Manonmaniam Sundaranar University,
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OPEN AND DISTANCE LEARNING(ODL) PROGRAMMES
(FOR THOSE WHO JOINED THE PROGRAMMES FROM THE ACADEMIC YEAR 2023–2024)

III YEAR

B.Sc. Physics

Course Material

Physics Practical -VII (JMPHP7)

General Physics Experiments-II

Prepared
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PRACTICAL V
GENERAL PHYSICS EXPERIMENTS

CONTENTS

1. SPECTRAL RESPONSE OF PHOTOCONDUCTOR (LDR)

Aim:

To study the spectral response of a photoconductor (Light Dependent Resistor – LDR) and to determine how its resistance (or current) varies with wavelength of incident light.

Apparatus required:

1. Light Dependent Resistor (LDR)
2. Monochromator / Optical filter set (visible region)
3. Tungsten / Halogen lamp (white light source)
4. DC power supply
5. Microammeter / Voltmeter
6. Series resistor (known value)
7. Optical bench
8. Connecting wires
9. Dark box or enclosure

Circuit Diagram:

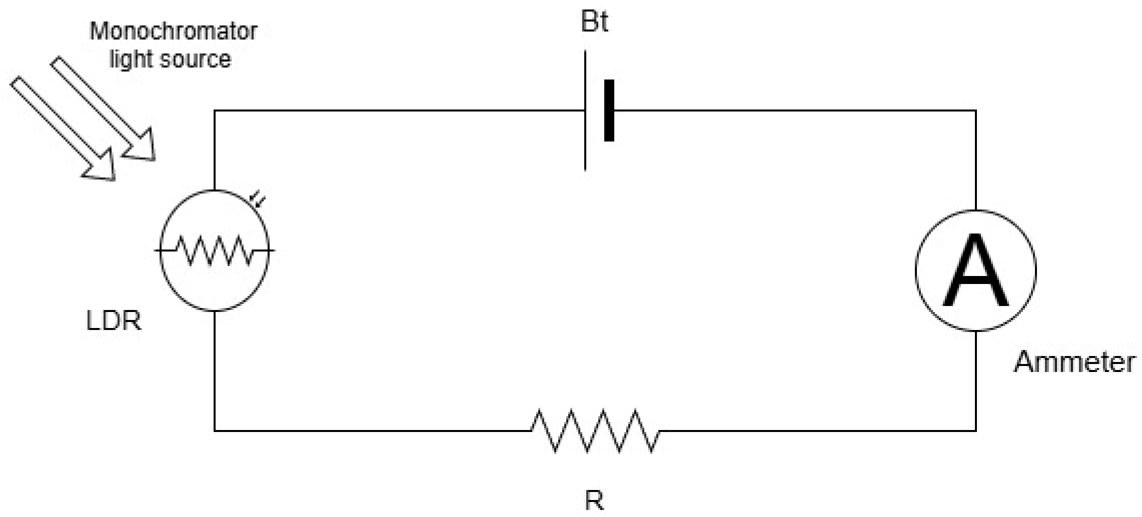


Figure 1: Spectral response of LDR

Theory:

A Light Dependent Resistor (LDR) is a photoconductive device made of cadmium sulphide (CdS), whose resistance decreases when light falls on it. In darkness, the LDR has high resistance due to the absence of free charge carriers. When light of suitable wavelength falls on the LDR, photons with energy greater than the band gap excite electrons from the valence band to the conduction band, producing electron–hole pairs. This increases the conductivity of the LDR. The electrical response of the LDR depends on the wavelength of the incident light. The variation of current or conductivity with wavelength is known as the spectral response of the photoconductor.

Principle:

The experiment is based on the principle of photoconductivity, according to which the conductivity of a semiconductor increases when it is illuminated with light of appropriate wavelength. By allowing monochromatic light of different wavelengths to fall on the LDR and measuring the corresponding current, the spectral response of the photoconductor is studied.

Formula:

The resistance of the LDR is given by

$$R = \frac{V}{I}$$

Where,

R= resistance of the LDR
V= applied voltage
I= current through the LDR

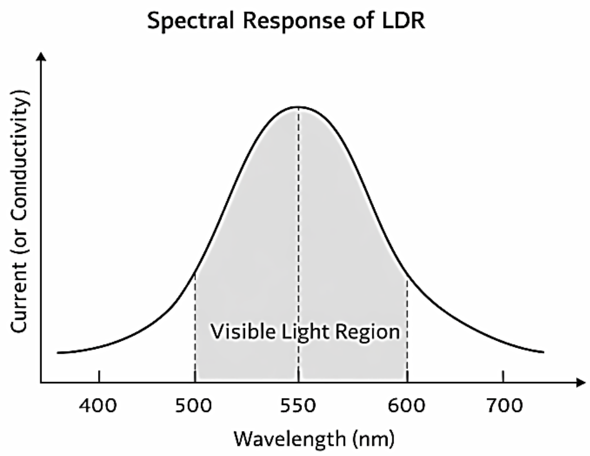
Procedure:

- The experimental setup is arranged as per the circuit diagram, with the LDR connected in series with a known resistor and a DC power supply. A microammeter is connected to measure the current through the LDR.
- The LDR is placed inside a dark enclosure to prevent the influence of stray and ambient light.
- The light source (tungsten or halogen lamp) is switched ON and allowed to stabilize for a few minutes to ensure constant light intensity.
- Monochromatic light of a known wavelength is obtained using a monochromator or suitable optical filter and is allowed to fall normally on the surface of the LDR.
- With the applied voltage kept constant, the current flowing through the LDR is noted for the selected wavelength.
- The wavelength of the incident light is then increased in equal steps, and for each wavelength, the corresponding current through the LDR is recorded.
- Care is taken to ensure that the alignment of the optical system and the intensity of light remain unchanged throughout the experiment.
- The procedure is repeated for all wavelengths in the visible region.

Observation Table

SI.NO	Wavelength(nm)	Current(µA)	Voltage(Ω)
1	400		
2	450		
3	500		
4	550		
5	600		
6	650		
7	700		

Model graph:



Result:

The spectral response of the photoconductor (LDR) is studied. The LDR shows maximum sensitivity in the visible region, confirming its suitability as a light sensor.

2. POTENTIOMETER – DETERMINATION OF RESISTANCE AND SPECIFIC RESISTANCE OF A GIVEN COIL

Aim:

To determine the resistance of a given coil and specific resistance (resistivity) of the material of the coil using a potentiometer.

Apparatus Required:

- Potentiometer
- Battery
- Rheostat
- Galvanometer
- Resistance box
- Ammeter
- Given resistance coil
- Screw gauge
- Key
- Connecting wires.

