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Current Electricity — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · PHYSICS · PATTERN OF JEE (MAIN)

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	100	25 (20 + 5)	

GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Take $e = 1.6 \times 10^{-19}$ C unless stated otherwise. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

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Topics covered: Electric current · Drift velocity and mobility · V–I characteristics and Ohm's law · Resistivity and conductivity · Temperature dependence of resistance · Electrical energy and power · Series and parallel combination of resistors · Internal resistance and emf of a cell · Combination of cells · Kirchhoff's laws · Wheatstone bridge · Metre bridge

SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

1. A copper wire of cross-sectional area 1 mm² carries a current of 1.6 A. The number density of free electrons in copper is 8×10^{28} m^{-3}. The drift speed of the electrons is

(1) 1.25 mm/s

(2) 12.5 mm/s

(3) 0.125 mm/s

(4) 0.0125 mm/s

2. A potential difference V across a metal wire of length L gives its free electrons a drift speed v_d. The wire is replaced by one of the same metal with length 2L and twice the diameter, and the same potential difference V is applied. The drift speed becomes

(1) $v_d/2$

(2) $2v_d$

(3) v_d

(4) $v_d/4$

3. A wire is stretched so that its length increases by 10%, its volume staying the same. Its resistance increases by

(1) 10%

(2) 20%

(3) 11%

(4) 21%

4. The resistance of a metal coil is 10 Ω at 20 °C and 12 Ω at 70 °C. Taking $R = R_{20}[1 + \alpha(T - 20\ °C)]$ with α constant, the temperature at which its resistance is 15 Ω is

(1) 170 °C

(2) 145 °C

(3) 125 °C

(4) 182.5 °C

5. Two bulbs rated 100 W, 220 V and 60 W, 220 V are connected in series across a 220 V supply. Taking their resistances as constant, the brighter bulb and its power are

(1) the 60 W bulb, dissipating about 23 W

(2) the 100 W bulb, dissipating about 23 W

(3) the 60 W bulb, dissipating about 14 W

(4) the 100 W bulb, dissipating about 37 W

6. Six resistors, each R, form the sides of a regular hexagon ABCDEF, and the centre O of the hexagon is joined to each of the six corners by a further resistor R. The equivalent resistance between the opposite corners A and D is

(1) R

(2) 2R/3

(3) 4R/5

(4) R/2

7. A cell gives a current of 1 A through a 4 Ω resistor and 0.5 A through a 9 Ω resistor. Its emf E and internal resistance r are

(1) E = 4.5 V, r = 0.5 Ω

(2) E = 5 V, r = 1 Ω

(3) E = 6 V, r = 2 Ω

(4) E = 5 V, r = 0.5 Ω

8. A battery of emf 6 V and internal resistance 2 Ω is connected to a variable external resistor. The largest power that can be delivered to the external resistor is

(1) 9 W

(2) 18 W

(3) 2.25 W

(4) 4.5 W

9. A cell of emf 2 V and internal resistance 1 Ω and a cell of emf 4 V and internal resistance 2 Ω are connected in parallel (positive to positive) across an external resistor of 2 Ω. The current in the external resistor is

(1) 2 A

(2) 4/3 A

(3) 0.5 A

(4) 1 A

10. Five identical cells, each of emf 2 V and internal resistance 1 Ω, send the same current through an external resistor R whether they are all joined in series or all joined in parallel. That current is

(1) 1.67 A

(2) 2 A

(3) 0.33 A

(4) 1 A

11. Three branches are connected in parallel between two points X and Y: a 12 V cell with a 2 Ω resistor, a 6 V cell with a 4 Ω resistor (both cells with their positive terminals towards X, internal resistances negligible), and a 4 Ω resistor alone. The current in the 4 Ω resistor that is alone is

(1) 1.5 A

(2) 2.25 A

(3) 1.875 A

(4) 0.75 A

12. In a Wheatstone bridge the four arms are P = 10 Ω, Q = 15 Ω, R = 4 Ω and S = 8 Ω, with P/Q = R/S needed for balance. The bridge can be balanced by connecting

(1) 2 Ω in series with S

(2) 24 Ω in parallel with S

(3) 6 Ω in parallel with S

(4) 48 Ω in parallel with S

13. A metre bridge has an unknown resistor in its left gap and 14 Ω in its right gap, and balances 30 cm from the left end. A resistor Y is then connected in parallel with the 14 Ω resistor, and the bridge now balances at the middle of the wire. The value of Y is

(1) 6 Ω

(2) 10.5 Ω

(3) 14 Ω

(4) 8.4 Ω

14. A kettle brings a certain amount of water to the boil in 10 minutes using coil A alone and in 15 minutes using coil B alone, on the same supply. Ignoring heat losses, the times taken with the two coils in series and with the two coils in parallel are

(1) 25 min and 12.5 min

(2) 12.5 min and 6 min

(3) 6 min and 25 min

(4) 25 min and 6 min

15. Two wires of the same metal have lengths in the ratio 1 : 2 and diameters in the ratio 2 : 1. They are connected in series across a battery. The ratio of the heat produced in them per second is

(1) 1 : 8

(2) 8 : 1

(3) 1 : 2

(4) 1 : 4

16. Consider the statements:
(A) The V–I graph of an ohmic conductor is a straight line through the origin.
(B) For a metal wire, the V–I graph (V on the vertical axis) taken at a higher temperature has a greater slope.
(C) A semiconductor diode is a non-ohmic device.
(D) The resistivity of a metal decreases as its temperature rises.
Choose the correct answer from the options given below:

(1) (A) and (D) only

(2) (B), (C) and (D) only

(3) (A), (B) and (C) only

(4) (A) and (C) only

17. A 12 V battery of internal resistance 0.5 Ω is being charged from a 20 V dc supply through a 3.5 Ω series resistor. The potential difference across the battery's terminals while it is charging is

(1) 13 V

(2) 11 V

(3) 12 V

(4) 20 V

18. An infinitely long ladder network has a 2 Ω resistor in each section of one rail and a 1 Ω resistor in each rung, as shown by the repeating unit: 2 Ω in series, then 1 Ω across the line. The equivalent resistance between the input terminals is

(1) $(1 + \sqrt{5})$ Ω

(2) $(1 + \sqrt{3})$ Ω

(3) $2\sqrt{3}$ Ω

(4) 3 Ω

19. A steady current flows through a metal conductor whose radius tapers smoothly from 2r at one end to r at the other. Compared with the wide end, at the narrow end the drift speed of the electrons and the electric field inside the metal are

(1) drift speed 2 times, field the same

(2) drift speed 4 times, field the same

(3) drift speed 2 times, field 4 times

(4) drift speed 4 times, field 4 times

20. Three identical resistors are connected with two of them in parallel and the third in series with that pair. Each resistor can safely dissipate at most 18 W. The largest power the whole combination can safely dissipate is

(1) 54 W

(2) 36 W

(3) 27 W

(4) 18 W

SECTION B (Q21–25) · Numerical value · +4 / 0 / −1

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

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21. A copper coil (temperature coefficient of resistance 4×10^{-3} per °C) and a carbon resistor (-5×10^{-4} per °C) are connected in series. The total resistance is 54 Ω and does not change with temperature. The resistance of the copper coil (in Ω) is _____.

Answer: _____

22. A bridge network has resistors 1 Ω between A and B, 2 Ω between B and C, 2 Ω between A and D, 1 Ω between D and C, and 1 Ω between B and D. A 21 V battery of negligible internal resistance is connected between A and C. The current (in A) in the resistor between B and D is _____.

Answer: _____

23. Thirty-two identical cells, each of emf 2 V and internal resistance 1 Ω, are to be arranged in equal rows (each row a number of cells in series, the rows in parallel) to send the largest possible current through an external resistor of 2 Ω. The largest current (in A) is _____.

Answer: _____

24. A heater is rated 1000 W, 220 V. Taking its resistance as constant, the power (in W) it dissipates when connected to a 200 V supply is _____ (to the nearest integer).

Answer: _____

25. The current in a conductor varies with time as $I = (2 + 3t)$ A, with t in seconds. The charge (in C) that flows through any cross-section in the first 4 s is _____.

Answer: _____

END OF THE QUESTION PAPER

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(3)	(1)	(4)	(2)	(1)	(3)	(2)	(4)	(4)	(1)

Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
(3)	(2)	(2)	(4)	(1)	(3)	(1)	(2)	(4)	(3)

Q21	Q22	Q23	Q24	Q25
6	3	4	826	32

WORKED SOLUTIONS

Q1. Answer (3). $I = neAv_d$, so $v_d = 1.6/(8 \times 10^{28} \times 1.6 \times 10^{-19} \times 10^{-6}) = 1.25 \times 10^{-4}$ m/s = 0.125 mm/s.

Q2. Answer (1). $v_d = \mu E$ with $E = V/L$. The cross-section does not matter: doubling the length halves the field, so v_d becomes $v_d/2$. (The current goes up, $R \propto L/d^2$ falling to half, but the area goes up four times.)

Q3. Answer (4). At constant volume $A \propto 1/L$, so $R = \rho L/A \propto L^2$. R becomes $1.1^2 = 1.21$ times: an increase of 21%. (20% is the small-change estimate 2 × 10%.)

Q4. Answer (2). $12 = 10(1 + 50\alpha)$, so $\alpha = 0.004$ per °C. $15 = 10[1 + 0.004(T - 20)]$ gives $T - 20 = 125$, T = 145 °C. (125 °C is the rise, not the temperature.)

Q5. Answer (1). $R = V^2/P$: 484 Ω and 806.7 Ω. In series $I = 220/1290.7 = 0.170$ A, and $P = I^2R$ is larger for the larger resistance: the 60 W bulb dissipates $0.170^2 \times 806.7 \approx 23$ W (the 100 W bulb about 14 W).

