,

$$X = R\frac{l}{(100-l)}$$

- If L is the length and r is the readius of the wire, the specific resistance (resistivity) of the given resistance wire can be calculated using the relation,

$$\rho = \frac{\pi r^2 X}{L}$$

(iv) With two or more knows resistances, repeat the operations, every time reversing the current. Then calculate the mean value of X.
(v) Carefully determine the length L of the wire between bends with a metre scale
(vi) Measure the diameter (d) of the wire with a screw gauge.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data collection:

Table 1: Reading for the balance point.

No. of observation	**Value of resistance, R(Ω)**	**Length, l cm**	**$(100-l)$ cm**	**X=$\frac{Rl}{(100-l)}$(Ω)**	**Mean X (Ω)**
1.					

2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					

Table 2: Reading for the radius of the experimental wire. (Using Slide Calipers)

No. of obs.	Liner scale reading (L.S.R) cm	Circular scale divisions (C.S.D)	Least count (L.C) cm	Circular scale reading (C.S.R) = (CSD x L.C) cm	Total diameter D Cm	Mean diameter D cm	Mean radius r=D/2 cm
1							
2							
3							

Data analysis and demonstration:

Length of the wire, L = ...cm

Resistance of the wire, X = ... Ω

Resistivity (specific resistance) of the wire,

$$\rho = \frac{\pi r^2 X}{L}$$

= ....Ω m

Result and Discussions

The specific resistance (resistivity) of the given resistance wire, ρ = ……...... Ω m

1.
2.
3.
4.

Conclusion: From the experiment, unknown resistance and specific resistance can be measured.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. http://amrita.olabs.edu.in/?sub=1&brch=6&sim=146&cnt=4

Knowledge Test

Pre-lab viva sample Question

1. Why is Metre Bridge called so?
2. What is null point?

Post-lab viva sample question

1. Why is bridge method better than Ohms law of measurement?
2. What is the range of measurement of resistance using a Wheatstone bridge?
3. How a Wheatstone bridge can be used for the measurement of physical parameters?

Experiment Number. 05

Name of the Experiment: To determine the e.m.f of a cell with a potentiometer of known resistance

Objectives:

a) Determination of the e.m.f of a cell with a potentiometer of known resistance

b) Comparison of the e .m .f of two cells with a potentiometer

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

<table>
<tr><th>Expt. No.</th><th>CO Statement</th><th>Corresponding PO</th><th>Domain / level of learning taxonomy</th><th>Delivery methods and activities</th><th>Assessment tools</th></tr>
<tr><td rowspan="2">04</td><td>Upon completion this experiment, students will be able to:
CO1: use the various procedures and techniques for using potentiometer for finding e.m.f of a cell</td><td>PO1–Engineering knowledge</td><td>Affective domain/ analyzing level</td><td rowspan="2">☐ Simulation
☑ Experiment
☑ Practice lab
☑ Group discussion
☐ Tutorial</td><td rowspan="2">☑ Lab tests
☑ Lab reports
☑ Final lab test
☐ Open ended lab
☐ Project show & project presentation</td></tr>
<tr><td>CO3: learn the writing techniques of lab report in a systematic way.</td><td>PO10-Communication</td><td>Affective domain</td></tr>
</table>

Theory:

A cell or any other source which supplies a potential difference to the circuit to which it is connected has within it some resistance called internal resistance. When there is no current in the cell i-e., at open circuit, the potential difference E between its terminal is maximum and is called its electro-motive force (e.m.f).When the cell is discharging i.e., at closed circuit, its terminal potential difference is reduced to e because of the internal drop of potential across its internal resistance b. In Fig. 1.1 the balance point for the cell E_1 whose internal resistance b is to be determined. is found out as usual, at a distance [1 from the end A of the potentiometer with key K_1 open. Then a resistance R is introduced in the resistance box RB and the key K_2 is closed. The potential difference between the terminals of the cell E_1 falls as a current i begins to flow through the circuit. A balance point is now found at a distance l_2 from the end A of the. Potentiometer. As E and e are the potential difference at the open and closed circuits and b is the internal resistance of the cell, we have b= (E-e/i) where i is the current flowing through the circuits when the key K_2 is closed. Again i=e/R.

b= (E-e/e) R = (E/e -1) R……………….(i)

But as E and e are proportional to l_1 and l_2. So E/e= l_1/l_2

From equation 1 b= (l_1/l_2 - 1) R= (l_1- l_2/l_2) R

Circuit Diagram:

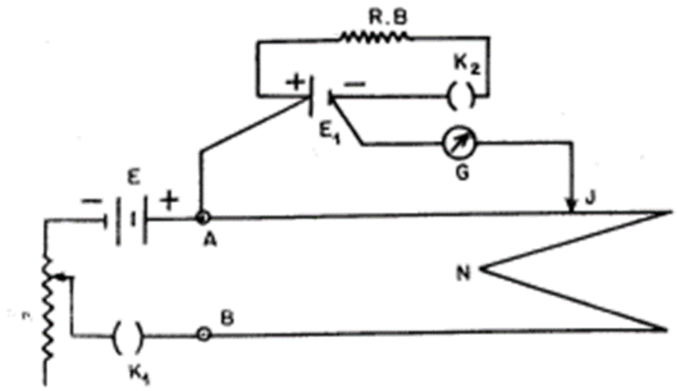


Fig: circuit diagram for determine the emf using potentiometer

Required equipment and devices:
Potentiometer, storage cell, the experimental cell, zero-center galvanometer, milli-ammeter, rheostat Rh, plug keys, a high resistance.

Procedure:

i. Connect the positive terminal of the battery E to the binding screw A of the potentiometer and the negative terminal of the battery through Rh and the key K_1 to the binding screw B of the potentiometer (Fig.). Join the positive terminal of the cell E_1 whose internal resistance is to be determined, to the binding screw A of the potentiometer and its negative terminal through the galvanometer G to the jockey J. Also connect the resistance box R.B through the key K_2 to the two terminals of the cell 81. It is better to put a shunt across the galvanometer.
ii. Adjust a small resistance in the rheostat Rh and close the key K_1. Keep the key K_2 open and press the jockey first near the end A and then near the end B of the potentiometer wire. If the galvanometer deflection are in the same direction, then either the resistance in Rh is too great or e.m.f. of E is too small. Decrease the resistance in Rh until the opposite deflections are obtained at the above two

contact points. If necessary increase the number of cells in the battery E. Adjustment of Rh should be such as to get a null point on the fifth or sixth wire.

iii. Remove the shunt of the galvanometer (if any) and find out the balance point accurately. Open the key K_1 and calculate the distance l_1 of the balance point from the end A of the potentiometer wire Determine l_1 three times and calculate the mean value of l_1.

iv. Close the key K_2 without changing Rh and take out a resistance 10 ohms from the RB and determine the balance point and calculate the distance l_2 of the balance point from A. Then remove 20,30,40,50 ohms from R and determine the value of [2 in each case]

v. Calculate the value of b from the relation (2) for each value of R and then calculate the mean value of b.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
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6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.

13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data collection:

(A) Resistance of the potentiometer wire, R = ……………Ω ohms

(B) Total length of the potentiometer, L= ………………………..cm.

Table-1: Determination of the electromotive force

No. of obs.	Miliammeter readings = i	Null points		Total length for balance l cm	e.m.f of the cell $E=\frac{iRl}{1000L}$ Volts.	Mean E' Volts.
		On wire no.	Scale readings in cm.			
1		**10^{th}**				
2		**9^{th}**				
3		**8^{th}**				
4		**7^{th}**				
5		**6^{th}**				

Data analysis and demnstration:

Result and discussion: The e.m.f of the cell….

i. ……………………………

ii. ………………………………

iii. …………………………………

Conclusion: The e.m.f of any cell can be measured by using potentiometer.

Reference:

1. Practical Physics”, Dr. Giasudin Ahmed and Md. Shahabuddin
2. https://amrita.olabs.edu.in/?sub=1&brch=6&sim=231&cnt=4

Knowledge Test

Pre-lab viva sample Question

1. Define E.M.F
2. Define internal resistance
3. What is potentiometer

Post-lab viva sample question

1. What do you understand by the internal resistance of a cell?
2. On what factor does internal resistance of cell depend?
3. Name cells of high and low internal resistance
4. Show a relation between the e.m.f.(E) and internal resistance of the cell. Is the internal resistance of a cell?

