Laboratory Manual

Course code: PHY 1208
Course title: Physics Practical

Department of Physics
Jashore University of Science and Technology

Prepared by:
Dr. Mohammad Abdur Rashid

List of Experiments:

1. To determine the modulus of rigidity of the material of a wire by the method of oscillation (Dynamic method).

2. To determine the value of acceleration due to gravity (g) by means of a compound pendulum.

3. To determine the moment of inertia of a flywheel about its axis of rotation.

4. To determine the specific heat of a liquid by the method of cooling.

5. To determine the value of the mechanical equivalent of heat (J) by electrical method with radiation correction.

6. To determine the end-corrections of a meter bridge.

7. To determine the value of a low resistance by the method of fall of potential.

8. To determine the resistance of a galvanometer by half deflection method.

9. To determine the radius of curvature of a convex lens by Newton’s rings.

Reference Books:

1. **Practical Physics,** Dr. Giasuddin Ahmed and Md. Shahabuddin
2. **Physics-I & II,** R. Resnick, D. Halliday

Experiment no 1: **Date:**

Name of the Experiment: Determination of the modulus of rigidity of the material of a wire by the method of oscillations (Dynamic Method).

Theory:

A cylindrical body is supported by a vertical wire of length l and radius r as shown in Fig. 1.1. The axis of the wire passes through its center of gravity. If the body is twisted through an angle and released, it will execute torsional oscillations about a vertical axis. Therefore, the motion is simple harmonic. If at any instant the angle of twist is θ, the moment of the torsional couple exerted by the wire will be

$$\frac{\eta \pi r^4}{2l}\theta = C\theta ,$$

where $C = \frac{\eta\pi r^4}{2l}$ is a constant and η is the modulus of rigidity of the material of the wire.

Therefore, the time period for torsional oscillations is,

$$T = 2\pi\sqrt{\frac{I}{C}} ,$$

where I is the moment of inertia of the cylindrical body which is given by $I = \frac{1}{2}Ma^2$. Here M and a are the mass and radius of the cylinder respectively.

From above two equations, we get

$$T^2 = \frac{4\pi^2 I}{C} = \frac{8\pi I l}{\eta r^4}$$

$$\text{or, } \eta = \frac{8\pi I l}{T^2 r^4} \text{ dynes/cm}^2$$

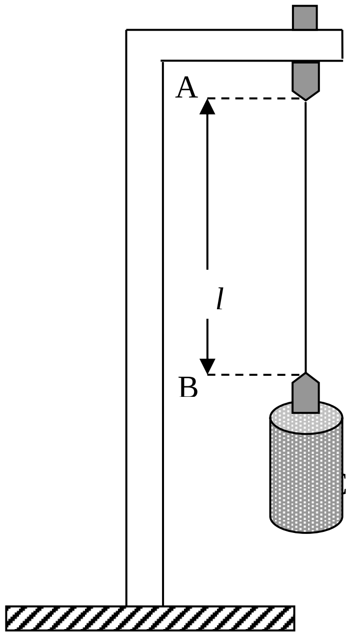


Fig. 1.1: Torsional pendulum

Apparatus:

A uniform wire, A cylindrical bar, Suitable clamp, Stopwatch, Screw gauge, Slide calipers, Meter scale, etc.

Brief Procedure:

1. Find out the value of one smallest division of the main scale and the total number of divisions of the vernier scale of the slide calipers and calculate vernier constant ($V.C$).
2. Find out the value of one smallest division of the linear scale, value of pitch (the distance along the linear scale traveled by circular scale when it completes one rotation) and the total number of divisions of the circular scale of the screw gauge and calculate least count ($L.C$).
3. Measure the radius, a of the cylinder by using the slide calipers.
4. Measure the mass, M of the cylinder. Calculate moment of inertia.
5. Measure the radius, r of the wire by using the screw gauge.

6. Measure the length, l of the wire between the point of suspension and the point at which the wire is attached to the cylinder with a meter scale.
7. Twist the cylinder from its equilibrium position through a small angle and release so that it begins to oscillate. Measure the time for 30 complete oscillations with a stop watch. Find out the time period of oscillation.
8. Calculate the value of the modulus of rigidity (η) of the material of the given wire.

Experimental Data:

Vernier Constant ($V.C.$) of the slide calipers,

$$V.\,C. = \frac{The\ value\ of\ one\ smallest\ division\ of\ the\ main\ scale}{Total\ number\ of\ divisions\ in\ the\ vernier\ scale}$$

Table-1: Table for the radius of the cylinder

No. of obs.	Main scale reading, x (cm)	Vernier scale division, d	Vernier constant, V_C (cm)	Vernier scale reading, $y = V_c \times d$ (cm)	Diameter, $x + y$ (cm)	Mean diameter, D (cm)	Instru-mental error (cm)	Corrected diameter, D (cm)	Radius, $a = \frac{D}{2}$ (cm)
1									
2									
3									
4									
5									

Least Count (L.C.) of the Screw Gauge

$$L.\,C. = \frac{Pitch}{Total\ number\ of\ divisions\ in\ the\ circular\ scale}$$

Table-2: Table for the radius of the wire

No. of obs.	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Circular scale reading, $y = d \times L_c$ (cm)	Diameter, $x + y$ (cm)	Mean diameter, D (cm)	Instru-mental error (cm)	Corrected diameter, D (cm)	Radius, $r = \frac{D}{2}$ (cm)
1									
2									
3									
4									
5									

Length of the wire, l = cm

Table-3: Table for the time period

No. of obs.	Time for 30 oscillations, t (sec)	Time period, $T = \frac{t}{30}$ (sec)	Mean T (sec)
1			
2			
3			
4			
5			

Calculations:

Moment of Inertia of the cylinder, $I = \frac{1}{2} Ma^2$ g-cm^2

Modulus of rigidity of the wire, $\eta = \frac{8\pi I l}{T^2 r^4}$ dynes/cm^2

Error Calculation:

Standard value of the modulus of rigidity of the material of the wire (steel) =

8.4×10^{11} dynes cm^{-2}.

$$\text{Percentage error} = \frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$$

Result:

Discussions:

Experiment no 2: **Date:**

Name of the Experiment: Determination of the value of the acceleration due to gravity (g) by means of a compound pendulum.

