Current Electricity — Assignment 2

Class 12 Physics · Higher-difficulty challenge set + integrated problems + figure-based NCERT (6 questions) · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. g = 10 m/s^2 unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Electric Current and Drift Velocity

2 Mark Questions

1. A steady current of 3.0 A flows through a copper wire of area of cross-section 2.0×10^{-6} m^2. Find the drift velocity of the free electrons if their number density is 8.5×10^{28} m^{-3}.

3 Mark Questions

1. A wire of cross-sectional area 1.0×10^{-6} m^2 carries a current of 2.0 A. If the free-electron number density is 8.5×10^{28} m^{-3}, find the time taken by an electron to drift through a 1.0 cm length of the wire.

Ohm's Law and Resistance

2 Mark Questions

1. A negligibly small current is passed through a wire of length 15 m and uniform cross-section 6.0×10^{-7} m^2, and its resistance is measured to be 5.0 Ω. Find the resistivity of the material.

3 Mark Questions

1. A wire of resistance 5 Ω is stretched so that its length becomes double. Find its new resistance, assuming the volume and resistivity remain unchanged.

Combination of Resistances

2 Mark Questions

1. Three resistors 1 Ω, 2 Ω and 3 Ω are combined in series and connected to a battery of emf 12 V (negligible internal resistance). Find the total resistance and the potential drop across each resistor.

3 Mark Questions

1. Given n resistors each of resistance R, how will you combine them to get (i) the maximum and (ii) the minimum effective resistance? What is the ratio of the maximum to the minimum resistance?

Kirchhoff's Laws

2 Mark Questions

1. At a junction, a current of 5 A enters and the currents leaving are I_1 and I_2. If I_2 = 2 A, find I_1.

3 Mark Questions

1. A cell of emf 4 V and internal resistance 2 Ω is connected in parallel with a cell of emf 2 V and internal resistance 2 Ω, and a 6 Ω resistor is connected across the common terminals. Using Kirchhoff's laws find the current in the 6 Ω resistor.

Wheatstone Bridge and Meter Bridge

2 Mark Questions

1. The four arms of a Wheatstone bridge are PQ = 2 Ω, QR = 4 Ω, RS = 3 Ω and SP = 6 Ω. Is the bridge balanced? A 3 Ω resistor is now placed in parallel with QR — is the bridge still balanced?

3 Mark Questions

1. Derive the balance condition P/Q = R/S of a Wheatstone bridge using Kirchhoff's laws.

EMF, Internal Resistance and Cells

2 Mark Questions

1. Six lead-acid secondary cells each of emf 2.0 V and internal resistance 0.015 Ω are joined in series to supply a resistance of 8.5 Ω. Find the current drawn from the supply and the terminal voltage.

3 Mark Questions

1. A secondary cell after long use has an emf of 1.9 V and a large internal resistance of 380 Ω. What maximum current can be drawn from the cell? Could the cell drive the starting motor of a car?

Ammeter, Voltmeter and Galvanometer

2 Mark Questions

1. A galvanometer of resistance 20 Ω gives full-scale deflection for a current of 10 mA. Find the shunt resistance that converts it into an ammeter of range 0–5 A.

3 Mark Questions

1. A galvanometer of resistance 30 Ω gives full-scale deflection for a current of 2 mA. Find (i) the shunt needed to measure currents up to 2 A and (ii) the series resistance needed to measure voltages up to 2 V.

Potentiometer

2 Mark Questions

1. In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35.0 cm of the wire. When the cell is replaced by another cell the balance point shifts to 63.0 cm. What is the emf of the second cell?

3 Mark Questions

1. Describe, with a labelled circuit diagram, how a potentiometer is used to compare the emfs of two cells.

Part B — Integrated problems (multi-topic)

1. A galvanometer of resistance G = 30 Ω gives full-scale deflection for I_g = 2 mA. Find (i) the shunt resistance to convert it into an ammeter of range 0–2 A, (ii) the series resistance to convert it into a voltmeter of range 0–2 V, and (iii) the power dissipated in the shunt at full-scale deflection.

2. In a potentiometer a standard cell of emf 1.02 V balances at 67.3 cm of the wire. The standard cell is replaced by a cell of unknown emf ε which balances at 82.3 cm. (i) Find ε. (ii) If the driver cell is 2.0 V with internal resistance 0.40 Ω and the wire is 10 m long with total resistance 10 Ω, find the potential gradient along the wire. (iii) Would the method work if the driver emf were reduced to 1.0 V? Explain.