Experiment Number: 06

Name of The Experiment: To compare the e.m.f of two cells with a potentiometer

Objectives:

Comparison of the **e .m .f** of two cells with a potentiometer

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
05	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using potentiometer to compare e.m.f of two cell	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-communication**	**Affective domain**		

Theory:

A cell or any other source which supplies a potential difference to the circuit to which it is connected has within it some resistance called internal resistance. When there is no current in the cell i-e., at open circuit, the potential difference E between its terminal is maximum and is called its electro-motiue force (e.mf). When the cell is discharging i.e., at closed circuit, its terminal potential difference is reduced to e because of the internal drop of potential across its internal resistance b. In Fig. 1.1 the balance point for the cell E_1 whose internal resistance b is to be determined. is found out as usual, at a distance [1 from the end A of the potentiometer with key K_1 open. Then a resistance R is introduced in the resistance box RB and the key K_2 is closed. The potential difference between the terminals of the cell E_1 falls as a current i begins to flow through the circuit. A balance point is now found at a distance l_2 from the end A of the. Potentiometer. As E and e are the potential difference at the open and closed circuits and b is the internal resistance of the cell, we have b= (E-e/i) where i is the current flowing through the circuits when the key K_2 is closed. Again i=e/R.

b= (E-e/e) R = (E/e -1) R……………….(i)

But as E and e are proportional to l_1 and l_2. So $E/e= l_1/l_2$

From equation 1 $b= (l_1/l_2 - 1) R= (l_1- l_2/l_2) R$

Potentiometer

Potentiometer is a device used to compare the e.m.f. (electromotive force) of two cells, to measure the internal resistance of a cell, and potential difference across a resistor. It consists of a long wire of uniform cross-sectional area and of 10 m in length. The material of wire should have a high resistivity and low temperature coefficient. The wires are stretched parallel to each other on a wooden board. The wires are joined in series by using thick copper strips. A metre scale is also attached on the wooden board. The potentiometer works on the principle that when a constant current flows through a wire of uniform cross sectional area, potential difference between its two points is directly proportional to the length of the wire between the two points.

Electromotive force (e.m.f) of a cell

Electromotive force (emf) is a measurement of the energy that causes current to flow through a circuit. It is the energy provided by a cell or battery per coulomb of charge passing through it. It can also be defined as the potential difference across the terminals of a cell, when no current flows through it. Electromotive force is also known as voltage, and it is measured in volts. Electromotive force is not truly a force; rather, it is a measurement of energy per unit charge.

$$\epsilon = \frac{E}{Q}$$, where E is the energy and Q is the charge.

Using a potentiometer, we can determine the emf of a cell by obtaining the balancing length l. Here, the fall of potential along the length l of the potentiometer wire is equal to the emf of the cell, as no current is being drawn from the cell.

Then,

$$E \propto l \quad \text{or,} \quad E = kl$$; where k is the potential gradient along the wire.

Thus it is possible to compare the emf's of two given cells by measuring the respective balancing lengths l_1 and l_2.

ie; $$E_1 = kl_1 \quad \text{and} \quad E_2 = kl_2$$

or $$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

Circuit Diagram:

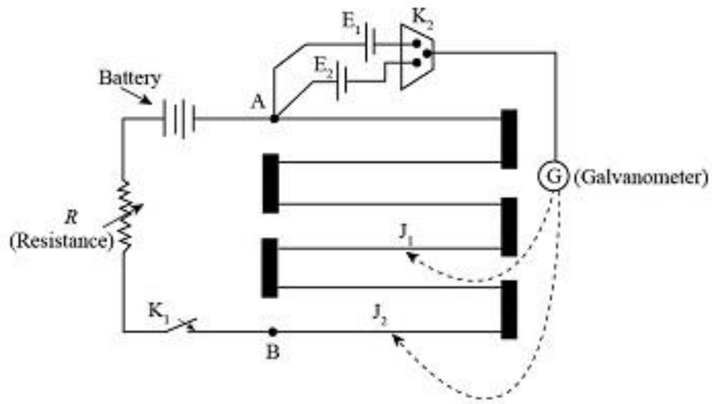

Fig: circuit diagram to compare the emf of two cells using potentiometer

Required equipment and devices:

1. Potentiometer, storage cell
2. the experimental cell
3. zero-center galvanometer
4. milli ammeter
5. rheostat Rh
6. plug keys
7. a high resistance

Procedures:

(i) Connect as shown in figure. Connect the positive terminal of the driving battery E (usually two or three lead accumulators or alkali cells in series) to the end A of the potentiometer wire and the negative terminal through the rheostat Rh and the plug key K_1nto the other end B of the potentiometer wire. Connect the positive terminals of the two cells C1 and C2 to A where the positive of E is joined, and the negative terminals to the binding screw O1 and O2 of a two way key K_2. Join the third binding screw to one terminal of the galvanometer G and connect the other terminal of the galvanometer through the resistance R’ to the jockey J. Put a plug key K parallel to R’.

(ii) Make the resistance Rh zero and the resistance R’ maximum and join the cell C_1 to the galvanometer. Put the jockey J in contact with the first and last wire. If the galvanometer deflections are in opposite directions, then the connection for C_1 is all right. Repeat the whole process with the cell C_2 and the deflections are again found in the opposite direction, the connection for both the cells are correct. Check again to see that the e.m.f. of the battery E is greater than those of $C_1$and $C_2$and see again that the positives of C_1, C_2 and battery E are connected to the same point.

(iii) After verifying that the deflection are in opposite directions, find approximate null points for both C_1 and C_2.If the length for C_1 is greater than that for C_2 then e.m.f. $E_1$for C_1 is greater than E_2 for C_2

(iv) Keeping the stronger of the two cells, say cell C_1 in the galvanometer circuit, increase the resistance in the rheostat Rh until a null point is located in the middle of the last wire. Now put in the plug K making R' zero and get the exact null point. Note this null point thrice and find the mean value of l_1.

(v) Now put the cell C_2 in the galvanometer circuit by changing the plug in the two-way key K_2. Without altering the values of resistance in the rheostat, obtain a null point for the call C_2. Note this null point

(vi) Now again put the cell C_1 in the galvanometer circuit and decrease the value of the resistance in the rheostat Rh thereby increasing the potentiometer current until the null point is located in the preceding wire. Keeping this value of the rheostat resistance the same, note the exact null points for both C_1 and C_2. Find the mean values of l_1 and l_2.

(vii) Find out the ratio of l_1/l_2 in each case. The mean of these ratios gives the value of E_1/E_2

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.

12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data collection:

No. of observations	Cell	Null points			Total length in cm	**$E_1/E_2 = l_1/l_2$**
		On wire number	Scale reading in cm	Mean scale reading in cm		
1	First (E_1)					
	Second (E_2)					
2	First (E_1)					
	Second (E_2)					
3	First (E_1)					
	Second (E_2)					

Data analysis and demonstration:

Calculate the ratio of E_1 and E_2 for each set of l_1 and l_2. The mean of the calculated values gives the ratio of emf's of the two given primary cells.

Result and Discussion:

The emf's of the two given primary cells are compared.

The ratio of emf's of the two given primary cells, E_1/E_2 = ...

Conclusion: The e.m.f of two cells are determined and compare the e.m.f.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. https://amrita.olabs.edu.in/?sub=1&brch=6&sim=231&cnt=4

Knowledge Test

Pre-lab viva sample Question

1. Define E.M.F
2. Define internal resistance
3. What is potentiometer

Post-lab viva sample question

1. What do you understand by the internal resistance of a cell?
2. On what factor does internal resistance of cell depend?
3. Name cells of high and low internal resistance
4. Show a relation between the e.m.f. E and internal resistance of the cell. Is the internal resistance of a cell?

Experiment Number: 07

Name of The Experiment: To determine the wavelength of various spectral lines by a spectrometer using a plane diffraction grating.

Objectives:

(i) To study diffraction of light using a diffraction grating spectrometer; and

(ii) To measure the wavelengths of certain lines in the spectrum of various discharge tubes.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	**CO Statement**	**Corresponding PO**	**Domain / level of learning taxonomy**	**Delivery methods and activities**	**Assessment tools**
06	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using diffraction grating to determine wavelength of certain spectrum;	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-communication**	**Affective domain**		

Theory:

If a parallel pencil of monochromatic light of wavelength λ, coming out of the collimator of a spectrometer falls normally on a plane diffraction grating placed vertically on the prism table, a series of diffracted image of the collimator slit will be seen on both sides of the direct image. Reckoning from the direction of the incident light (direct image), if θ be the deviation of the light which forms the nth image and, (a+b) be the grating element, then

$$(a + b)\sin\theta = n\lambda \text{ .... (i)}$$

Since (a + b) = $\frac{1}{N}$, where N is the grating constant i.e., the number of lines or rulings per cm of the grating surface,

$$\Rightarrow \sin\theta = Nn\lambda$$

$$\therefore \lambda = \frac{\sin\theta}{nN} \quad \text{...... (ii)}$$

The wavelength of spectral lines of various discharge tubes can be determined by equation (ii).

Required equipment and devices:

1. Spectrometer
2. Spirit level
3. a Plane Diffraction Grating
4. Discharge Tubes etc.

Description of Apparatus:

Spectrometer has application in a wide range of areas including determining the constituents of stars, to investigate the structure of the atom. You will use a simple but high precision student spectrometer similar to the picture shown in Fig. 1, which consists of three basic components: a collimator, a diffraction grating, and a telescope.

