UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2010 question paper for the guidance of teachers

9702 PHYSICS

9702/41 Paper 4 (A2 Structured Questions), maximum raw mark 100

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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Section A

1 **(a)** force per unit mass (*ratio idea essential*) B1 [1]

(b) graph: correct curvature M1
from (R,1.0 g_S) & at least one other correct point A1 [2]

(c) **(i)** fields of Earth and Moon are in opposite directions M1
either resultant field found by subtraction of the field strength
or any other sensible comment A1
so there is a point where it is zero A0 [2]
(*allow* $F_E = -F_M$ *for 2 marks*)

(ii) $GM_E / x^2 = GM_M / (D - x)^2$ C1
$(6.0 \times 10^{24}) / (7.4 \times 10^{22}) = x^2 / (60R_E - x)^2$ C1
$x = 54\,R_E$ A1 [3]

(iii) graph: $g = 0$ at least ⅔ distance to Moon B1
g_E and g_M in opposite directions M1
correct curvature (by eye) and $g_E > g_M$ at surface A1 [3]

2 **(a)** **(i)** no forces (of attraction or repulsion) between atoms / molecules / particles B1 [1]

(ii) sum of kinetic and potential energy of atoms / molecules M1
due to random motion A1 [2]

(iii) (random) kinetic energy increases with temperature M1
no potential energy
(so increase in temperature increases internal energy) A1 [2]

(b) **(i)** zero A1 [1]

(ii) work done $= p\Delta V$ C1
$= 4.0 \times 10^5 \times 6 \times 10^{4}$
$= 240\,\text{J}$ (*ignore any sign*) A1 [2]

(iii)

change	work done / J	heating / J	increase in internal energy / J
P → Q	**+240**	–600	**–360**
Q → R	0	+720	**+720**
R → P	**–840**	+480	**–360**

(*correct signs essential*)
(*each horizontal line correct, 1 mark – max 3*) B3 [3]

3 (a) (i)	resonance	B1	[1]
(ii)	amplitude 16 mm <u>and</u> frequency 4.6 Hz	A1	[1]
(b) (i)	$a = (–)\omega^2 x$ and $\omega = 2\pi f$	C1	
	$a = 4\pi^2 \times 4.6^2 \times 16 \times 10^{3}$	C1	
	$= 13.4\,\text{m s}^{2}$	A1	[3]
(ii)	$F = ma$	C1	
	$= 150 \times 10^{3} \times 13.4$		
	$= 2.0\,\text{N}$	A1	[2]
(c)	line always 'below' given line and never zero	M1	
	peak is at 4.6 Hz (or slightly less) and flatter	A1	[2]
4 (a)	charge / potential (difference) (*ratio must be clear)*	B1	[1]
(b) (i)	$V = Q / 4\pi\varepsilon_0 r$	B1	[1]
(ii)	$C = Q / V = 4\pi\varepsilon_0 r$ and <u>$4\pi\varepsilon_0$ is constant</u>	M1	
	so $C \propto r$	A0	[1]
(c) (i)	$r = C / 4\pi\varepsilon_0 r$	C1	
	$r = (6.8 \times 10^{12}) / (4\pi \times 8.85 \times 10^{12})$	C1	
	$= 6.1 \times 10^{2}\,\text{m}$	A1	[3]
(ii)	$Q = CV = 6.8 \times 10^{12} \times 220$		
	$= 1.5 \times 10^{9}\,\text{C}$	A1	[1]
(d) (i)	$V = Q/C = (1.5 \times 10^{9}) / (18 \times 10^{12})$		
	$= 83\,\text{V}$	A1	[1]
(ii)	*either* energy = $\frac{1}{2}CV^2$	C1	
	$\Delta E = \frac{1}{2} \times 6.8 \times 10^{12} \times 220^2 – \frac{1}{2} \times 18 \times 10^{12} \times 83^2$	C1	
	$= 1.65 \times 10^{7} – 6.2 \times 10^{8}$		
	$= 1.03 \times 10^{7}\,\text{J}$	A1	[3]
	or energy = $\frac{1}{2}QV$	(C1)	
	$\Delta E = \frac{1}{2} \times 1.5 \times 10^{9} \times 220 – \frac{1}{2} \times 1.5 \times 10^{9} \times 83$	(C1)	
	$= 1.03 \times 10^{7}\,\text{J}$	(A1)	