Circuit diagram:

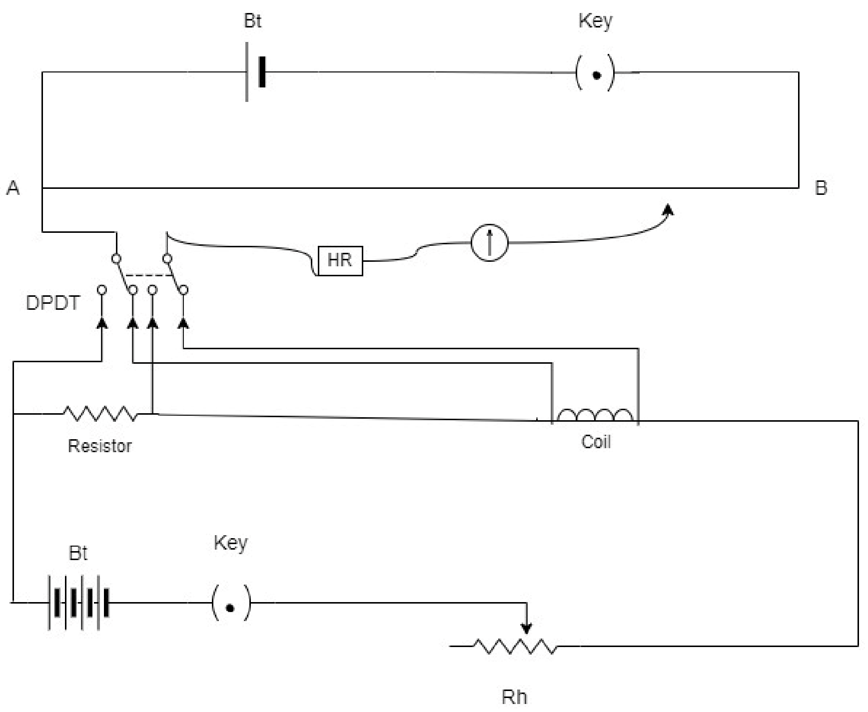


Figure 1: Resistance of a given coil

Theory:

A potentiometer is an instrument used to measure potential difference accurately. When a steady current flows through a uniform potentiometer wire, the potential drop along the wire is directly proportional to its length. In this experiment, the potential difference across a given resistance coil is measured using a potentiometer without drawing current from the source. The resistance of the coil is calculated using Ohm's law. By measuring the length and radius of the wire, the specific resistance of the material of the coil is determined.

Formula:

The resistance of the coil is given by

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

The specific resistance(resistivity) of the coil

$\rho = X\pi r^2$ /L

Where, X is the resistance of the coil.
R is standard resistance.
l_1, l_2 are balancing lengths.
r is the thickness of the coil.
L is the length of coil wire.

Procedure:

1. **Potentiometer Circuit Setup**
   - Connect the potentiometer wire in series with a 6 V battery**,** rheostat (Rh)**,** and key (K) as shown in the diagram.
   - Adjust the rheostat so that a steady and suitable current flows through the potentiometer wire, ensuring a uniform potential gradient.
2. Secondary Circuit (Resistance Circuit)
   - Connect the standard resistance (R) and the given coil (X) in series with a battery, key, and rheostat.
   - Connect a DPDT switch such that:
     - In position 1, the standard resistance R is connected across the potentiometer.
     - In position 2, the unknown coil X is connected across the potentiometer.
   - This arrangement ensures that the same current flows through both R and X.
3. Connection of Galvanometer
   - Connect one end of the galvanometer to the central terminal of the DPDT switch**.**
   - Connect the other end of the galvanometer to the jockey, which slides over the potentiometer wire.
4. Balancing for Standard Resistance (R)

- Close the keys in both circuits.
- Keep the DPDT switch in the position connecting standard resistance R**.**
- Slide the jockey along the potentiometer wire to obtain a null deflection in the galvanometer.
- Note the corresponding balancing length l_1.

5. Balancing for Unknown Coil (X)
- Without changing the rheostat settings or disturbing the current, flip the DPDT switch to connect the unknown coil X**.**
- Again, slide the jockey to get null deflection.
- Note the balancing length l_2.

6. Repeat Observations
- Take several readings of $l_1$and $l_2$by slightly adjusting the rheostat in the resistance circuit.
- Calculate the mean values of balancing lengths.

7. Measurement of Coil Dimensions
- Measure the length (L) of the coil using a meter scale.
- Measure the diameter of the wire at several places using a screw gauge and find the mean radius r.

Observation Table:

1. Potentiometer Readings

   To determine the balancing lengths l_1 and l_2.

SI.NO	**Standard resistance R(Ω)**	**Balancing Length l_1 (cm)**	**Balancing Length l_2 (cm)**
1			
2			
3			
4			

Mean l_1=_________ (cm).

Mean l_2=_________ (cm).

2. Screw Gauge Readings

   To determine the cross sectional radius of the coil wire.

SI.NO	**PSR (mm)**	**HSC**	**HSR (mm)**	**TR (mm)**
1				
2				
3				
4				
5				

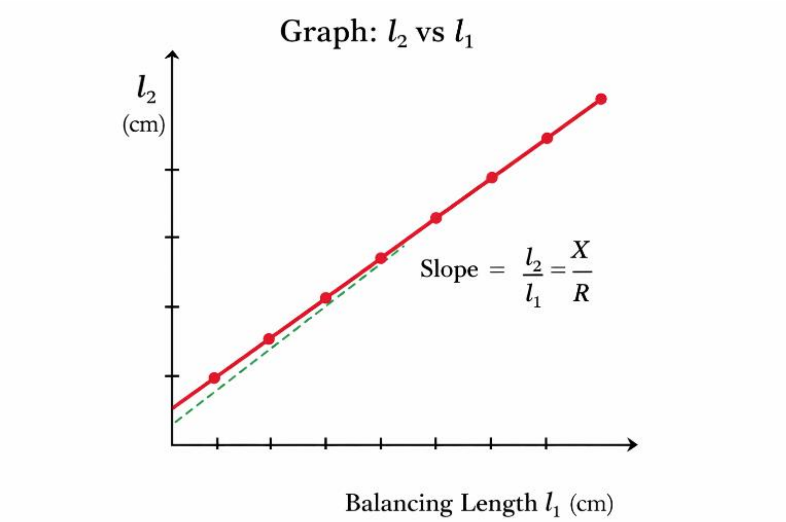
Mean diameter d=_______(mm)
Radius r = d/2 (mm)

Calculations:

Resistance of the coil $X = R\frac{l_2}{l_1}$

Specific resistance of the coil $\rho = X\pi r^2$ /L

Model Graph:



Result:

The specific resistance (resistivity) of the material of the given coil is

$$\rho = \_\_\_\_\_ \ \Omega\,\text{m}$$

3.POTENTIOMETER- EMF OF A THERMOCOUPLE

Aim:

To study the variation of thermo e.m.f. with temperature, for copper-iron thermocouple with the help of potentiometer.

