Chapter 3: Electric Current And Direct-Current Circuits

3.1 Electric Conduction

L.O 3.1.1 Describe the microscopic model of current

<table>
<thead>
<tr>
<th>Mechanism of Electric Conduction in Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before applying electric field</strong></td>
</tr>
</tbody>
</table>

- Electron move freely and random.
- Frequently interact with each other.
- **Drift velocity is zero** because the free electrons are in constant random motion.

\[ v_d = 0 \]

- The freely moving electron experience an electric force and tend to drift towards a direction **opposite** to the direction of electric field (positive terminal of the battery).
- The electric current is flowing in the **opposite** direction of the electron flows.
- Drift velocity is the mean velocity of the electrons parallel to the direction of the electric field when a potential difference is applied.

\[ v_d = \frac{I}{nAe} \]

L.O 3.1.2 Define and use electric current

Electric current, \( I \) is defined as the total charge, \( Q \) flowing through an area per unit time, \( t \).

Mathematically,

\[ I = \frac{Q}{t} \]

OR

\[ I = \frac{dQ}{dt} \]

- It is a scalar quantity.
- The S.I. unit for electric current is ampere (A).
- 1 ampere of current is defined to be one coulomb of charge passing through the surface area in one second.

\[ 1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}} = 1 \text{ C s}^{-1} \]
3.2 Ohm’s Law and Resistivity

L.O 3.2.1 State and use Ohm’s law

Ohm’s law states that the potential difference across a conductor, \( V \) is directly proportional to the current, \( I \) through it, if its physical conditions and the temperature are constant.

\[ V \propto I \text{ where } T \text{ is constant} \]

Mathematically,

\[ V = IR \]

where

- \( V \): potential difference (voltage)
- \( I \): current
- \( R \): resistance

<table>
<thead>
<tr>
<th>Ohmic Conductor</th>
<th>Non-ohmic Conductor</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Ohmic Conductor Diagram" /></td>
<td><img src="image" alt="Non-ohmic Conductor Diagram" /></td>
</tr>
<tr>
<td>( V ): potential difference</td>
<td>( V ): potential difference</td>
</tr>
<tr>
<td>( I ): current</td>
<td>( I ): current</td>
</tr>
<tr>
<td>( R ): resistance</td>
<td>( R ): resistance</td>
</tr>
<tr>
<td><strong>Must start from zero</strong></td>
<td><strong>Non-ohmic conductors do not obey Ohm’s law. Example: junction diode.</strong></td>
</tr>
<tr>
<td><strong>Ohmic conductors</strong> are conductors which obey Ohm’s law. Examples: pure metals.</td>
<td></td>
</tr>
</tbody>
</table>

L.O 3.2.2 Define and use resistivity

Resistivity is defined as the resistance of a unit cross-sectional area per unit length of the material.

\[ \rho = \frac{RA}{l} \]

where

- \( \rho \): resistivity
- \( A \): cross-sectional area
- \( l \): length of the metal

- It is a scalar quantity
- Unit is ohm meter (\( \Omega \) m)
- It is a measure of a material’s ability to oppose the flow of an electric current.
- Resistivity depends on the material. Same materials have same resistivity. It ONLY changes when the temperature of wire/material changes.
3.3 Variation of Resistance with Temperature

L.O 3.3.1 Explain the effect of temperature on electrical resistance in metals

L.O 3.3.2 Use resistance, \( R = R_0 [1 + \alpha (T - T_0)] \)

The resistance of a metal (conductor) depends on

- the nature of the material, 
  \( (\rho, \text{ resistivity}) \)
- the size of the conductor, 
  \( (l, \text{ the length and } A, \text{ cross-sectional area}) \)
- the temperature of the conductor.

The resistance of metals increases with increasing temperature. \( (T \uparrow, R \uparrow) \)

Explanation:

1. As temperature increases, the ions of the conductor vibrate with greater amplitude.
2. More collisions occur between free electrons and ions.
3. These electrons are slowed down thus increases the resistance.

