3.10 Physics: Fields (Gravitational, Electric, Magnetic): 1-hour Pack

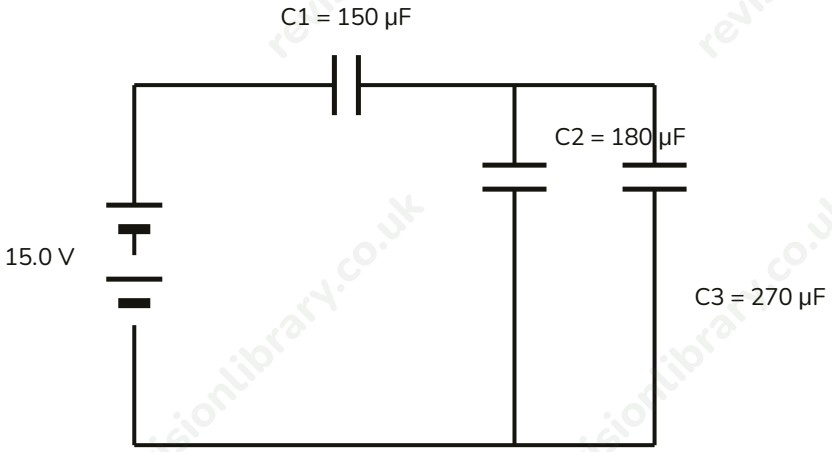
Total Marks

AQA 7408 · Calculator allowed · about 60 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 In the circuit shown, a capacitor C1 of capacitance 150 uF is connected in series with a parallel combination of two capacitors, C2 = 180 uF and C3 = 270 uF. The combination is connected to a 15.0 V d.c. supply and allowed to charge fully.



(a) Calculate the combined capacitance of C2 and C3 in parallel. **(1)**

(b) Calculate the total capacitance of the circuit. **(3)**

(c) Calculate the total charge supplied by the 15.0 V source when the capacitor network is fully charged. **(2)**

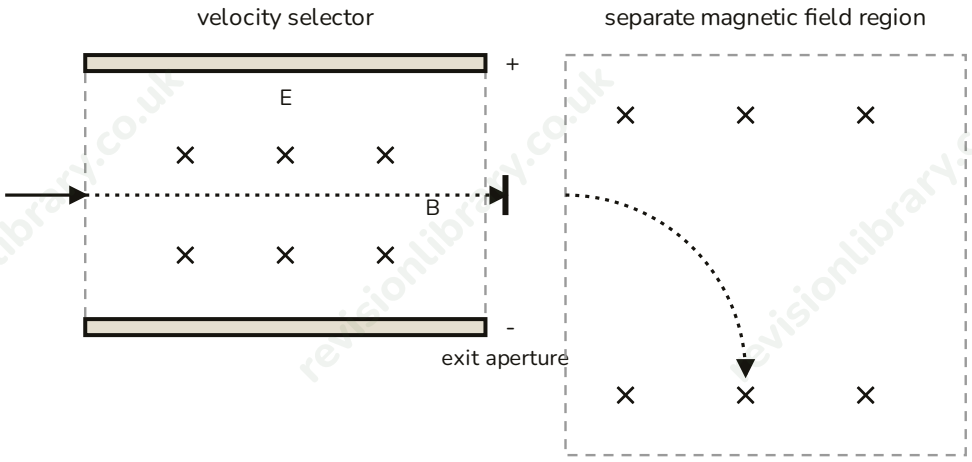
(d) Calculate the potential difference across C1. **(2)**

(e) Calculate the total energy stored in the fully charged capacitor network. **(3)**

(Total for Question 1 is 11 marks)

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2 A velocity selector consists of a region where a uniform electric field and a uniform magnetic field act at right angles to each other and to the velocity of charged particles passing through. A beam of ions passes through undeviated when the electric force and the magnetic force on each ion are equal and opposite. The electric field strength is 6.00×10^4 V/m and the magnetic flux density in the selector is 0.120 T.



(a) Show that the speed of ions that pass through the selector undeviated is given by $v = E/B$, and calculate this speed for the values given. **(3)**

(b) Ions leaving the selector then enter a separate uniform magnetic field of flux density 0.350 T, directed perpendicular to their velocity, where they follow a circular path of radius 4.20×10^{-2} m. Calculate the specific charge (charge-to-mass ratio, q/m) of the ions. **(3)**

(c) Suggest why, in practice, it can be difficult to obtain a truly uniform electric field over the whole region through which the ions travel in the velocity selector, and state one consequence of this for the beam of ions leaving the selector. **(2)**

(Total for Question 2 is 8 marks)

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3 A meteoroid of mass 2.50×10^3 kg travels from deep space towards the Earth. Treat the Earth as an isolated uniform sphere (ignore the Sun and Moon), take the gravitational potential at infinity to be zero, and use $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, M(Earth) $= 5.97 \times 10^{24}$ kg, R(Earth) $= 6.37 \times 10^6$ m. You are given: gravitational potential $V = -GM/r$, and escape velocity $v = \sqrt{2GM/r}$.