Apparatus Required:

- Potentiometer,
- Thermometer
- DC Power supply
- Copper-iron thermocouple
- High resistance box
- Temperature bath/ice bath/ hot bath
- Thermometers
- High resistance rheostat
- Key
- Galvanometer
- Connection wires

Circuit Diagram:

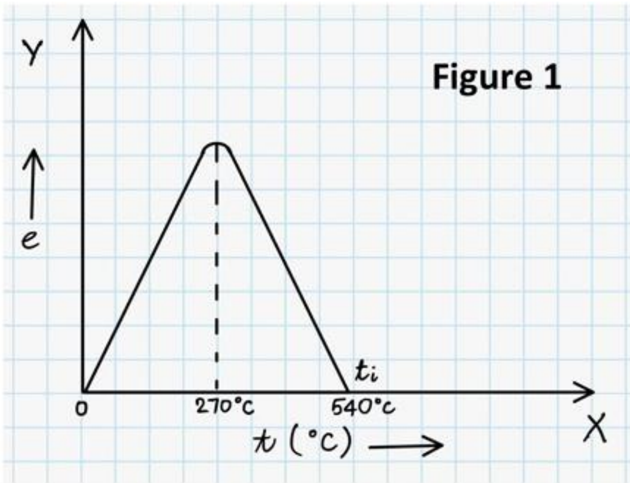


Figure 1: Thermo emf vs temperature

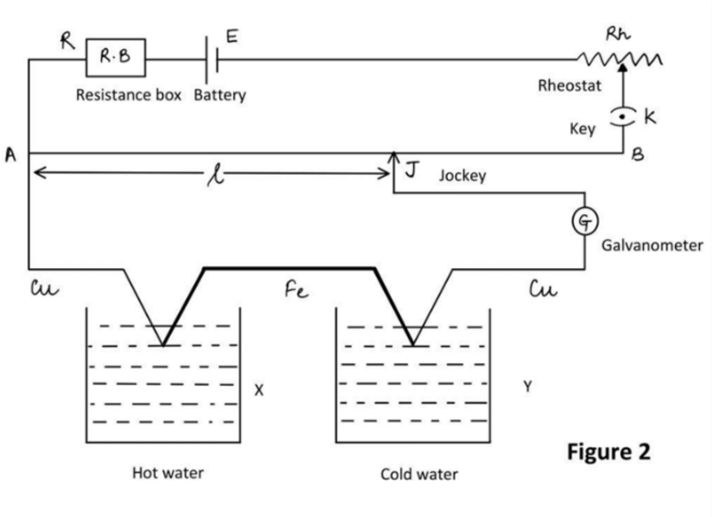


Figure 2: circuit diagram

Theory:

When two junctions are made by joining the wires of two different metals (such as copper and iron) and they are placed at different temperatures, an emf. is developed in the circuit which is called the thermo emf. Due to this thermo emf., a thermo electric current flows in the circuit from the copper wire to the iron wire through the hot junction. The value of thermo emf., depends on the nature of metals and the difference in temperatures of the junctions. On increasing the temperature of the hot junction, the thermo emf. increases and it becomes maximum at a particular temperature tn. This temperature is called the neutral temperature. For copper-iron thermocouple, the neutral temperature is nearly 270°C. On further increasing the temperature of hot junction, the thermo emf. begins to decrease and at a particular temperature ti, which is called the temperature of inversion, the thermo emf. becomes zero. Then on further increasing the temperature of hot junction, the direction of thermo emf. reverses. If the temperature of cold junction is 0°C, ti = 2tn. The value of neutral temperature is constant for a given thermocouple (i.e., its value does not depend on the temperature of cold junction), but the temperature of depends on the temperature of cold junction. Remember that the value of thermo emf. is of the order of micro-volt, hence a potentiometer is used to measure it. Fig .1 shows the variation of thermo emf. e with the temperature of the hot junction when the temperature of cold junction is 0°C.

Formula:

At a given temperature of hot junction of the thermo-couple, thermo emf.

$$e = \left(\frac{E}{R+r}\right)\frac{rl}{L}\ \ volt$$

E = emf. of the battery used in the primary circuit,
R = resistance connected in series with the potentiometer wire from the resistance box,
resistance of the potentiometer wire AB,
L = length of the potentiometer wire AB,
l = balancing length for the thermocouple when there is zero deflection in the galvanometer.

Procedure:

1. First, complete the electric circuit shown in Fig. 2 for which across the potentiometer wire AB, a resistance box R.B., a battery E, rheostat Rh and a key K are connected in series to form the primary circuit. Take care that the positive terminal of the battery is joined at the end A of the potentiometer wire. Then the copper and iron wires are joined together to form two junctions and as shown in Fig. 2, one junction is kept immersed in the beaker X of cold water, while the other junction is kept immersed in the beaker Y of the hot water. The beaker Y is placed on the heater. The end of copper wire of the junction kept in cold water is then joined at the terminal A of the potentiometer, while the end of copper wire of the junction kept in hot water is joined to a galvanometer G and then to the jockey J of potentiometer.

2. When the water in beaker Y begins to boil, the heater is removed.

3. Now introduce a resistance of the order of 1000 ohm in the circuit from the resistance box and insert the plug in the key.

4. Note the temperature of cold junction (which is at room temperature) by means of a thermometer.

5. Then note the temperature of hot junction and slide the jockey on the potentiometer wire AB to adjust it in a position when no deflection is obtained in the galvanometer G. In this position, note the distance l of the jockey from the end A of the potentiometer wire (i.e., the balancing length).
6. Now repeat the step (5) described above for the different decreasing temperatures of the hot junction (since now heating of the beaker Y by the heater has been stopped) to find the balancing length of the potentiometer wire corresponding to each temperature.
7. Then measure and note the emf. E of the battery used in the primary circuit with the help of voltmeter(ormultimeter).
8. Now measure and note the resistance r of the potentiometer wire AB with the help of multimeter.
9. Then measure and note the total length L of the potentiometer wire AB.

Observations:

1. E.m.f. of the battery used in the primary circuit E = ……… volt (measure using multimeter).

2. Resistance of the potentiometer wire = 40 Ω

3. Length of the potentiometer wire = 1000 cm

4. For thermo emf. corresponding to different temperatures of hot junction.

SI. NO	**Temperature of Cold junction (room temperature) t_1 °C**	**Temperature of hot junction t_2 °C**	**Difference in temperatures t °C**	**Balancing Length l (cm)**	**Thermo emf** $e = \left(\frac{E}{R+r}\right)\frac{rl}{L}$ $volt$
1					
2					
3					
4					
5					
6					

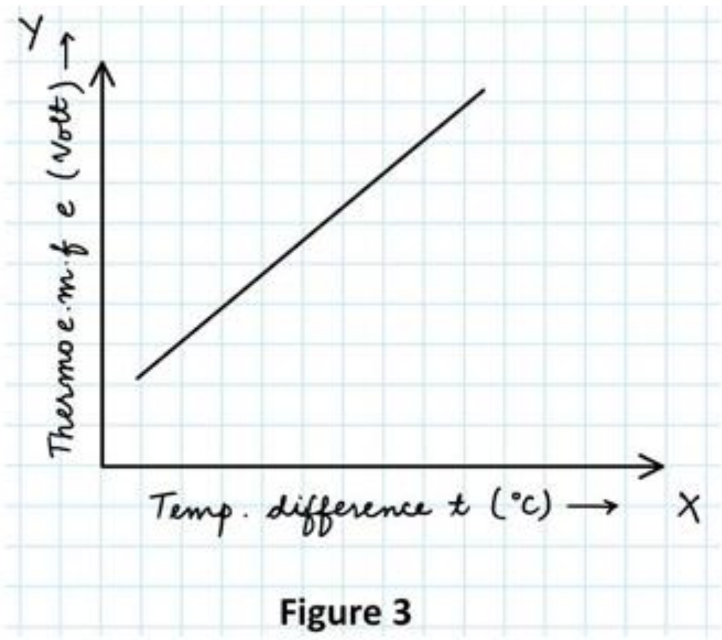


Figure 3: model graph

Result:

The variation in thermo emf. with temperature difference for the copper iron thermocouple is shown graphically.