The fractional change in resistance per unit rise in temperature is known as temperature coefficient of resistance, \( \alpha \).

\[
\alpha = \frac{\Delta R}{R_0 \Delta T}
\]

Since \( \Delta R = R - R_0 \), the resistance of a metal can be represented by the equation below:

\[
R = R_0 [1 + \alpha (T - T_0)]
\]

where \( R = \text{the resistance at temperature } T, \)

\( R_0 = \text{the resistance at temperature } T_0 = 20^\circ \text{C or } 0^\circ \text{C}, \)

\( T = \text{final temperature } \)

\( T_0 = \text{reference temperature } (20^\circ \text{C or } 0^\circ \text{C}) \)

\( \alpha = \text{the temperature coefficient of resistance } (^\circ \text{C}^{-1}) \)

Since resistivity is directly proportional to resistance, the resistivity of a metal can be written as

\[
\rho = \rho_0 [1 + \alpha (T - T_0)]
\]
### Example

<table>
<thead>
<tr>
<th>Question</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A current of 2.0 A flows through a copper wire. Calculate</td>
<td></td>
</tr>
<tr>
<td>a. the amount of charge, and</td>
<td></td>
</tr>
<tr>
<td>b. the number of electrons flow through a cross-sectional area of the</td>
<td></td>
</tr>
<tr>
<td>copper wire in 30 s.</td>
<td></td>
</tr>
<tr>
<td>(Given the charge of electron, $e=1.60 \times 10^{-19}$ C)</td>
<td></td>
</tr>
<tr>
<td>A wire 4.00 m long and 6.00 mm in diameter has a resistance of 15 mΩ.</td>
<td></td>
</tr>
<tr>
<td>A potential difference of 23.0 V is applied between both end. Determine</td>
<td></td>
</tr>
<tr>
<td>a. the current in the wire.</td>
<td></td>
</tr>
<tr>
<td>b. the resistivity of the wire material</td>
<td></td>
</tr>
<tr>
<td>Two wires $P$ and $Q$ with circular cross section are made of the same</td>
<td></td>
</tr>
<tr>
<td>metal and have equal length. If the resistance of wire $P$ is three</td>
<td></td>
</tr>
<tr>
<td>times greater than that of wire $Q$, determine the ratio of their</td>
<td></td>
</tr>
<tr>
<td>diameters.</td>
<td></td>
</tr>
<tr>
<td>A platinum wire has a resistance of 0.5 Ω at 0°C. It is placed in a</td>
<td></td>
</tr>
<tr>
<td>water bath where its resistance rises to a final value of 0.6 Ω. What is</td>
<td></td>
</tr>
<tr>
<td>the temperature of the bath?</td>
<td></td>
</tr>
<tr>
<td>(Given the temperature coefficient of resistance of platinum is $3.93 \times 10^{-3}$ °C$^{-1}$)</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Solution</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>A copper wire has a resistance of 25 mΩ at 20°C. When the wire is</td>
<td></td>
</tr>
<tr>
<td>carrying a current, heat produced by the current causes the temperature</td>
<td></td>
</tr>
<tr>
<td>of the wire to increase by 27 °C.</td>
<td></td>
</tr>
<tr>
<td>a. Calculate the change in the wire’s resistance.</td>
<td></td>
</tr>
<tr>
<td>b. If its original current was 10.0 mA and the potential difference</td>
<td></td>
</tr>
<tr>
<td>across wire remains constant, determine the final current of the</td>
<td></td>
</tr>
<tr>
<td>copper wire.</td>
<td></td>
</tr>
<tr>
<td>(Given the temperature coefficient of resistance of copper is 6.80 ×</td>
<td></td>
</tr>
<tr>
<td>10⁻³ °C⁻¹)</td>
<td></td>
</tr>
</tbody>
</table>

**Exercise**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>An electron beam in a television tube is 0.50 m long. The speed of</td>
<td>7.81 × 10⁷ electrons</td>
</tr>
<tr>
<td>the electrons in the beam is 8.0 × 10⁷ m s⁻¹, and the current is 2.0 mA.</td>
<td></td>
</tr>
<tr>
<td>Calculate the number of electrons in the beam.</td>
<td></td>
</tr>
</tbody>
</table>

A bird stands on a high voltage transmission wire with its feet 4.00 cm  | 3.37 × 10⁻⁶ Ω , 3.37 × 10⁻⁴ V                                                              |
| apart. The wire is made of aluminium with diameter 2.00 cm and carries  |                                                                                           |
| a current of 100 A. Determine                                           |                                                                                           |
| a. the resistance of the wire between the bird’s feet.                  |                                                                                           |
| b. the potential difference between the bird’s feet.                    |                                                                                           |
| (Given the resistivity of aluminium = 2.65 × 10⁻⁸ Ωm)                  |                                                                                           |
| Answer: 3.37 × 10⁻⁶ Ω , 3.37 × 10⁻⁴ V                                    |                                                                                           |

