

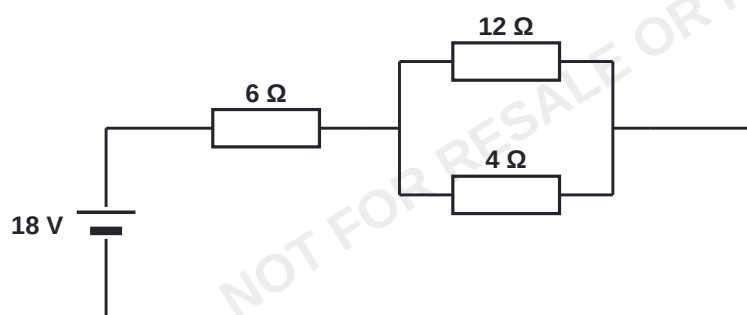
FREE SAMPLE: THE FIRST QUESTION

Question 1 (50 marks)

(a) A cell of e.m.f. 18 V and negligible internal resistance is connected to the resistor network shown.

- (i) Calculate the effective resistance of the circuit.
- (ii) Calculate the current supplied by the cell.
- (iii) Calculate the potential difference across the parallel combination of the 12 Ω and 4 Ω resistors.
- (iv) Calculate the current in the 12 Ω resistor.
- (v) Calculate the power dissipated in the 6 Ω resistor.

[10 marks]



Circuit diagram (not to scale).

(b) A lift and its passengers have a total mass of 650 kg. Take $g = 9.81 \text{ m s}^{-2}$.

- (i) State Newton's second law of motion.
- (ii) The lift accelerates upwards at 1.2 m s^{-2} . Calculate the tension in the cable.
- (iii) The lift later accelerates downwards at 1.2 m s^{-2} . Calculate the tension in the cable.

(iv) Explain why a passenger feels heavier when the lift accelerates upwards.

[10 marks]

(c) The gravitational field strength at the surface of the Earth is 9.81 N kg^{-1} and the radius of the Earth is 6371 km. A satellite orbits 600 km above the surface of the Earth.

- (i) Calculate the gravitational field strength at the height of the satellite.
- (ii) Calculate the escape velocity at this height.
- (iii) Explain why the escape velocity of a rocket does not depend on the mass of the rocket.

[10 marks]

(d) A coil of 500 turns and cross-sectional area $3.0 \times 10^{-3} \text{ m}^2$ is placed with its plane perpendicular to a magnetic field. The magnetic flux density through the coil decreases by 0.40 T in 0.050 s.

- (i) State Faraday's law of electromagnetic induction.
- (ii) Calculate the average e.m.f. induced in the coil.
- (iii) Explain, with reference to Lenz's law, the direction of the induced current.
- (iv) State two ways of increasing the induced e.m.f. for the same change in field.

[10 marks]

(e) The mass of a helium-4 nucleus is 6.64466×10^{-27} kg. Mass of a proton = 1.67262×10^{-27} kg; mass of a neutron = 1.67493×10^{-27} kg; $c = 3.00 \times 10^8$ m s⁻¹; 1 MeV = 1.602×10^{-13} J.

- (i) What is meant by the mass defect of a nucleus?
- (ii) Calculate the mass defect of the helium-4 nucleus.
- (iii) Calculate the binding energy of the nucleus in joules and in MeV.
- (iv) Calculate the binding energy per nucleon.

[10 marks]

QUESTIONS 2 TO 7

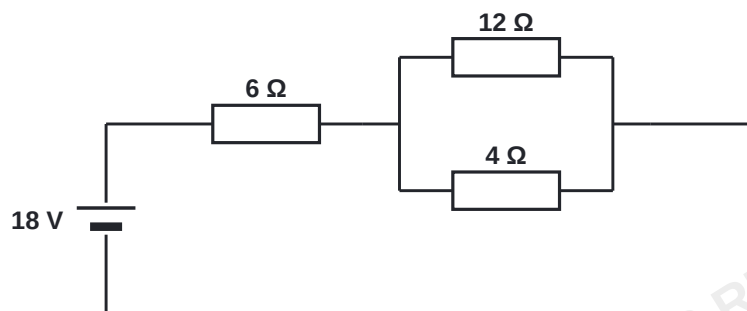
50 marks each · in the real paper you answer any FIVE

This practice paper prints all six so you can choose your best five, or attempt more than the real paper allows.

THE WORKED ANSWER TO THAT QUESTION

Question 1 (50 marks) [Circuits, forces, gravitation, induction and the nucleus]

- (a) A cell of e.m.f. 18 V and negligible internal resistance is connected to the resistor network shown. (i) Calculate the effective resistance of the circuit. (ii) Calculate the current supplied by the cell. (iii) Calculate the potential difference across the parallel combination of the 12 Ω and 4 Ω resistors. (iv) Calculate the current in the 12 Ω resistor. (v) Calculate the power dissipated in the 6 Ω resistor.



Circuit diagram (not to scale).