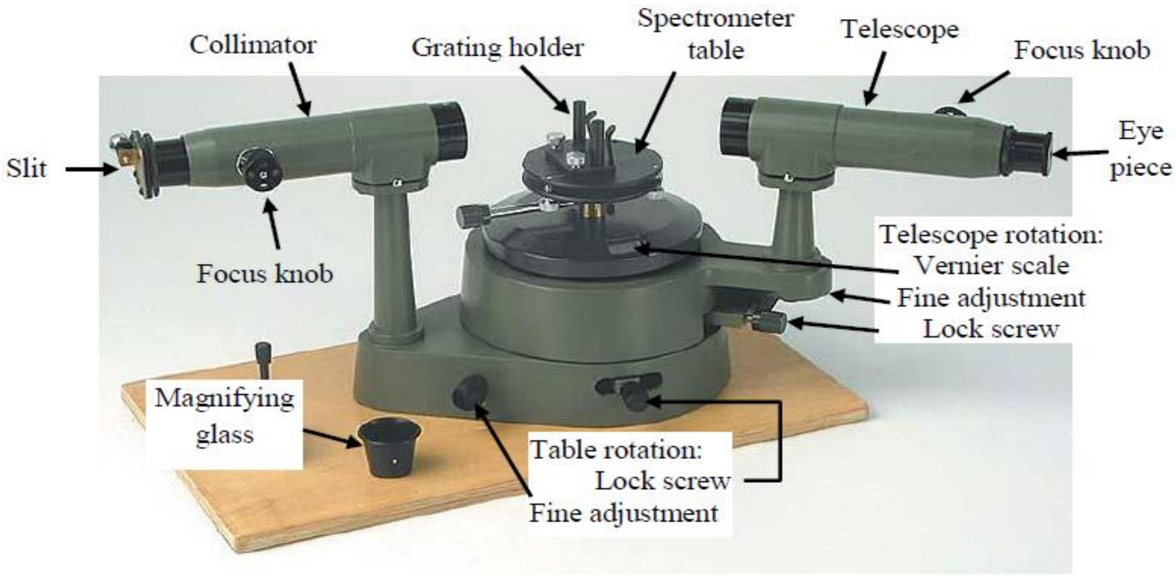

Fig. 1: Spectrometer and its components.

Light enters through a narrow slit positioned at the focal point of the collimating lens. The light leaving the collimator is therefore a thin, parallel beam, which ensures that all the light from the slit strikes the diffraction grating at the same angle of incidence. The grating diffracts the light of different color light at different angles. The telescope is focused at infinity to collect the parallel diffracted beam of light and can be rotated at very precisely measured angles. There are two Vernier readings on two opposite sides on the table, Vernier A and B. You can treat these two reading as measured by two different scales. The Vernier reading has least count of 1' [$(1/60)^0$]. To aid viewing the Vernier scale reading a magnifying glass is provided. The table and the telescope can be fine adjusted by tightening the lock screw and rotating the fine adjustment knobs.

Procedures:

To make the plane of the grating vertical and set it for normal incidence:

(i) Focus the telescope towards the direct light coming through the collimator. Note the position of the telescope (direct reading). Then turn the telescope through exactly 90^0 and fix it there.

(ii) Place the grating, mounted in its holder, on the prism table. The grating should be so placed that the lines of the grating are perpendicular to the table and the plane of the grating, defined by the ruled surface, passes through the centre of the table so that the ruled surface, extends equally on both sides of the centre.

(iii) Rotate the prism table till you get, on the cross wire of the telescope, an image of the slit formed by reflection at the grating surface. The image may not be at the centre of the cross-wires. If so, turn one of the screws till the the centre of the image reaches the intersection of the cross-wires. In this position the plane of the grating has been adjusted to be vertical.

(iv) Now look carefully at the grating on the table and ascertain whether the surface of the grating which first receives the light is the one which also contains the lines.

(v) Record the grating constant.

(vi) Find out the value of one smallest division of the main scale and the total number of divisions of the vernier scale of the spectrometer and calculate vernier constant (*V.C*).

(vii) Mount the grating on the spectrometer table with the grating ruling parallel to the collimator slit and plane of grating perpendicular to the collimator axis. Do not move it throughout the experiment.

(viii) Focus the eyepiece on the cross-wires illuminated by the light from the slit by sliding the eyepiece lens in and out until the cross-wires appear sharpest.

(ix) Turn the telescope to one side of central position (Say left side, *A*) until an image of first order diffraction appears on the cross-wires and then record the readings from both scales I & II.

(x) Similarly find the image of first order diffraction on the other side (e.g. right side, *B*) of central position and record the readings as before.

(xi) Calculate the differences ($A \sim B$) between scale I and scale II readings and determine the angle of diffraction.

(xii) Calculate the wavelength of the spectral lines of various discharge tube using the given equations.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
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    2. when using any type of projectile.
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8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.

11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Collection:

Table 1: Data for determination of grating constant

Wave length (λ) for Yellow line A.U(Angstrom Unit)	Order number (n)	Readings of the angle of diffraction								2θ=(L~R)	θ	Gratings constant N=$\frac{sin\theta}{n\lambda}$
		Left side				Right side						
		M.S.R (degree)	V.S.D	V.C	Total R (degree)	M.S.R (degree)	V.S.D	V.C	Total L (degree)			
5770												

Table 2: Data for determination of wavelength of spectral lines for Mercury discharge tube

Order number (n)	Color of the spectral lines	Readings of the angle of diffraction								2θ=(L~R)	θ	Wavelength, (λ) =$\frac{sin\theta}{Nn}$	Standard wavelength from table (A.U)
		Left side				Right side							
		M.S.R	V.S.D	V.C	Total R	M.S.R	V.S.D	V.C	Total L				
1^{st} order (n=1)	Violet												4078

	Blue-Violet												4358
	Blue-Green												4916
	Green												5461
	Yellow												5770

Data analysis and demonstration:

1. Wavelength of Violet, $\lambda = \frac{\sin\theta}{nN} =$
2. Wavelength of Blue-Violet, $\lambda = \frac{\sin\theta}{nN} =$
3. Wavelength of Blue-Green, $\lambda = \frac{\sin\theta}{nN} =$
4. Wavelength of Green, $\lambda = \frac{\sin\theta}{nN} =$
5. Wavelength of Yellow, $\lambda = \frac{\sin\theta}{nN} =$

Results and discussions: The wavelengths of spectral lines of Mercury discharge tubes are given in the following table:

Color of spectral lines	Wavelength in Å	Standard wavelength in Å
Violet		4078
Blue-Violet		4358
Blue-Green		4916
Green		5461
Yellow		5770

Conclusion:

The diffraction of light using a diffraction grating spectrometer can be studied and the wavelengths of certain lines in the spectrum of various discharge tubes can be measured.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. http://ov-au.vlabs.ac.in/optics/Diffraction_Grating/

Knowledge Test

Pre-lab viva sample Question:

1. What is diffraction?
2. What is spectral line?
3. Explain discharge tube
4. What is diffraction grating

Post-lab viva sample question:

1. What is spectrometer?
2. Why we use discharge tube?
3. How diffraction grating can work?

Experiment Number. 08

Name of the Experiment: To determine the mechanical equivalent of heat ‘J’ by electrical method. **Objectives:**

To find the mechanical equivalent of heat ‘J’ by electrical method.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

<table>
<tr><th>Expt. No.</th><th>CO Statement</th><th>Correspon ding PO</th><th>Domain / level of learning taxonomy</th><th>Delivery methods and activities</th><th>Assessment tools</th></tr>
<tr><td rowspan="2">08</td><td>Upon completion this experiment, students will be able to:
CO1: use the various procedures and techniques to determine the temperature coefficient of resistance</td><td>PO1–Engineering knowledge</td><td>Affective domain/ analyzing level</td><td rowspan="2">☐ Simulation
☑ Experiment
☑ Practice lab
☑ Group discussion
☐ Tutorial</td><td rowspan="2">☑ Lab tests
☑ Lab reports
☑ Final lab test
☐ Open ended lab
☐ Project show & project presentation</td></tr>
<tr><td>CO3: learn the writing techniques of lab report in a systematic way.</td><td>PO10-communication</td><td>Affective domain</td></tr>
</table>

Theory:

The mechanical equation of heat J is the number of joules of electrical energy required to generate one calorie of heat. If E is the potential difference across a conducting coil and I ampere of current flowing through the coil for t seconds, then electrical energy expended in the coil is Eit. Hence if this energy is converted into H calories of heat we shall have,

$$J = \frac{Vit}{H} - - - - - - - - - - - - - - - (i)$$

If the heat thus developed be measured by means of a calorimeter, then the temperature of the calorimeter with its contents will rise from θ_1℃ c to θ_2℃. Hence the heat taken up by the calorimeter and its contents is given by

$$H = (Ms + w)(\theta_2 - \theta_1) - - - - - (ii)$$

$Here\ M = mass\ of\ the\ liquid\ in\ the\ calorimeter$

$S = specific\ heat\ of\ the\ liquid$

$W = water\ equivalent\ of\ the\ calorimeter\ and\ the\ stirrer.$

$From\ (i)\ and\ (ii)$, we get,

$$J = \frac{Eit}{(Ms + w)\,(\theta_2 - \theta_1)}\ Joules\ per\ calorie$$

$$\therefore J = \frac{VIt}{(Ms + w)\,(\theta_2 - \theta_1)} \times 10^7\ Ergs\ per\ Calorie$$

The final temperature θ_2 should be recorded after radiation correction.