The resistance of the tungsten filament of a bulb is 190 Ω when the bulb | 2623 °C                                                                                   |
| is alight and 15 Ω when it is switched off. The room temperature is 30  |                                                                                           |
| °C and the temperature coefficient of resistance of tungsten is 4.5 ×  |                                                                                           |
| 10⁻³ °C⁻¹. Estimate the temperature of the filament when alight.        |                                                                                           |

An electric stove contains a wire with the length 1.1 m and cross-       | 29 Ω                                                                                      |
| sectional area 3.1 mm². When the electric stove is switched on, the   |                                                                                           |
| wire becomes hot in response to the flowing charge. The material of    |                                                                                           |
| the wire has a resistivity of ρ₀ = 6.8 × 10⁻⁵ Ωm at T₀ = 20 °C and the|                                                                                           |
| temperature coefficient of resistance a = 2.0 × 10⁻³ °C⁻¹. Determine   |                                                                                           |
| the resistance of the wire at an operating temperature of 120 °C.     |                                                                                           |
3.4 Electromotive Force (emf), internal resistance and potential difference

L.O 3.4.1 Define emf

L.O 3.4.2 Explain the relationship between emf of a battery and potential difference across the battery terminals.

L.O 3.4.3 Use terminal voltage, $V = \varepsilon - Ir$

- **Electromotive force (e.m.f.),** $\varepsilon$ is defined as the energy provided by the source (battery/cell) to each unit charge that flows from the source.

- **Terminal potential difference (voltage),** $V_{AB}$ is defined as the work done in bringing a unit (test) charge from point B to point A.

  $$V_{AB} = V_A - V_B$$

- The **unit** for both e.m.f. and potential difference is volt (V).

- **Internal resistance,** $r$ is defined as the resistance of the chemicals inside the cell (battery) between the poles.

**NOTE!**

a) $V_{AB} < \varepsilon$ when the battery of emf $\varepsilon$ is connected to the external circuit with resistance $R$.

b) $V_{AB} > \varepsilon$ when the battery of emf $\varepsilon$ is being charged by other battery.

c) $V_{AB} = \varepsilon$ when the battery of emf $\varepsilon$ has no internal resistance ($r = 0$) and connected to the external circuit with resistance $R$.

**EXTRA KNOWLEDGE – HOW DO BATTERIES WORK?**

The chemical reaction in the battery causes a build-up of electrons at the anode. This results in an electrical difference between the anode and the cathode. When there is potential difference, the electrons want to rearrange themselves to get rid of this difference; hence the electrons repel each other and try to go to a place with fewer electrons. In a battery, the only place to go is to the cathode. But, the electrolyte keeps the electrons from going straight from the anode to the cathode within the battery. When the circuit is closed (a wire connects the cathode and the anode) the electrons will be able to get to the cathode through wire.
Example

<table>
<thead>
<tr>
<th>Question</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A battery of internal resistance 0.3 Ω is connected across a 5.0 Ω resistor. The terminal potential difference measured by the voltmeter is 2.15 V. Calculate the e.m.f. of the battery.</td>
<td></td>
</tr>
<tr>
<td>When a 10 Ω resistor is connected across the terminals of a cell of e.m.f. ( \varepsilon ) and internal resistance ( r ), a current of 0.10 A flows through the resistor. If the 10 Ω resistor is replaced with a 3.0 Ω resistor, the current increases to 0.24 A. Find ( \varepsilon ) and ( r ).</td>
<td></td>
</tr>
</tbody>
</table>
| A battery has an e.m.f. of 9.0 V and an internal resistance of 6.0 Ω. Determine  
  a. the potential difference across its terminals when it is supplying a current of 0.50 A, 
  b. the maximum current which the battery could supply. |          |

Exercise

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer: 1Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td>The battery in a circuit has an e.m.f. of 9.0 V. It is attached to a resistor and an ammeter that shows a current of 0.10 A. If a voltmeter across the battery’s terminals reads 8.9 V, what is its internal resistance?</td>
<td></td>
</tr>
<tr>
<td>A car battery has an e.m.f. of 12.0 V and an internal resistance of 1.0 Ω. The external resistor of resistance 5.0 Ω is connected in series with the battery. Determine the reading of the ammeter and voltmeter if both meters are ideal.</td>
<td>Answer: 2.0 A, 10.0 V</td>
</tr>
</tbody>
</table>
3.5 Electrical Energy and Power

**L.O 3.5.1** Use power, \( P = IV \) and electrical energy, \( W = IVt \)

*Electrical (potential) energy,* \( W \) is the energy gained by the charge \( Q \) from a voltage source (battery) having a terminal voltage \( V \). The faster the electric charges are moving the more electrical energy they carry.

