FREE SAMPLE: THE FIRST QUESTION

Question One (15 marks)

(a) A battery has an emf of 9.00 V and an internal resistance of 0.200 Ω. It is connected to an external resistor of 8.00 Ω.

(i) Calculate the current and the terminal voltage.

(ii) Calculate the power dissipated in the internal resistance and in the external resistor.

(iii) Explain why the terminal voltage is less than the emf when a current flows.

[5 marks]

(b) Two batteries are connected in parallel across a 4.00 Ω resistor. Battery A has an emf of 9.00 V and internal resistance 3.00 Ω; battery B has an emf of 6.00 V and internal resistance 1.00 Ω.

(i) Use Kirchhoff's laws to write equations for the two loops and the junction.

(ii) Calculate the current from each battery and the current in the 4.00 Ω resistor.

[5 marks]

(c) An AC supply has a peak voltage of 18.0 V and a frequency of 1000 Hz and is connected across a 10.0 Ω resistor.

(i) Calculate the rms voltage, the rms current and the peak current.

(ii) Calculate the average power dissipated, and explain why a DC supply of the rms voltage would dissipate the same power.

[5 marks]

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THE WORKED ANSWER TO THAT QUESTION

Question 1 (15 marks) [DC circuits]

(a) A battery has an emf of 9.00 V and an internal resistance of 0.200 Ω. It is connected to an external resistor of 8.00 Ω. (i) Calculate the current and the terminal voltage. (ii) Calculate the power dissipated in the internal resistance and in the external resistor. (iii) Explain why the terminal voltage is less than the emf when a current flows.

(a) Answer: (i) 1.10 A and 8.78 V; (ii) 0.241 W and 9.64 W; (iii) the lost volts Ir across the internal resistance reduce the terminal voltage

- Evidence level: Excellence (treat the internal resistance as a resistor in series, then explain the lost volts).
- (i) $I = \varepsilon/(R + r) = 9.00 \div (8.00 + 0.200) = 1.10$ A. Terminal voltage $V = IR = 1.10 \times 8.00 = 8.78$ V.
- (ii) $P_{int} = I^2r = 1.10^2 \times 0.200 = 0.241$ W; $P_{load} = I^2R = 9.64$ W.
- Achievement: (iii) States that some of the emf is lost across the internal resistance.
- Merit: Links to the cause: the battery's internal resistance has a voltage Ir across it when a current flows, so $V = \varepsilon - Ir$.
- Excellence: Full explanation: the emf is the total energy per coulomb supplied by the chemical reactions; some of it (the lost volts Ir = 0.220 V) is transformed to heat in the battery's own internal resistance, leaving 8.78 V across the terminals. The larger the current, the larger the lost volts.

> **KEY TAKEAWAY**
> Internal resistance: $\varepsilon = I(R + r)$, $V = \varepsilon - Ir$; the 'lost volts' Ir are heated inside the battery, and the energy is shared between R and r in proportion to resistance.

(b) Two batteries are connected in parallel across a 4.00 Ω resistor. Battery A has an emf of 9.00 V and internal resistance 3.00 Ω; battery B has an emf of 6.00 V and internal resistance 1.00 Ω. (i) Use Kirchhoff's laws to write equations for the two loops and the junction. (ii) Calculate the current from each battery and the current in the 4.00 Ω resistor.

(b) Answer: (ii) $I_1 = 1.11$ A, $I_2 = 0.316$ A, $I_3 = 1.42$ A

- Evidence level: Excellence (write junction and loop equations and solve them simultaneously).
- (i) Junction: $I_3 = I_1 + I_2$. Loop A: $9.00 - 3.00I_1 - 4.00I_3 = 0$. Loop B: $6.00 - 1.00I_2 - 4.00I_3 = 0$.
- (ii) Substitute $I_3 = I_1 + I_2$: $7.00I_1 + 4.00I_2 = 9.00$... solving the pair gives $I_1 = 1.11$ A and $I_2 = 0.316$ A.
- The current in the common resistor is $I_3 = 1.11 + 0.316 = 1.42$ A.

> **KEY TAKEAWAY**
> Kirchhoff: currents into a junction equal currents out, and the emfs round any loop equal the sum of the voltage drops; write one equation per loop plus the junction rule and solve.

(c) An AC supply has a peak voltage of 18.0 V and a frequency of 1000 Hz and is connected across a 10.0 Ω resistor. (i) Calculate the rms voltage, the rms current and the peak current. (ii) Calculate the average power dissipated, and explain why a DC supply of the rms voltage would dissipate the same power.

(c) Answer: (i) 12.7 V, 1.27 A, 1.80 A; (ii) 16.2 W, the same as DC at the rms voltage

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• Evidence level: Merit (use Vrms = Vmax/√2 and compare with DC).

• (i) Vrms = 18.0 ÷ √2 = 12.7 V. Irms = Vrms/R = 1.27 A. Imax = Vmax/R = 1.80 A.

• (ii) P = VrmsIrms = 12.7 × 1.27 = 16.2 W.

• Achievement: States that the rms value is the DC value that gives the same power.

• Merit: Links to heating: the power in a resistor is proportional to V^2, whose average over a cycle is $V_{max}^2/2$.

• Excellence: Full explanation: the instantaneous power V^2/R varies between 0 and V_{max}^2/R, averaging to $V_{max}^2/2R$; a DC voltage $V_{rms} = V_{max}/\sqrt{2}$ gives $V_{rms}^2/R = V_{max}^2/2R$, the same average power.

KEY TAKEAWAY

AC and rms: $V_{rms} = V_{max}/\sqrt{2}$; the rms value gives the same average heating power in a resistor as the equivalent DC value.

LOS: DC circuits (91526)

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