5	**(a)**	field into (the plane of) the paper	B1	[1]
	(b)	force due to magnetic field <u>provides</u> the centripetal force	B1	
		$mv^2 / r = Bqv$	C1	
		$B = (20 \times 1.66 \times 10^{27} \times 1.40 \times 10^5) / (1.6 \times 10^{19} \times 6.4 \times 10^{2})$	B1	
		$= 0.454\,\text{T}$	A0	[3]
	(c) (i)	<u>semicircle</u> with diameter greater than 12.8 cm	B1	[1]
	(ii)	new flux density = $\frac{22}{20} \times 0.454$	C1	
		$B = 0.499\,\text{T}$	A1	[2]
6	**(a) (i)**	e.g. prevent flux losses / improve flux linkage	B1	[1]
	(ii)	flux in core is changing	B1	
		e.m.f. / current (induced) <u>in core</u>	B1	
		induced current in core causes heating	B1	[3]
	(b) (i)	that value of the direct current producing same (mean) power / heating	M1	
		in a resistor	A1	[2]
	(ii)	power in primary = power in secondary	M1	
		$V_P I_P = V_S I_S$	A1	[2]
7	**(a) (i)**	e.g. electron / particle diffraction	B1	[1]
	(ii)	e.g. photoelectric effect	B1	[1]
	(b) (i)	6	A1	[1]
	(ii)	change in energy = 4.57×10^{19} J		
		$\lambda = hc / E$	C1	
		$= (6.63 \times 10^{34} \times 3.0 \times 10^8) / (4.57 \times 10^{19})$		
		$= 4.4 \times 10^{7}\,\text{m}$	A1	[2]
8	**(a)**	splitting of a heavy nucleus (*not atom/nuclide*)	M1	
		into two (lighter) nuclei of <u>approximately same mass</u>	A1	[2]
	(b)	$^{1}_{0}\text{n}$		
		$^{4}_{2}\text{He}$ (*allow* $^{4}_{2}\alpha$)	M2	
		$^{7}_{3}\text{Li}$	A1	[3]
	(c)	emitted particles have kinetic energy	B1	
		range of particles in the control rods is short / particles stopped in rods / lose kinetic energy in rods	B1	
		kinetic energy of particles converted to thermal energy	B1	[3]

Section B

9 (a) (i) non-inverting (amplifier) — B1 [1]

(ii) (G =) 1 + R_2 / R_1 — B1 [1]

(b) (i) gain = 1 + 100 / 820 — C1
output = 17 mV — A1 [2]

(ii) 9 V — A1 [1]
(R_2 / R_1 scores 0 in **(a)(ii)** but possible 1 mark in each of **(b)(i)** and **(b)(ii)**
(1 + R_1 / R_2) scores 0 in **(a)(ii)**, no mark in **(b)(i)**, possible 1 mark in **(b)(ii)**
(1 – R_2 / R_1) or R_1 / R_2 scores 0 in **(a)(ii), (b)(i)** and **(b)(ii)**)

10 (a) (i) density × <u>speed of wave</u> (in the medium) — B1 [1]

(ii) ρ = (7.0 × 10^{6}) / 4100
= 1700 kg m ^{3} — A1 [1]

(b) (i) $I = I_T + I_R$ — B1 [1]

(ii) 1. α = (0.1 × $10^{6})^2$ / (3.1 × $10^{6})^2$ — C1
= 0.001 — A1 [2]

2. $\alpha \approx 1$ — A1 [1]

(c) *either* very little transmission at an air-skin boundary — M1
(almost) complete transmission at a gel-skin boundary — M1
when wave travels in or out of the body — A1 [3]
or no gel, majority reflection — (M1)
with gel, little reflection — (M1)
when wave travels in or out of the body — (A1)

11 (a) (i) unwanted random power / signal / energy — B1 [1]