The work done by the source on the charge is given by:

\[
W = QV
\]

But \( Q = It \) (the amount of charges flow from negative terminal to positive terminal in time \( t \)),

\[
W = VIt
\]

Since \( V = IR \), electrical energy can also be written as:

\[
W = I^2Rt \quad \text{OR} \quad W = \frac{V^2t}{R}
\]

The **unit** for electrical energy is **Joule** (J).

**NOTE!**

Energy supplied = Energy dissipated by external resistance + Energy dissipated by internal resistance.

**Electric power** is defined as the rate of energy delivered to the external circuit by the battery.

\[
P = \frac{W}{t} = \frac{VIt}{t}
\]

\[
P = IV
\]

Since \( V = IR \), electrical power can also be written as:

\[
P = I^2R \quad \text{OR} \quad P = \frac{V^2}{R}
\]

The **unit** for electrical power is **Watt** (W).

**NOTE!**

Power output = Power dissipated by external resistance + Power dissipated by internal resistance.
3.6 Resistors in Series and Parallel

L.O 3.6.1 Derive and determine effective resistance of resistors in series and parallel

Resistors in series:

\[ V = V_1 + V_2 + V_3 \quad I = I_1 = I_2 = I_3 \]

Resistors in parallel:

\[ V = V_1 = V_2 = V_3 \quad I = I_1 + I_2 + I_3 \]
# Example

<table>
<thead>
<tr>
<th>Question</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Calculate the resistance of a 40 W automobile headlight designed for 12 V?</td>
<td></td>
</tr>
<tr>
<td>b. The current through a refrigerator of resistance 12 Ω is 13 A. What is the power consumed by the refrigerator?</td>
<td></td>
</tr>
</tbody>
</table>

In figure above, a battery with an e.m.f. of 12 V and an internal resistance of 1.0 Ω is connected to a 5Ω resistor. Determine

a. the rate of energy transferred to electrical energy in the battery,
b. the rate of heat dissipated in the battery,
c. the amount of heat loss in the 5.0 Ω resistor if the current flows through it for 20 minutes.

For the circuit shown below,

![Circuit Diagram](image)

Calculate :

a. the total resistance of the circuit.
b. the total current in the circuit.
c. the potential difference across 4.0 Ω resistor.
For the circuit shown below, calculate the equivalent resistance between points x and y.

Exercise

Question

A wire 5.0 m long and 3.0 mm in diameter has a resistance of 100 Ω. A 15 V of potential difference is applied across the wire. Determine

a. the current in the wire,
b. the resistivity of the wire,
c. the rate at which heat is being produced in the wire.

Answer: 0.15 A; 1.414 \times 10^{-4} \text{ Ω m}; 2.25 W

For the circuit shown below, calculate the equivalent resistance between points x and y.

For the circuit above, calculate

a. the effective resistance of the circuit,
b. the current passes through the 12 Ω resistor,
c. the potential difference across 4.0 Ω resistor,
d. the power delivered by the battery.

The internal resistance of the battery may be ignored.

Answer: 1.28 Ω ; 0.50A ; 2 V ; 36 W
3.7 Kirchhoff’s Laws

L.O 3.7.1 State and use Kirchhoff’s Laws

Kirchhoff’s First Law:
- Also known as Kirchhoff’s Junction/Current Law
- States the algebraic sum of the currents entering any junctions in a circuit must equal the algebraic sum of the currents leaving that junction.
- Obeys the principle of conservation of charge.
- Mathematically,

$$\sum I_{in} = \sum I_{out}$$

- For example:

$$I_1 + I_2 = I_3$$

Kirchhoff’s Second Law:
- Also known as Kirchhoff’s Loop/Voltage Law
- States in any closed loop, the algebraic sum of e.m.f.s is equal to the algebraic sum of the products of current and resistance or in any closed loop.
- Obeys the principle of conservation of energy.
- Mathematically,

$$\sum \varepsilon = \sum IR$$

- Sign convention for e.m.f., $\varepsilon$:

- Sign convention for the product of $IR$:
**Problem Solving Strategy** (for two closed circuits)

1. Label the diagram
2. Apply Kirchhoff’s **First** Law → 1 equation
3. Apply Kirchhoff’s **Second** Law → 2 equations
4. Use scientific calculator to solve the simultaneous equations