Theory:

A compound pendulum is a rigid body of arbitrary shape which is capable of oscillating about a horizontal axis passing through it. For small angles of swinging, its motion is simple harmonic with a period given by

$$T = 2\pi\sqrt{\frac{I}{mgh}}$$

where I is the pendulum's rotational inertia about the pivot, m is the pendulum's mass, and h is the distance between the pivot and the pendulum's centre of gravity as shown in Fig. 5.1.

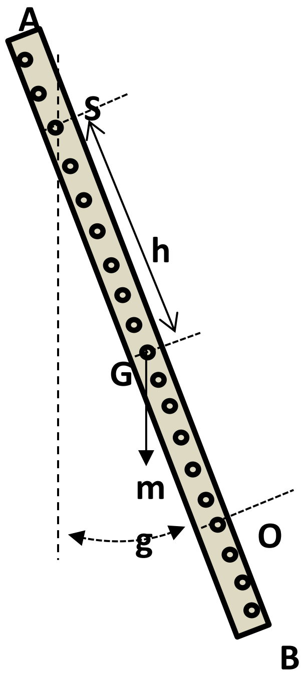


Fig. 5.1: Compound Pendulum

A compound pendulum that oscillates from a suspension point (S) with period T (as shown in Fig. 5.1) can be compared with a simple pendulum of length L with the same period T. L is called the equivalent length of the compound pendulum. The point along the compound pendulum at a distance L from the suspension point is called the oscillation point (Fig. 5.1). In a compound pendulum these two points are interchangeable.

Now using the time period expression of a simple pendulum,

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

$$\text{or, } g = 4\pi^2\frac{L}{T^2}$$

The acceleration due to gravity (g) at the place of the experiment can be measured by finding L and T graphically.

Apparatus:

A bar pendulum, Stop watch, Meter Scale, Metal wedge, etc

Brief Procedure:

1. Label the ends of the compound pendulum bar as *A* and *B*.
2. Locate the centre of gravity (*G*) of the bar.
3. Measure the distance of holes (1, 2, 3,… and 9) from *G* for both sides.
4. Insert a metal wedge in the 1st hole at end *A* and place the wedge on the clamp so that the bar can oscillate freely.
5. Oscillate the bar horizontally. Be careful not to make the amplitude of oscillation too large. (Should be less than 5°). Note the time for 20 complete oscillations. Calculate the time period.
6. Do this process at different holes (2, 3, …..and 9).
7. Repeat steps 3, 4 and 5 for end *B*.
8. Draw a graph with distance as abscissa and time period as ordinate with the origin at the centre of gravity which is put at the middle of the graph paper along the abscissa. Put the length measured towards the end A to the left and that measured toward the end B to the right of the origin (see Graph 1). Draw a line parallel to the abscissa in such a way that it intersects at four points of the two curves as shown in Graph 1. Label these points as *P, Q, R* and *S*, respectively.
9. Find out the equivalent length of the pendulum, *L* and time period, *T* (value of the period at point *O*) from the graph.
10. Calculate the value of acceleration due to gravity using the given equation.

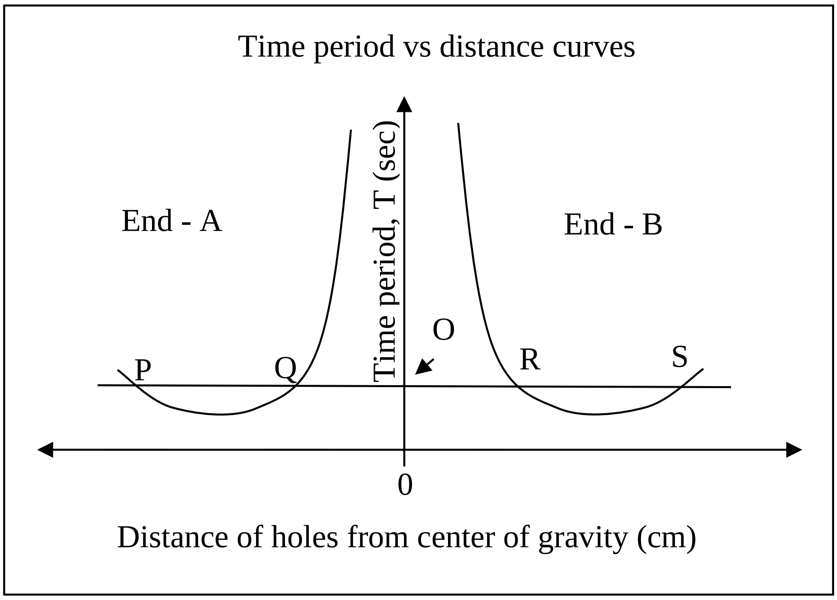
<u>Experimental Data:</u>

Table-1: Table for the time period for end-*A*

	Hole no.	Distance of the hole from center of gravity (cm.)	Time for 20 oscillations, (sec.)		Mean time, t (sec.)	Time period $T = \frac{t}{20}$ (sec.)
End-A	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					

Table-2: Table for the time period for end-B

	Hole no.	Distance of the hole from center of gravity (cm.)	Time for 20 oscillations, (sec.)		Mean time, t (sec.)	Time period $T = \frac{t}{20}$ (sec.)
End-B	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					



Graph I

<u>Calculations:</u>

From graph 1: Length, $PR = (PO+OR) =$ cm

Length, $QS = (QO+OS) =$ cm

Equivalent length to the Simple Pendulum, $L = \dfrac{PR + QS}{2} =$ cm

Time period, $T =$ sec

The value of acceleration due to gravity, $g = 4\pi^2 \dfrac{L}{T^2} =$ cm/s^2

Error Calculation:

Standard value of the acceleration due to gravity = 981 cm/s^2

Percentage error = $\dfrac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$

<u>Result:</u>

<u>Discussions:</u>

Experiment no 3: **Date:**

Name of the experiment: To determine the moment of inertia of a flywheel about its axis of rotation.

Experiment no 4: **Date:**

Name of the Experiment: Determination of the specific heat of a liquid by the method of cooling

Theory: Newton's law of cooling can be used to determine the specific heat of a liquid by observing the time taken by the liquid in cooling from one temperature to another.

