CLASS XII – PHYSICS (042)
STEP-BY-STEP SOLUTIONS AND MARKING SCHEME

Chapter 3: Current Electricity – Practice Paper (35 Marks)

Answer key – Section A

Q.	1	2	3	4	5	6	7	8	9
Ans.	(b)	(c)	(b)	(c)	(d)	(c)	(b)	(a)	(c)

Marks are shown in square brackets. Equivalent correct methods are acceptable.

SECTION A

Q.1 (b)

In a semiconductor the resistivity decreases as temperature rises (curve R). Alloys such as nichrome, manganin and constantan have a very weak dependence of resistivity on temperature, so they are used for standard resistors (curve Q). P, rising steeply, is a metal like copper. **[1]**

Q.2 (c)

$R = \rho l/A \propto l/d^2$. Relative values: P = 1/1 = 1; Q = 2/4 = 0.5; R = 1.5/1 = 1.5; S = 3/4 = 0.75. Wire R has the maximum resistance. **[1]**

Q.3 (b)

Slope of a V–I line = R. $R_X = 6/2 = 3\ \Omega$; $R_Y = 6/3 = 2\ \Omega$. For the same material and length $R \propto 1/A$, so $A_X : A_Y = R_Y : R_X = 2 : 3$. **[1]**

Q.4 (c)

$I = \varepsilon/(R + r) = 12/(4 + 2) = 2$ A. The voltmeter reads the terminal voltage $V = \varepsilon - Ir = 12 - 2 \times 2 = 8$ V ($= IR = 2 \times 4$). **[1]**

Q.5 (d)

Balance: AB/BC = AD/DC, i.e. 6/9 = 8/X, so $X = 8 \times 9/6 = 12\ \Omega$. **[1]**

Q.6 (c)

$I = neAv_d$ with n, e and I constant gives $v_d \propto 1/A$. For $A \to A/3$ the drift speed becomes 3 times, so the ratio is 3 : 1. **[1]**

Q.7 (b)

Net emf for opposing cells = 10 − 4 = 6 V; total resistance = 1 + 1 + 2 = 4 Ω. I = 6/4 = 1.5 A. **[1]**

Q.8 (a)

Both are true and R explains A: the field propagates at nearly the speed of light, so electrons all along the circuit begin to drift immediately; the electrons themselves do not have to travel from the switch to the lamp. **[1]**

Q.9 (c)

A is true: current is defined as charge per unit time (a scalar) and the arrow only indicates the sense of flow. R is false: currents add algebraically, not as vectors. **[1]**

SECTION B

Q.10

From the graph $R_0 = 5.0\ \Omega$ at 0 °C and $R = 5.5\ \Omega$ at 100 °C. $\alpha = (R - R_0)/(R_0 t) = 0.5/(5.0 \times 100) = 1.0 \times 10^{-3}\ °C^{-1}$. **[1]**

$R = R_0(1 + \alpha t)$: $5.85 = 5.0(1 + 0.001t)$ gives $0.17 = 0.001t$, so t = 170 °C. **[1]**

Q.11

(i) $j = I/A = 4/(2.0 \times 10^{-6}) = 2 \times 10^6\ A\ m^{-2}$. **[1]**

(ii) $j = nev_d$, so $v_d = j/ne = (2 \times 10^6)/(8.5 \times 10^{28} \times 1.6 \times 10^{-19}) \approx 1.5 \times 10^{-4}\ m\ s^{-1}$ (about 0.15 mm s^{-1}). **[1]**

Q.12 (A)

$V = \varepsilon - Ir$. For the two readings: $2.4 = \varepsilon - 1.0r$ and $2.0 = \varepsilon - 2.0r$. **[1]**

Subtracting: $r = 0.4\ \Omega$; then $\varepsilon = 2.4 + 0.4 = 2.8$ V. **[1]**

Q.12 (B)

Stretching does not change the volume, so $A'l' = Al$: for $l' = 3l$, $A' = A/3$. $R' = \rho l'/A' = \rho(3l)/(A/3) = 9R$. **[1]**

$R' = 9 \times 8 = 72\ \Omega$ (assuming the volume and resistivity of the wire stay constant). **[1]**

Q.13

(i) No, the device does not obey Ohm's law. **[1]**

(ii) Any two: the I–V graph is non-linear (not a straight line through the origin); the current for a given magnitude of V depends on the sign of V (forward current in mA, reverse current only in μA), i.e. the device is a rectifier (diode); the resistance V/I is not constant. **[1]**

SECTION C

Q.14

Let I_1 (from the 12 V cell), I_3 (from the 4 V cell) flow upward into junction A and I_2 flow down through the 3 Ω resistor. Junction rule at A: $I_2 = I_1 + I_3$. **[1]**

Loop rule, left loop: $12 - 2I_1 - 3I_2 = 0$. Right loop: $4 - 2I_3 - 3I_2 = 0$. With $I_2 = I_1 + I_3$ these become $5I_1 + 3I_3 = 12$ and $3I_1 + 5I_3 = 4$. **[1]**

Solving: $I_3 = -1$ A, $I_1 = 3$ A, $I_2 = 2$ A. So 3 A flows out of the 12 V cell, 2 A flows from A to B through the 3 Ω resistor, and 1 A flows *into* the positive terminal of the 4 V cell (it is being charged). **[1]**

Q.15 (A)

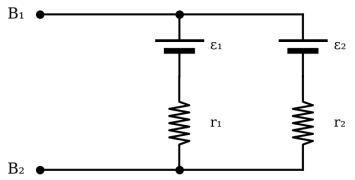
Drift velocity is the average velocity with which the free electrons drift in the direction opposite to the applied electric field. **[½]**