(a) Answer: (i) $\frac{1}{R} = \frac{1}{12} + \frac{1}{4} = \frac{1}{3}$, so the parallel part is 3.0 Ω ; $R = 6 + 3 = 9.0 \Omega$. (ii) $I = V/R = 18 \div 9.0 = 2.0 \text{ A}$. (iii) $V = IR = 2.0 \times 3.0 = 6.0 \text{ V}$. (iv) $I = V/R = 6.0 \div 12 = 0.50 \text{ A}$. (v) $P = I^2 R = (2.0)^2 \times 6 = 24 \text{ W}$.

- Approach: reduce the parallel part to one resistor, add the series resistor, then work back through the circuit using $V = IR$.
- (i) For parallel resistors $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{12} + \frac{1}{4} = \frac{4}{12}$, so $R = 3.0 \Omega$. This is in series with 6 Ω : $R(\text{total}) = 6 + 3.0 = 9.0 \Omega$. 3 marks.
- (ii) $I = V \div R = 18 \div 9.0 = 2.0 \text{ A}$ (the whole current flows through the 6 Ω resistor). 2 marks.
- (iii) The p.d. across the parallel part is $V = IR = 2.0 \text{ A} \times 3.0 \Omega = 6.0 \text{ V}$. 2 marks.
- (iv) The 12 Ω resistor has 6.0 V across it: $I = 6.0 \div 12 = 0.50 \text{ A}$ (the other 1.5 A goes through the 4 Ω resistor). 2 marks.
- (v) $P = I^2 R = 2.0^2 \times 6 = 24 \text{ W}$. 1 mark.

KEY TAKEAWAY

Series: add the resistances; parallel: add the reciprocals; the current splits in a parallel network, and the same p.d. is across each branch.

- (b) A lift and its passengers have a total mass of 650 kg. Take $g = 9.81 \text{ m s}^{-2}$. (i) State Newton's second law of motion. (ii) The lift accelerates upwards at 1.2 m s^{-2} . Calculate the tension in the cable. (iii) The lift later accelerates downwards at 1.2 m s^{-2} . Calculate the tension in the cable. (iv) Explain why a passenger feels heavier when the lift accelerates upwards.

(b) Answer: (i) The acceleration of an object is directly proportional to the resultant force acting on it and inversely proportional to its mass, in the direction of the force ($F = ma$). (ii) $T - mg = ma$, so $T = m(g + a) = 650 \times (9.81 + 1.2) = 7.16 \times 10^3 \text{ N}$. (iii) $T = m(g - a) = 650 \times (9.81 - 1.2) = 5.60 \times 10^3 \text{ N}$. (iv) The floor must exert a normal reaction greater than the passenger's weight to give an upward resultant force; the reaction force is what the passenger feels as

'weight'.

- Approach: draw the two forces (tension up, weight down), then apply $F = ma$ with the resultant in the direction of acceleration.
- (i) Resultant force = mass $\times$ acceleration, $F = ma$, acting in the direction of the acceleration. 2 marks.
- (ii) Upwards positive: $T - mg = ma$. $T = m(g + a) = 650 \times (9.81 + 1.2) = 650 \times 11.01 = 7156 \text{ N} \approx 7.16 \times 10^3 \text{ N}$. 3 marks.
- (iii) Downward acceleration: $mg - T = ma$, so $T = m(g - a) = 650 \times (9.81 - 1.2) = 650 \times 8.61 = 5597 \text{ N} \approx 5.60 \times 10^3 \text{ N}$. 2 marks.
- (iv) For an upward acceleration the resultant force on the passenger is upwards, so the normal reaction N from the floor is greater than the weight mg ($N - mg = ma$). The sensation of weight is the reaction force, so it feels larger. 3 marks.

KEY TAKEAWAY

Always write $F = ma$ for the direction of acceleration: $T = m(g + a)$ going up, $T = m(g - a)$ going down.

(c) The gravitational field strength at the surface of the Earth is 9.81 N kg^{-1} and the radius of the Earth is 6371 km. A satellite orbits 600 km above the surface of the Earth. (i) Calculate the gravitational field strength at the height of the satellite. (ii) Calculate the escape velocity at this height. (iii) Explain why the escape velocity of a rocket does not depend on the mass of the rocket.

(c) Answer: (i) $g \propto 1/r^2$: $g = 9.81 \times (6371 \div 6971)^2 = 8.19 \text{ N kg}^{-1}$. (ii) $v = \sqrt{2gr} = \sqrt{2 \times 8.194 \times 6.971 \times 10^6} = 1.07 \times 10^4 \text{ m s}^{-1}$. (iii) The kinetic energy needed ($\frac{1}{2}mv^2$) and the gravitational potential energy to be overcome (GmM/r) are both proportional to the mass of the rocket, so m cancels.

- Approach: g follows an inverse square law with the distance from the centre of the Earth; escape velocity comes from $\frac{1}{2}mv^2 = GMm/r$.
- (i) Distance from the centre $r = 6371 + 600 = 6971 \text{ km}$. $g = g_0 (R/r)^2 = 9.81 \times (6371 \div 6971)^2 = 9.81 \times 0.8353 = 8.19 \text{ N kg}^{-1}$. 4 marks.
- (ii) $v = \sqrt{2GM/r} = \sqrt{2gr}$ where g is the local field strength: $v = \sqrt{2 \times 8.194 \times 6.971 \times 10^6} = \sqrt{1.1424 \times 10^8} = 1.07 \times 10^4 \text{ m s}^{-1}$. 4 marks.
- (iii) Set the kinetic energy equal to the work needed to escape: $\frac{1}{2}mv^2 = GMm/r$. m appears on both sides and cancels, so $v = \sqrt{2GM/r}$ depends only on the planet's mass and the distance. 2 marks.