(ii) loss of (signal) power / energy — B1 [1]

(b) (i) *either* signal-to-noise ratio at mic. = 10 lg (P_2 / P_1) — C1
= 10 lg ({2.9 × 10 ^{6}} / {3.4 × 10 ^{9}})
= 29 dB — A1
maximum length = (29 – 24) / 12 — C1
= 0.42 km = 420 m — A1 [4]

or signal-to-noise ratio at receiver = 10 lg (P_2 / P_1) — (C1)
at receiver, 24 = 10 lg(P / {3.4 × 10 ^{9}})
P = 8.54 × 10 ^{7} W — (A1)
power loss in cables = 10 lg({2.9 × 10 ^{6}} / {8.54 × 10 ^{7}}) — (C1)
= 5.3 dB
length = 5.3 / 12 km
= 440 m — (A1)

(ii) use an amplifier			M1	
coupled to the microphone			A1	[2]
(*repeater amplifiers scores no mark*)				

12	**(a)** (carrier wave) transmitted from Earth to satellite	(1)			
	satellite receives greatly attenuated signal	(1)			
	signal amplified and transmitted <u>back to Earth</u>			B1	
	at a different (carrier) frequency			B1	
	different frequencies prevent swamping of uplink signal	(1)			
	e.g. of frequencies used (6/4 GHz, 14/11 GHz, 30/20 GHz)	(1)			
	(*two B1 marks plus any two other for additional physics*)			B2	[4]

(b) advantage:	e.g.	much shorter time delay		M1	
		because orbits are much lower		A1	
	e.g.	whole Earth may be covered	(M1)		
		in several orbits / with network	(A1)		
disadvantage:	e.g.	*either* must be tracked			
		or limited use in any one orbit		M1	
		more satellites required for continuous operation		A1	[4]

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from (R,1.0 g_S) & at least one other correct point A1 [2]

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(c) **(i)** $r = C / 4\pi\varepsilon_0 r$	C1	
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5	**(a)** field into (the plane of) the paper	B1	[1]
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	induced current in core causes heating	B1	[3]
	(b) (i) that value of the direct current producing same (mean) power / heating	M1	
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	(ii) power in primary = power in secondary	M1	
	$V_P I_P = V_S I_S$	A1	[2]
7	**(a) (i)** e.g. electron / particle diffraction	B1	[1]
	(ii) e.g. photoelectric effect	B1	[1]
	(b) (i) 6	A1	[1]
	(ii) change in energy = 4.57×10^{19} J		
	$\lambda = hc / E$	C1	
	$= (6.63 \times 10^{34} \times 3.0 \times 10^8) / (4.57 \times 10^{19})$		
	$= 4.4 \times 10^{7}\,\text{m}$	A1	[2]
8	**(a)** splitting of a heavy nucleus (*not atom/nuclide*)	M1	
	into two (lighter) nuclei of <u>approximately same mass</u>	A1	[2]
	(b) ${}^{1}_{0}\text{n}$		
	${}^{4}_{2}\text{He}$ (*allow* ${}^{4}_{2}\alpha$)	M2	
	${}^{7}_{3}\text{Li}$	A1	[3]
	(c) emitted particles have kinetic energy	B1	
	range of particles in the control rods is short / particles stopped in rods / lose kinetic energy in rods	B1	
	kinetic energy of particles converted to thermal energy	B1	[3]

Section B

9 **(a)** **(i)** non-inverting (amplifier) B1 [1]

(ii) (G =) 1 + R_2 / R_1 B1 [1]

(b) **(i)** gain = 1 + 100 / 820 C1
output = 17 mV A1 [2]

(ii) 9 V A1 [1]
(R_2 / R_1 scores 0 in **(a)(ii)** but possible 1 mark in each of **(b)(i)** and **(b)(ii)**
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10 **(a)** **(i)** density × <u>speed of wave</u> (in the medium) B1 [1]

(ii) ρ = (7.0 × 10^{6}) / 4100
= 1700 kg m ^{3} A1 [1]

(b) **(i)** $I = I_T + I_R$ B1 [1]