4. CAREY FOSTER BRIDGE – TEMPERATURE COEFFICIENT OF RESISTANCE OF THE COIL.

Aim:

To determine the temperature coefficient of resistance (α) of a given coil using a Carey–Foster bridge.

Apparatus Required:

- Carey–Foster bridge
- Given resistance wire (coil)
- Standard resistance box
- Galvanometer
- Battery eliminator / cell
- Rheostat
- Plug key
- Two-way key
- Thermometer
- Water bath (for heating)
- Ice bath (optional)
- Connecting wires

Circuit diagram:

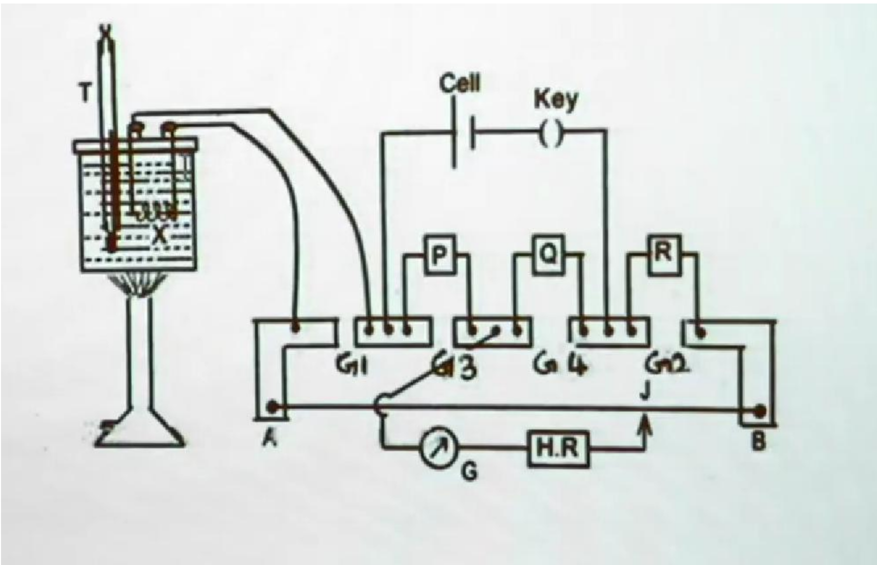


Figure 1: carey foster bridge resistance at higher temperature

Theory:

The Carey–Foster bridge is a modified form of Wheatstone bridge used to compare two nearly equal resistances accurately. It works on the principle that the difference between two resistances is proportional to the difference in their balancing lengths on a uniform bridge wire.

In this experiment, the resistance of a given wire is measured at two different temperatures, usually at room temperature and at an elevated temperature. As temperature increases, the resistance of a metallic conductor increases. The temperature coefficient of resistance (α) is defined as the increase in resistance per unit original resistance per degree rise in temperature. By measuring the resistance of the wire at two known temperatures using the Carey–Foster bridge, the value of α can be calculated.

Formula:

1.Difference of resistance $R - X = \rho(l_1 - l_2)$

where
R= unknown resistance
S= standard resistance
ρ= resistance per unit length of bridge wire
l_1, l_2= balancing lengths

2. Temperature coefficient of resistance

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

where
R_1= resistance at temperature T_1
R_2= resistance at temperature T_2

Procedure:

• Initial arrangement of the circuit
Set up the Carey–Foster bridge by connecting the driver battery, rheostat, plug key, galvanometer, jockey, and the uniform bridge wire as shown in the circuit diagram. Ensure all connections are tight and clean.

• Placement of resistances
Connect the given resistance coil (R) in one gap of the Carey–Foster bridge and a standard resistance (S) from the resistance box in the other gap.

• Adjustment of current
Close the plug key and adjust the rheostat so that a steady and moderate current flows through the bridge wire. The galvanometer should show a small, sensitive deflection.

• Finding the first balance point
Slide the jockey gently along the bridge wire and locate the point at which the galvanometer shows zero deflection. Note the balancing length $l_1$from the zero end of the bridge wire.

• Interchanging the resistances
Open the key and interchange the positions of the given resistance (R) and the standard resistance (S) using the two-way switch or by physically interchanging the connections.

• Finding the second balance point
Close the key again and determine the new balancing length $l_2$corresponding to zero galvanometer deflection.

• Calculation of resistance at room temperature
Using the observed values of $l_1$and l_2, calculate the resistance of the given wire at room temperature T_1.

• Heating the given resistance
Place the given resistance coil in a water bath and heat it gradually. Stir the water gently to ensure uniform temperature. Note the temperature T_2using a thermometer.

• Balancing at higher temperature
Repeat steps 4 to 6 while the resistance coil is maintained at the higher temperature. Record the new balancing lengths and calculate the resistance R_2.

• Repetition for accuracy
Repeat the measurements for at least two different higher temperatures and take the mean value of resistance at each temperature.

• Determination of temperature coefficient
Substitute the values of R_1, R_2, T_1, and T_2in the formula

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

to calculate the temperature coefficient of resistance of the given wire.

Observation Table:

1. Determination of resistance per unit length of bridge wire.

S. No.	Standard Resistance (S) (Ω)	Given Resistance (R) (Ω)	Balancing Length (l_1) (cm)	Balancing Length after Interchange (l_2) (cm)	(l_1 - l_2) (cm)
1					

2. Resistance of Given Wire at Room Temperature T_1

S. No.	Temperature (T_1) (°C)	(l_1) (cm)	(l_2) (cm)	(l_1 - l_2) (cm)	Resistance (R_1) (Ω)
1					

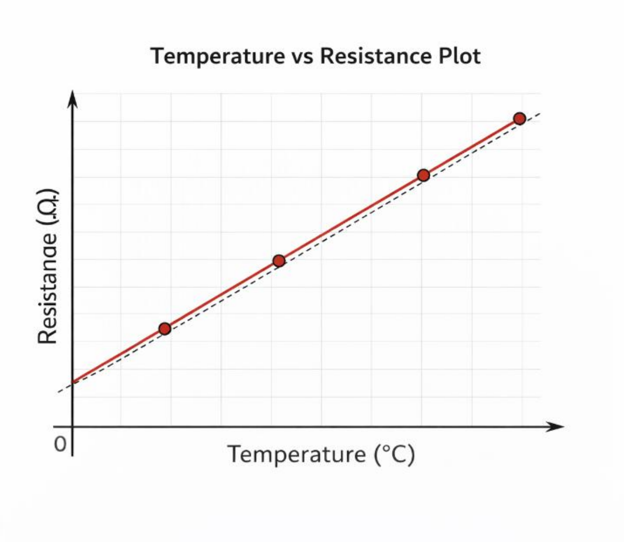
3. Resistance of Given Wire at Higher Temperature T_2