KEY TAKEAWAY

$g = g_0(R/r)^2$, and escape speed $v = \sqrt{2GM/r} = \sqrt{2gr}$ is independent of the escaping object's mass.

(d) A coil of 500 turns and cross-sectional area $3.0 \times 10^{-3} \text{ m}^2$ is placed with its plane perpendicular to a magnetic field. The magnetic flux density through the coil decreases by 0.40 T in 0.050 s. (i) State Faraday's law of electromagnetic induction. (ii) Calculate the average e.m.f. induced in the coil. (iii) Explain, with reference to Lenz's law, the direction of the induced current. (iv) State two ways of increasing the induced e.m.f. for the same change in field.

(d) Answer: (i) The induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage ($E = -N \Delta\Phi/\Delta t$). (ii) $E = N A \Delta B/\Delta t = 500 \times 3.0 \times 10^{-3} \times 0.40 \div 0.050 = 12 \text{ V}$. (iii) The induced current flows in a direction such that its magnetic field opposes the change that produced it, here the decreasing field, so the coil's field is in the same direction as the original field (conservation of energy). (iv) Increase the number of turns, increase the area, or change the field faster (shorter time).

- Approach: flux linkage = NBA , so $E = N A \Delta B/\Delta t$.

- (i) The magnitude of the induced e.m.f. is proportional to the rate of change of flux linkage. 2 marks.
- (ii) $E = N A (\Delta B / \Delta t) = 500 \times 3.0 \times 10^{-3} \times (0.40 \div 0.050) = 500 \times 3.0 \times 10^{-3} \times 8.0 = 12 \text{ V}$. 4 marks.
- (iii) The flux through the coil is falling, so the induced current creates a field that tries to keep the flux up: it acts in the same direction as the original field. Lenz's law is conservation of energy: opposing the change means work must be done to cause it. 2 marks.
- (iv) Any two: more turns, larger area, a quicker change of field. 2 marks.

KEY TAKEAWAY

$E = N A \Delta B / \Delta t$; the induced current always opposes the change in flux (Lenz's law).

(e) The mass of a helium-4 nucleus is $6.64466 \times 10^{-27} \text{ kg}$. Mass of a proton = $1.67262 \times 10^{-27} \text{ kg}$; mass of a neutron = $1.67493 \times 10^{-27} \text{ kg}$; $c = 3.00 \times 10^8 \text{ m s}^{-1}$; $1 \text{ MeV} = 1.602 \times 10^{-13} \text{ J}$. (i) What is meant by the mass defect of a nucleus? (ii) Calculate the mass defect of the helium-4 nucleus. (iii) Calculate the binding energy of the nucleus in joules and in MeV. (iv) Calculate the binding energy per nucleon.

(e) Answer: (i) The difference between the total mass of the separate nucleons and the mass of the nucleus. (ii) $2(1.67262) + 2(1.67493) - 6.64466 = 6.69510 - 6.64466 = 5.044 \times 10^{-29} \text{ kg}$. (iii) $E = mc^2 = 5.044 \times 10^{-29} \times (3.00 \times 10^8)^2 = 4.54 \times 10^{-12} \text{ J} = 28.3 \text{ MeV}$. (iv) $28.3 \div 4 = 7.08 \text{ MeV per nucleon}$.

- Approach: add the masses of 2 protons and 2 neutrons, subtract the nuclear mass, then use $E = mc^2$.
- (i) The mass defect is the amount by which the mass of the nucleus is less than the total mass of its separated protons and neutrons; this mass is released as energy when the nucleus forms. 2 marks.
- (ii) Mass of nucleons = $2 \times 1.67262 + 2 \times 1.67493 = 3.34524 + 3.34986 = 6.69510 \times 10^{-27} \text{ kg}$. Mass defect = $6.69510 - 6.64466 = 0.05044 \times 10^{-27} = 5.044 \times 10^{-29} \text{ kg}$. 3 marks.
- (iii) $E = mc^2 = 5.044 \times 10^{-29} \times 9.00 \times 10^{16} = 4.54 \times 10^{-12} \text{ J}$. In MeV: $4.54 \times 10^{-12} \div 1.602 \times 10^{-13} = 28.3 \text{ MeV}$. 3 marks.
- (iv) Helium-4 has 4 nucleons: $28.3 \div 4 = 7.08 \text{ MeV per nucleon}$. 2 marks.

KEY TAKEAWAY

Binding energy = (mass defect) $\times c^2$; divide by the number of nucleons to compare nuclei.

LOS: Circuits, forces, gravitation, induction and the nucleus (Leaving Certificate Physics, Higher Level written paper, Strands 1, 3, 4)

QUESTIONS 2 TO 7

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