(ii) **1.** α = (0.1 × 10^{6})^2 / (3.1 × 10^{6})^2 C1
= 0.001 A1 [2]

2. $\alpha \approx 1$ A1 [1]

(c) *either* very little transmission at an air-skin boundary M1
(almost) complete transmission at a gel-skin boundary M1
when wave travels in or out of the body A1 [3]
or no gel, majority reflection (M1)
with gel, little reflection (M1)
when wave travels in or out of the body (A1)

11 **(a)** **(i)** unwanted random power / signal / energy B1 [1]

(ii) loss of (signal) power / energy B1 [1]

(b) **(i)** *either* signal-to-noise ratio at mic. = 10 lg (P_2 / P_1) C1
= 10 lg ({2.9 × 10 ^{6}} / {3.4 × 10 ^{9}})
= 29 dB A1
maximum length = (29 – 24) / 12 C1
= 0.42 km = 420 m A1 [4]

or signal-to-noise ratio at receiver = 10 lg (P_2 / P_1) (C1)
at receiver, 24 = 10 lg(P / {3.4 × 10 ^{9}})
P = 8.54 × 10 ^{7} W (A1)
power loss in cables = 10 lg({2.9 × 10 ^{6}} / {8.54 × 10 ^{7}}) (C1)
= 5.3 dB
length = 5.3 / 12 km
= 440 m (A1)

(ii) use an amplifier			M1	
coupled to the microphone			A1	[2]
(*repeater amplifiers scores no mark*)				

12	**(a)** (carrier wave) transmitted from Earth to satellite	(1)			
	satellite receives greatly attenuated signal	(1)			
	signal amplified and transmitted <u>back to Earth</u>		B1		
	at a different (carrier) frequency		B1		
	different frequencies prevent swamping of uplink signal	(1)			
	e.g. of frequencies used (6/4 GHz, 14/11 GHz, 30/20 GHz)	(1)			
	(*two B1 marks plus any two other for additional physics*)		B2	[4]	

(b) advantage:	e.g.	much shorter time delay	M1	
		because orbits are much lower	A1	
	e.g.	whole Earth may be covered	(M1)	
		in several orbits / with network	(A1)	
disadvantage:	e.g.	*either* must be tracked		
		or limited use in any one orbit	M1	
		more satellites required for continuous operation	A1	[4]

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Section A

1 **(a)** **(i)** rate of change of angle / angular displacement — M1
swept out by radius — A1 [2]

(ii) $\omega \times T = 2\pi$ — B1 [1]

(b) centripetal force is provided by the gravitational force — B1
either $mr(2\pi/T)^2 = GMm/r^2$ *or* $mr\omega^2 = GMm/r^2$ — M1
$r^3 \times 4\pi^2 = GM \times T^2$ — A1
$GM/4\pi^2$ is a constant (c) — A1
$T^2 = cr^3$ — A0 [4]

(c) **(i)** *either* $T^2 = (45/1.08)^3 \times 0.615^2$ *or* $T^2 = 0.30 \times 45^3$ — C1
T = 165 years — A1 [2]

(ii) speed = $(2\pi \times 1.08 \times 10^8) / (0.615 \times 365 \times 24 \times 3600)$ — C1
= 35 km s ^{1} — A1 [2]

2 **(a)** atoms / molecules / particles behave as elastic (identical) spheres — (1)
volume of atoms / molecules negligible compared to volume of containing vessel — (1)
time of collision negligible to time between collisions — (1)
no forces of attraction or repulsion between atoms / molecules — (1)
atoms / molecules / particles are in (continuous) random motion — (1)
(*any four, 1 each*) — B4 [4]

(b) $pV = \frac{1}{3} Nm<c^2>$ and $pV = nRT$ *or* $pV = NkT$ — B1
$\frac{1}{3} Nm<c^2> = nRT$ or $= NkT$ and $<E_K> = ½m<c^2>$ — B1
$n = N/N_A$ *or* $k = R/N_A$ — B1
$<E_K> = \frac{3}{2} \times R/N_A \times T$ — A0 [3]