S. No.	Temperature (T_2) (°C)	(l_1) (cm)	(l_2) (cm)	(l_1 - l_2) (cm)	Resistance (R_2) (Ω)
1					

Calculation:

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

Model graph:



Result:

The temperature coefficient of resistance of the given metal wire was determined using the Carey–Foster bridge. The resistance of the wire was found to increase linearly with temperature, and the temperature coefficient of resistance **α** was calculated from the slope of the resistance–temperature graph. The result is in agreement with the expected behavior of a metallic conductor.

5. CONVERSION OF A GALVANOMETER INTO AN AMMETER AND A VOLTMETER

Aim:

1. To convert a given galvanometer into an **ammeter** of desired range.
2. To convert the same galvanometer into a **voltmeter** of desired range.

Apparatus Required:

- Given galvanometer
- Resistance box
- Low resistance wire (shunt)
- High resistance wire (multiplier)
- Ammeter (standard)
- Voltmeter (standard)
- DC power supply / battery
- Rheostat
- Plug key
- Connecting wires

Theory:

A galvanometer is a sensitive instrument used to detect small currents. It cannot measure large currents or high voltages directly. By connecting suitable external resistances, a galvanometer can be converted into an ammeter or a voltmeter.

1. Conversion into Ammeter

To measure large currents, a low resistance shunt is connected in parallel with the galvanometer. Most of the current flows through the shunt, protecting the galvanometer.

2. Conversion into Voltmeter

To measure high voltage, a high resistance (multiplier) is connected in series with the galvanometer. This limits the current flowing through the galvanometer.

Formula:

A. Galvanometer to Ammeter

Let

- G= resistance of galvanometer
- I_g= current for full scale deflection
- I= desired ammeter range
- S= shunt resistance

$$S = \frac{I_g G}{I - I_g}$$

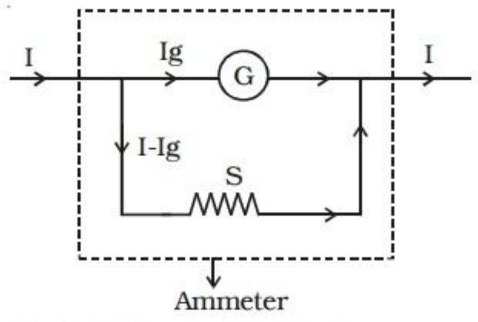
B. Galvanometer to Voltmeter

Let

- V= desired voltmeter range
- R= series (multiplier) resistance

$$R = \frac{V}{I_g} - G$$

Circuit Diagram:



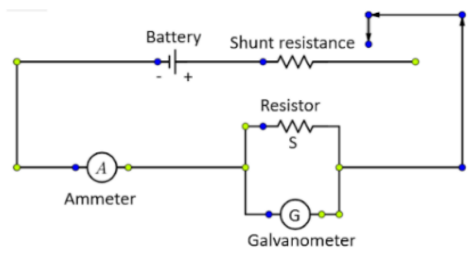
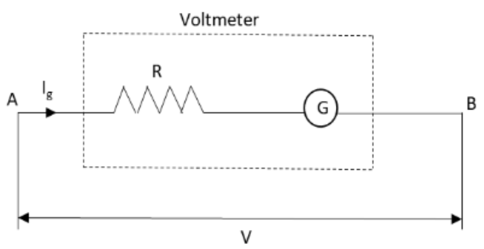


Figure 1 conversion of galvanometer to ammeter



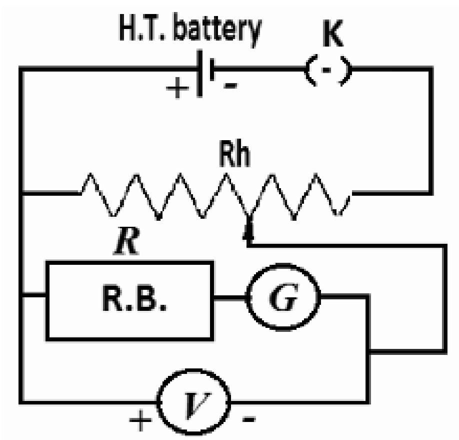


Figure 2: conversion of galvanometer to voltmeter

Procedure:

A) Conversion of Galvanometer into Ammeter

1. Note the given values of resistance of galvanometer $G$and its full-scale deflection current I_g.
2. Calculate the value of shunt resistance Susing the formula
   a. $S = \frac{I_g G}{I - I_g}$
3. Connect the galvanometer and shunt resistance in parallel as shown in the circuit diagram.
4. Connect this combination in series with a battery, rheostat, key, and a standard ammeter.
5. Close the key and adjust the rheostat to allow a small current to flow.
6. Note the reading of the standard ammeter and the corresponding galvanometer deflection.
7. Increase the current in steps and take several readings.
8. Compare the current measured by the converted ammeter with the standard ammeter readings.
9. Tabulate the observations.

B) Conversion of Galvanometer into Voltmeter

1. Calculate the value of high series resistance Rusing the formula
2. $R = \frac{V}{I_g} - G$
3. Connect the calculated resistance **in series** with the galvanometer.
4. Connect this combination across a **DC supply** along with a **rheostat** and **key**.
5. Connect a **standard voltmeter** in parallel for comparison.
6. Close the key and vary the voltage using the rheostat.
7. Note the reading of the standard voltmeter and the corresponding galvanometer deflection.
8. Take several sets of readings for different voltages.
9. Compare the readings of the converted voltmeter with the standard voltmeter.
10. Record the observations in the table.

Observation Table:

Ammeter

Resistance of galvanometer, $G =$______ Ω

Full scale deflection current, $I_g =$______ A

Desired range of ammeter, $I =$______ A

Calculated shunt resistance, $S =$______ Ω

S. No.	Standard ammeter reading (I) (A)	Galvanometer deflection (θ) (divisions)	Current from galvanometer (I_g = kθ) (A)
1			
2			
3			
4			
5			

Voltmeter conversion

Resistance of galvanometer, $G =$______ Ω
Full scale deflection current, $I_g =$______ A
Desired range of voltmeter, $V =$______ V
Calculated series resistance, $R =$______ Ω

S. No.	Standard voltmeter reading (V) (V)	Galvanometer deflection (θ) (divisions)	Voltage from galvanometer (V_g = k'θ) (V)
1			
2			
3			
4			
5			

Result:

The given galvanometer was successfully converted into an ammeter and a voltmeter of the desired ranges. The readings of the converted instruments were found to agree closely with the standard ammeter and voltmeter.