3. The network of Fig 3.30 (AB = 10 Ω, BC = 5 Ω, CD = 10 Ω, DA = 5 Ω, BD = 5 Ω) is connected to a 10 V battery of negligible internal resistance in series with a 10 Ω resistor across A–C. Using Kirchhoff's laws, determine the current in each branch and the total current drawn from the battery.

4. In a metre bridge experiment, the balance point is found at 39.5 cm from the end A when the resistor S in the right gap is 12.5 Ω. (i) Determine R. (ii) If R and S are interchanged, find the new balance point. (iii) What happens if the galvanometer and the cell are interchanged at the balance point?

5. A potentiometer compares the emfs of two cells: a cell of emf ε_1 = 1.25 V balances at l_1 = 35.0 cm while a second cell balances at l_2 = 63.0 cm. (i) Find the emf of the second cell. (ii) Using the principle of the potentiometer, explain why a potentiometer measures the true emf of a cell while a voltmeter does not.

6. Six lead-acid secondary cells, each of emf 2.0 V and internal resistance 0.015 Ω, are joined in series to supply a resistance of 8.5 Ω. (i) Find the current drawn from the supply and the terminal voltage. (ii) If the whole set is short-circuited, find the maximum current the set can supply.

Part C — Figure-based NCERT questions (answers at the end)

1. 3.9) Determine the current in each branch of the network shown in Fig 3.30.

2. 3.10) (a) In a metre bridge [Fig 3.27], the balance point is found to be at 39.5 cm from the end A when the resistor S is 12.5 Ω. Determine the resistance R. (b) Determine the balance point of the bridge above if R and S are interchanged. (c) What happens if the galvanometer and the cell are interchanged at the balance point of the bridge? Would the galvanometer show any current?

3. 3.20) (c) Determine the equivalent resistance of the networks shown in Fig 3.31.

4. 3.21) Determine the current drawn from a 12 V supply with internal resistance 0.5 Ω by the infinite network shown in Fig 3.32. Each resistor has 1 Ω resistance.

5. 3.22) Figure 3.33 shows a potentiometer with a cell of 2.0 V and internal resistance 0.40 Ω maintaining a potential drop across the resistor wire AB. A standard cell which maintains a constant emf of 1.02 V gives a balance point at 67.3 cm length of the wire. A very high resistance of 600 kΩ is put in series with the standard cell, which is shorted close to the balance point. The standard cell is then replaced by a cell of unknown emf ε and the balance point is found at 82.3 cm. (a) What is the value of ε? (b) What purpose does the high resistance of 600 kΩ have? (c) Is the balance point affected by this high resistance?

6. 3.23) Figure 3.34 shows a 2.0 V potentiometer used for the determination of internal resistance of a 1.5 V cell. The balance point of the cell in open circuit is 76.3 cm. When a resistor of 9.5 Ω is used in the external circuit of the cell, the balance point shifts to 64.8 cm length of the potentiometer wire. Determine the internal resistance of the cell.

Answer Key

Electric Current and Drift Velocity

2M: $v_d = I/(nAe) = 3.0/(8.5\times10^{28} \times 2.0\times10^{-6} \times 1.6\times10^{-19}) = 1.10\times10^{-4}$ m/s. 3M: $v_d = 2.0/(8.5\times10^{28} \times 1.0\times10^{-6} \times 1.6\times10^{-19}) = 1.47\times10^{-4}$ m/s; $t = 1.0\text{ cm}/v_d = 68$ s.

Ohm's Law and Resistance

2M: $\rho = RA/L = 5.0 \times 6.0\times10^{-7}/15 = 2.0\times10^{-7}\ \Omega$ m. 3M: length doubled at constant volume Ò A halves; $R' = \rho(2L)/(A/2) = 4R = 20\ \Omega$.

Combination of Resistances

2M: (a) $R = 1+2+3 = 6\ \Omega$; $I = 12/6 = 2$ A Ò drops 2 V, 4 V, 6 V. 3M: (i) all n in series Ò nR; (ii) all in parallel Ò R/n; ratio n^2.