Suppose a liquid of mass M_1 and specific heat S_1 is enclosed within a calorimeter of mass m and specific heat s. The thermal capacity of the system is (M_1S_1+ms). If the temperature of the liquid falls from θ_1 to θ_2 in time t_1, then the average rate of loss of heat is

$$(M_1S_1+ms)\frac{(\theta_1-\theta_2)}{t_1}$$

If now the first liquid be replaced by an equal volume of second liquid of known specific heat (say water) under similar conditions and if the time taken by the second liquid to cool through the same range of temperature from θ_1 to θ_2 be t_2, then the average rate of loss of heat is

$$(M_2S_2+ms)\frac{(\theta_1-\theta_2)}{t_2},$$

where M_2 and S_2 are the mass and specific heat of the second liquid, respectively.

Since the conditions are similar, these two rates are equal

$$(M_1S_1+ms)\frac{(\theta_1-\theta_2)}{t_1}=(M_2S_2+ms)\frac{(\theta_1-\theta_2)}{t_2}$$

or,

$$S_1=\frac{M_2S_2t_1+ms(t_1-t_2)}{M_1t_2}$$

Apparatus: Double walled enclosure, Calorimeter, Thermometer, Heater, Stopwatch, etc.

Brief Procedure:

1. Clean and dry the calorimeter and measure the mass (m) of the calorimeter and stirrer using a balance.
2. Pour water up to two-third volume of the calorimeter. Measure the total mass (m'') of the calorimeter, water and stirrer. Calculate the mass (M_2) of water.
3. Put the calorimeter on the heater and hold the thermometer bulb in the middle of the water and raise the temperature around 62 ^{o}C. Keep the calorimeter into the double walled enclosure with the help of a tongs. Close the lid and fix the thermometer with holder so that its bulb is in the middle of the water.
4. Start the stopwatch when the temperature just falls to 60 °C. Note this temperature in the table. Go on recording the temperature of water up to 20-25 minutes at an interval of one minute. Gently stir the water during the whole process.
5. Pour out the water from the calorimeter and wipe it dry. Take experimental liquid in the calorimeter as the same volume of water. Repeat steps 2, 3 and 4 for liquid.
6. On a graph paper, plot curves (both for water and liquid) by taking temperature as ordinate and time as abscissa (see Graph 1). Calculate t_1 and t_2 from the graph.
7. Using the given formula, determine the specific heat of the given liquid.

<u>Experimental data:</u>

Table: Time–temperature record for water and liquid

No. of obs.	Time (min)	Temperature of water (℃)	Temperature of liquid (℃)
1	00		
2	01		
3	02		
4	03		
5	04		
6	05		
7	06		
8	07		
9	08		
10	09		
11	10		
12	11		
13	12		
14	13		
15	14		
16	15		
17	16		
18	17		
19	18		
20	19		
21	20		
22	21		
23	22		
24	23		
25	24		
26	25		

Mass of the calorimeter + stirrer, m = g

Mass of the calorimeter + stirrer + liquid, m' = g

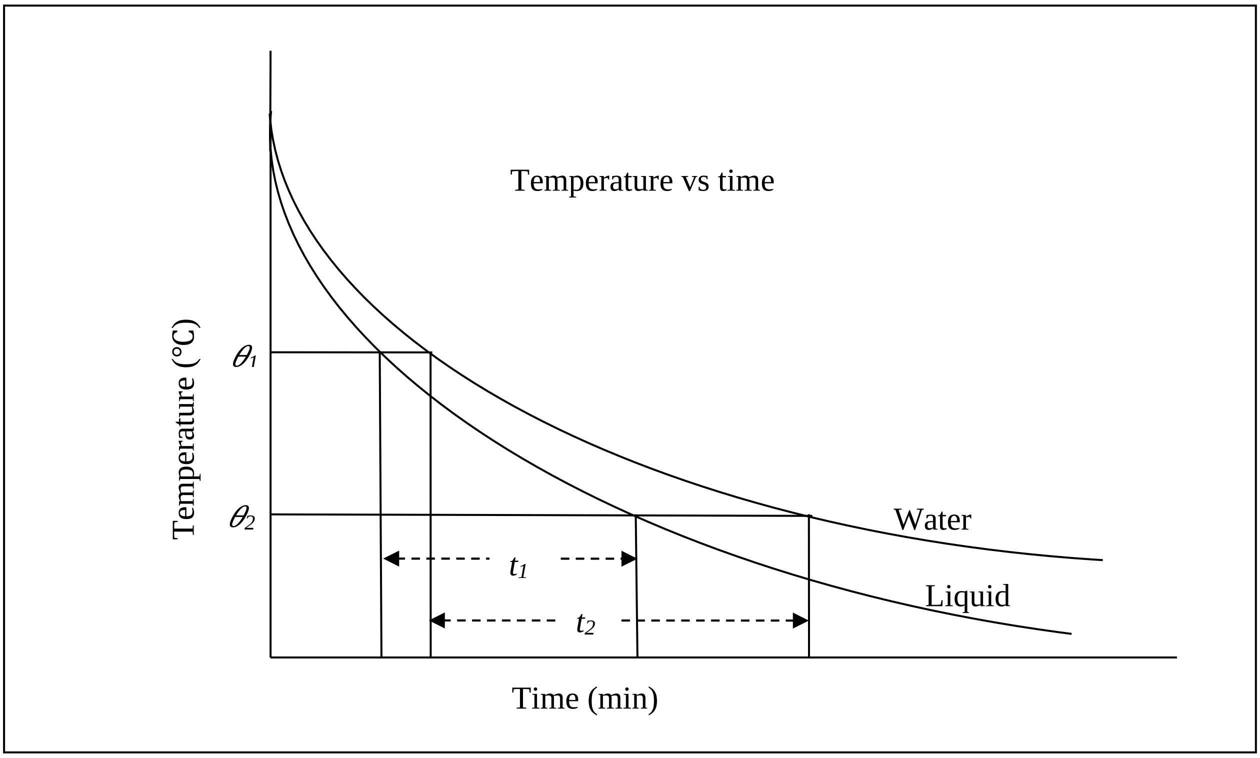
Mass of the liquid, $M_1 = m' - m =$ g

Mass of the calorimeter + stirrer + water, $m'' =$ g

Mass of the water, $M_2 = m'' - m =$ g

Specific heat of the water, $S_2 = 1.00$ Cal g^{-1}°C^{-1}

Specific heat of the material of the calorimeter (Aluminum), $s = 0.2096$ Cal g^{-1}°C^{-1}
(Copper), $s = 0.0909$ Cal g^{-1}°C^{-1}