(a) Calculate the gravitational potential at the Earth's surface. **(2)**

(b) Calculate the minimum kinetic energy the meteoroid would need at the Earth's surface so that it could, in principle, escape to infinity (ignore atmospheric resistance). **(3)**

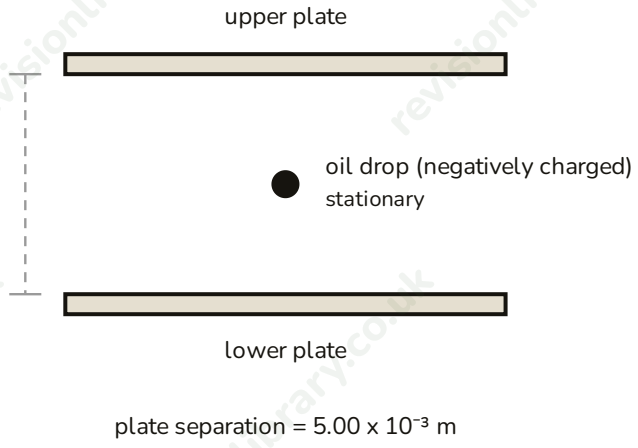
(c) Show that the escape velocity from the Earth's surface is about 1.12×10^4 m/s. **(3)**

(d) The meteoroid actually approaches the Earth with a speed of 1.60×10^4 m/s while still very far away (effectively at infinity). Using conservation of energy, and ignoring atmospheric drag, calculate its speed just above the atmosphere, at a distance R from the Earth's centre. **(4)**

(Total for Question 3 is 12 marks)

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4 A small charged oil drop of mass 9.80×10^{-15} kg carries a charge of -3.20×10^{-19} C. The drop is held stationary between two horizontal parallel plates separated by a distance of 5.00×10^{-3} m, in a Millikan-type experiment. Take $g = 9.81$ N kg^{-1}.



(a) Show that the electric field strength required to hold the drop stationary is about 3.00×10^5 N/C. **(3)**

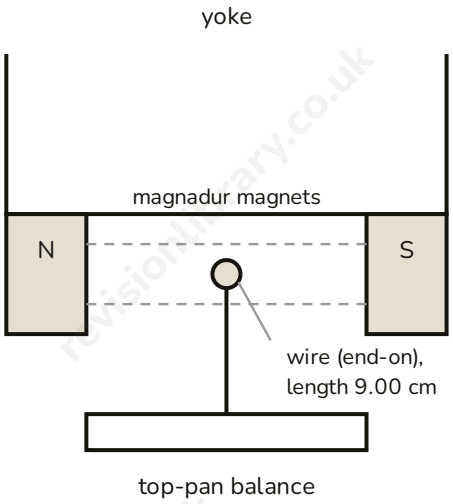
(b) Calculate the potential difference between the plates needed to produce this field. **(2)**

(c) State which plate, upper or lower, must be at the higher potential, explaining your reasoning. **(2)**

(Total for Question 4 is 7 marks)

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5 REQUIRED PRACTICAL. A student determines the magnetic flux density between the poles of a strong magnet using a current balance. A straight horizontal wire of length 9.00 x 10^{-2} m is placed at right angles to the magnetic field, resting on a support connected to a top-pan balance. You are given F = B*I*L for a wire at right angles to a uniform field. Take g = 9.81 N kg^{-1}.



(a) With no current flowing, the balance reads 152.40 g. When a current of 3.50 A flows through the wire, the balance reading changes to 152.87 g. Calculate the magnetic force on the wire corresponding to this change in balance reading. **(3)**

(b) Calculate the magnetic flux density between the poles of the magnet. **(2)**

(c) The student repeats the experiment for a range of currents and plots a graph of force F (y-axis) against current I (x-axis). Explain how this graph gives a more reliable value of B than using a single pair of readings. **(3)**

(Total for Question 5 is 8 marks)

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Mark scheme · 3.10 Physics: Fields (Gravitational, Electric, Magnetic): 1-hour Pack

Question 1

(a) C23 = C2 + C3 = 450 uF **B1**

(a) Answer: C23 = 450 uF

(b) uses 1/C(total) = 1/C1 + 1/C23 **M1**

(b) correctly substitutes C1 = 150 uF and their C23 = 450 uF **A1**

(b) C(total) = 112.5 uF (awrt), allow ecf **A1**

(b) Answer: C(total) = 112.5 uF

(c) uses Q = C(total) x V **M1**

(c) Q = 1.69 x 10^{-3} C (awrt, allow 1.69 mC), allow ecf **A1**

(c) Answer: Q = 1.69 x 10^{-3} C

(d) uses V1 = Q/C1, using the total charge from part (c) (charge is the same through both series elements) **M1**