The acceleration of an electron is $a = -eE/m$. The velocity of the i-th electron at time t is $v_i + (-eE/m)t_i$, where t_i is the time since its last collision. The average of the random initial velocities v_i is zero, and the average of t_i is the relaxation time τ. **[1]**

Hence $v_d = -eE\tau/m$ (magnitude $eE\tau/m$). **[½]**

Current $I = neAv_d$, so $j = I/A = ne^2\tau E/m$. Comparing with $j = \sigma E$: $\sigma = ne^2\tau/m$, so the resistivity $\rho = 1/\sigma = m/(ne^2\tau)$. **[1]**

Q.15 (B)



Let I_1 and I_2 be the currents leaving the positive terminals; the total current is $I = I_1 + I_2$. Let $V = V(B_1) - V(B_2)$ be the common potential difference. **[½]**

$V = \varepsilon_1 - I_1r_1$ and $V = \varepsilon_2 - I_2r_2$, so $I = (\varepsilon_1 - V)/r_1 + (\varepsilon_2 - V)/r_2 = (\varepsilon_1/r_1 + \varepsilon_2/r_2) - V(1/r_1 + 1/r_2)$. **[1]**

Hence $V = (\varepsilon_1r_2 + \varepsilon_2r_1)/(r_1 + r_2) - I\, r_1r_2/(r_1 + r_2)$. Comparing with $V = \varepsilon_{eq} - I\, r_{eq}$: **[½]**

$\varepsilon_{eq} = (\varepsilon_1r_2 + \varepsilon_2r_1)/(r_1 + r_2)$ and $r_{eq} = r_1r_2/(r_1 + r_2)$ (i.e. $1/r_{eq} = 1/r_1 + 1/r_2$). **[1]**

Q.16

(a) $V = \varepsilon - Ir$. At $I = 0$ the graph gives $V = \varepsilon = 6$ V. **[1]**

Slope $= (5 - 6)/2 = -0.5\ \text{V A}^{-1} = -r$, so $r = 0.5\ \Omega$ (check: at 4 A, $6 - 0.5 \times 4 = 4$ V ✓). **[1]**

(b) The maximum current flows when the external resistance is zero ($V = 0$): $I_{max} = \varepsilon/r = 6/0.5 = 12$ A. **[1]**

SECTION D

Q.17 (Case study)

(i) **(c)** $I = P/V = (2.2 \times 10^6)/(11 \times 10^3) = 200$ A. **[1]**

(ii) **(d)** $P_{loss} = I^2R_c = (200)^2 \times 10 = 4 \times 10^5$ W = 400 kW. **[1]**

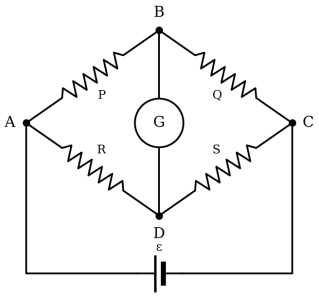
(iii) **(a)** At 220 kV: $I = 2.2 \times 10^6/(2.2 \times 10^5) = 10$ A; $P_{loss} = 10^2 \times 10 = 1000$ W = 1 kW. **[1]**

(iv) **(b)** $P_{loss} = P^2R_c/V^2 \propto 1/V^2$. Doubling V reduces the loss to one-fourth. **[1]**

OR (iv) (d) $R \propto 1/d^2$, so halving the diameter makes R four times; at the same voltage and power I is unchanged, so the loss $P = I^2R$ becomes four times. **[1]**

SECTION E

Q.18 (A)



Circuit: four resistors P, Q, R, S in the arms AB, BC, AD, DC; a battery between A and C; a galvanometer G between B and D. **[½]**

For a balanced bridge the galvanometer current is zero. Junction rule at B and D: the current in AB and BC is I_1; in AD and DC it is I_2. **[½]**

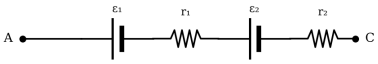
Loop rule for ABDA (no current in G): $-I_1P + I_2R = 0$. For BCDB: $-I_1Q + I_2S = 0$. **[1]**

Dividing the two: P/Q = R/S, which is the balance condition. **[1]**

Numerical: AB/BC = AD/DC, so 12/18 = 20/DC, giving DC = 30 Ω. **[1]**

The arm ABC has 12 + 18 = 30 Ω and the arm ADC has 20 + 30 = 50 Ω, in parallel across 10 V (G carries no current). I = 10/30 + 10/50 = 0.333 + 0.2 = 0.53 A (8/15 A). **[1]**

Q.18 (B)



Let the cells be joined with the negative terminal of the first to the positive terminal of the second, and let current I flow from A to C through both. **[½]**

$V_{AB} = \varepsilon_1 - Ir_1$ and $V_{BC} = \varepsilon_2 - Ir_2$. **[1]**

$V_{AC} = V_{AB} + V_{BC} = (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2)$. Comparing with $V_{AC} = \varepsilon_{eq} - Ir_{eq}$: $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ and $r_{eq} = r_1 + r_2$. **[1½]**

Numerical: $\varepsilon_{eq} = 3 \times 2 = 6$ V; $r_{eq} = 3 \times 0.5 = 1.5$ Ω. $I = \varepsilon_{eq}/(R + r_{eq}) = 6/(2.5 + 1.5) = 1.5$ A. **[1]**

Potential difference across the external resistor: $V = IR = 1.5 \times 2.5 = 3.75$ V. **[1]**

— End of Solutions —