Graph 1: Variation of temperature with time

<u>Calculations:</u>

Time taken by water to cool from $\theta_1 =$ °C to $\theta_2 =$ °C as obtained from the graph 1, $t_2 =$ min

Time taken by the liquid to cool from $\theta_1 =$ °C to $\theta_2 =$ °C as obtained from the graph 1, $t_1 =$ min

Specific heat of the liquid,

$$S_1 = \frac{M_2 S_2 t_1 + ms(t_1 - t_2)}{M_1 t_2}$$

Error Calculation:

Standard value of the specific heat of turpentine is 0.42 Cal $g^{-1}{}^{\circ}C^{-1}$.

Percentage error = $\frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$

Result:

Discussions:

Experiment no 5: **Date:**

Name of the Experiment: Determination of the value of the mechanical equivalent of heat (J) by electrical method

Theory: The mechanical equivalent of heat J is the amount of electrical energy required to generate one calorie of heat. If E volt be the potential difference across a conducting coil (Fig. 8.1) and i ampere be the current flowing through the coil for t seconds, then the electrical energy in the coil is Eit. If this energy is converted into heat H (calories) then the mechanical equivalent of heat J is

$$J = \frac{Eit}{H} \text{ Joules/Calorie} \quad (1)$$

If H is measured by means of a calorimeter with its contents where the temperature raises from θ_1° C to θ_2° C then

$$H = (Ms + W)(\theta_2 - \theta_1), \quad (2)$$

where M is the mass of the water in the calorimeter, s is the specific heat of water and W is the water equivalent of the calorimeter and stirrer. W can be calculated from the mass and specific heat of the calorimeter and stirrer.

From equations (1) and (2), we get

$$J = \frac{Eit}{(Ms + W)(\theta_2 - \theta_1)} \text{Joules/Calories}$$

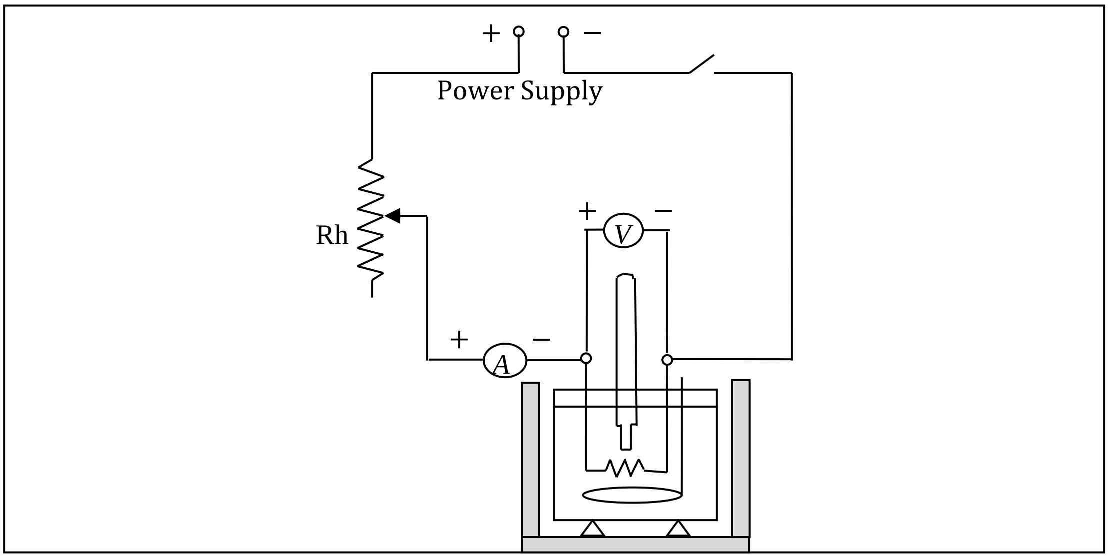


Fig. 8.1: Experimental setup for measuring the mechanical equivalent of heat

Apparatus:

Joule's calorimeter set, Ammeter, Voltmeter, Stopwatch, Thermometer, Balance, Power Supply, Rheostat, Key, etc.

Brief Procedure:

1. Measure the mass (m_1) of the calorimeter and stirrer using a balance.
2. Pour water into the calorimeter which is just enough to dip the heating coil and the bulb of the thermometer. Then measure the total mass (m_2) of the calorimeter, stirrer and water. Calculate the mass (M) of water.
3. Place the heating coil into the calorimeter. Keep the calorimeter with heating coil into its insulating box. Fix the thermometer with holder so that its bulb is in the middle of the water but never touching the coil and the calorimeter.
4. Complete the circuit as shown in Fig.8.1. Switch on the circuit temporarily and adjust the control knob of the power supply until the current is about 2 amperes. Then switch off the circuit and stir the water until a steady temperature is shown by the thermometer. Record this temperature as initial temperature.
5. Switch on the circuit and start the stopwatch simultaneously. Then start recording the temperature, current and voltage in the table at an interval of every 1 minute. Keeping the current supply and stopwatch on, record these values for 10 minutes. Then switch off the circuit but allow the stopwatch to run on and record the temperature for further 10 minutes in the same manner. Stir the water gently during the whole process.
6. Find the maximum and final temperatures. Use them to calculate the radiation correction.
7. Calculate the water equivalent of the calorimeter.
8. Using the given formula, determine the value of the mechanical equivalent of heat.