**Example**

**Question:** Calculate \( I, \varepsilon_\text{X} \) and \( R \)

\[
\begin{align*}
\varepsilon_\text{X} &= 7.2 \text{ V} \\
4.0 \Omega &\quad 0.84 \text{ A} \\
\varepsilon_\text{Y} &\quad 8.0 \Omega \\
R &\quad 0.32 \text{ A}
\end{align*}
\]

**Step 1:** Label the diagram

\[
\begin{align*}
\varepsilon_\text{X} &= 7.2 \text{ V} \\
4.0 \Omega &\quad I_1 \quad 0.84 \text{ A} \\
\varepsilon_\text{Y} &\quad R_1 \\
R &\quad 0.32 \text{ A} \\
I_2
\end{align*}
\]

**Step 2:** Apply Kirchhoff’s **First** Law

**Step 3:** Apply Kirchhoff’s **Second** Law

**Loop 1:**

**Loop 2**

**Step 4:** Solving the simultaneous equations
**Example**

<table>
<thead>
<tr>
<th>Question</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using Kirchhoff’s rules, find the current in each resistor.</td>
<td>![Circuit Diagram]</td>
</tr>
<tr>
<td>$\varepsilon_1 = 20 \text{ V}$</td>
<td></td>
</tr>
<tr>
<td>$R_2 = 20 \Omega$</td>
<td></td>
</tr>
<tr>
<td>$R_1 = 10 \Omega$</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_2 = 10 \text{ V}$</td>
<td></td>
</tr>
</tbody>
</table>

**Using Kirchhoff’s rules, find the current in each resistor.**

![Circuit Diagram]

**For the circuit shown below,**

Given $\varepsilon_1 = 8 \text{ V}$, $R_2 = 2 \Omega$, $R_3 = 3 \Omega$, $R_1 = 1 \Omega$ and $I = 3 \text{ A}$. Ignore the internal resistance in each battery. Calculate

a. the currents $I_1$ and $I_2$.

b. the e.m.f. $\varepsilon_2$.  

---

*Note: The diagrams are not drawn to scale.*
### Example

<table>
<thead>
<tr>
<th>Question</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>For the circuit shown below,</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Circuit Diagram" /></td>
<td></td>
</tr>
<tr>
<td>Determine</td>
<td></td>
</tr>
<tr>
<td>a. the currents $I_1$, $I_2$, and $I_3$,</td>
<td></td>
</tr>
<tr>
<td>b. the potential difference across the 6.7 $\Omega$ resistor,</td>
<td></td>
</tr>
<tr>
<td>c. the power dissipated from the 1.2 $\Omega$ resistor.</td>
<td></td>
</tr>
</tbody>
</table>

### Exercise

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer: 0.5 A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using Kirchhoff’s rules, find the current $I$.</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Circuit Diagram" /></td>
<td></td>
</tr>
</tbody>
</table>

Calculate the currents $I_1$, $I_2$, and $I_3$. Neglect the internal resistance in each battery.

| ![Circuit Diagram](image) | Answer: 17.69 A, 14.62 A, 3.07 A |
3.8 Potential Divider

L.O 3.8.1 Explain principle of potential divider

L.O 3.8.2 Use equation of potential divider

A potential divider is used as a source of variable voltage. It produces an output voltage that is a fraction of the supply voltage.

\[
V_1 = \frac{R_1}{R_1 + R_2} V \quad \text{OR} \quad V_2 = \frac{R_2}{R_1 + R_2} V
\]

3.9 Potentiometer and Wheatstone Bridge

L.O 3.9.1 Explain the principles of potentiometer and Wheatstone Bridge and their application

L.O 3.9.2 Use related equation for potentiometer and for Wheatstone Bridge

Potentiometer

The working of potentiometer is based upon the fact that fall of the potential across any portion of the wire is directly proportional to the length of the wire provided wire has uniform cross section area and constant current flowing through it. The potentiometer is balanced when the jockey (sliding contact) is at such a position on wire AB that there is no current through the galvanometer.