Q6. Answer (3). Put A at potential V and D at 0. By symmetry O is at V/2, B and F are at the same potential x, and C and E at V − x. Current law at B (neighbours A, C and O): $(V - x) + (V - x - x) + (V/2 - x) = 0$, so $x = 5V/8$. Current leaving A: $2 \times (3V/8)/R$ to B and F, plus $(V/2)/R$ to O, total $5V/(4R)$. So the resistance between A and D is 4R/5.

Q7. Answer (2). $E = 1 \times (4 + r) = 0.5 \times (9 + r)$, so $4 + r = 4.5 + 0.5r$, r = 1 Ω and E = 5 V.

Q8. Answer (4). $P = E^2R/(R + r)^2$ is largest when R = r = 2 Ω: $P = 36 \times 2/16 = 4.5$ W. (9 W is the total power drawn at that point, half of it wasted inside the battery.)

Q9. Answer (4). Equivalent cell: $E = (E_1/r_1 + E_2/r_2)/(1/r_1 + 1/r_2) = (2 + 2)/(1.5) = 8/3$ V and r = 2/3 Ω. $I = (8/3)/(2 + 2/3) = 1$ A. (Kirchhoff's laws give the same: the terminal voltage is 2 V.)

Q10. Answer (1). Series: $I = 10/(5 + R)$. Parallel: emf 2 V, internal resistance 1/5 Ω, $I = 2/(0.2 + R)$. Equal when $10(0.2 + R) = 2(5 + R)$, i.e. $8R = 8$ and R = 1 Ω (equal to the internal resistance of one cell). Then $I = 10/6 \approx 1.67$ A.

Q11. Answer (3). Take $V_Y = 0$ and $V_X = V$. Kirchhoff's current law at X: $(12 - V)/2 + (6 - V)/4 = V/4$, so $24 - 2V + 6 - V = V$, V = 7.5 V. Current in the lone resistor 7.5/4 = 1.875 A.

Q12. Answer (2). Balance needs $S' = QR/P = 15 \times 4/10 = 6$ Ω, less than 8 Ω, so a resistor X must go in parallel with S: $8X/(8 + X) = 6$ gives X = 24 Ω.

Q13. Answer (2). X/14 = 30/70, so X = 6 Ω. Balance at 50 cm needs the right gap to equal 6 Ω too: $14Y/(14 + Y) = 6$ gives $8Y = 84$, Y = 10.5 Ω.

Q14. Answer (4). $t = Q/P = QR/V^2$, so $t \propto R$. In series the resistances add: t = 10 + 15 = 25 min. In parallel the powers add: $1/t = 1/10 + 1/15$, t = 6 min.

Q15. Answer (1). $R \propto L/d^2$: $R_1 : R_2 = (1/4) : (2/1) = 1 : 8$. In series the current is the same, so $H = I^2R$ is in the ratio 1 : 8.

Q16. Answer (3). (A) true: V = IR with R constant. (B) true: the slope V/I is R, which rises with temperature in a metal. (C) true: a diode's current is not proportional to the voltage and depends on its direction. (D) false: the resistivity of a metal increases with temperature.

Q17. Answer (1). The supply drives current against the battery's emf: I = (20 − 12)/(3.5 + 0.5) = 2 A. While charging, the terminal voltage is E + Ir = 12 + 2 × 0.5 = 13 V, more than the emf.

Q18. Answer (2). Removing the first unit leaves the same infinite ladder, so R = 2 + (1 × R)/(1 + R). Then $R^2 + R = 2 + 2R + R$, $R^2 - 2R - 2 = 0$ and $R = 1 + \sqrt{3}\ \Omega$.

Q19. Answer (4). The current I is the same at every section. $v_d = I/(neA)$ and J = I/A both go as 1/A, which is $(2r/r)^2 = 4$ times larger at the narrow end. The field E = ρJ is also 4 times larger.

Q20. Answer (3). The series resistor carries the full current I, each parallel one I/2. The series one reaches its limit first: I^2R = 18 W, and then each of the others has $(I/2)^2R$ = 4.5 W. Total 18 + 4.5 + 4.5 = 27 W.

Q21. Answer 6. For the total not to change, with R_1 for copper and R_2 for carbon, $R_1 \times 0.004 + R_2 \times (-0.0005) = 0$, so $R_2 = 8R_1$. Then $9R_1 = 54$ and $R_1 = 6\ \Omega$.

Q22. Answer 3. Take $V_C = 0$, $V_A = 21$. Current law at B: $(21 - V_B)/1 = V_B/2 + (V_B - V_D)/1$; at D: $(21 - V_D)/2 + (V_B - V_D)/1 = V_D/1$. These give $V_B = 14$ V and $V_D = 11$ V, so the current from B to D is 3 A.

Q23. Answer 4. With n cells in series in each of m rows (nm = 32), I = 2n/(2 + n/m). The current is largest when the internal resistance n/m equals 2 Ω: n = 8, m = 4, giving I = 16/(2 + 2) = 4 A.

Q24. Answer 826. $R = 220^2/1000 = 48.4\ \Omega$. $P = 200^2/48.4 = 826.4$ W, i.e. 826.

Q25. Answer 32. $q = \int I\,dt$ from 0 to 4 = $[2t + 1.5t^2]$ = 8 + 24 = 32 C.

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