Experimental data:

Mass of the calorimeter + stirrer, m_1 = g

Mass of the calorimeter + stirrer + water, m_2 = g

Mass of the water, $M = m_2 - m_1$ = g

Specific heat of the water, s = 1 Cal g^{-1}°C^{-1}

Specific heat of the material of the calorimeter (Aluminum), s_1= 0.2096 Cal g^{-1}°C^{-1}
(Copper), s_1= 0.0909 Cal g^{-1}°C^{-1}

Table 1: Table for current, voltage and temperature

No of observations	Times (min)	Current, i (amp.)	Voltage, E (Volt)	Temperature, T (℃)
1	00	0	0	θ_i =
2	01			
3	02			
4	03			
5	04			
6	05			
7	06			
8	07			
9	08			
10	09			
11	10			
Current Stopped				
12	11	0	0	
13	12	0	0	
14	13	0	0	
15	14	0	0	
16	15	0	0	
17	16	0	0	
18	17	0	0	
19	18	0	0	
20	19	0	0	
21	20	0	0	θ_f =

Calculations:

Water equivalent of the calorimeter, $W = m_1 s_1$ = g

Initial temperature of the calorimeter + contents, θ_i= ℃

Maximum temperature of the calorimeter + contents, θ_m = ℃

Final temperature of the calorimeter + contents, θ_f = ℃

Rise of temperature, $\theta = (\theta_m - \theta_i)$ ℃

Radiation correction, $\theta_r = (\theta_m - \theta_f)/2$ = ℃

Corrected rise of temperature $(\theta_2 - \theta_1) = (\theta + \theta_r)$ = ℃

Time during which the current is passed, t = sec

Mean current during the interval t, i = amp.

Mean voltage during the interval t, E = volt

Mechanical equivalent of heat,

$$J = \frac{Eit}{(Ms + W)(\theta_2 - \theta_1)} \text{Joules/Calories}$$

Error Calculation:

Standard value of the mechanical equivalent of heat, J is 4.2 Joules/Calories

Percentage error = $\frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$

Result:

Discussions:

Experiment no 6: **Date:**

Name of the Experiment: Determination of the end-corrections of a meter bridge.

Theory:

A meter bridge consists of one meter long wire and has two gaps in which two resistances are placed. Consider, *P* and *Q* are the resistances in the two gaps in a meter bridge and when balance is obtained at the point *N* (say) of the wire (Fig. 4.1), applying the principle of Wheatstone bridge, we get

$$\frac{P}{Q} = \frac{l\rho}{m\rho} = \frac{l}{m} = \frac{l}{100-l}, \cdots\cdots\cdots\cdots\cdots\cdots (i)$$

where *l* and *m* are the lengths of the bridge wire on the left and right hand side of the balance point and ρ is the resistance per unit length of the wire.

Usually there are some resistances at the two ends of the bridge wire due to soldering by which the wire is joined to the copper plates for which measured length of the bridge may not exactly coincide with the zero of the meter scale. These errors are known as end-errors. Due to these errors, eq. (1) has to be modified.

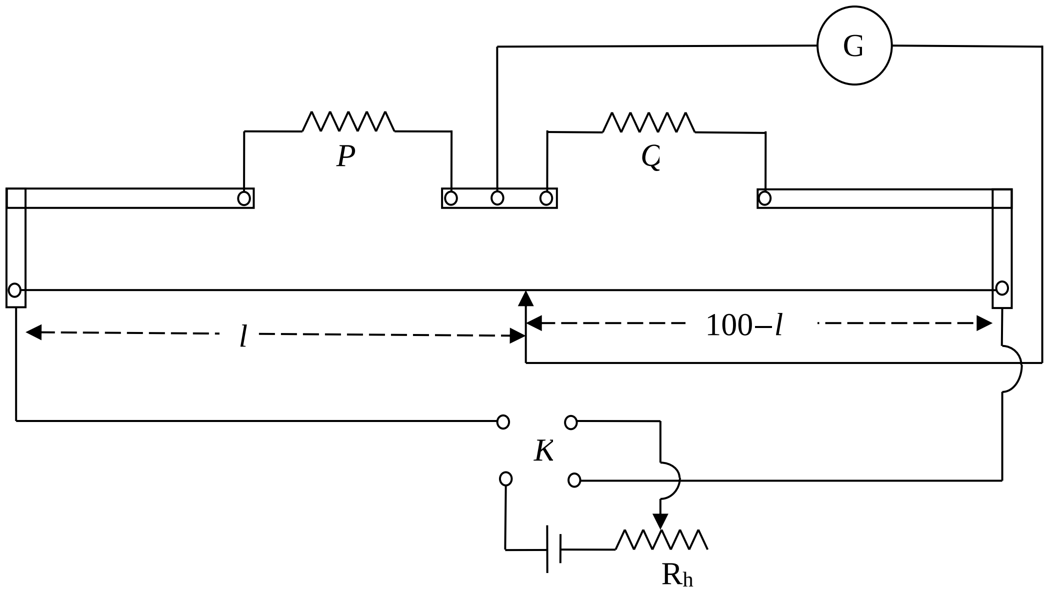


Fig. 4.1: Circuit diagram for measuring the end corrections of a meter bridge

The corrections are actually calculated in terms of two definite lengths *x* and *y* of the bridge wire for the two ends. These lengths should be added to the observed lengths *l and m* for balance. The values of *x* and *y* are called end-corrections. eq. (*i*) then becomes,

$$\frac{P}{\mathrm{Q}} = \frac{(l+x)\rho}{(m+y)\rho} = \frac{l+x}{m+y} = \frac{l+x}{(100-l)+y} \cdots\cdots\cdots\cdots\cdots\cdots (ii)$$

If the two resistances P and Q are interchanged, a new balance is obtained at N'(say). If L is the length of the wire at N' from the left hand side *(i.e.,* from zero), then

$$\frac{Q}{P} = \frac{L+x}{(100-L)+y} \dots\dots\dots\dots\dots\dots\dots\ (iii)$$

Combining eq. (ii) and eq. (iii) we get,

$$\frac{l+x}{(100-l)+y} = \frac{(100-L)+y}{L+x} \cdots\cdots\cdots\cdots\cdots\cdots (iv)$$

Adding 1 on both sides of this eq. we get,

$$\frac{100+x+y}{100-l+y} = \frac{100+x+y}{L+x} \cdots\cdots\cdots\cdots\cdots\cdots (v)$$

So, we can write

$$100 - l + y = L + x \cdots\cdots\cdots\cdots\cdots (vi)$$

From eq. (*vi*) we get,

$$y = L + x - 100 + l \cdots\cdots\cdots\cdots\cdots\cdots\cdots (vii)$$

Calling the ratio $\frac{P}{Q} = r$ and substituting eq. (vii) into eq. *(ii)* on right hand side, finally we get,

$$x = \frac{l - rL}{r - 1} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (ix)$$

Again substituting eq. (*ix*) into eq. (*vii*), finally we get

$$y = \frac{rl - L}{r - 1} - 100 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (ix)$$

Apparatus:

Meter bridge, Commutator, Battery, Resistance boxes, Rheostat, Jockey, Galvanometer, Connecting wires, etc.