If the galvanometer shows deflection in one direction only, it may be due to:

- The connections of the terminals of the cells are wrong. The positive terminal of the cell must be connected to the positive terminal of another cell.
- The e.m.f. of the unknown cell is more than the e.m.f. of the cell connected across the wire of the potentiometer, AB.
- The connections are not tight and the current does not flow in certain part of the circuit.
To measure the unknown e.m.f.

\[ \varepsilon = V_{AB}; \quad \varepsilon_X = V_{AC} \]

\[ \frac{l_{AC}}{l_{AB}} = \frac{V_{AC}}{V_{AB}} \]

To measure the unknown e.m.f. (with external resistance)

\[ \varepsilon - IR = V_{AB}; \quad \varepsilon_X = V_{AC} \]

\[ \frac{l_{AC}}{l_{AB}} = \frac{V_{AC}}{V_{AB}} \]

To compare two e.m.f.

\[ \frac{l_{AC}}{l_{AB}} = \frac{V_{AC}}{V_{AB}}; \quad \varepsilon_1 = \frac{l_1}{l_2} \]

To measure the internal resistance of a cell

\[ S \text{ open: } \varepsilon_1 = V_{AC}; \quad S \text{ closed: } \varepsilon_1 - Ir = V_{AC} \]

\[ \frac{l_{AC}}{l_{AB}} = \frac{V_{AC}}{V_{AB}}; \quad V_{AC} = IR \]
Wheatstone Bridge

The Wheatstone bridge is said to be balanced when no current flows through the galvanometer.

### Wheatstone Bridge

![Wheatstone Bridge Diagram]

\[ R_x = \left( \frac{R_2}{R_1} \right) R_3 \]

### Application: Meter Bridge

![Application Diagram]

\[ R_x = \left( \frac{l_1}{l_2} \right) R \]
Example

<table>
<thead>
<tr>
<th>Question</th>
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</tbody>
</table>

Calculate the currents $I_1$, $I_2$ and $I_3$. Neglect the internal resistance in each battery.

![Circuit Diagram](image) | |
| Answer: 17.69 A, 14.62 A, 3.07 A | |
Example

<table>
<thead>
<tr>
<th>Question</th>
<th>Solution</th>
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</thead>
<tbody>
<tr>
<td>Resistors of 3.0 ( \Omega ) and 6.0 ( \Omega ) are connected in series to a 12.0 V battery of negligible internal resistance. Determine the potential difference across the</td>
<td></td>
</tr>
<tr>
<td>a. 3.0 ( \Omega ) resistor</td>
<td></td>
</tr>
<tr>
<td>b. 6.0 ( \Omega ) resistors</td>
<td></td>
</tr>
</tbody>
</table>

Consider a potentiometer. If a standard battery with an e.m.f. of 1.0186 V is used in the circuit. When the resistance is 36 \( \Omega \), the galvanometer reads zero. If the standard battery is replaced by an unknown e.m.f. the galvanometer reads zero when the resistance is adjusted to 48 \( \Omega \). What is the value of the unknown e.m.f.?

In the potentiometer circuit shown below, \( \textbf{PQ} \) is a uniform wire of length 1.0 m and resistance 10.0 \( \Omega \).

\( \varepsilon_1 \) is an accumulator of e.m.f. 2.0 V and negligible internal resistance. \( R_1 \) is a 15 \( \Omega \) resistor and \( R_2 \) is a 5.0 \( \Omega \) resistor when \( S_1 \) and \( S_2 \) open, galvanometer \( \textbf{G} \) is balanced when \( QT \) is 62.5 cm. When both \( S_1 \) and \( S_2 \) are closed, the balance length is 10.0 cm. Calculate

a. the e.m.f. of cell \( \varepsilon_2 \).

b. the internal resistance of cell \( \varepsilon_2 \).
Question

An unknown length of platinum wire 0.920 mm in diameter is placed as the unknown resistance in a Wheatstone bridge as shown in figure below.

Resistors $R_1$ and $R_2$ have resistance of 38.0 $\Omega$ and 46.0 $\Omega$ respectively. Balance is achieved when the switch closed and $R_3$ is 3.48 $\Omega$. Find the length of the platinum wire if its resistivity is $10.6 \times 10^{-8}$ $\Omega$ m.

Exercise

Question

Cells A and B and centre-zero galvanometer G are connected to a uniform wire OS using jockeys X and Y as shown in figure below.

The length of the uniform wire OS is 1.00 m and its resistance is 12 $\Omega$.

When OY is 75.0 cm, the galvanometer does not show any deflection when OX = 50.0 cm. If Y touches the end S of the wire, OX = 62.5 cm when the galvanometer is balanced. The e.m.f. of the cell B is 1.0 V. Calculate

a. the potential difference across OY when OY = 75.0 cm.
b. the potential difference across OY when Y touches S and the galvanometer is balanced.
c. the internal resistance of the cell A.
d. the e.m.f. of cell A.