6. POTENTIOMETER – TEMPERATURE COEFFICIENT OF RESISTANCE

Aim:

To determine the temperature coefficient of resistance (α) of a given metal wire using a DC potentiometer.

Apparatus required:

- DC potentiometer
- Given resistance coil (metal wire)
- Standard resistance box
- DC power supply / accumulator
- Rheostat
- Galvanometer
- Plug key
- Two-way key
- Water bath with heater
- Thermometer
- Connecting wires

Circuit Diagram:

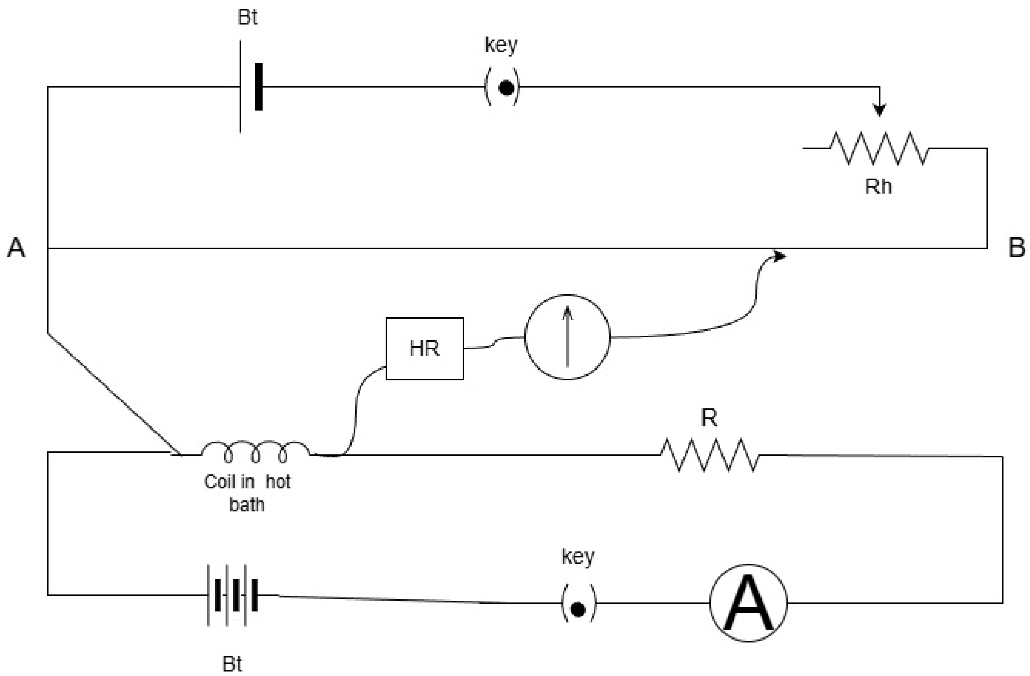


Figure 1:potentiometer with resistance coil

Theory:

The resistance of a metallic conductor increases with increase in temperature. The temperature coefficient of resistance (α) is defined as the increase in resistance per unit resistance per degree rise in temperature.

A potentiometer is a null-type instrument used to measure potential difference accurately without drawing current. In this experiment, the potential difference across the given resistance is measured at two different temperatures while maintaining a constant current through the circuit.

Using the potentiometer, the potential drops across the resistance at different temperatures are measured in terms of balancing lengths. Since the current is kept constant, the resistance is proportional to the potential drop.

Formula:

Let

- l_1= balancing length at temperature T_1
- l_2= balancing length at temperature T_2
- R_1= resistance at temperature T_1
- R_2= resistance at temperature T_2

Since $R \propto V \propto l$,

$$\frac{R_2}{R_1} = \frac{l_2}{l_1}$$

Temperature coefficient of resistance:

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

or

$$\alpha = \frac{l_2 - l_1}{l_1(T_2 - T_1)}$$

Procedure:

1. Connect the potentiometer circuit with the driver battery, rheostat, key, and galvanometer as shown in the circuit diagram.
2. Adjust the rheostat so that a steady current flows through the potentiometer wire, producing a uniform potential gradient.
3. Connect the given resistance coil in series with a constant current source.
4. Keep the resistance coil at room temperature and note the temperature T_1.
5. Measure the balancing length $l_1$corresponding to the potential drop across the resistance.
6. Place the resistance coil in a water bath and heat it gradually.
7. Note the higher temperature T_2using a thermometer.
8. Measure the new balancing length l_2.
9. Repeat the observations for different temperatures if required.
10. Substitute the values in the formula to calculate the temperature coefficient of resistance.

Observation Table:

S. No.	**Temperature (T) (°C)**	**Balancing Length (l) (cm)**
1		
2		
3		

Calculation:

- Lower temperature = T_1 =____
- Higher temperature = T_2 = ____
- Balancing length at T_1= l_1 = ___ cm
- Balancing length at T_2= l_2 = ___ cm

Since resistance is proportional to balancing length,

$$\alpha = \frac{l_2 - l_1}{l_1(T_2 - T_1)}$$

Model Graph:

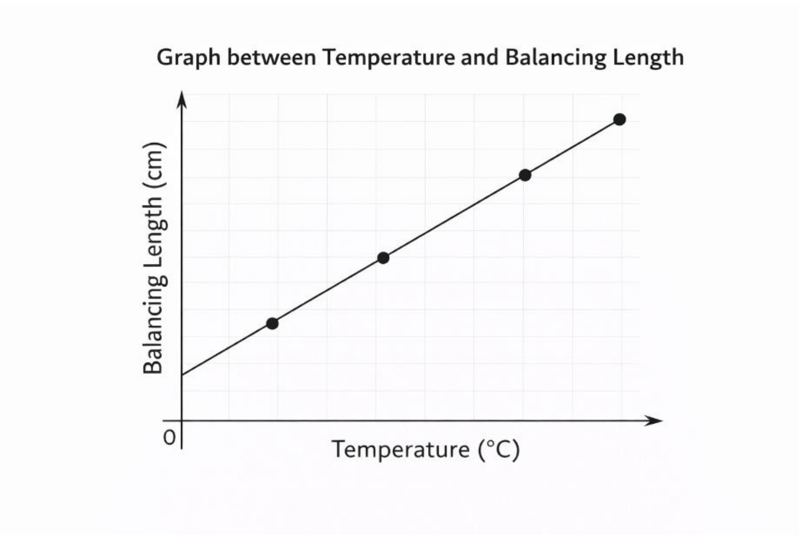


Figure 4 model graph temperature vs balancing length

Result:

The temperature coefficient of resistance of the given metal wire was determined using a potentiometer. The resistance of the wire was found to increase linearly with temperature, confirming the metallic nature of the conductor.

7. IMPEDANCE AND POWERFACTOR – LR CIRCUIT

Aim:

To determine the impedance(Z) and power factor (cos φ) of the given L-R circuit using voltmeter-ammeter method.