Brief procedure:

1. Connect the circuit as shown in the Fig. 4.1. In order to check the correctness of the circuit, with the commutator on, put the jockey in contact to the left side and then to right side of the meter bridge wire. If deflections of the galvanometer are in opposite directions, the connections are correct.
2. Select 1 Ω in left gap (*P*) and 10 Ω in right gap (*Q*). Slide the jockey on the wire until the galvanometer shows zero deflection. Record the distance (*l)* of the null point from the left end of the wire. Reverse the current with commutator and measure *l* again. Record mean distance *l* in the table.
3. Interchange the resistances *P* and *Q* by selecting 10 Ω in the left gap and 1 Ω in the right gap. Record the distance (*L)* of the null point from the left end of the wire. Reverse the current with commutator and measure *L* again. Record mean distance Lin the table.
4. Calculate *x* and *y* by using the given equations.
5. Repeat step 2 and step 3 for different sets of values for *P* and *Q* (e.g. *P* = 1, *Q* = 15; *P* = 1, *Q* = 20; *P* = 1, *Q* = 25;……; etc) and calculate the corresponding values of *x* and *y*.
6. Calculate mean values of *x* and *y*.

Experimental Data:

Table: Data for the end corrections of the meter bridge

No. of obs.	Resistance (Ω)		Ratio	Balance points (cm.)			x (cm)	y (cm)	Mean x (cm)	Mean y (cm)
	Left gap	Right gap	$r=\frac{P}{Q}$	Direct	Reverse	mean				
1	$P=$	$Q=$				$l=$				
	$Q=$	$P=$				$L=$				
2										
3										
4										
5										

Calculation:

$$x=\frac{l-rL}{r-1}\ \mathrm{cm}=$$

$$y=\frac{rl-L}{r-1}-100\ \ \mathrm{cm}=$$

Result:

Discussions:

Experiment no 7: **Date:**

Name of the Experiment: Determination of the value of a given low resistance by the method of fall of potential.

Theory:

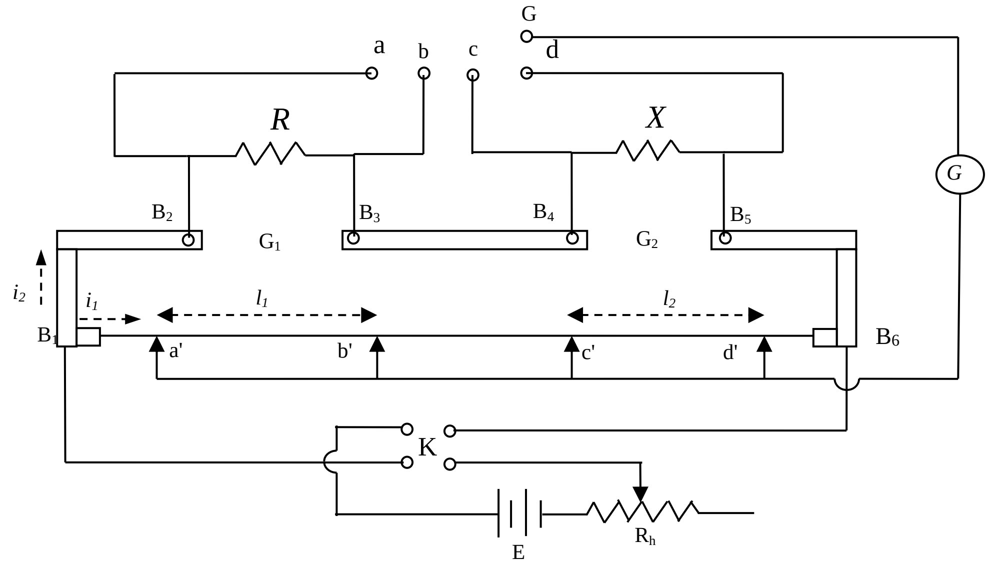


Fig. 1.1: Circuit diagram for measuring the low resistance

The circuit arrangement required for determining an unknown low resistance by the method of fall of potential is shown in Figure 1.1. In this circuit R is a low resistance of known value while X is an unknown low resistance connected to the gaps G_1 and G_2, respectively of a meter bridge. Through a commutator two poles of the power supply are connected to the two terminals B_1 and B_6 of the meter bridge. On reaching the terminal B_1 the current is divided into two directionsi_1 and i_2. i_2 flows through the low resistance while i_1 flows through the bridge wire. When the four way key points *a*, *b*, *c* and *d*are connected in turn to the galvanometer it will produce null deflections for*a*', *b*', *c*' and *d*' points on the bridge wire, i.e., the points *a*, *b*, *c* and *d* are equipotential with *a*', *b*', *c*' and *d*', respectively. Then

$$V_a = V_{a'}, V_b = V_{b'} V_c = V_{c'}, \qquad \text{and} \qquad V_d = V_{d'}$$

or,

$$V_a - V_b = V_{a'} - V_{b'} \text{and} V_c - V_d = V_{c'} - V_{d'}$$

or,

$$i_2 R = i_1 l_1 \rho \text{and} i_2 X = i_1 l_2 \rho,$$

where $l_1 = \mathrm{b}' - \mathrm{a}'$, $l_2 = \mathrm{d}' - \mathrm{c}'$ and ρ is the resistance per unit length of the bridge wire. From the last pair of equations we have

$$\frac{R}{X} = \frac{l_1}{l_2}$$

or,

$$X = R\frac{l_2}{l_1}$$

Now knowing *R*, *X* can be determined by measuring l_1 and l_2.

