3.7 Fields and their Consequences: 1-hour Pack

AQA 7408 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Three capacitors are connected in a circuit: C1 = 100 uF and C2 = 220 uF are connected in parallel with each other, and this combination is connected in series with C3 = 150 uF. The network is connected across a 12 V supply.

(a) Calculate the combined capacitance of C1 and C2 in parallel. **(1)**

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

(c) Calculate the total charge supplied by the 12 V source. **(2)**

(d) Calculate the total energy stored in the network. **(3)**

(Total for Question 1 is 9 marks)

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2 REQUIRED PRACTICAL. A student measures the magnetic flux density between two magnadur magnets using a current balance method. A straight horizontal wire of length 0.12 m carrying a current of 3.5 A is placed in the field, perpendicular to it. When the current is switched on, the reading on a top-pan balance beneath the magnet assembly changes by an apparent mass of 0.42 g. Take g = 9.81 m/s^2.

(a) Calculate the force on the wire due to the magnetic field. **(2)**

(b) Calculate the magnetic flux density of the field. **(3)**

(c) Using Newton's third law, explain why switching on the current changes the reading on the balance beneath the magnets. **(3)**

(Total for Question 2 is 8 marks)

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3 A proton (mass 1.67 x 10^{-27} kg, charge 1.60 x 10^{-19} C) travels at 2.5 x 10^{6} m/s perpendicular to a uniform magnetic field of flux density 0.40 T, which occupies a region of width 5.0 cm. The proton enters the field travelling perpendicular to the boundary of the field region.

(a) Calculate the magnetic force on the proton as it enters the field. Use F = BQv. **(2)**

(b) Explain why this magnetic force causes the proton to move at constant speed along a circular path. **(2)**

(c) By equating the magnetic force BQv to the centripetal force mv^2/r, show that the radius of the circular path is given by r = mv/(BQ). **(2)**

(d) Calculate the radius of the circular path followed by this proton. **(2)**

(e) The magnetic field region has a width of 5.0 cm, measured in the direction the proton was initially travelling. For a particle entering perpendicular to the boundary of a field region, the maximum distance it can penetrate into the field before curving back out of the same boundary is equal to the radius r of its circular path. Using your value of r from part (d), determine, with reasoning, whether this proton crosses completely through the 5.0 cm field region or curves back out of the boundary it entered through. **(3)**

(Total for Question 3 is 11 marks)

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4 A Mars communications satellite moves in a circular orbit of radius r about the centre of Mars, held in orbit by the gravitational force. Continue to use GM(Mars) = 4.28×10^{13} N m^2 kg^{-1}.

(a) By equating the gravitational force GMm/r^2 to the centripetal force $m(4\pi^2 r)/T^2$, show that the orbital period T of the satellite is given by $T^2 = (4\pi^2 r^3) / (GM)$. **(3)**

(b) The satellite orbits at a radius of 2.0×10^7 m from the centre of Mars. Calculate its orbital period, giving your answer in hours. **(4)**

(c) Mars rotates on its axis once every 24.6 hours. State what is meant by a synchronous orbit, and use your answer to part (b) to decide, with a reason, whether this satellite is in a synchronous orbit around Mars. **(2)**

(Total for Question 4 is 9 marks)

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5 Two isolated point charges are held fixed 0.30 m apart in air: Q1 = $+5.0 \times 10^{-6}$ C and Q2 = -2.0×10^{-6} C. Take k = 8.99×10^9 N m^2/C^2.

(a) Calculate the magnitude of the electrostatic force between the two charges, and state whether it is attractive or repulsive. **(3)**

(b) Calculate the electric field strength at the midpoint between the two charges due to both charges, explaining why the contributions from the two charges add together rather than cancel. **(4)**

(c) Calculate the electric potential at the midpoint due to both charges. **(3)**

(Total for Question 5 is 10 marks)

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Mark scheme · 3.7 Fields and their Consequences: 1-hour Pack

Question 1

(a) C12 = C1 + C2 = 100 + 220 = 320 uF cao **B1**

(a) Answer: 320 uF

(b) quote 1/C(total) = 1/C12 + 1/C3 **M1**

(b) substitute 1/C(total) = 1/320 + 1/150 **M1**

(b) C(total) = 102 uF cao **A1**

(b) Answer: 102 uF

(c) Q = C(total) x V = 102 x 10^{-6} x 12 **M1**

(c) Q = 1.23 x 10^{-3} C cao **A1**

(c) Answer: 1.23 x 10^{-3} C

(d) quote E = 1/2 C V^2 **M1**

(d) substitute E = 0.5 x 102 x 10^{-6} x 12^2 **M1**

(d) E = 7.35 x 10^{-3} J cao **A1**

(d) Answer: 7.35 x 10^{-3} J

Question 2

(a) F = (change in mass) x g = 0.42 x 10^{-3} x 9.81 **M1**

(a) F = 4.12 x 10^{-3} N cao **A1**

(a) Answer: 4.12 x 10^{-3} N

(b) quote F = BIL **M1**

(b) rearrange and substitute B = 4.12 x 10^{-3} / (3.5 x 0.12) **M1**

(b) B = 9.81 x 10^{-3} T cao **A1**

(b) Answer: 9.81 x 10^{-3} T

(c) the magnetic field exerts a force on the current-carrying wire (the force being measured) **B1**

(c) by Newton's third law, the wire exerts an equal and opposite force on the magnets (and hence on the balance holding them) **B1**

(c) this reaction force changes the apparent weight registered by the balance, which is read as an apparent change in mass oe **B1**

(c) Answer: The field exerts a force on the wire; by Newton's third law the wire exerts an equal and opposite force back on the magnets, which sit on the balance, so the balance registers this reaction force as an apparent change in mass.

Question 3

(a) correct substitution F = 0.40 x 1.6 x 10^{-19} x 2.5 x 10^{6} **M1**

(a) F = 1.6 x 10^{-13} N (cao) **A1**

(a) Answer: F = 1.6 x 10^{-13} N

(b) the magnetic force is always perpendicular to the proton's velocity, so it does no work on the proton and its speed (kinetic energy) stays constant (oe) **B1**

(b) the force therefore acts only to change the direction of motion, providing a centripetal force, which produces circular motion (oe) **B1**

(b) Answer: Force always perpendicular to velocity does no work (constant speed) and acts as the centripetal force (circular path)

(c) correctly equates BQv = mv^2/r **M1**

(c) correctly rearranges (cancelling one factor of v) to give r = mv/(BQ) (cso, matches given expression) **A1**

(c) Answer: r = mv/(BQ)

(d) correct substitution r = (1.67 x 10^{-27} x 2.5 x 10^{6}) / (0.40 x 1.6 x 10^{-19}) **M1**

(d) r = 6.5 x 10^{-2} m (awrt 6.5 x 10^{-2} m, cao) **A1**

(d) Answer: r = 6.52 x 10^{-2} m (awrt 6.5 cm)

(e) compares r (6.5 cm) with the field width (5.0 cm) **M1**

(e) correctly identifies that since r is greater than the field width, the proton reaches the far boundary before its path can curve back towards the entry boundary **M1**

(e) correct conclusion: the proton crosses completely through the field region and emerges from the far boundary, since r (6.5 cm) > field width (5.0 cm) **A1**

(e) Answer: The proton crosses completely through the field region, since r = 6.5 cm is greater than the 5.0 cm field width

Question 4

(a) correctly equates $GMm/r^2 = m(4\pi^2 r)/T^2$ **M1**

(a) cancels m from both sides and rearranges to isolate T^2 (e.g. $GM/r^2 = 4\pi^2 r / T^2$) **M1**

(a) $T^2 = 4\pi^2 r^3 / (GM)$ (cso, matches the given expression) **A1**

(a) Answer: $T^2 = 4\pi^2 r^3 / (GM)$

(b) correct substitution $T^2 = 4\pi^2$ x $(2.0 \times 10^7)^3$ / (4.28 x 10^{13}) **M1**

(b) T^2 evaluated as awrt 7.4 x 10^9 s^2 **M1**

(b) $T = \sqrt{T^2}$ evaluated as awrt 8.6 x 10^4 s **M1**

(b) T = 23.9 hours (awrt 23.9 hours, cao, after dividing by 3600) **A1**

(b) Answer: T = 8.59 x 10^4 s = 23.9 hours

(c) a synchronous orbit is one where the orbital period equals the rotation period of the planet (oe); remaining above the same point additionally requires a circular, equatorial orbit in the direction of the planet's rotation **B1**

(c) not synchronous, since 23.9 hours does not equal 24.6 hours; a slightly larger orbital radius would be needed to increase T to 24.6 hours (oe, allow ft on T from (b)) **B1**

(c) Answer: A synchronous orbit has the same period as the planet's rotation. This satellite is not synchronous: T = 23.9 h is not equal to Mars's 24.6 h rotation period

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Question 5

(a) quote $F = k\ Q1\ Q2 / r^2$ **M1**

(a) substitute $F = (8.99 \times 10^9 \times 5.0 \times 10^{-6} \times 2.0 \times 10^{-6}) / 0.30^2$ **M1**

(a) F = 1.0 N, attractive (since the charges have opposite signs) cao **A1**

(a) Answer: 1.0 N, attractive

(b) calculate the field from Q1 alone at the midpoint (r = 0.15m): $E1 = kQ1/r^2 = 2.0 \times 10^6$ N/C, directed away from Q1 (towards Q2) **M1**

(b) calculate the field from Q2 alone at the midpoint: $E2 = kQ2/r^2 = 7.99 \times 10^5$ N/C, directed towards Q2 (since Q2 is negative) **M1**

(b) both fields point in the same direction (from the positive charge towards the negative charge), because the field from a positive charge points away from it while the field from a negative charge points towards it, so at the midpoint they reinforce rather than cancel **B1**

(b) total $E = 2.80 \times 10^6$ N/C cao **A1**

(b) Answer: 2.80×10^6 N/C, directed from Q1 towards Q2

(c) quote $V = k(Q1 + Q2)/r$, using the signed values of Q1 and Q2 (potential is scalar) **M1**

(c) substitute $V = 8.99 \times 10^9 \times (5.0 \times 10^{-6} - 2.0 \times 10^{-6}) / 0.15$ **M1**

(c) $V = 1.80 \times 10^5$ V cao **A1**

(c) Answer: 1.80×10^5 V

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