Circuit Diagram:

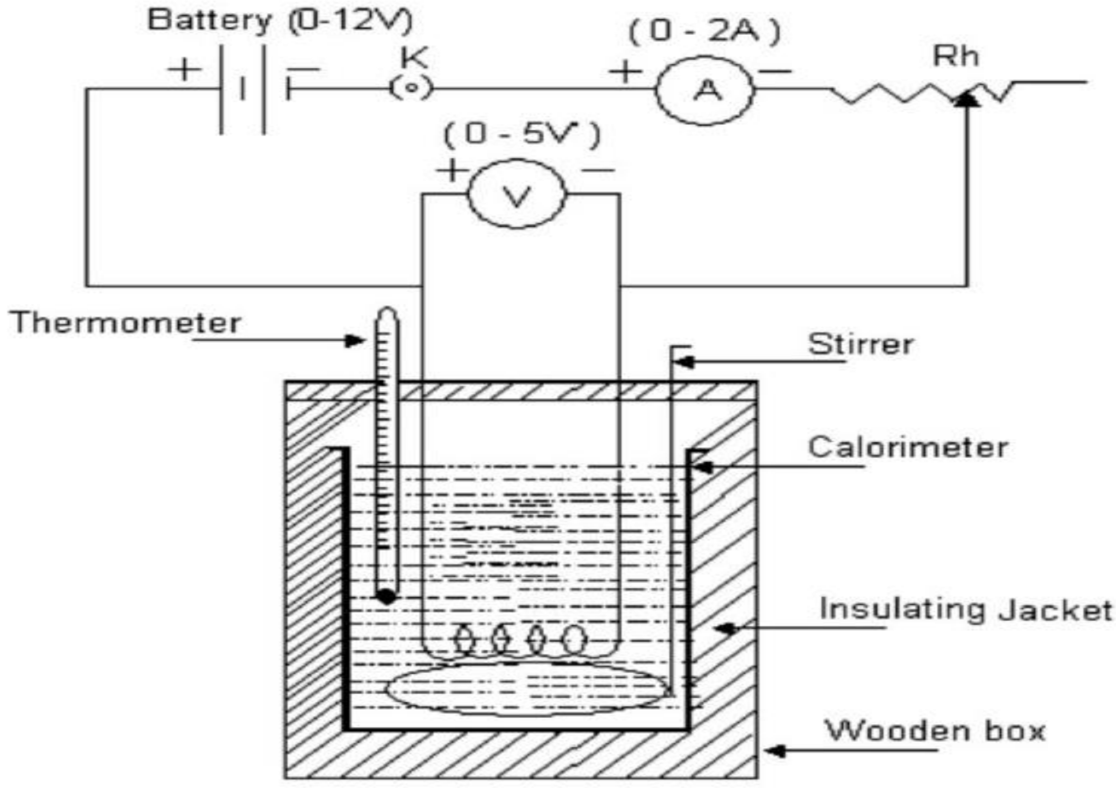

Fig.1: Experimental set up of J

Required equipment and devices:

1. Joules calorimeter with the heating coil in it,
2. voltmeter
3. rheostat Rh to control current from
4. switch, stop-watch,
5. a liquid of known specific heat
6. weight box, connecting wires.

Procedures:

1. After cleaning of the apparatus using cotton pad, weigh the calorimeter and the stirrer. Pour some liquid in the calorimeter. Again weigh this. The difference of these two weights gives the mass of liquid taken in the calorimeter.
2. Put the heating coil in the calorimeter. Insert the thermometer.
3. Check the connections whether voltmeter and ammeter are connected properly. Close the circuit temporally and adjust the control knob of the power pack until a current of about 2 amperes. Then put off the switch and stir the liquid to get a steady temperature for at least 5 minutes, record the temperature θ.
4. Now start the stopwatch and the current simultaneously and go on stirring the liquid. Record the current, voltage and temperature in interval of every minute. When the temp. has risen about 8 degree Celsius, stop the current. Simultaneously noting the time for which the current flowed but allow the stopwatch to run on. The temperature will further rise. Note the time from the beginning of starting the stop watch to the maximum rise of the temperature θ_2. Record this temperature and go on stirring liquid as before. Now allow the calorimeter to cool for the same length of the time as it has been rising in temperature. And again note the temperature. That actual loss in temperature, by radiation during the heating process, is half of this fall in temperature. Add this loss to the observed max. Temperature θ_2 to get the max. temp. of the liquid.

Precautions: -

15. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.

16. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
17. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
18. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
19. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.
20. Use equipment with care for the purpose for which it is intended.
21. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
22. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
23. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
24. Ask the instructor to check all electrical circuits before you turn on the power.
25. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
26. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
27. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
28. Leave your lab area cleaner than you found it.

Data Collection:

Table-1: Current- Voltage Record

No of obs.	Time minutes	Current amp (I)	Voltage volt (V)	Temperature $^\circ C$
1				
2				
3				
4				
5				
6				
7				
8				

9				
10				
11				
12				
13				
14				
15				

Data analysis and demonstration:

i. Mass of calorimeter + stirrer, m_1=……………………gm.

ii. Mass of calorimeter + stirrer + liquid, m_2 =………………gm.

iii. Mass of the liquid $M = m_2 - m_1 =$ ………………… gm

iv. Specific heat of the given liquid, s =………………..

v. Specific heat of the material of the calorimeter, s_1 = ……………

vi. Water equivalent of the calorimeter, w = ………………… gm.

vii. Initial temperature of the calorimeter + contents, θ_1 = ……..$°_C$

viii. Time during which the current is passed, t = ………. secs (say)

ix. Mean current during interval t, I = … … … Amp

x. Mean voltage during the interval t, V = … … … Volts.

xi. Rise of temperature = ………… = …………………

xii. Radiation correction = ……………………..

xiii. Corrected rise of temperature = ………………..

xiv. Heat produced, H = (Ms + w) $(\theta_2 - \theta_1)$ = ………………………cal.

xv. Work done electrically, W = VIt Joules

$$J = \frac{VIt}{(ms + w)(corrected\ rise\ of\ temp)}\ Jules/calorie$$

Results and Discussions:

the mechanical equivalent of heat 'J' is obtained

5. ……………………………………..
6. ……………………………………….
7. ………………………………………

Conclusion:

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. http://emv-au.vlabs.ac.in/electricity-magnetism/Temperature_Coefficient_of_Resistance/

Knowledge Test

Pre-lab viva sample Question

1.Define temperature
2.Define resistivity
3.Define conductivity

Post-lab viva sample question

(I) Define mechanical equivalent of heat and state its unit.

(II) What precaution should be taken so that the current in the circuit remains fairly steady?

(III) Is it possible to measure the specific heat of a liquid by this method?

(IV) Instead of DC, can you AC in the circuit?

Experiment Number: 09

Name of the Experiment: To determine the value of unknown resistance and verify the laws of series and parallel resistance by Post Office Box.

Objectives:

a) Determination the value of unknown resistance
b) Verification the laws of series and parallel resistance

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
09	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using ammeter voltmeter for verification of Ohm's law.	**PO1– Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-communication**	**Affective domain**		

Theory:

a) Determination the value of unknown resistance:

Theory: If P and Q are the known resistances in the ratio arms and R that in the third arm (see Figs. Z.2g and 7. 3O). the unknown resistance S in the fourth arm is obtained, when there is no deflection of the galvanometer, from the relation

$$\frac{P}{Q} = \frac{R}{S}$$

Or, $S = \frac{RQ}{P}$

Circuit Diagram:

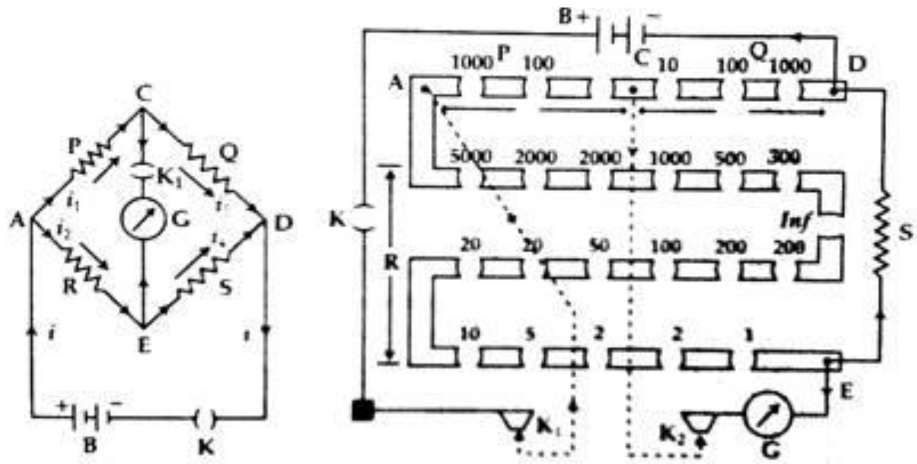

Fig. Circuit diagram of a P.O. Box to determine unknown resistance

Required equipment and devices:

1. PO box unknown resistance
2. zero-center galvanometer,
3. Cell,
4. commutator,
5. connecting wires.

Procedure:

1) Connect the terminals of the galvanometer between D and K_2 of the P.O. box, K_2 being internally connected to the point B. Connect the poles of the cell E through a rheostat Rh to the point K_1 and C, K_1 being internally connected to A. Connect the terminals of unknown resistance S to the points C and D.
2) Take out resistances 10 and 10 from the ratio arms BA and BC. See that alt other plugs in the box are tight. This means zero resistance in the third arm. Put the maximum resistance in the rheostat. Press the battery key K_1 and then press the galvanometer key K_2. Observe the direction of the deflection in the galvanometer. Next take out the infinity plug from the third arm and press the keys as done before. If opposite deflection is obtained then the connection is correct. If not check the connections again.
3) Then go on gradually reducing the resistance in the third arm until a resistance, say R_1, is found for which there is no deflection in the galvanometer when the circuit is closed. Then the unknown resistance S is given by $S = \frac{10}{10} R_1 = R_1$(say 5 ohms).