Apparatus Required:

- AC power supply (low voltage, 50 Hz)
- Inductor (L)
- Known resistor (R)
- AC ammeter
- AC voltmeter
- Rheostat
- Key (switch)
- Connecting wires

Circuit diagram:

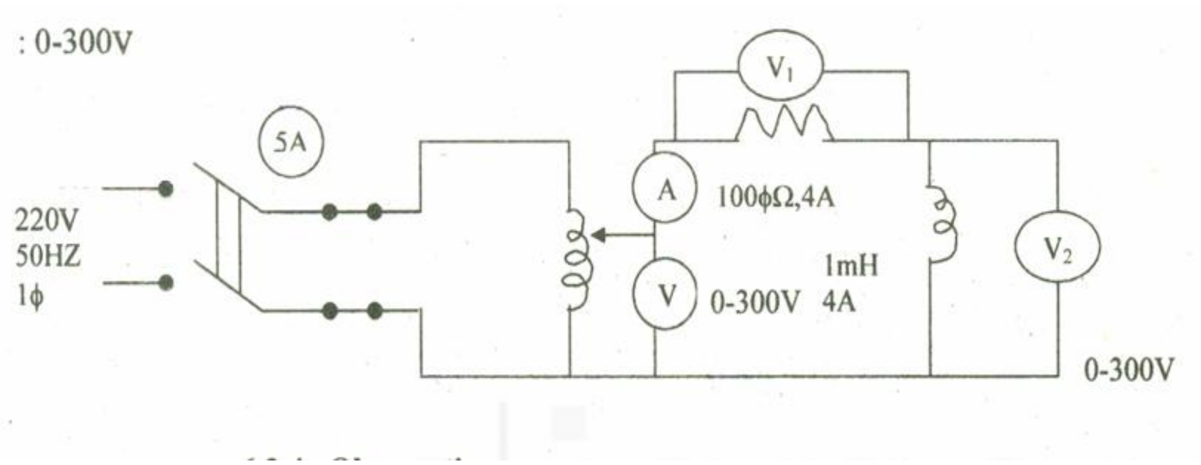


Figure 1: LR circuit for impedance and power factor

Theory:

When a resistor and an inductor are connected in series to an AC supply, the circuit is called an L–R circuit. In such a circuit, the current does not remain in phase with the applied voltage due to the inductive nature of the coil. The current lags behind the voltage by a phase angle ϕ.The opposition offered by the circuit to the flow of alternating current is called impedance (Z). It is the vector sum of resistance and inductive reactance. In the voltmeter–ammeter method, the current through the circuit is measured using an ammeter, while voltmeters measure:

- the voltage across the resistor (V_R)
- the total voltage across the L–R combination (V)

The power factor of the circuit is defined as the cosine of the phase angle between voltage and current and can be obtained from the ratio of voltage drops.

Formula:

1. **Impedance**

$$Z = \frac{V}{I}$$

2. **Resistance**

$$R = \frac{V_R}{I}$$

3.Inductive reactance

$$X_L = \sqrt{Z^2 - R^2}$$

4. **Power factor**

$$\cos\ \phi = \frac{V_R}{V}$$

where
V= voltage across L–R circuit
V_R= voltage across resistor
I= current in the circuit

Procedure:

1. The circuit is connected as per the circuit diagram by arranging the resistor and inductor in series with the AC supply. A rheostat is connected in series to control the current in the circuit.
2. Formula:
3. I= current in the circuit
4. Procedure:
5. An AC ammeter (moving iron type) is connected in series with the L–R circuit so that it measures the same current flowing through both the resistor and the inductor.
6. Two AC voltmeters (moving iron type) are used. One voltmeter is connected across the resistor to measure the voltage drop V_R, and the other voltmeter is connected across the entire L–R combination to measure the applied voltage V.
7. Before switching ON the supply, the rheostat is adjusted to its maximum resistance position to ensure that a large current does not suddenly flow through the circuit and damage the instruments.
8. The key is then closed and the AC supply is switched ON. The rheostat is slowly adjusted to allow a suitable current to flow through the circuit.

9. After the readings become steady, the readings of the ammeter, the voltmeter across the resistor, and the voltmeter across the L–R circuit are carefully noted.
10. The rheostat is again adjusted to change the current, and a new set of readings is taken. In this manner, several observations are recorded for different values of current.
11. All the observed readings are tabulated in the observation table. Using these readings, the impedance of the circuit is calculated using $Z = V/I$, and the power factor is calculated using $\cos\ \phi = V_R/V$.
12. The experiment is repeated carefully to ensure accuracy, and the average value of the power factor may be calculated if required.

Observation Table:

Sl. No.	**Voltage across L-R circuit (V)**	**Voltage across resistor V_R(V)**	**Current I (A)**	**Impedance Z = V/I (Ω)**	**Power factor $\cos\ \phi = V_R/V$**
1					
2					
3					
4					

Calculations:

For each set of readings:

1. **Impedance**

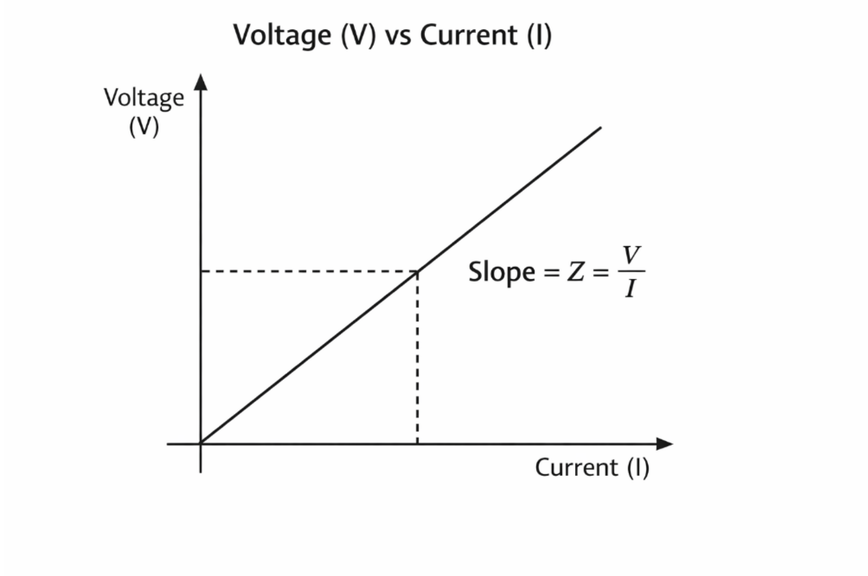
$$Z = \frac{V}{I}$$

2. **Power factor**

$$\cos\ \phi = \frac{V_R}{V}$$

Calculate the mean value of impedance and power factor.

Model Graph:



Result:

The impedance and power factor of the given L–R circuit are determined using the voltmeter–ammeter method.

Impedance of the given L–R circuit Z=________Ω

Power factor of the circuit cos ϕ=_____.

