
PHYSICS

9702/41

Paper 4 A Level Structured Questions

May/June 2016

MARK SCHEME

Maximum Mark: 100

Published

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	Cambridge International AS/A Level – May/June 2016	9702	41

- 1 (a) (gravitational) potential at infinity defined as/is zero B1
- (gravitational) force attractive so work got out/done as object moves from infinity
(so potential is negative) B1 [2]
- (b) (i) $\Delta E = m\Delta\phi$
 $= 180 \times (14 - 10) \times 10^8$ C1
 $= 7.2 \times 10^{10} \text{ J}$ A1
increase B1 [3]
- (ii) energy required $= 180 \times (10 - 4.4) \times 10^8$
or
energy per unit mass $= (10 - 4.4) \times 10^8$ C1
- $\frac{1}{2} \times 180 \times v^2 = 180 \times (10 - 4.4) \times 10^8$
or
 $\frac{1}{2} \times v^2 = (10 - 4.4) \times 10^8$ C1
 $v = 3.3 \times 10^4 \text{ ms}^{-1}$ A1 [3]
- 2 (a) e.g. time of collisions negligible compared to time between collisions
- no intermolecular forces (except during collisions)
- random motion (of molecules)
- large numbers of molecules
- (total) volume of molecules negligible compared to volume of containing vessel
or
average/mean separation large compared with size of molecules
- any two B2 [2]
- 2 (b) (i) mass $= 4.0 / (6.02 \times 10^{23}) = 6.6 \times 10^{-24} \text{ g}$
or
mass $= 4.0 \times 1.66 \times 10^{-27} \times 10^3 = 6.6 \times 10^{-24} \text{ g}$ B1 [1]
- (ii) $\frac{3}{2} kT = \frac{1}{2} m \langle c^2 \rangle$ C1
- $\frac{3}{2} \times 1.38 \times 10^{-23} \times 300 = \frac{1}{2} \times 6.6 \times 10^{-27} \times \langle c^2 \rangle$
- $\langle c^2 \rangle = 1.88 \times 10^6 \text{ (m}^2\text{s}^{-2}\text{)}$ C1
- r.m.s. speed $= 1.4 \times 10^3 \text{ ms}^{-1}$ A1 [3]

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- 3 (a) acceleration/force proportional to displacement (from fixed point) M1
acceleration/force and displacement in opposite directions A1 [2]
- (b) maximum displacements/accelerations are different B1
graph is curved/not a straight line B1 [2]
- (c) (i) $\omega = 2\pi / T$ and $T = 0.8 \text{ s}$ C1
 $\omega = 7.9 \text{ rad s}^{-1}$ A1 [2]
- (ii) $a = (-)\omega^2 x$ C1
 $= 7.85^2 \times 1.5 \times 10^{-2}$
 $= 0.93 \text{ ms}^{-2}$ or 0.94 ms^{-2} A1 [2]
- (iii) $\Delta E = \frac{1}{2} m \omega^2 (x_0^2 - x^2)$ C1
 $= \frac{1}{2} \times 120 \times 10^{-3} \times 7.85^2 \times \{(1.5 \times 10^{-2})^2 - (0.9 \times 10^{-2})^2\}$ C1
 $= 5.3 \times 10^{-4} \text{ J}$ A1 [3]
- 4 (a) (i) product of speed and density M1
reference to speed in medium (and density of medium) A1 [2]
- (ii) α : ratio of reflected intensity and/to incident intensity B1
 Z_1 and Z_2 : (specific) acoustic impedances of media (on each side of boundary) B1 [2]
- (b) in muscle: $I_M = I_0 e^{-\mu x}$
 $= I_0 \exp(-23 \times 3.4 \times 10^{-2})$ C1
 $I_M / I_0 = 0.457$ C1
at boundary: $\alpha = (6.3 - 1.7)^2 / (6.3 + 1.7)^2$
 $= 0.33$ C1
 $I_T / I_M = [(1 - \alpha)] = 0.67$ C1
 $I_T / I_0 = 0.457 \times 0.67$
 $= 0.31$ A1 [5]

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5 (a) (i) 1011 A1 [1]

(ii)

0	0.25	0.50	0.75	1.00	1.25	1.50
1011	0110	1000	1110	0101	0011	0001

All 6 correct, 2 marks. 5 correct, 1 mark.

A2 [2]

(b) sketch: 6 horizontal steps of width 0.25 ms shown

M1

steps at correct heights and all steps shown

A1

steps shown in correct time intervals

A1 [3]

(c) increase sampling frequency/rate

M1

so that step width/depth is reduced

A1

increase number of bits (in each number)

M1

so that step height is reduced

A1 [4]

6 (a) sketch: from $x = 0$ to $x = R$, potential is constant at V_s

B1

smooth curve through (R, V_s) and $(2R, 0.5V_s)$

B1

smooth curve continues to $(3R, 0.33V_s)$

B1 [3]

(b) sketch: from $x = 0$ to $x = R$, field strength is zero

B1

smooth curve through (R, E) and $(2R, 0.25E)$

B1

smooth curve continues to $(3R, 0.11E)$

B1 [3]

7 (a) line has non-zero intercept/line does not pass through origin

B1

charge is/should be proportional to potential (difference)

or

charge is/should be zero when p.d. is zero

(therefore there is a systematic error)

B1 [2]

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	(b) reasonable attempt at line of best fit	B1	
	use of gradient of line of best fit clear	M1	
	$C = 2800 \mu\text{F}$ (allow $\pm 200 \mu\text{F}$)	A1	[3]
	(c) energy = $\frac{1}{2} CV^2$ or energy = $\frac{1}{2} QV$ <u>and</u> $C = Q / V$	C1	
	$\Delta \text{ energy} = \frac{1}{2} \times 2800 \times 10^{-6} \times (9.0^2 - 6.0^2)$	C1	
	$= 6.3 \times 10^{-2} \text{ J}$	A1	[3]
8	(a) op-amp has infinite/(very) large gain	B1	
	op-amp saturates if $V^+ \neq V^-$	M1	
	V^+ is at earth potential so P (or V^-) must be at earth	A1	[3]
	(b) input resistance to op-amp is very large		
	or		
	current in R_2 = current in R_1	B1	
	$V_{\text{IN}} (-0) = IR_2$ <u>and</u> $(0) - V_{\text{OUT}} = IR_1$	M1	
	$V_{\text{OUT}} / V_{\text{IN}} = -R_1 / R_2$	A1	[3]
	(c) relay coil connected between V_{OUT} and earth	M1	
	correct diode symbol connected between V_{OUT} and coil or between coil and earth	M1	
	correct polarity for diode ('clockwise')	A1	[3]
9	(a) 0.10 mm	B1	[1]
	(b) $V_{\text{H}} = (0.13 \times 3.8) / (6.0 \times 10^{28} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1	
	$= 5.1 \times 10^{-7} \text{ V}$	A1	[2]
10	(a) (non-uniform) magnetic flux <u>in core</u> is changing	M1	
	induces (different) e.m.f. in (different parts of) the core	A1	
	(eddy) currents form in the core	M1	
	which give rise to heating	A1	[4]

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(b)	as magnet falls, tube cuts magnetic flux	M1	
	e.m.f./ (eddy) currents induced in metal/aluminium (tube)	A1	
	(eddy) current heating of tube	M1	
	with energy taken from falling magnet	A1	
	or		
	(eddy) currents produce magnetic field	(M1)	
	that opposes motion of magnet	(A1)	
	so magnet B has acceleration $< g$		
	or		
	magnet B has smaller acceleration/reaches terminal speed	A1	[5]
11 (a)	period = 15 ms	C1	
	frequency $(= 1 / T) = 67 \text{ Hz}$	A1	[2]
(b)	zero	A1	[1]
(c)	$I_{\text{r.m.s.}} = I_0 / \sqrt{2}$	C1	
	= 0.53 A	A1	[2]
(d)	energy = $I_{\text{r.m.s.}}^2 \times R \times t$ or $\frac{1}{2} I_0^2 \times R \times t$		
	or		
	power = $I_{\text{r.m.s.}}^2 \times R$ and energy = power $\times t$	C1	
	energy = $0.53^2 \times 450 \times 30 \times 10^{-3}$		
	= 3.8 J	A1	[2]
12 (a)	(in a solid electrons in) neighbouring atoms are close together (and influence/interact with each other)	M1	
	this changes their electron energy levels	M1	
	(many atoms in lattice) cause a spread of energy levels into a band	A1	[3]

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- (b) photons of light give energy to electrons in valence band B1
- electrons move into the conduction band M1
- leaving holes in the valence band A1
- these electrons and holes are charge carriers B1
- increased number/increased current, hence reduced resistance B1 [5]

13 (a) e.g. background count (rate)/radiation

multiple possible counts from each decay

radiation emitted in all directions

dead-time of counter

(daughter) product unstable/also emits radiation

self-absorption of radiation in sample or absorption in air/detector window

three sensible suggestions, 1 each B3 [3]

(b) $A = A_0 \exp(-\ln 2 \times t / T_{1/2})$

$$1.21 \times 10^2 = 3.62 \times 10^4 \exp(-\ln 2 \times 42.0 / T_{1/2})$$

or

$$1.21 \times 10^2 = 3.62 \times 10^4 \exp(-\lambda \times 42.0)$$

C1

$$T_{1/2} = 5.1 \text{ minutes (306 s)}$$

A1 [2]

(c) discrete energy levels (in nuclei)

B1 [1]

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- 1 (a) (i) gravitational force provides/is the centripetal force B1
same gravitational force (by Newton III) B1 [2]
- (ii) $\omega = 2\pi / T$
 $= 2\pi / (4.0 \times 365 \times 24 \times 3600)$ C1
 $= 5.0 (4.98) \times 10^{-8} \text{ rad s}^{-1}$ A1 [2]
- (b) (i) (centripetal force $=$) $M_A d \omega^2 = M_B (2.8 \times 10^8 - d) \omega^2$
or
 $M_A d_A = M_B d_B$ C1
 $M_A / M_B = 3.0 = (2.8 \times 10^8 - d) / d$ C1
 $d = 7.0 \times 10^7 \text{ km}$ A1 [3]
- (ii) $GM_A M_B / (2.8 \times 10^{11})^2 = M_A d \omega^2$ B1
 $M_B = (2.8 \times 10^{11})^2 \times d \omega^2 / G$
 $= (2.8 \times 10^{11})^2 \times (7.0 \times 10^{10}) \times (4.98 \times 10^{-8})^2 / (6.67 \times 10^{-11})$ C1
 $= 2.0 \times 10^{29} \text{ kg}$ A1 [3]
- 2 (a) (i) number of atoms/nuclei in 12 g of carbon-12 B1 [1]
(ii) amount of substance M1
containing N_A (or 6.02×10^{23}) particles/molecules/atoms
or
which contains the same number of particles/atoms/molecules as there are atoms in 12 g of carbon-12 A1 [2]
- (b) $pV = nRT$
 $2.0 \times 10^7 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 290$, so $n = 149 \text{ mol}$ or 150 mol A1 [1]
- (c) (i) V and T constant and so pressure reduced by 5.0%
pressure $= 0.95 \times 2.0 \times 10^7$ C1
or
calculation of new n ($= 142.5 \text{ mol}$) and correct substitution into $pV = nRT$ (C1)
pressure $= 1.9 \times 10^7 \text{ Pa}$ A1 [2]

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(ii) loss is $5/100 \times 150 \text{ mol} = 7.5 \text{ mol}$

or

$$\Delta N = 4.52 \times 10^{24}$$

C1

$$t = (7.5 \times 6.02 \times 10^{23}) / 1.5 \times 10^{19}$$

or

$$t = 4.52 \times 10^{24} / 1.5 \times 10^{19}$$

C1

$$= 3.0 \times 10^5 \text{ s}$$

A1 [3]

3 (a) no net energy transfer between the bodies

or

bodies are at the same temperature

B1 [1]

(b) (i) thermocouple, platinum/metal resistance thermometer, pyrometer

B1 [1]

(ii) thermistor, thermocouple

B1 [1]

(c) (i) change = 11.5 K

B1 [1]

(ii) final temperature = 311.2 K

B1 [1]

4 (a) (i) $T = 0.60 \text{ s}$ and $\omega = 2\pi / T$

C1

$$\omega = 10(10.47) \text{ rad s}^{-1}$$

A1 [2]

(ii) energy = $\frac{1}{2}m\omega^2x_0^2$ or $\frac{1}{2}mv^2$ and $v = \omega x_0$

C1

$$= \frac{1}{2} \times 120 \times 10^{-3} \times (10.5)^2 \times (2.0 \times 10^{-2})^2$$

$$= 2.6 \times 10^{-3} \text{ J}$$

A1 [2]

(b) sketch: smooth curve in correct directions

B1

peak at f

M1

amplitude never zero and line extends from $0.7f$ to $1.3f$

A1 [3]

(c) sketch: peaked line always below a peaked line A

M1

peak not as sharp and at (or slightly less than) frequency of peak in line A

A1 [2]

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- 5 (a) amplitude of the carrier wave varies M1
in synchrony with displacement of the information/audio signal A1 [2]
- (b) (i) 10 kHz A1 [1]
(ii) 5 kHz A1 [1]
- (c) (i) $24 = 10 \lg (P_{\text{MIN}} / \{5.0 \times 10^{-13}\})$ C1
 $P_{\text{MIN}} = 1.3 (1.26) \times 10^{-10} \text{ W}$ A1 [2]
- (ii) $45 \times 2 = 10 \lg (\{500 \times 10^{-3}\} / P)$
 $P = 5.0 \times 10^{-10} \text{ (W)}$ M1
 $P > P_{\text{MIN}}$ so yes A1
or
maximum attenuation calculated to be 96 (dB) (M1)
 $96 \text{ dB} > 2 \times 45 \text{ dB}$ so yes (A1)
or
maximum length of wire calculated to be 48 (km) (M1)
actual length 45 km < 48 km so yes (A1)
or
maximum attenuation per unit length calculated to be 2.2 dB km^{-1} (M1)
 $2.2 \text{ dB km}^{-1} > 2.0 \text{ dB km}^{-1}$ so yes (A1) [2]
- 6 (a) lines perpendicular to surface
or
lines are radial M1
lines appear to come from centre A1 [2]
- (b) (i) $F_E = (1.6 \times 10^{-19})^2 / 4\pi\epsilon_0 x^2$ C1
 $F_G = G \times (1.67 \times 10^{-27})^2 / x^2$ C1
 $F_E / F_G = (1.6 \times 10^{-19})^2 \times (8.99 \times 10^9) / [(1.67 \times 10^{-27})^2 \times (6.67 \times 10^{-11})]$
 $= 1.2 (1.24) \times 10^{36}$ A1 [3]
- (ii) $F_E \gg F_G$ B1 [1]

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- 7 (a) e.g. storing energy
blocking d.c.
in oscillator circuits
in tuning circuits
in timing circuits
- any two* B2 [2]
- (b) (i) $1/6 + 1/C + 1/C = 1/4$ C1
- $C = 24\ \mu\text{F}$ A1 [2]
- (ii) $Q = CV$
 $= 4.0 \times 10^{-6} \times 12$ C1
- $= 48\ \mu\text{C}$ A1 [2]
- (iii) 1. $48\ \mu\text{C}$ A1
2. $24\ \mu\text{C}$ A1 [2]
- 8 (a) (i) gain = voltage output / voltage input B1 [1]
- (ii) changes in V_{OUT}
occur immediately when V_{IN} changes M1
A1
- or*
- changes in V_{IN} (M1)
result in immediate changes to V_{OUT} (A1) [2]
- (b) $12 = 1 + R/(1.5 \times 10^3)$ C1
- $R = 16.5\ \text{k}\Omega$ A1 [2]
- (c) straight line from (0,0) to $(0.75t_1, 9.0\ \text{V})$ B1
- horizontal line from endpoint of straight line to t_1 B1
- +9 V to –9 V (or v.v.) at t_1 B1
- correct line to t_2 B1 [4]

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- 9 (a) (i) number density of charge carriers/free electrons
or
number per unit volume of charge carriers/free electrons B1 [1]
- (ii) PX or QY or RZ B1 [1]
- (b) (i) V_H is inversely proportional to n B1
for semiconductors, n is (much) smaller than for metals B1 [2]
- (ii) magnetic field would deflect holes and electrons in same direction B1
(because) electrons are (–)ve, holes are (+)ve M1
so V_H has opposite polarity/opposite sign A1 [3]
- 10 (a) iron rod changes flux (density)/field B1
change of flux in coil Q causes induced e.m.f. B1 [2]
- (b) constant reading (either polarity) from time zero to near t_1 B1
spike in one direction near t_1 clearly showing a larger voltage M1
of opposite polarity A1
zero reading from near t_1 to t_2 B1 [4]
- 11 (a) point P shown at ‘lower end’ of load B1 [1]
- (b) $V_{r.m.s.} = 6.0/\sqrt{2} = 4.24\text{ V}$ C1
 $I_{r.m.s.} = 4.24/(2.4 \times 10^3)$
 $= 1.8 \times 10^{-3}\text{ A}$ A1 [2]
- (c) (i) capacitor in parallel with load B1 [1]
- (ii) line from peak to curve at 3.0 V for either half- or full-wave rectified M1
correct curvature on line (gradient becoming more shallow) A1
line drawn as for full-wave rectified A1 [3]

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- 12 (a) (i)** (X-ray) photon produced when electron/charged particle is stopped/accelerated (suddenly) B1
- range of accelerations (in target) M1
- hence distribution of wavelengths A1 [3]
- (ii)** electron gives all its energy to one photon B1
- electron stopped in single collision B1 [2]
- (iii)** de-excitation of (orbital) electrons in target/anode/metal B1 [1]
- (b) (i)** aluminium sheet/filter/foil (placed in beam from tube) B1 [1]
- (ii)** (long wavelength X-rays) do not pass through the body B1 [1]
- 13 (a)** (photons of) electromagnetic radiation M1
- emitted from nuclei A1 [2]
- (b)** line of best fit drawn B1
- recognises μ as given by the gradient of best-fit line
- or
- $\ln C = \ln C_0 - \mu x$ B1
- $\mu = 0.061 \text{ mm}^{-1}$ (within $\pm 0.004 \text{ mm}^{-1}$, 1 mark; within $\pm 0.002 \text{ mm}^{-1}$, 2 marks) A2 [4]
- (c)** aluminium is less absorbing (than lead)
- or
- gradient of graph would be less M1
- so μ is smaller A1 [2]

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- 1 (a) (gravitational) potential at infinity defined as/is zero B1
- (gravitational) force attractive so work got out/done as object moves from infinity
(so potential is negative) B1 [2]
- (b) (i) $\Delta E = m\Delta\phi$
 $= 180 \times (14 - 10) \times 10^8$ C1
 $= 7.2 \times 10^{10} \text{ J}$ A1
increase B1 [3]
- (ii) energy required $= 180 \times (10 - 4.4) \times 10^8$
or
energy per unit mass $= (10 - 4.4) \times 10^8$ C1
- $\frac{1}{2} \times 180 \times v^2 = 180 \times (10 - 4.4) \times 10^8$
or
 $\frac{1}{2} \times v^2 = (10 - 4.4) \times 10^8$ C1
 $v = 3.3 \times 10^4 \text{ ms}^{-1}$ A1 [3]
- 2 (a) e.g. time of collisions negligible compared to time between collisions
- no intermolecular forces (except during collisions)
- random motion (of molecules)
- large numbers of molecules
- (total) volume of molecules negligible compared to volume of containing vessel
or
average/mean separation large compared with size of molecules
- any two B2 [2]
- 2 (b) (i) mass $= 4.0 / (6.02 \times 10^{23}) = 6.6 \times 10^{-24} \text{ g}$
or
mass $= 4.0 \times 1.66 \times 10^{-27} \times 10^3 = 6.6 \times 10^{-24} \text{ g}$ B1 [1]
- (ii) $\frac{3}{2} kT = \frac{1}{2} m \langle c^2 \rangle$ C1
- $\frac{3}{2} \times 1.38 \times 10^{-23} \times 300 = \frac{1}{2} \times 6.6 \times 10^{-27} \times \langle c^2 \rangle$
- $\langle c^2 \rangle = 1.88 \times 10^6 \text{ (m}^2\text{s}^{-2}\text{)}$ C1
- r.m.s. speed $= 1.4 \times 10^3 \text{ ms}^{-1}$ A1 [3]

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- 3 (a) acceleration/force proportional to displacement (from fixed point) M1
acceleration/force and displacement in opposite directions A1 [2]
- (b) maximum displacements/accelerations are different B1
graph is curved/not a straight line B1 [2]
- (c) (i) $\omega = 2\pi / T$ and $T = 0.8 \text{ s}$ C1
 $\omega = 7.9 \text{ rad s}^{-1}$ A1 [2]
- (ii) $a = (-)\omega^2 x$ C1
 $= 7.85^2 \times 1.5 \times 10^{-2}$
 $= 0.93 \text{ ms}^{-2}$ or 0.94 ms^{-2} A1 [2]
- (iii) $\Delta E = \frac{1}{2} m \omega^2 (x_0^2 - x^2)$ C1
 $= \frac{1}{2} \times 120 \times 10^{-3} \times 7.85^2 \times \{(1.5 \times 10^{-2})^2 - (0.9 \times 10^{-2})^2\}$ C1
 $= 5.3 \times 10^{-4} \text{ J}$ A1 [3]
- 4 (a) (i) product of speed and density M1
reference to speed in medium (and density of medium) A1 [2]
- (ii) α : ratio of reflected intensity and/to incident intensity B1
 Z_1 and Z_2 : (specific) acoustic impedances of media (on each side of boundary) B1 [2]
- (b) in muscle: $I_M = I_0 e^{-\mu x}$
 $= I_0 \exp(-23 \times 3.4 \times 10^{-2})$ C1
 $I_M / I_0 = 0.457$ C1
at boundary: $\alpha = (6.3 - 1.7)^2 / (6.3 + 1.7)^2$
 $= 0.33$ C1
 $I_T / I_M = [(1 - \alpha)] = 0.67$ C1
 $I_T / I_0 = 0.457 \times 0.67$
 $= 0.31$ A1 [5]

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5 (a) (i) 1011 A1 [1]

(ii)

0	0.25	0.50	0.75	1.00	1.25	1.50
1011	0110	1000	1110	0101	0011	0001

All 6 correct, 2 marks. 5 correct, 1 mark. A2 [2]

(b) sketch: 6 horizontal steps of width 0.25 ms shown M1
 steps at correct heights and all steps shown A1
 steps shown in correct time intervals A1 [3]

(c) increase sampling frequency/rate M1
 so that step width/depth is reduced A1
 increase number of bits (in each number) M1
 so that step height is reduced A1 [4]

6 (a) sketch: from $x = 0$ to $x = R$, potential is constant at V_s B1
 smooth curve through (R, V_s) and $(2R, 0.5V_s)$ B1
 smooth curve continues to $(3R, 0.33V_s)$ B1 [3]

(b) sketch: from $x = 0$ to $x = R$, field strength is zero B1
 smooth curve through (R, E) and $(2R, 0.25E)$ B1
 smooth curve continues to $(3R, 0.11E)$ B1 [3]

7 (a) line has non-zero intercept/line does not pass through origin B1
 charge is/should be proportional to potential (difference)
 or
 charge is/should be zero when p.d. is zero
 (therefore there is a systematic error) B1 [2]

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	(b) reasonable attempt at line of best fit	B1	
	use of gradient of line of best fit clear	M1	
	$C = 2800 \mu\text{F}$ (allow $\pm 200 \mu\text{F}$)	A1	[3]
	(c) energy = $\frac{1}{2} CV^2$ or energy = $\frac{1}{2} QV$ <u>and</u> $C = Q / V$	C1	
	$\Delta \text{ energy} = \frac{1}{2} \times 2800 \times 10^{-6} \times (9.0^2 - 6.0^2)$	C1	
	$= 6.3 \times 10^{-2} \text{ J}$	A1	[3]
8	(a) op-amp has infinite/(very) large gain	B1	
	op-amp saturates if $V^+ \neq V^-$	M1	
	V^+ is at earth potential so P (or V^-) must be at earth	A1	[3]
	(b) input resistance to op-amp is very large or current in R_2 = current in R_1	B1	
	$V_{\text{IN}} (-0) = IR_2$ <u>and</u> $(0) - V_{\text{OUT}} = IR_1$	M1	
	$V_{\text{OUT}} / V_{\text{IN}} = -R_1 / R_2$	A1	[3]
	(c) relay coil connected between V_{OUT} and earth	M1	
	correct diode symbol connected between V_{OUT} and coil or between coil and earth	M1	
	correct polarity for diode ('clockwise')	A1	[3]
9	(a) 0.10 mm	B1	[1]
	(b) $V_{\text{H}} = (0.13 \times 3.8) / (6.0 \times 10^{28} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1	
	$= 5.1 \times 10^{-7} \text{ V}$	A1	[2]
10	(a) (non-uniform) magnetic flux <u>in core</u> is changing	M1	
	induces (different) e.m.f. in (different parts of) the core	A1	
	(eddy) currents form in the core	M1	
	which give rise to heating	A1	[4]

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(b)	as magnet falls, tube cuts magnetic flux	M1	
	e.m.f./ (eddy) currents induced in metal/aluminium (tube)	A1	
	(eddy) current heating of tube	M1	
	with energy taken from falling magnet	A1	
	or		
	(eddy) currents produce magnetic field	(M1)	
	that opposes motion of magnet	(A1)	
	so magnet B has acceleration $< g$		
	or		
	magnet B has smaller acceleration/reaches terminal speed	A1	[5]
11 (a)	period = 15 ms	C1	
	frequency $(= 1 / T) = 67 \text{ Hz}$	A1	[2]
(b)	zero	A1	[1]
(c)	$I_{\text{r.m.s.}} = I_0 / \sqrt{2}$	C1	
	= 0.53 A	A1	[2]
(d)	energy = $I_{\text{r.m.s.}}^2 \times R \times t$ or $\frac{1}{2} I_0^2 \times R \times t$		
	or		
	power = $I_{\text{r.m.s.}}^2 \times R$ and energy = power $\times t$	C1	
	energy = $0.53^2 \times 450 \times 30 \times 10^{-3}$		
	= 3.8 J	A1	[2]
12 (a)	(in a solid electrons in) neighbouring atoms are close together (and influence/interact with each other)	M1	
	this changes their electron energy levels	M1	
	(many atoms in lattice) cause a spread of energy levels into a band	A1	[3]

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- (b) photons of light give energy to electrons in valence band B1
- electrons move into the conduction band M1
- leaving holes in the valence band A1
- these electrons and holes are charge carriers B1
- increased number/increased current, hence reduced resistance B1 [5]

13 (a) e.g. background count (rate)/radiation

multiple possible counts from each decay

radiation emitted in all directions

dead-time of counter

(daughter) product unstable/also emits radiation

self-absorption of radiation in sample or absorption in air/detector window

three sensible suggestions, 1 each B3 [3]

(b) $A = A_0 \exp(-\ln 2 \times t / T_{1/2})$

$$1.21 \times 10^2 = 3.62 \times 10^4 \exp(-\ln 2 \times 42.0 / T_{1/2})$$

or

$$1.21 \times 10^2 = 3.62 \times 10^4 \exp(-\lambda \times 42.0)$$

C1

$$T_{1/2} = 5.1 \text{ minutes (306 s)}$$

A1 [2]

(c) discrete energy levels (in nuclei)

B1 [1]