4) If instead of null point, there is a deflection in one direction with R_1 and an opposite deflection with (R_1 + l) in the third arm, the unknown resistance is partly integral and partly fractional i.e., it lies between 5 and 6 ohms.

5) Now take out the resistance of 100 ohms in the arms P (BA) keeping 10 ohms in the arm Q (BC) so that the ratio is now $\frac{P}{Q} = \frac{10}{100} = \frac{1}{10}$. Hence the null point should occur when the resistance in the third arm is of some value between $10R_1$ and 10 (R_1+1) i.e., between 50 and 6O (if R_1 =5);.

   Observe the opposite deflection and as before narrow down the range to obtain the null point at R_2 = 53 (say).Then S = $\frac{53}{10}$= 5.3 ohms. In that case, the resistance is found correct to one decimal Place.

6) (If the null point cannot be obtained at this stage also i.e.., if opposite deflections are observed for R_2 and R_2 + 1 (viz. for 53 and 54) in the third arm, it ties between 5.3 and 5.4 ohms. Repeat the observations with 1000 ohms in P arm and 1O ohms in Q arm. The resistance in the third arm should be between 530 and 540 for which opposite deflections will be obtained. Narrow down the range to obtain a null point at R_3 = 535 (say).

   Then S = R/10 = 5.35 ohms (say). The resistance is now correct to two decimal Place.

7) If even at this stage there are opposite deflections for a change of resistance of I ohm in the third arm, the unknown resistance can be determined to the third decimal place by proportional parts. But it is futile to expect that much accuracy from the P.O. box. However, if it is desired to go further, proceed as follows: Count the number of divisions for which the galvanometer is deflected when R_3 is put in the third arm. Suppose it is d_1 divisions to the left. If now for (R_3 + l) in the third arm, the deflection is d_2 to the right, then for a change of t ohm in the third arm, the pointer moves through $d_1 + d_2$ divisions. Hence to bring the pointer to zero of the scale (i.e., for no deflection) a resistance R_3 + $\frac{d_1+d_2}{d_1}$ is to be inserted in the third arm. Hence the value of the unknown resistance S is given by S=1/100 (R_3 + $\frac{d_1+d_2}{d_1}$)

8) While taking the final reading with the ratio 1000: 10, reverse the current and take mean value of S.

Data collection:

Table 1: Reading for the Unknown resistance.

Value of P (Ω)	Value of Q (Ω)	Value of R (Ω)	Value of S = $\frac{QxR}{P}$(Ω)	Mean , S(Ω)
10	10			
100	10			
1000	100			
10	100			
100	1000			

Data analysis and demonstration:

The unknown resistance, $S = \frac{RQ}{P}$ = ………

Results and Discussions:

The unknown resistance is ………… Ω

b) To verify the laws of series and parallel resistance by PO box

Theory: Resistance S are said to be connected in series when they are connected with the end of one joined to the beginning of the next and so on as shown in Fig. 7 34 [a].The equivalent resistance to a number of resistances connected in series is equal to the sum of the individual resistances, i.e.,

$R = R_1 + R_2 + R_3 + R_4$ ……………………(l)

If ,then resistances are arranged with their respective ends connected to common terminals, they are said to be connected in parallel as shown in Fig. 7.34 (b) The reciprocal of equivalent resistance to a number of resistances connected in parallel is equal to the sum of the

$R = \frac{1}{R1+R2+R3+R4}$ ………………… (2)

Measuring R_1, R_2,R_3 etc. separately and the equivalent resistance R by connecting them in series and in parallel' the relation (l) and (2) may be verified.

Circuit Diagram:

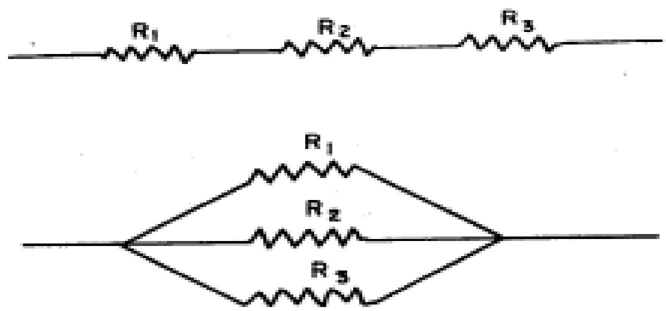

Fig. 7.34

Procedure:

1) Measure the resistances, R1, R2, resistances separately by means of a P.O. Box.
2) Join the resistance R_1, R_2, R_3 etc. in series as in Fig7.34 (a) and determine the equivalent resistance of the series combination by means of the P.O. Box' Show that relation (1) holds good.
3) [iii) Connect the resistances R_1, R_2, R_3 etc.in parallel as in Fig 7.34 (b] and determine the equivalent resistance of the parallel combination as before. Show that relation (2) holds good.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
4. Dress appropriately. Avoid wearing overly-bulky or loose-fitting clothing, or dangling jewelry that may become entangled in your experimental apparatus. Pin or tie back long hair and roll up loose sleeves.
5. Use goggles:
    1. when heating anything.
    2. when using any type of projectile.
    3. when instructed to do so.

6. Use equipment with care for the purpose for which it is intended.
7. **Do not perform unauthorized experiments**. Get the instructor's permission before you try something original.
8. Be careful when working with apparatus that may be hot. If you must pick it up, use tongs, a wet paper towel, or other appropriate holder.
9. If a thermometer breaks, inform the instructor immediately. Do not touch either the broken glass or the mercury with your bare skin.
10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data collection:

Table 2: Reading for the series resistance, S_s

Value of P (Ω)	**Value of Q (Ω)**	**Value of R (Ω)**	**Series resistance, $S_s=\frac{QxR}{P}$(Ω)**	**Mean S_s(Ω)**
10	10			
100	10			
1000	100			

Table 3: Reading for the parallel resistance, S

Value of P (Ω)	**Value of Q (Ω)**	**Value of R (Ω)**	**Parallel resistance $S_p=\frac{QxR}{P}$(Ω)**	**Mean, S_p(Ω)**
10	10			
100	10			
1000	100			

Data analysis and demonstration:

Record data for R_1, R_2, R_3 etc. and for the combination.

Results and Discussions:

From the observed and calculated values of the equivalent resistances, show that they are equal. This verifies the laws of series and parallel

Conclusion:

The laws of series and parallel resistance is verified.

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. https://cdac.olabs.edu.in/?sub=74&brch=9&sim=75&cnt=4

Knowledge Test

Pre-lab viva sample Question

1. What is a P.O. Box and why is it so called ?
2. What is the principle on which it works?

Post-lab viva sample question

1. Principle of Wheatstone's bridge, is it suitable for measuring very high or Low resistance?
2. If the resistance coils of the box be calibrated at 20; will they give the same value at other temperatures?

Experiment Number: 10
Name of the Experiment: To verify the laws of transverse vibration of tuning fork and to determine the frequency of a tuning fork by Melde's experiment**.**

Objectives:

To determine the frequency of an electrically maintained tuning fork by,

i. Transverse mode of vibration
ii. Longitudinal mode of vibration

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
10	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques to determine the frequency of tuning fork both transverse and longitudinal mode.	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-communication**	**Affective domain**		

Theory:

Speed of waves in a stretched string*:* A string means a wire or a fiber which has a uniform diameter and is perfectly flexible. The speed of a wave in a flexible stretched string depends upon the tension in the string and mass per unit length of the string.

$$v = \sqrt{\frac{T}{\mu}} \qquad (1)$$

Where, the tension T in the string equal to Mg.
M - Mass suspended and g is acceleration due to gravity.

μ - linear density or mass per unit length of the string.

$$\mu = \frac{m}{L} \qquad (2)$$

Where m is the mass of the string and L is the total length of the string.

Vibrations of a stretched string: When the wire is clamped to a rigid support, the transverse progressive waves travel towards each end of the wire. By the superposition of incident and reflected waves, transverse stationary waves are set up in the wire. Since ends of the wire are clamped, there is node N at each end and anti node A in the middle as shown in Fig: 1.

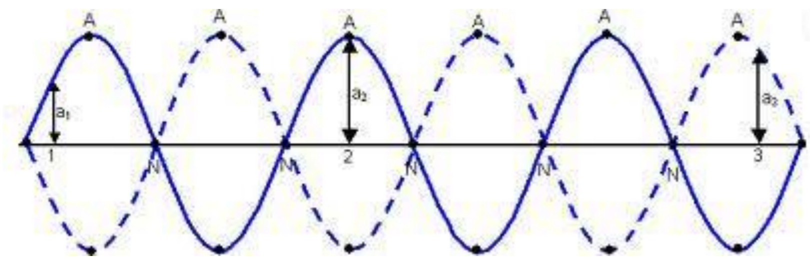

Fig.1

The points of the medium which have no displacements called ***nodes*** and there are some points which vibrate with maximum amplitude called ***antinodes.***

The distance between two consecutive nodes is λ/2, (λ - wavelength). Because l is half a wavelength in the equations,

$$l = \frac{\lambda}{2} \qquad (3)$$

If 'f' be the frequency of vibration the wire,

$$f = \frac{v}{\lambda} = \frac{v}{2l} \qquad (4)$$

Substituting the value of ' v ' in equation (4)

$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \qquad (5)$$

Transverse drive mode : In this arrangement the vibrations of the prongs of the tuning fork are in the direction perpendicular to the length of the string.