(c) **(i)** reaction represents *either* build-up of nucleus from light nuclei
or build-up of heavy nucleus from nuclei — M1
so fusion reaction — A1 [2]

(ii) proton and deuterium nucleus will have equal kinetic energies — B1
$1.2 \times 10^{\ 14} = \frac{3}{2} \times 8.31 / (6.02 \times 10^{23}) \times T$ — C1
$T = 5.8 \times 10^8$ K — A1 [3]
(*use of $E = 2.4 \times 10^{\ 14}$ giving 1.16×10^9 K scores 1 mark*)

(iii) *either* inter-molecular / atomic / nuclear forces exist
or proton and deuterium nucleus are positively charged / repel — B1 [1]

3	**(a)**	**(i)**	8.0 cm	A1	[1]
		(ii)	$2\pi f = 220$	C1	
			$f = 35$ (*condone unit*)	A1	[2]
		(iii)	line drawn mid-way between AB and CD (*allow* ±*2 mm*)	B1	[1]
		(iv)	$v = \omega a$	C1	
			$= 220 \times 4.0$		
			$= 880$ cm s ^{1}	A1	[2]
	(b)	**(i)**	**1.** line drawn 3 cm above AB (*allow* ±*2 mm*)	B1	[1]
			2. arrow pointing upwards	B1	[1]
		(ii)	**1.** line drawn 3 cm above AB (*allow* ±*2 mm*)	B1	[1]
			2. arrow pointing downwards	B1	[1]
		(iii)	$v = \omega\sqrt{(a^2 - x^2)}$		
			$= 220 \times \sqrt{(4.0^2 - 2.0^2)}$	C1	
			$= 760$ cm s ^{1}	A1	[2]
			(*incorrect value for x, 0/2 marks*)		
4	**(a)**	**(i)**	work done moving unit positive charge	M1	
			from infinity <u>to the point</u>	A1	[2]
		(ii)	charge / potential (difference) (*ratio must be clear*)	B1	[1]
	(b)	**(i)**	capacitance = $(2.7 \times 10^{\ 6}) / (150 \times 10^{3})$	C1	
			(*allow any appropriate values*)		
			capacitance = $1.8 \times 10^{\ 11}$ (*allow 1.8* ±*0.05)*	A1	[2]
		(ii)	*either* energy = $\frac{1}{2}CV^2$ *or* energy = $\frac{1}{2}QV$ <u>*and*</u> $Q = CV$	C1	
			energy $= \frac{1}{2} \times 1.8 \times 10^{\ 11} \times (150 \times 10^{3})^2$ *or* $\frac{1}{2} \times 2.7 \times 10^{\ 6} \times 150 \times 10^{3}$		
			$= 0.20$ J	A1	[2]
	(c)		*either* since energy $\propto V^2$, capacitor has $(\frac{1}{2})^2$ of its energy left		
			or full formula treatment	C1	
			energy lost = 0.15 J	A1	[2]