Kirchhoff's Laws

2M: junction rule: $I_1 = 5 - 2 = 3$ A. 3M: V_AB branch 1: $4 - 2I_1$; branch 2: $2 - 2I_2$; branch 3: $6I_3$ with $I_3 = I_1 + I_2$. $4 - 2I_1 = 2 - 2I_2$ Ò $I_1 - I_2 = 1$; and $4 - 2I_1 = 6(I_1+I_2)$ Ò $8I_1 + 6I_2 = 4$. Solving: $I_1 = 5/7$ A, $I_2 = -2/7$ A Ò $I_3 = 3/7 \approx 0.43$ A.

Wheatstone Bridge and Meter Bridge

2M: $P/Q = 2/4 = 1/2$ and $R/S = 3/6 = 1/2$ Ò balanced. With 3 Ω %Q R: QR' = 4%= 12/7 Ω Ò $P/Q = 2/(12/7) = 7/6 \neq 3/6$ Ò no longer balanced. 3M: at balance no current through the galvanometer arm; equating potentials, $P/Q = R/S$ (full derivation in the note).

EMF, Internal Resistance and Cells

2M: $\varepsilon = 12$ V, $r = 6\times0.015 = 0.09\ \Omega$; $I = 12/(8.5 + 0.09) = 1.4$ A; $V = IR = 1.4 \times 8.5 = 11.9$ V. 3M: $I\_max = \varepsilon/r = 1.9/380 = 0.005$ A; a car-starter needs ~100 A Ò impossible.

Ammeter, Voltmeter and Galvanometer

2M: $S = I\_g\, G/(I - I\_g) = (0.010 \times 20)/(5 - 0.010) = 0.20/4.99 = 0.040\ \Omega$. 3M: (i) $S = (0.002 \times 30)/(2 - 0.002) = 0.060/1.998 = 0.030\ \Omega$; (ii) $R = V/I\_g - G = 2/0.002 - 30 = 970\ \Omega$.

Potentiometer

2M: $\varepsilon_2 = \varepsilon_1\, l_2/l_1 = 1.25 \times 63.0/35.0 = 2.25$ V. 3M: with jockey at balance, the cell is in open circuit Ò true emf; $\varepsilon_1/\varepsilon_2 = l_1/l_2$ (draw the labelled circuit in the answer).

Integrated problems

1: (i) $S = 0.030\ \Omega$; (ii) $R = 970\ \Omega$; (iii) $P = (I - I\_g)(I\_g\, G) = (1.998)(0.06) = 0.12$ W. 2: (i) $\varepsilon = 1.02 \times 82.3/67.3 = 1.25$ V; (ii) $I = 2.0/(10 + 0.4) = 0.192$ A, gradient $= IR/L = 0.192 \times 10/10 = 0.19$ V/m $\approx 1.9\times10^{-3}$ V/cm; (iii) no — with a 1.0 V driver the gradient falls and measured emfs can no longer be balanced on the wire. 3: total current 10/17 A; branch currents AB = 4/17 A, BC = 6/17 A, CD = −4/17 A, AD = 6/17 A, BD = −2/17 A. 4: (i) $R = 12.5 \times 39.5/60.5 = 8.2\ \Omega$; (ii) 60.5 cm; (iii) bridge stays balanced, galvanometer shows zero. 5: (i) $\varepsilon_2 = 2.25$ V; (ii) at balance the cell draws no current, so the terminal voltage equals the true emf. 6: (i) I = 1.4 A, V = 11.9 V; (ii) $I\_max = 12/0.09 \approx 133$ A.

Part C – figure-based NCERT questions

3.9: AB = 4/17 A, BC = 6/17 A, CD = −4/17 A, AD = 6/17 A, BD = −2/17 A; total = 10/17 A. 3.10: (a) $R = 8.2\ \Omega$ ($R/S = l/(100-l) = 39.5/60.5 \times 12.5$); thick copper keeps connection resistance negligible. (b) 60.5 cm. (c) No current — bridge stays balanced. 3.20(c): (i) each loop = (1+1)(2 /(2+2) = 4/3 Ω; four loops in series Ò 4 × 4/3 = 16/3 Ω; (ii) five R in series Ò 5R. 3.21: $X = (1+\sqrt{3})\ \Omega \approx 2.73\ \Omega$; $I = 12/(0.5 + 2.73) \approx 3.7$ A. 3.22: (a) $\varepsilon = 1.25$ V; (b) it limits the current through the standard cell when the jockey is far from balance; (c) no — at the balance point no current flows in the secondary. 3.23: $r = (l_1/l_2 - 1)R = (76.3/64.8 - 1) \times 9.5 = 1.685 \approx 1.7\ \Omega$.