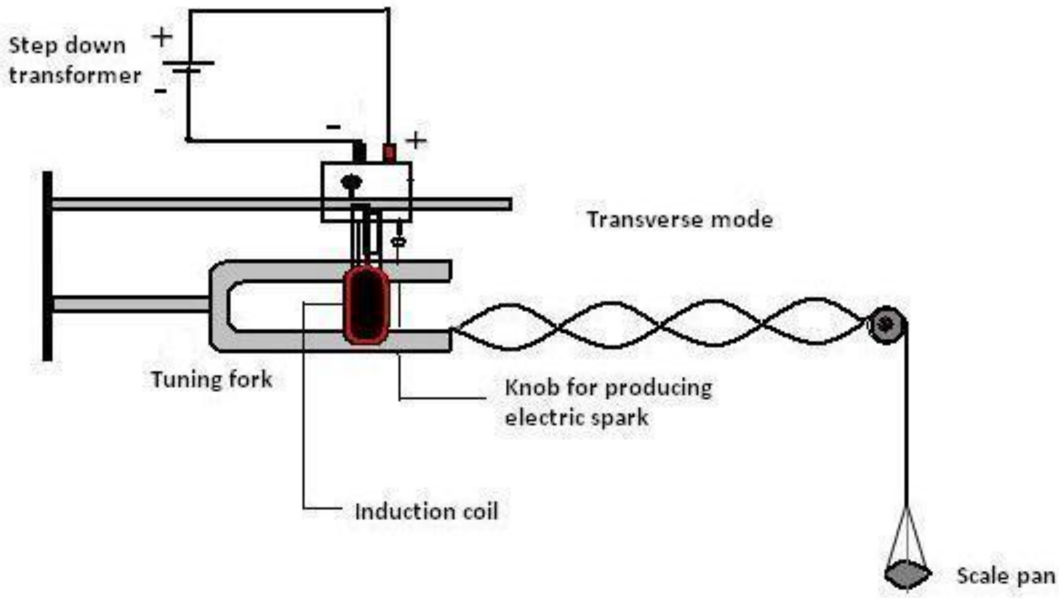

Fig.2

The time, during which the tuning fork completes one vibration, the string also completes one vibration. In this mode, frequency of the string is equal to the frequency of the tuning fork.

From equation (5),

$$\text{Frequency} \quad f = \sqrt{\frac{gM}{4\mu l^2}} \qquad (6)$$

Where,

The total mass M is equal to the mass M' of the weight in the scale pan plus the mass M0 of the scale pane, $M = M' + M_0$.

Longitudinal drive mode: In this arrangement the tuning fork is set in such a manner that the vibrations of the prongs are parallel to the length of the string.

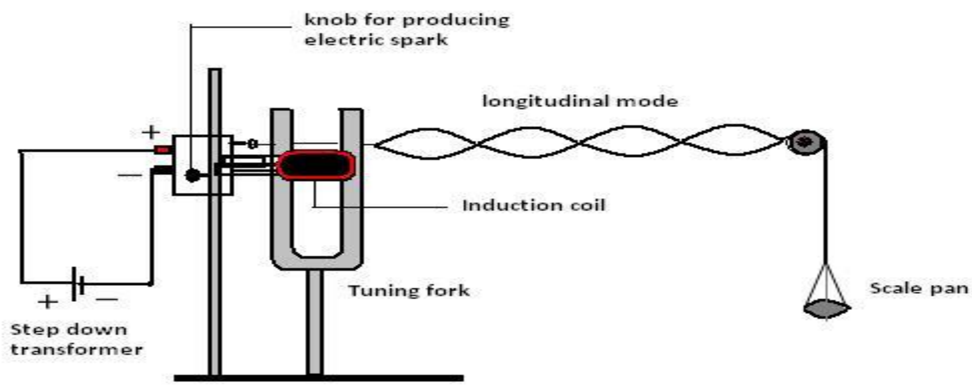

Fig.3

The time, during which the tuning fork completes one vibration, the string completes half of its vibration. In this mode, frequency of the fork is twice the frequency of the string.

$$\text{Frequency} \quad f = \sqrt{\frac{gM}{\mu l^2}} \qquad (7)$$

Using equation (6) and (7) we can calculate the frequency of electrically maintained tuning fork in two different modes of vibration.
In transverse drive mode the string follows the motion of the tuning fork, up and down, once up and once down per cycle of tuning fork vibration.

However, one cycle of up and down vibration for transverse waves on the string is two cycles of string tension increase and decrease. The tension is maximum both at the loops' maximum up position and again at maximum down position. Therefore, in longitudinal drive mode, since the string tension increases and decreases once per tuning fork vibration, it takes one tuning fork vibration to move the string loop to maximum up position and one to move it to maximum down position. This is two tuning fork vibrations for one up and down string vibration, so the tuning fork frequency is half the string frequency.

Required equipment and device:

1. Electrically maintained tuning fork
2. fine thread
3. scale pan
4. weights
5. meter scale.

Procedure:

Transverse mode of vibration of the string

(i) The apparatus is arranged with the length of the string is parallel to the prong of the tuning fork on which one end of the string is attached. The other end of the string carrying a scale pan is passed over a pulley fixed at one end of the table. When the tuning fork is excited, it vibrates perpendicular to the length of the string.

(ii) The scale pan is detached from the string and its mass and length is determined using common balance and meter scale. Hence linear density is calculated.

(iii) The scale pan is again suspended at the end of the string and mass is added in the scale pan. The circuit is closed and tuning fork is set into vibration. The string vibrates transversely producing stationary waves. The length of the string is so adjusted to get well defined loops.

(iv) Keeping two long knitting needle at two nodes, length of N loops is measured and average length is calculated. Using equation, frequency of the tuning fork is calculated.

Longitudinal mode of vibration of the string

(i) The apparatus is arranged with length of the string is perpendicular to the prong of the fork. In this case, when the tuning is vibrated parallel to the length of the string.
(ii) The experiment is performed exactly as in the previous case.

Precautions: -

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10. Ask the instructor to check all electrical circuits before you turn on the power.
11. When working with electrical circuits, be sure that the current is turned off before making adjustments in the circuit.
12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data Collection:

Table-1: Determination of frequency for both longitudinal and transverse wave

No. of obs	Mode of vibration	Mass suspended (M’) gm	Total mass M gm	No. of loops x	Length of one loop l cm	Length of x loops L cm	Frequency
1	Longitudinal						
2							
3							
1.	Transverse						
2.							
3.							

Data analysis and demonstration:
Here, M is the total mass-=mass of the scale pan + mass suspended.
Mass of the scale pan - 0 .5g.

Transverse mode

$$f = \sqrt{\frac{gM}{4\mu l^2}}$$ ....Hz

f - frequncy of tuning fork in Hz
μ - linear density in kg/m - mass of the string / length of the string.
Here, mass - 350mg and length - 3m and μ - 1.17 x 10^{-4} kgm^{-1}.
l - length of one loop in m

Longitudinal mode

$$f = \sqrt{\frac{gM}{\mu l^2}}$$ ....Hz

Results and Discussions:

1. The frequency of electrically maintained tuning fork at longitudinal mode of vibration = ... Hz

2. The frequency of electrically maintained tuning fork at transverse mode of vibration = ... Hz

Conclusion:
The frequency of electrically maintained tuning fork at transverse mode and longitudinal mode can be calculated

Reference: Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin

Knowledge Test

Pre-lab viva sample Question

1. Define longitudinal wave
2. Define transverse wave
3. Define frequency

Post-lab viva sample question

1. What is transformer?
2. What is loop?
3. How tuning fork can work?

Experiment Number-11
Name of the Experiment: To determine the stopping potential from the photocurrent versus applied potential graph.

Objectives:

1. To understand the phenomenon Photoelectric effect as a whole.
2. To draw kinetic energy of photoelectrons as a function of frequency of incident radiation.
3. To determine the Planck's constant from kinetic energy versus frequency graph.
4. To plot a graph connecting photocurrent and applied potential.
5. To determine the stopping potential from the photocurrent versus applied potential graph.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
11	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and techniques for using ammeter, voltmeter for determine the stopping voltage in photo electric experiment	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-communication**	**Affective domain**		

Theory:

During his experiments on electromagnetic radiation (to demonstrate light consists of e-m waves), Hertz noticed a spark between the two metallic balls when a high frequency radiation incident on it. This is called photoelectric effect. Photoelectric effect is the emission of electrons when electromagnetic radiations having sufficient frequency incident on certain metal surfaces. We call the emitted electrons as photoelectrons and the current they constitute as photocurrent. The phenomenon was first observed by Heinrich Hertz in 1880 and explained by Albert Einstein in 1905 using Max Planck's quantum theory of light. As the first experiment which demonstrated the quantum theory of energy levels, photoelectric effect experiment is of great historical importance.