Apparatus:

Meter bridge, Battery, Low resistances, A four way key, Commutator, Rheostat, Galvanometer, Jockey, Connecting wires, etc.

Brief procedure:

1. Clean connecting wires with sand paper and make neat and tight connections as per the circuit shown in fig. 1.1. In order to check the correctness of the circuit, with the commutator on, put the plug key to *b* of the four-way key and place the jockey in contact to the left side of the meter bridge wire. Then put the jockey to right side of the meter bridge wire. If deflections of the galvanometer are in opposite directions, the connections are correct.

2. Introduce a value of known resistance, R (Say $R = 0.1\ \Omega$).

3. Put the plug key to *a* of the four-way key and then slide the jockey on the meter bridge wire to get a null point (i.e. the galvanometer deflection is zero) on the meter bridge for both direct and reverse current.

4. In the similar way, find the null points for *b*, *c* and *d* of the four-way key.

5. Calculate the value of low resistance, X by using the given formula.

6. Repeat steps 2 to 5 for different values of R.

Experimental data:

Table 1: Data for the low resistance

No of obs. (N)	Known resistance, R (Ω)	Position of null points	Null points (cm)			$l_1 = b'-a'$ (cm)	$l_2 = d'-c'$ (cm)	$X_i = Rl_2/l_1$ (Ω)
			Direct	Reverse	Mean			
01	0.1	a'						
		b'						
		c'						
		d'						
02	0.2	a'						
		b'						
		c'						
		d'						
03	0.4	a'						
		b'						
		c'						
		d'						
04	0.6	a'						
		b'						
		c'						
		d'						
05	0.8	a'						
		b'						
		c'						
		d'						

Table 2: Data for standard deviation

No of obs. *(N)*	X_i (Ω)	Mean $\bar{X}$ (Ω)	$(X_i - \bar{X})^2$ (Ω^2)	$\sigma = \pm\sqrt{\frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N}}$ (Ω)
1				
2				
3				
4				
5				
			$\sum_{i=1}^{N}(X_i - \bar{X})^2 =$	

Calculation:

$$X = R\,\frac{l_2}{l_1} =$$

$$\sigma = \pm\sqrt{\frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N}} =$$

Result:

Discussions:

Experiment no 8: **Date:**

Name of the Experiment: Determination of the resistance of a galvanometer by half deflection method.

Theory:

The circuit arrangement required for finding the resistance 'G' of a galvanometer by half deflection method is shown in Figure 2.1. In this circuit the shunt resistance S is very small compared to the galvanometer resistance G, and then the potential difference, V between the ends of the shunt resistance S remains nearly constant for all values of R_1.

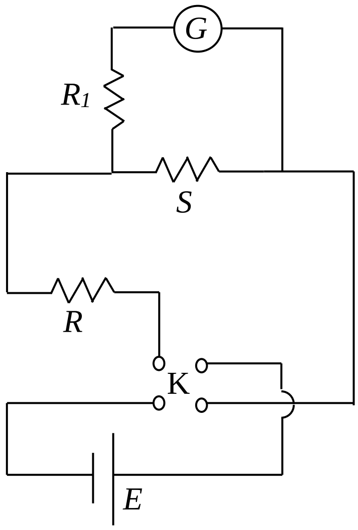


Fig. 2.1: Circuit diagram for measuring the resistance of galvanometer

When $R_1 = 0$, then the galvanometer current I_g is given by

$$I_g = \frac{V}{G} = kd, \qquad (1)$$

where d is the deflection in the galvanometer, k is the galvanometer constant. If now a resistance R_1 is introduced in the galvanometer circuit such that the deflection reduced to $d/2$, then

$$I'_g = \frac{V}{G + R_1} = k\frac{d}{2}, \qquad (2)$$

where I'_g is the new galvanometer current in the changed circumstances.

Dividing equation (1) by equation (2), we get

$$\frac{G + R_1}{G} = 2$$

or,

$$G + R_1 = 2G$$

or,

$$G = R_1$$

Hence by measuring R_1, G can be found.

Apparatus:

Galvanometer, Shunt Box, Resistance boxes, Commutator, Battery, Connecting wires, etc.

Brief procedure:

1. Clean connecting wires with sand paper and make neat and tight connections as per the circuit shown in fig. 2.1. In order to check the correctness of the circuit, place two plugs in the opposite holes of the commutator and see the direction of defection of the galvanometer pointer. Now place the plugs in the other holes of the commutator and see the deflection of the galvanometer pointer again. If the deflections are in opposite directions, the connections are correct.
2. Insert a small value of shunt resistance S (e.g. $S = 0.1\ \Omega$).
3. Making R_1=0, Apply a suitable value of resistance (20 Ω, 50 Ω, etc) from resistance box R in the circuit and change it until you obtain a measurable even number deflection (16 – 30 divisions) on the galvanometer dial. Note this deflection.
4. Keeping the resistance R constant, adjust the value of R_1 until the deflection is reduced to half.
5. Record the value of R_1 which is numerically equal to the galvanometer resistance G.
6. Reverse the current with the commutator K and repeat the whole operation to get the resistance of the galvanometer with reverse current.
7. Repeat the steps 2 to 6 for other value of S.

