Electrical Circuits Questions – OCR A Level Physics

Praneel Physics

1. State Kirchhoff's first law (the junction rule). **(P)**

Working and Answer:

The total current entering a junction equals the total current leaving it.
Mathematically:

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

2. Define resistance and state its SI unit. **(P)**

Working and Answer:

Resistance is the opposition to the flow of electric current in a conductor.

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

Unit: Ohm (Ω)

3. State Ohm's law. **(P)**

Working and Answer:

Ohm's law states that the current through a metallic conductor is directly proportional to the potential difference across it, provided temperature remains constant.

$$V = IR$$

4. Calculate the resistance of a resistor if the potential difference across it is 9 V and the current through it is 3 A. **(P)**

Working and Answer:

$$R = \frac{V}{I} = \frac{9}{3} = 3\,\Omega$$

5. Write down the equation for power dissipated in a resistor. **(P)**

Working and Answer:

$$P = IV$$

Alternatively,

$$P = I^2R = \frac{V^2}{R}$$

6. A 12 V battery is connected across a 6 Ω resistor. Calculate the current and power dissipated. **(PP)**

Working and Answer:

$$I = \frac{V}{R} = \frac{12}{6} = 2\,\text{A}$$

$$P = IV = 2 \times 12 = 24\,\text{W}$$

7. State Kirchhoff's second law (the loop rule). **(PP)**

Working and Answer:

The algebraic sum of the electromotive forces (emfs) and potential differences (pds) in any closed loop of a circuit is zero:

$$\sum \text{emf} = \sum \text{p.d.}$$

8. A 3 Ω resistor carries a current of 0.5 A for 2 minutes. Calculate the energy transferred. **(PP)**

Working and Answer:

$$V = IR = 0.5 \times 3 = 1.5\,\text{V}$$

$$E = IVt = 0.5 \times 1.5 \times 120 = 90\,\text{J}$$

9. Explain why filament lamps do not obey Ohm's law. **(PP)**

Working and Answer:

The filament's resistance increases as it heats up due to the increasing temperature, causing the current and voltage to no longer be directly proportional. Hence, Ohm's law does not hold.

10. What is meant by an ohmic conductor? **(PP)**

Working and Answer:

An ohmic conductor is one where current is directly proportional to voltage at a constant temperature, so the resistance remains constant.

11. Calculate the total resistance of three resistors 2 Ω, 3 Ω and 5 Ω connected in series. **(PPP)**

Working and Answer:

$$R_{\text{total}} = R_1 + R_2 + R_3 = 2 + 3 + 5 = 10\,\Omega$$

12. Calculate the total resistance of two resistors, 4 Ω and 6 Ω, connected in parallel. **(PPP)**

Working and Answer:

$$\frac{1}{R_{\text{total}}} = \frac{1}{4} + \frac{1}{6} = \frac{3}{12} + \frac{2}{12} = \frac{5}{12}$$

$$R_{\text{total}} = \frac{12}{5} = 2.4\,\Omega$$

13. A 9 V battery is connected across two resistors in series: 2 Ω and 4 Ω. Calculate the current through the circuit. **(PPP)**

Working and Answer:

$$R_{\text{total}} = 2 + 4 = 6\,\Omega$$

$$I = \frac{V}{R_{\text{total}}} = \frac{9}{6} = 1.5\,\text{A}$$

14. State the formula for the emf of a power supply in terms of terminal potential difference and internal resistance. **(PPP)**

Working and Answer:

$$\text{emf} = V + Ir$$

where V is the terminal voltage, I is current, and r is internal resistance.

15. A battery with emf 12 V and internal resistance 1.5 Ω supplies a current of 3 A. Calculate the terminal voltage. **(PPP)**

Working and Answer:

$$V = \text{emf} - Ir = 12 - (3 \times 1.5) = 12 - 4.5 = 7.5\,\text{V}$$

16. Derive an expression for the total resistance of resistors connected in parallel. **(PPPP)**

Working and Answer:

For n resistors $R_1, R_2, ..., R_n$ in parallel:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

This follows because the potential difference across each resistor is the same and currents add.