The important observations on Photoelectric effect which demand quantum theory for its explanation are:

1. The Photoelectric effect is an instantaneous phenomenon. There is no time delay between the incidence of light and emission of photoelectrons.
2. The number of photoelectrons emitted is proportional to the intensity of incident light. Also, the energy of emitted photoelectrons is independent of the intensity of incident light.
3. The energy of emitted photoelectrons is directly proportional to the frequency of incident light.

The basic experimental set up which explains Photoelectric effect is as given below, It has been observed that there must be a minimum energy needed for electrons to escape from a particular metal surface and is called work function 'W' for that metal. The work function can be expressed in terms of frequency as,

$$W = h\nu_0 \ldots\ldots\ldots\ldots\ldots(1)$$

Where h is the Planck's constant and ν_0 is the threshold frequency (minimum frequency for photoelectric effect). The work function for some metals are listed in the table.

According to Einstein the Photoelectric effect should obey the equation,

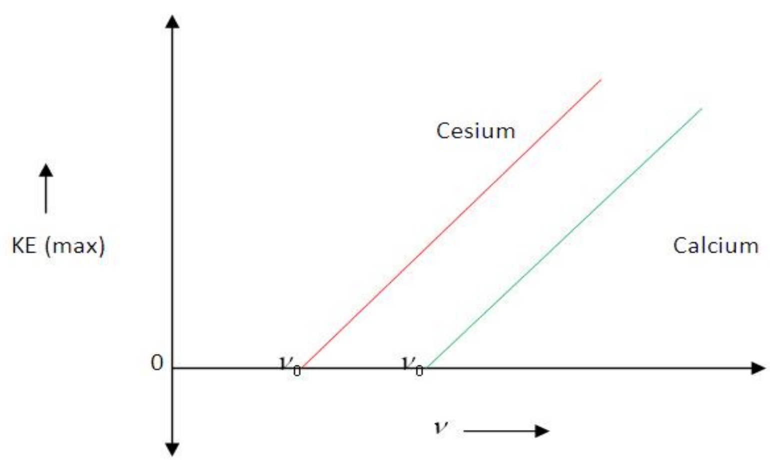
$$h\nu = KE_{max} + W \ldots\ldots\ldots(2)$$

From the above expression,

$$KE_{max} = h\nu - h\nu_0$$

$$KE_{max} = h(\nu - \nu_0) \ldots\ldots\ldots(3)$$

Graph connecting 'KE_{max}' and frequency:



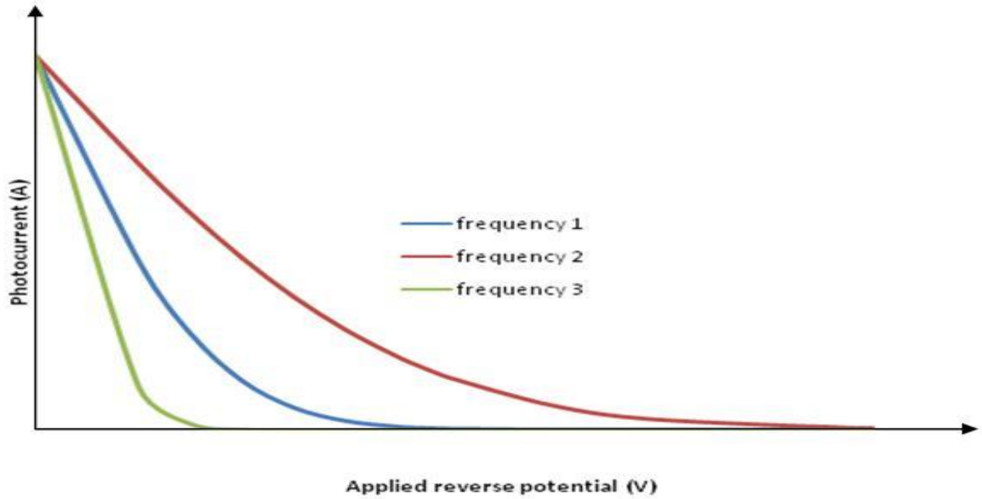
Maximum kinetic energy of photoelectrons versus frequency of incident radiation graph

Now, if we increase the reverse potential, the photocurrent gradually decreases and becomes zero at a particular reverse potential. This minimum applied reverse potential is called ***stopping potential V_0***. Hence the maximum kinetic energy of photoelectrons can be written as,

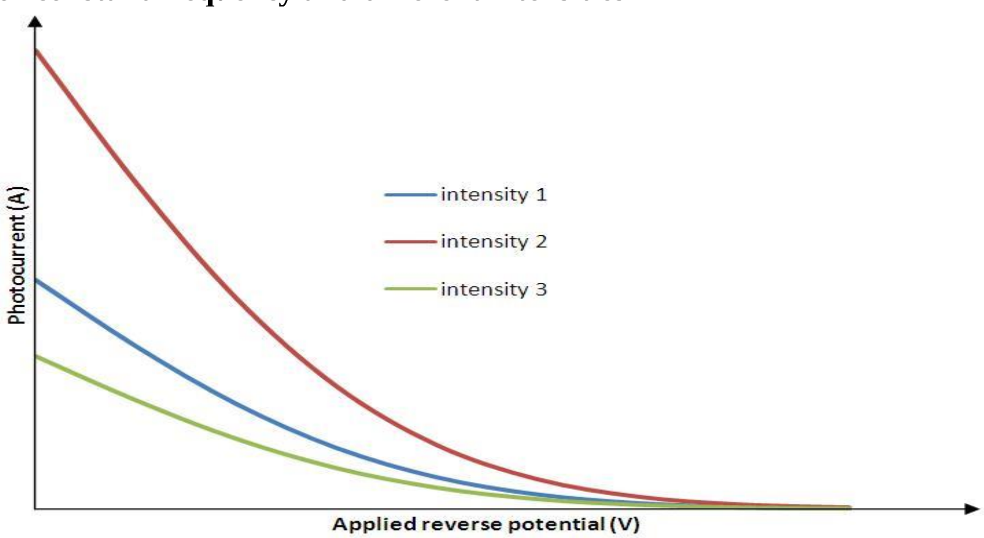
$$KE_{max} = eV_0 \ldots\ldots\ldots\ldots(4)$$

Graph connecting photocurrent and applied reverse potential:

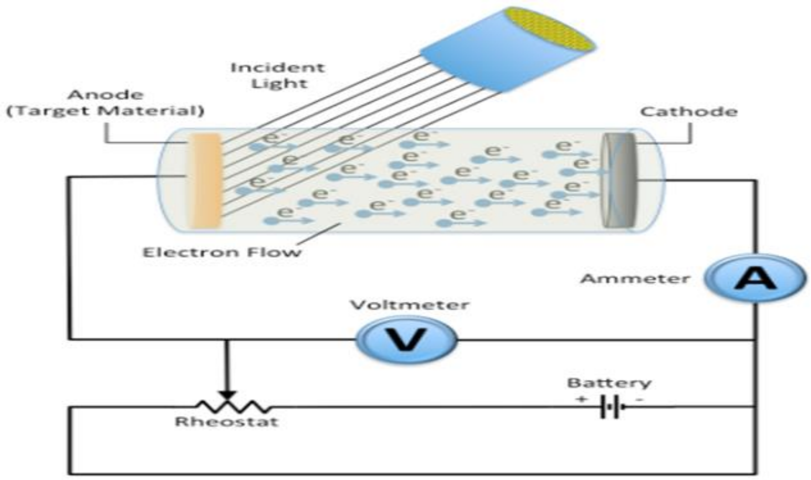
For constant intensity and different frequencies



For constant frequency and different intensities



Circuit Diagram:



Procedure:

1. Select the material for studying photoelectric effect.

2. Calculate area of the material, wave-length, intensity of incident light.

3. Switch on the light source.

4. Measure the reverse current for various reverse voltages.

5. Plot the current-voltage graph and determine the threshold voltage.

6. Repeat the experiment by varying the intensity for a particular wavelength of incident light.

7. Repeat the experiment by varying the wavelength for a particular intensity of the incident light .

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
2. **Absolutely no horseplay**. Be alert and attentive at all times. Act like an adult.
3. Report all accidents, injuries or breakage to the instructor immediately. Also, report any equipment that you suspect is malfunctioning.
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12. Do not connect the terminals of a battery or power supply to each other with a wire. Such a wire will become dangerously hot.
13. Return all equipment, clean and in good condition, to the designated location at the end of the lab period.
14. Leave your lab area cleaner than you found it.

Data collection:

Table-1: determine current for various voltage

No. of obs.	Current	Voltage

Data analysis and Demonstration:

Results and discussions: From graph………………..

Conclusion:

The stopping potential from the photocurrent versus applied potential graph can be determined

Reference:

1. Practical Physics", Dr. Giasudin Ahmed and Md. Shahabuddin
2. https://vlab.amrita.edu/?sub=1&brch=195&sim=840&cnt=2

Knowledge Test

Pre-lab viva sample Question

1. Define photoelectric effect
2. What is Planck’s constant?
3. Write laws of photoelectric effect
4. Who discover photoelectric effect first?

Post-lab viva sample question

1. Difference between photoelectric effect and photovoltaic effect
2. Define stopping potential
3. Define threshold frequency
4. Define Photo current
5. Define photo electron.

Experiment Number: 12
Name of the Experiment: To find the temperature coefficient of resistance of a given coil.

Objectives:

To find the temperature coefficient of resistance of a given coil.

Course Outcomes (COs), Program Outcomes (POs) and Assessment:

Expt. No.	CO Statement	Corresponding PO	Domain / level of learning taxonomy	Delivery methods and activities	Assessment tools
12	Upon completion this experiment, students will be able to: **CO1: use** the various procedures and to determine the force on a current carrying conductor	**PO1–Engineering knowledge**	**Affective domain/ analyzing level**	☐ Simulation ☑ Experiment ☑ Practice lab ☑ Group discussion ☐ Tutorial	☑ Lab tests ☑ Lab reports ☑ Final lab test ☐ Open ended lab ☐ Project show & project presentation
	CO3: learn the writing techniques of lab report in a systematic way.	**PO10-communication**	**Affective domain**		

Theory:

A Carey foster bridge is principally same as a meter bridge, which consists of four resistances P, Q, R and X that are connected to each other as shown in figure 1.

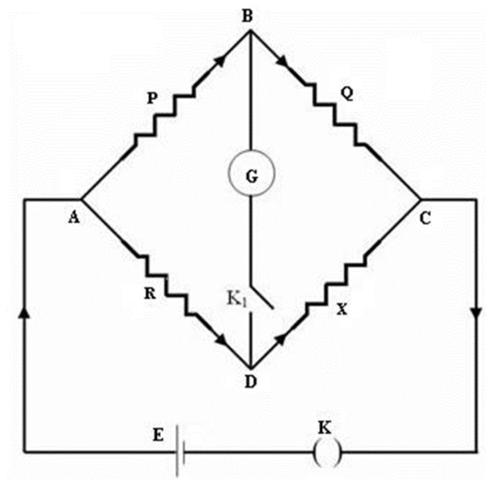


Figure 1: Wheatstone's bridge

In this circuit G is the galvanometer and E is a lead accumulator and $K1$and K are the galvanometer key and accumulator key respectively. If the values of the resistances are adjusted so that no current flows through the galvanometer, and if any of three resistances P,Q,R and X are known, the unknown resistance can be determined using the relationship,

$$\frac{P}{Q} = \frac{R}{X}$$

The Carey foster bridge is used to measure the difference between two nearly equal resistances and knowing the value of one, the other can be calculated. In this bridge, the end resistances are eliminated in calculation. Which is an advantage and hence it can conveniently used to measure a given resistance.

Let *P* and *Q* be the equal resistances connected in the inner gaps 2 and 3, the standard resistance R is connected in gap 1 and the unknown resistance X is connected in the gap 4.Let l_1 be the balancing length ED measured from the end *E*. By whetstone's principle,

$$\frac{P}{Q} = \frac{R + a + l_1\rho}{X + b + (100 - l_1)\rho} \quad \textbf{........................ (1)}$$

Where, a and b are the end corrections at the ends E and F, and is the resistance per unit length of the bridge wire.
If the experiment is repeated with X and R interchanged and if l_2 is the balancing length measured from the end E,

$$\frac{P}{Q} = \frac{X + a + l_2\,\rho}{R + b + (100 - \;l_2)\rho} \quad \textbf{..............................(2)}$$

From equation (1) & (2)

$$X = R + \rho(l_1 - l_2) \quad \text{......................} \; \textbf{(3)}$$

Let l_1' and l_2' are the balancing lengths when the above experiment is done with a standard resistance r (say 0.1) in the place of R and a thick copper strip of zero resistance in place of X From equation (3),

$$0 = r + \rho(l_1' - l_2')$$

$$\rho = \frac{r}{l_1' - l_2'}$$

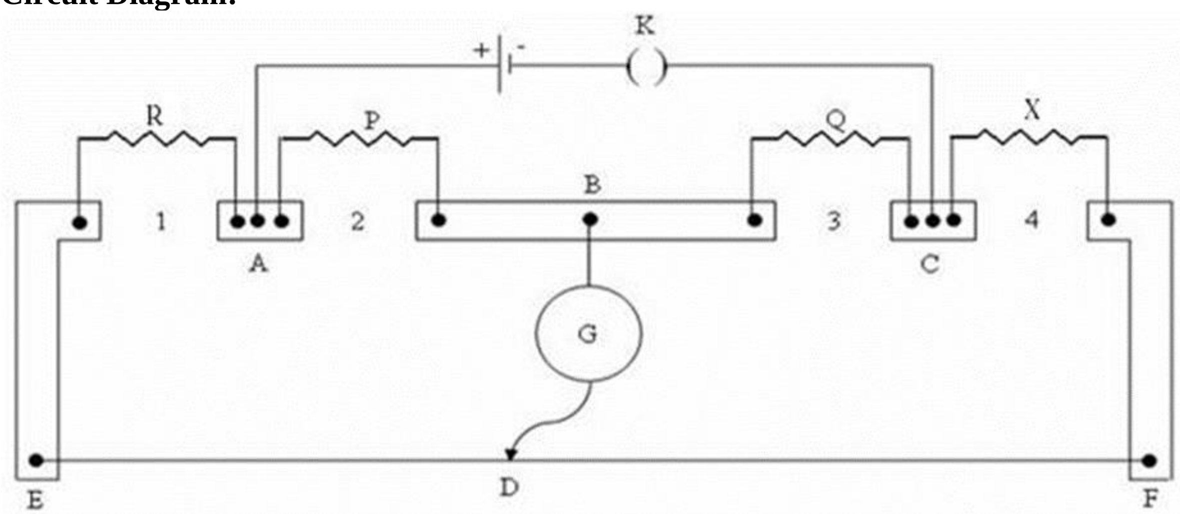
If $X1$ and $X2$ are the resistance of a coil at temperatures $t_1{}^o c$ and $t_2{}^o c$, the temperature coefficient of resistances is given by the equation,

$$\alpha = \frac{X_2 - X_1}{X_1 t_2 - X_2 t_1}$$

Also, if X_0 and X_{100} are the resistance of the coil at 0^oc and 100^oc,

$$\alpha = \frac{X_{100} - X_0}{X_0 \times 100}$$

Circuit Diagram:



Required equipment and devices:

1.Unknown low resistor

2.Resistance box
3.Lead accumulator
4.Jockey
5.one way key
6.Galvanometer
7.connecting wires.

Procedure:

(i) Make connection as shown in figure. Join the coil R of which the temperature coefficient is to be determined to the gap G1 of the metre bridge through two connecting wires. Join a resistance box S in the gap G2. Connect the battery E to binding screw A and B of the metre bridge through commutator K and a variable resistance Rh. Join the two terminals of a galvanometer to the binding screw at O and the jocket J. Connect a resistance box and a plug key in parallel to the galvanometer.

(ii) After making connection as described in (i) take out suitable resistance from the box S and find the balance point and for reverse currents. The resistance in S should be so chosen that the null point lies at the central region of the metrw bridge wire. Record the room temperature $t1^0$C. Repeat the operations three times with three different values of the box resistance. Interchange the position of the resistance coil and resistance box in the gaps G1 and G2. Repeat the operation.

(iii) Boil some water in the hypsometer and go on noting the temperature of the resistance coil. When the thermometer reading shows a steady maximum value $t2^0$C, find out the null point. Again interchange the positions of the resistance coil and resistance box and determine the null point again.

(iv) Calculate the resistance at the two temperatures and find the mean values. Then calculate α from the relation.

Precautions: -

1. **Follow directions**. Come to lab prepared to perform the experiment. Follow all written and verbal instructions. When in doubt, ask.
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14. Leave your lab area cleaner than you found it.

Data Collection:

<table>
<tr><td rowspan="2">Temp.</td><td rowspan="2">No.of obs</td><td colspan="2">Resistance in</td><td colspan="2">Null points</td><td rowspan="2">Mean null points (cm)</td><td rowspan="2">Unknown resitance Ω</td><td rowspan="2">Mean resistance Ω</td></tr>
<tr><td>Left gap</td><td>Right gap</td><td>Direct current</td><td>Reverse current</td></tr>
<tr><td>T1^{0}C</td><td></td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td>T2^{0}C</td><td></td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
</table>

Data analysis and demonstration:

A graph is plotted between values of X and t , which gives a straight line, whose slope is α.

Results and Discussions:

Temperature coefficient is

1. ……………………………………..
2. ……………………………………….
3. ………………………………………

Conclusion:

The temperature coefficient of resistance of a given coil.

Reference:

1. Practical Physics”, Dr. Giasudin Ahmed and Md. Shahabuddin
2. http://emv-au.vlabs.ac.in/electricity-magnetism/Temperature_Coefficient_of_Resistance/

Knowledge Test

Pre-lab viva sample Question

1.Define temperature
2.Define resistivity
3.Define conductivity

Post-lab viva sample question

1. What is temperature coefficient?
2. If temperature coefficient can be negative? Explain
3. Why use reverse connection?