Experimental Data:

Table 1: Table for the resistance of the galvanometer

No of obs. (N)	Shunt Resistance, S (Ω)	Resistance, R (Ω)	Current direction	Resistance, R_1 (Ω)	Deflection, d (arbitrary unit)	Galvanometer resistance, $G = R_1$ (Ω)	Mean, G_i(Ω)
1	0.1		Direct				
			Reverse				
2	0.2		Direct				
			Reverse				
3	0.4		Direct				
			Reverse				
4	0.5		Direct				
			Reverse				
5	0.6		Direct				
			Reverse				
6	0.7		Direct				
			Reverse				
7	0.8		Direct				
			Reverse				

Table 2: Calculation of standard deviation

No of obs. (N)	Galvanometer resistance, G_i (Ω)	Mean $\bar{G}$ (Ω)	$(G_i - \bar{G})^2$ (Ω^2)	$\sigma = \pm\sqrt{\frac{\sum_{i=1}^{N}(G_i - \bar{G})^2}{N}}$ (Ω)
1				
2				
3				
4				
5				
6				
7				
			$\sum_{i=1}^{N}(G_i - \bar{G})^2 =$	

Calculation:

$$\sigma = \pm\sqrt{\frac{\sum_{i=1}^{N}(G_i - \bar{G})^2}{N}}$$

Result:

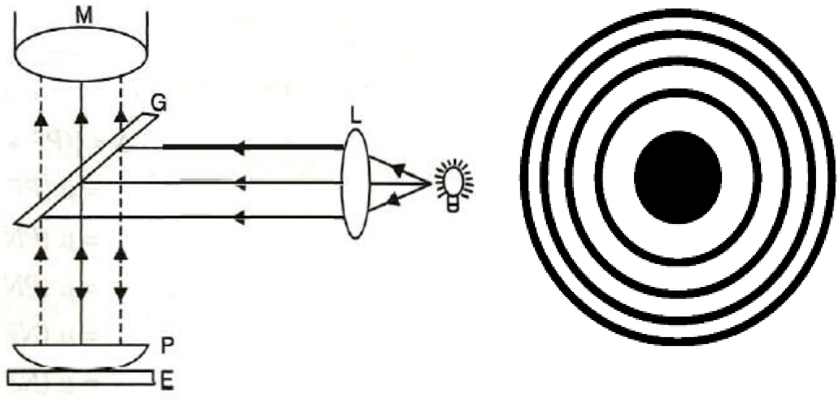
Discussions:

Experiment no 9: **Date:**

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

Theory:

The phenomenon of Newton's rings is an interference pattern caused by the reflection and transmission of light between a spherical surface and an adjacent flat surface which form a air thin film. When viewed with monochromatic light as shown in Fig. 6.1a, it appears as a series of concentric, alternating bright and dark rings as shown in Fig. 6.1b centered at the point of contact between the two surfaces.



(a) (b)

Fig.6.1: (a) Experimental setup of Newton's rings. (b) Pattern of the rings

Now the diameters of the n^{th} bright or dark rings are

$$D_n^2 = 2(2n + 1)\lambda R \qquad \text{(Bright Rings)}$$

$$D_n^2 = 4n\lambda R, \qquad \text{(Dark Rings)}$$

where R is the radius of curvature of the lens and λ is the wavelength of the monochromatic light.

Similarly, the diameters of the $(n+p)^{\text{th}}$ bright or dark rings are

$$D_{n+p}^2 = 2[2(n+ p) + 1]\lambda R \qquad \text{(Bright Rings)}$$

$$D_{n+p}^2 = 4(n + p)\lambda R \qquad \text{(Dark Rings)}$$

Subtracting D_n^2 from D_{n+p}^2, we have

$$D_{n+p}^2 - D_n^2 = 4p\lambda R, \text{ for either bright or dark rings,}$$

$$\text{or, } R = \frac{D^2_{n+p} - D_n^2}{4p\lambda}$$

The above equation is employed to compute the radius of curvature R of a lens.

Apparatus:

Travelling microscope, Plano-convex lens, Sodium lamp set, etc.

Brief Procedure:

1. Determine the least count (*L. C.*) (mentioned in experiment no. 1) of the micrometer screw of the travelling microscope.
2. Set the intersecting point of the cross-wires of the eye piece at the middle of the central dark spot.
3. Slide the cross-wires to 12^{th} dark ring on the left side of the central dark spot.
4. Set the vertical line of the cross-wire tangentially to 10^{th} dark ring and note the readings of the linear scale and circular divisions.
5. Set the cross-wire in the same manner to the 9^{th}, 8^{th},………., 1st rings by sliding the microscope in the same direction.
6. Cross the central dark spot by sliding the cross-wires and note the scale readings by setting the cross-wire to the right side of the 1^{st} ring.
7. Now move the cross-wires in the same direction and record the scale readings in the same manner for successive dark rings up to the 10^{th} ring on the right side.
8. Draw a best fit straight line through origin on a graph paper with square of the diameter as ordinate and number of the ring as abscissa. Calculate the slope of the line.
9. Calculate the radius of curvature of the plano-convex lens by using the given equation.

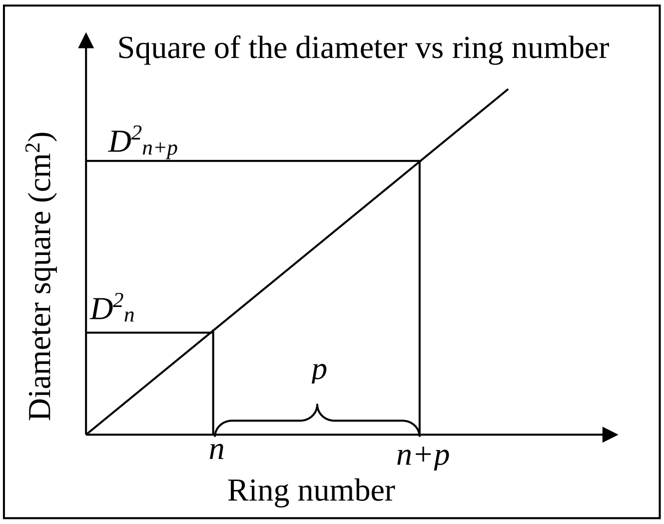
Experimental Data:

Least Count (*L.C.*) of the micrometer scale

$$L.\ C. = \frac{Pitch}{Total\ number\ of\ divisions\ in\ the\ circular\ scale}$$

Table: Table for the diameter of the rings

Ring no.	Readings of the microscope										Diameter, $D = L{\sim}R$ (cm)	D^2 (cm^2)
	Left Side (L)					Right Side (R)						
	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Circular scale reading, $y=d\times L_c$ (cm)	Total, $x+y$ (cm)	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c(cm)	Circular scale reading, $y=d\times L_c$ (cm)	Total, $x+y$(cm)		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												



Graph 1

Calculation:

From graph 1, slope = $\dfrac{D^2_{n+p} - D_n^2}{(n+p)-n}$

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

Result:

Discussions: