3.7 Fields and their Consequences: Test Pack

AQA 7408 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A capacitor of capacitance 470 uF is charged until the potential difference across it is 9.0 V.

(a) State what is meant by the capacitance of a capacitor. **(1)**

(b) Calculate the charge stored on the capacitor. Use Q = CV. **(2)**

(c) Calculate the energy stored in the capacitor. Use $W = (1/2)CV^2$. **(2)**

(d) This 470 uF capacitor is now connected in series with a 220 uF capacitor, and the combination is charged by a 9.0 V supply. Calculate the total capacitance of the combination and hence the charge stored. **(4)**

(Total for Question 1 is 9 marks)

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2 A flat coil of 250 turns has a cross-sectional area of 4.0×10^{-3} m^2. Its plane is perpendicular to a uniform magnetic field. The flux density is increased steadily from 0.020 T to 0.080 T over a time of 0.50 s.

(a) Calculate the change in magnetic flux through the coil. Use flux = BA. **(2)**

(b) Calculate the average emf induced in the coil during this time. Use emf = N (delta flux) / (delta t). **(3)**

(c) State Lenz's law and use it to explain the direction in which the induced current acts in the coil while the flux is increasing. **(3)**

(d) The coil is connected to a resistor of resistance 15 Ohm. Calculate the average induced current during the 0.50 s interval. Use I = emf/R. **(2)**

(Total for Question 2 is 10 marks)

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3 A flat search coil of 250 turns and cross-sectional area 3.5×10^{-3} m^2 is placed with its plane perpendicular to a uniform magnetic field of flux density 0.045 T. The coil is then pulled completely out of the field in a time of 0.080 s.

(a) Calculate the magnetic flux through the coil while it is in the field. **(2)**

(b) Calculate the flux linkage of the coil while it is in the field. **(1)**

(c) Calculate the average EMF induced in the coil while it is being removed from the field. **(3)**

(d) State Lenz's law and use it to explain the direction of the induced current in the coil as it is removed from the field. **(2)**

(Total for Question 3 is 8 marks)

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4 REQUIRED PRACTICAL. A student investigates the discharge of a capacitor of capacitance C through a resistor of resistance R = 15 kOhm. The capacitor is charged to V0 = 6.0 V and then allowed to discharge, with the pd V across the capacitor recorded at intervals using a voltmeter and a stopwatch. The equation for the discharge is V = V0 exp(-t/RC). Results are shown below.

t / s: 0, 20, 40, 60, 80, 100

V / V: 6.0, 3.3, 1.8, 0.97, 0.53, 0.29

Time (s)	Voltage (V)
0	6.0
20	3.3
40	1.8
60	0.97
80	0.53
100	0.29

(a) Explain how the equation V = V0 exp(-t/RC) can be rearranged into a form suitable for plotting a straight-line graph, stating what should be plotted on each axis and what the gradient represents. **(3)**

(b) Using the table of results, calculate ln(V) for t = 0 s and for t = 100 s, giving each answer to 2 decimal places. **(2)**

(c) Using your two values of ln(V) from part (b), calculate the gradient of the ln(V) against t graph, and hence determine the time constant RC of the circuit. **(4)**

(d) The resistor used has resistance 15 kOhm. Calculate the capacitance of the capacitor, giving your answer to an appropriate number of significant figures. **(2)**

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(e) State one source of systematic error in this experiment and suggest a way of reducing it. **(2)**

(Total for Question 4 is 13 marks)

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Mark scheme · 3.7 Fields and their Consequences: Test Pack

Question 1

(a) the charge stored per unit potential difference across the capacitor (oe, C = Q/V) **B1**

(a) Answer: Charge stored per unit potential difference, C = Q/V

(b) correct substitution Q = 470 x 10^{-6} x 9.0 **M1**

(b) Q = 4.2 x 10^{-3} C (awrt 4.2 x 10^{-3} C, cao) **A1**

(b) Answer: Q = 4.23 x 10^{-3} C (awrt 4.2 mC)

(c) correct substitution W = 0.5 x 470 x 10^{-6} x 9.0^2 **M1**

(c) W = 1.9 x 10^{-2} J (awrt 1.9 x 10^{-2} J, cao) **A1**

(c) Answer: W = 1.90 x 10^{-2} J (19 mJ)

(d) correct use of series formula 1/C = 1/470 + 1/220 (in uF, or SI equivalent) **M1**

(d) C = 1.5 x 10^{-4} F (awrt 150 uF, cao) **A1**

(d) correct substitution Q = C x V using their C (ft) **M1**

(d) Q = 1.34869565... x 10^{-3} C; accept 1.35 x 10^{-3} C or 1.3 x 10^{-3} C, or a more precise correct value; ft from their capacitance **A1**

(d) Answer: C = 149.855... uF (150 uF to 2 s.f.); Q = 1.34869565... x 10^{-3} C (1.35 x 10^{-3} C to 3 s.f., or 1.3 x 10^{-3} C to 2 s.f.)

Question 2

(a) correct substitution using change in B: (0.080 - 0.020) x 4.0 x 10^{-3} **M1**

(a) change in flux = 2.4 x 10^{-4} Wb (cao) **A1**

(a) Answer: delta(flux) = 2.4 x 10^{-4} Wb

(b) correct substitution emf = 250 x 2.4 x 10^{-4} / 0.50 (ft from (a)) **M1**

(b) flux linkage change N x (delta flux) evaluated as 0.060 Wb-turns **M1**

(b) emf = 0.12 V (cao, ft) **A1**

(b) Answer: emf = 0.12 V

(c) Lenz's law: the direction of an induced emf (and current) is such as to oppose the change that produces it (oe, consistent with conservation of energy) **B1**

(c) since the flux through the coil is increasing, the induced current flows in a direction that creates its own magnetic field opposing this increase (i.e. a field in the opposite sense to the applied field, inside the coil) **B1**

(c) the direction of current flow around the coil (e.g. clockwise or anticlockwise as viewed along the field) can then be found from the right-hand grip rule applied to the opposing field **B1**

(c) Answer: Induced current opposes the increasing flux; its direction found from the right-hand grip rule applied to the opposing field

(d) correct substitution I = 0.12/15 (ft from (b)) **M1**

(d) I = 8.0 x 10^{-3} A (cao, ft) **A1**

(d) Answer: I = 8.0 x 10^{-3} A (8.0 mA)

Question 3

(a) flux = B A = 0.045 x 3.5 x 10^{-3} **M1**

(a) flux = 1.58 x 10^{-4} Wb cao **A1**

(a) Answer: 1.58 x 10^{-4} Wb

(b) flux linkage = N x flux = 250 x 1.575 x 10^{-4} = 0.0394 Wb turns cao **B1**

(b) Answer: 0.0394 Wb turns

(c) quote EMF = change in flux linkage / time taken **M1**

(c) substitute EMF = 0.0394 / 0.080 **M1**

(c) EMF = 0.49 V cao **A1**

(c) Answer: 0.49 V

(d) Lenz's law: the direction of an induced current is such that it opposes the change (in flux) that produced it **B1**

(d) as the coil is removed, the flux through it is decreasing, so the induced current flows in the direction that creates a magnetic field trying to maintain the original flux (oppose the decrease) through the coil oe **B1**

(d) Answer: Lenz's law states the induced current opposes the change that produced it; as the coil leaves the field the flux decreases, so the induced current flows in the direction that creates its own magnetic field to try to maintain (oppose the decrease in) the original flux through the coil.

Question 4

(a) taking natural logs of both sides gives ln V = ln V0 - t/(RC) **M1**

(a) plot ln V (y-axis) against t (x-axis) to give a straight line **A1**

(a) the gradient of the line is equal to -1/(RC), i.e. -1/tau **A1**

(a) Answer: ln V = ln V0 - t/(RC); plot ln V against t; gradient = -1/(RC)

(b) ln(6.0) = 1.79 **B1**

(b) ln(0.29) = -1.24 **B1**

(b) Answer: ln(6.0) = 1.79; ln(0.29) = -1.24

(c) correct gradient calculation, gradient = (-1.24 - 1.79)/(100 - 0) (ft from (b)) **M1**

(c) gradient = -0.0303 s^{-1} (awrt -0.030 s^{-1}, ft) **A1**

(c) correct use of tau = -1/gradient **M1**

(c) tau = 33 s (awrt 33 s, ft) **A1**

(c) Answer: gradient = -0.0303 s^{-1}; time constant RC = 33 s

(d) correct rearrangement and substitution C = tau/R = 33/15000 (ft from (c)) **M1**

(d) C = 2.2 x 10^{-3} F (2200 uF) (awrt 2.2 x 10^{-3} F, 2 sf, ft) **A1**

(d) Answer: C = 2.2 x 10^{-3} F (2200 uF)

(e) a voltmeter zero offset adds a consistent bias to the voltage readings (oe); accept a consistently delayed start of the stopwatch as a systematic timing error, but not variable reaction delays **B1**

(e) check the voltmeter zero and correct for its offset or calibrate the voltmeter (oe); for a consistently delayed stopwatch start, use a data logger with a voltage sensor triggered when discharge begins **B1**

(e) Answer: A voltmeter zero offset biases the voltage readings; check and correct its zero or calibrate it

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