(d) V1 = 11.3 V (awrt), allow ecf **A1**

(d) Answer: V1 = 11.3 V

(e) uses W = (1/2)*C(total)*V^2 **M1**

(e) correctly substitutes C(total) = 112.5 uF and V = 15.0 V **A1**

(e) W = 1.27 x 10^{-2} J (awrt, allow 12.7 mJ), allow ecf **A1**

(e) Answer: W = 1.27 x 10^{-2} J

Question 2

(a) equates the electric force q*E to the magnetic force q*v*B for an undeviated ion **M1**

(a) correctly cancels q and rearranges to v = E/B **A1**

(a) v = 5.00 x 10^5 m/s **A1**

(a) Answer: v = 5.00 x 10^5 m/s

(b) uses r = m*v/(q*B), rearranged to q/m = v/(r*B) **M1**

(b) correctly substitutes v = 5.00 x 10^5 m/s (from part (a)), r = 4.20 x 10^{-2} m and B = 0.350 T **A1**

(b) q/m = 3.40 x 10^7 C/kg (awrt), allow ecf **A1**

(b) Answer: q/m = 3.40 x 10^7 C kg^{-1}

(c) identifies that the field lines spread out (fringing/edge effects) near the edges of the parallel plates, so the field is not perfectly uniform close to the plate edges **B1**

(c) states a suitable consequence, e.g. ions travelling near the edges experience a slightly different force balance and are not perfectly velocity-selected, so the emerging beam has a small spread of speeds rather than being purely monochromatic **B1**

(c) Answer: Fringing (edge) effects mean the field is weaker or less uniform near the plate edges; ions passing close to the edges are not perfectly velocity-selected, so the emerging beam has a small spread of speeds.

Question 3

(a) substitutes correctly into V = -GM/R **M1**

(a) V = -6.25 x 10^7 J kg^{-1} (awrt 3 sf), correct sign and unit **A1**

(a) Answer: V = -6.25 x 10^7 J kg^{-1}

(b) recognises that total mechanical energy per unit mass must be at least zero for escape: KE_{min} = -m*V(surface) **M1**

(b) substitutes m = 2.50 x 10^3 kg and their V from part (a) **A1**

(b) KE_{min} = 1.56 x 10^{11} J (awrt 3 sf), allow ecf **A1**

(b) Answer: KE_{min} = 1.56 x 10^{11} J

(c) quotes and uses v = $\sqrt{2GM/R}$ **M1**

(c) correct substitution of GM and R **A1**

(c) evaluates to v = 1.12 x 10^4 m/s (cao), matching the value given **A1**

(c) Answer: v = 1.12 x 10^4 m/s

(d) states energy conservation per unit mass: (1/2)*v_∞^2 + 0 = (1/2)*v_R^2 + (-GM/R) **M1**

(d) correctly rearranges to $v_R = \sqrt{v_\infty^2 + 2GM/R}$, equivalently $v_R = \sqrt{v_\infty^2 + v_{esc}^2}$ **M1**

(d) correctly substitutes v_∞ = 1.60 x 10^4 m/s and 2GM/R (or their v_{esc} from part (c)) **A1**

(d) v_R = 1.95 x 10^4 m/s (awrt 3 sf), allow ecf **A1**

(d) Answer: v_R = 1.95 x 10^4 m/s

Question 4

(a) states the equilibrium condition q*E = m*g **B1**

(a) rearranges to E = m*g/q and substitutes the given values **M1**

(a) E = 3.00 x 10^5 N/C (cao), matching the given value **A1**

(a) Answer: E = 3.00 x 10^5 N C^{-1}

(b) uses V = E*d **M1**

(b) V = 1.50 x 10^3 V (awrt, accept 1500 V), allow ecf **A1**

(b) Answer: V = 1.50 x 10^3 V

(c) recognises that, for a negative charge, the electric force is opposite to the field direction, so the field must point downward for the force on the drop to act upward **B1**

(c) states the upper plate must be at the higher potential, since field lines point from high to low potential **B1**

(c) Answer: The upper plate is at the higher potential.

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Question 5

(a) finds the change in mass reading: delta m = 152.87 - 152.40 = 0.47 g = 4.70 x 10^{-4} kg **M1**

(a) uses F = delta m * g **M1**

(a) F = 4.61 x 10^{-3} N (awrt 3 sf) **A1**

(a) Answer: F = 4.61 x 10^{-3} N

(b) uses B = F/(I*L) **M1**

(b) B = 1.46 x 10^{-2} T (awrt, allow 14.6 mT), allow ecf **A1**

(b) Answer: B = 1.46 x 10^{-2} T

(c) states the graph should be a straight line through the origin, with gradient equal to B*L **B1**

(c) states B is found from B = gradient/L **B1**

(c) explains that using the gradient of a line of best fit through several data points averages out random errors, giving a more reliable value than relying on a single (potentially anomalous) measurement **B1**

(c) Answer: Plot F against I; the gradient equals B*L, so B = gradient/L. Using a line of best fit through many points reduces the effect of random error compared with a single reading.

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