8. DETERMINATION OF MUTUAL INDUCTANCES M_1 AND M_2 USING A BALLISTIC GALVANOMETER

Aim:

To determine the mutual inductance between a pair of coils using a ballistic galvanometer by Kirchhoff's-method.

Apparatus Required:

- Pair of coils (primary P with N_p turns, secondary S with N_s turns).
- Ballistic galvanometer (BG), DC power supply, rheostat (Rh), resistance boxes (large R, fractional r).
- Sequence key, two 4-plug commutator keys (K1, K2), connecting wires.

Circuit Diagram

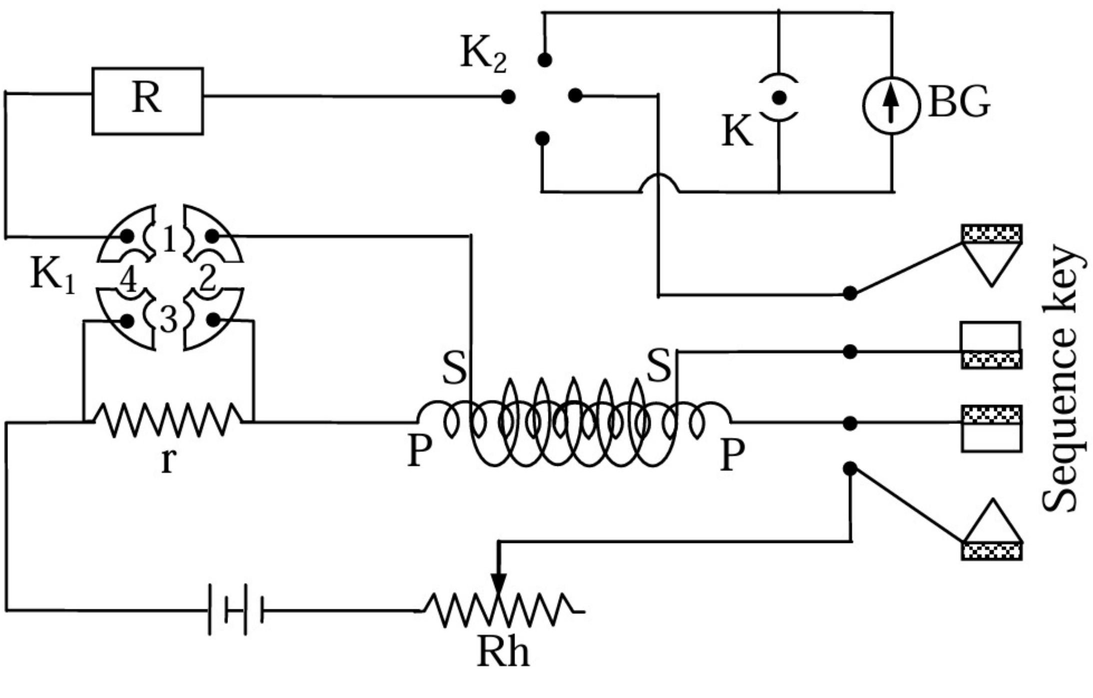


Figure 1: mutual inductance of two coils

Principle:

A ballistic galvanometer measures the quantity of charge passing through it due to a transient current. When current in the primary coil is suddenly made or broken, the magnetic flux linked with the secondary coil changes. This change induces an emf in the secondary coil, producing a momentary current through the ballistic galvanometer.

The first throw (θ) of the ballistic galvanometer is proportional to the charge (q) passed, which is proportional to the mutual inductance (M) of the coil system.

$$q \propto M \Rightarrow \theta \propto M$$

Theory and Formula:

Mutual inductance $M = \frac{N_s \phi_{21}}{dI_p}$, where ϕ_{21} is flux linkage in S due to current change dI_p in P.

Apply Kirchhoff's voltage law to secondary circuit during transient:

induced emf $\epsilon_s = -M\frac{dI_p}{dt}$, current $I_s = \frac{\epsilon_s}{R_s+R+G}$,

total charge $Q = \int I_s dt = \frac{M\Delta I_p}{R_s+R+G}$.

BG measures $Q = K\theta'$ (K: ballistic constant, θ': corrected first throw).

Thus, $M = K\theta'(R_s + R + G)/I_0$, with damping correction

$\theta' = \frac{\theta_1+0.5\theta_2}{1+\lambda/2}$ (λ = log (θ_1/θ_3)).

Proedure:

Preliminary Setup

- Level the BG table and set lamp-scale at 1 m from mirror.
- Close damping key (or fully insert K2 plugs); zero the light spot on scale.
- Determine BG period T: partially open K2 for free oscillation, time 20 oscillations (3 trials), average T = total time / 60.

Measurements for Coil Pair 1 (S1)

- Connect secondary S1; position primary P and S1 coaxially at fixed separation (e.g., 5-10 cm).
- Adjust rheostat Rh for steady primary current $I_1 \approx 0.5$ A via ammeter; fully close sequence key (SK).
- Open damping key (or partial K2); quickly release one SK plug for sudden current drop to zero, inducing impulse.
- Record first throw θ_1 (max deflection) and third throw θ_3 (same direction).
- Reverse commutator K2; repeat for opposite throw, averaging pairs.
- Calculate damping correction $\lambda = \log_e (\theta_1 / \theta_3)$, then $\theta_1' = (\theta_1 + 0.5\ \theta_2) / (1 + \lambda/2)$.
- Repeat 4-6 trials: vary I_1 (0.3-1 A) or R (500-2000 Ω) to keep θ < 20 cm.

Measurements for Coil Pair 2 (S2)

- Switch to secondary S2, keeping exact same P position and separations.
- Repeat all steps from Coil Pair 1 identically, matching I_2 to I_1 values.
- Record θ_2' with same damping corrections.

Calculations and Checks

- Compute ratio M_1/M_2 = average $(\theta_1' / I_1) / (\theta_2' / I_2)$, using same total resistance.
- Verify BG sensitivity consistency between pairs; average multiple sets for accuracy.

Observation table:

Value of the standard resistance, r =_________ohm

Sl. No.	Mean throw in the galvanometer						Mean θ mm	Steady deflection 'd' with voltage across 'r'			$\frac{\theta}{d}$
	Left			Right							
	θ_1 mm	θ_3 mm	$\theta = \theta_1\left(\frac{\theta_1}{\theta_3}\right)^{1/4}$ mm	θ_1 mm	θ_3 mm	$\theta = \theta_1\left(\frac{\theta_1}{\theta_3}\right)^{1/4}$ mm		Left mm	Right mm	Mean d mm	
1											
2											
3											
4											
5											
6											

Mean $\frac{\theta}{d}$ = ……….

Time 't' for 20 free oscillations in seconds			Period of oscillation T= t/20 seconds
1	2	Mean	

Mutual inductance, $M = \left(\frac{Tr}{2\pi}\right)\frac{\theta}{d} =$ = ………. Henry

Result:

Mutual inductance of the given pair of coils =____________henry.