17. A circuit has two resistors 4 Ω and 6 Ω connected in parallel, powered by a 12 V battery. Calculate the current through each resistor and the total current supplied by the battery. **(PPPP)**

Working and Answer:

$$I_1 = \frac{V}{R_1} = \frac{12}{4} = 3\,\text{A}, \quad I_2 = \frac{12}{6} = 2\,\text{A}$$

$$I_{\text{total}} = I_1 + I_2 = 3 + 2 = 5\,\text{A}$$

18. Explain the effect of internal resistance on the terminal potential difference of a battery. **(PPPP)**

Working and Answer:

When current flows, internal resistance causes a voltage drop inside the battery, reducing terminal voltage:

$$V = \text{emf} - Ir$$

So terminal voltage decreases as current increases.

19. A cell with emf 1.5 V and internal resistance 0.5 Ω is connected to a resistor of 4.5 Ω. Calculate the current in the circuit and the terminal voltage. **(PPPP)**

Working and Answer:

Total resistance:

$$R_{\text{total}} = 4.5 + 0.5 = 5\,\Omega$$

Current:

$$I = \frac{\text{emf}}{R_{\text{total}}} = \frac{1.5}{5} = 0.3\,\text{A}$$

Terminal voltage:

$$V = \text{emf} - Ir = 1.5 - (0.3 \times 0.5) = 1.35\,\text{V}$$

20. Describe how you would experimentally determine the internal resistance of a battery. **(PPPP)**

Working and Answer:

Connect the battery to a variable resistor and measure current and terminal voltage for different resistances. Plot terminal voltage against current. The y-intercept is the emf, and the negative slope is the internal resistance.

21. A battery has an emf of 12 V and internal resistance 0.5 Ω. It supplies 2 A current. Calculate the power dissipated inside the battery. **(PPPPP)**

Working and Answer:

Power dissipated in internal resistance:

$$P = I^2 r = 2^2 \times 0.5 = 2\,\text{W}$$

22. Calculate the energy delivered by the battery in 5 minutes when supplying 2 A current. **(PPPPP)**

Working and Answer:

Time $t = 5 \times 60 = 300\,\text{s}$
Energy:

$$E = VIt = 12 \times 2 \times 300 = 7200\,\text{J}$$

23. Explain why the terminal voltage of a battery falls as the current increases. **(PPPPP)**

Working and Answer:

As current increases, the voltage drop Ir across internal resistance increases, reducing terminal voltage $V = \text{emf} - Ir$.

24. Two resistors 5 Ω and 10 Ω are connected in parallel to a 12 V supply. Calculate the total power dissipated in the resistors. **(PPPPP)**

Working and Answer:

Calculate total resistance:

$$\frac{1}{R_{\text{total}}} = \frac{1}{5} + \frac{1}{10} = \frac{3}{10} \implies R_{\text{total}} = \frac{10}{3} \approx 3.33\,\Omega$$

Current supplied:

$$I = \frac{V}{R_{\text{total}}} = \frac{12}{3.33} \approx 3.6\,\text{A}$$

Power dissipated:

$$P = IV = 3.6 \times 12 = 43.2\,\text{W}$$

25. A 1.5 V cell with internal resistance 0.25 Ω supplies current to a 10 Ω resistor. Calculate the power delivered to the resistor. **(PPPPP)**

Working and Answer:

Total resistance:

$$R_{\text{total}} = 10 + 0.25 = 10.25\,\Omega$$

Current:

$$I = \frac{1.5}{10.25} \approx 0.146\,\text{A}$$

Power delivered:

$$P = I^2R = (0.146)^2 \times 10 \approx 0.213\,\text{W}$$