5 **(a)** magnetic flux $= BA$		
$= 89 \times 10^{3} \times 5.0 \times 10^{2} \times 2.4 \times 10^{2}$	C1	
$= 1.07 \times 10^{4}$ Wb	A1	[2]
(b) **(i)** e.m.f. $= \Delta\phi / \Delta t$	C1	
(for $\Delta\phi = 1.07 \times 10^{4}$ Wb), $\Delta t = 2.4 \times 10^{2} / 1.8 = 1.33 \times 10^{2}$ s	C1	
e.m.f. $= (1.07 \times 10^{4}) / (1.33 \times 10^{2})$		
$= 8.0 \times 10^{3}$ V	A1	[3]
(ii) current $= 8.0 \times 10^{3} / 0.12$	M1	
≈ 70 mA	A0	[1]
(c) force on wire $= BIL$		
$= 89 \times 10^{3} \times 70 \times 10^{3} \times 5.0 \times 10^{2}$	C1	
$\approx 3 \times 10^{4}$ (N)	M1	
suitable comment e.g. this force is too / very small (to be felt)	A1	[3]
6 **(a)** power / heating depends on I^2	M1	
so independent of current direction	A1	[2]
(b) *either* maximum power $= I_0^2 R$ *or* average power $= I_{RMS}^2 R$	M1	
$I_0 = \sqrt{2} \times I_{RMS}$	M1	
maximum power = 2 × average power		
ratio = 0.5	A1	[3]
7 **(a)** force due to *E*-field is <u>equal and opposite</u> to force due to *B*-field	B1	
$Eq = Bqv$	B1	
$v = E/B$	B1	[3]
(b) *either* charge and mass are not involved in the equation in **(a)**		
or F_E and F_B are both doubled		
or *E, B* and *v* do not change	M1	
so no deviation	A1	[2]
8 **(a)** minimum frequency for electron to be emitted (from surface)	M1	
of electromagnetic radiation / light / photons	A1	[2]
(b) $E = hc / \lambda$ *or* $E = hf$ <u>and</u> $c = f\lambda$	C1	
either threshold wavelength $= (6.63 \times 10^{34} \times 3.0 \times 10^{8}) / (5.8 \times 10^{19})$		
$= 340$ nm		
or energy of 340 nm photon $= 4.4 \times 10^{19}$ J		
or threshold frequency $= 8.7 \times 10^{14}$ Hz		
or 450 nm → 6.7×10^{14} Hz	A1	
appropriate comment comparing wavelengths / energies / frequencies	B1	
so no effect on photo-electric current	B1	[4]

Section B

9	**(a)**	**(i)**	edges can be (clearly) distinguished	B1	[1]
		(ii)	e.g. size of X-ray source / anode / target / aperture scattering of X-ray beam pixel size (*any two, 1 each*)	B2	
			further detail e.g. use of lead grid	B1	[3]
	(b)		X-ray image involves a <u>single</u> exposure	B1	
			CT scan: exposure of a <u>slice</u> from many different angles	M1	
			repeated for different slices	A1	
			CT scan involves a (much) <u>greater exposure</u>	B1	[4]
10	**(a)**		e.g. infinite input impedance / resistance zero output impedance / resistance infinite gain infinite bandwidth infinite slew rate (*any three, 1 each*)	B3	[3]
	(b)	**(i)**	with switch open, V^- is less (positive) than V^+	M1	
			output is positive	A1	
			with switch closed, V^- is more (positive) than V^+ so output is negative (*allow similar scheme if V^- more positive than V^+ treated first*)	A1	[3]
		(ii)	**1.** diodes connected correctly between output and earth	M1	
			2. green identified correctly (*do not allow this mark if not argued in* ***(i)***)	A1	[2]
11	**(a)**	**(i)**	I / I_0 = exp(–1.5 × 2.9)	C1	
			= 0.013	A1	[2]
		(ii)	I / I_0 = exp(–4.6 × 0.95) = 0.013	A1	[1]
	(b)		attenuation (coefficients) in muscle and in fat are similar	B1	
			attenuation (coefficients) in bone and muscle / fat are different	B1	
			contrast depends on difference in attenuation	B1	[3]

12	**(a)**	**(i)**	**1.** signal has same variation (with time) as the data	B1	
			2. consists of (a series of) 'highs' and 'lows'	B1	
			either analogue is continuously variable (between limits)		
			or digital has no intermediate values	B1	[3]
		(ii)	e.g. can be regenerated / noise can be eliminated		
			extra data can be added to check / correct transmitted signal		
			(*any two reasonable suggestions, 1 each*)	B2	[2]
	(b)	**(i)**	analogue signal is sampled at (regular time) intervals	B1	
			sampled signal is converted into a binary number	B1	[2]
		(ii)	one channel is required for each bit (of the digital number)	B1	[1]

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

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9702 PHYSICS

9702/51 Paper 5 (Planning, Analysis and Evaluation), maximum raw mark 30

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1 Planning (15 marks)

Defining the problem (3 marks)

P1 *f* is the independent variable and *V* is the dependent variable or vary *f* and measure *V* [1]
P2 Keep the current in coil X constant [1]
P3 Keep the number of turns on coil (Y)/area of coil Y constant
Do not credit reference to coil X only. [1]

Methods of data collection (5 marks)

M1 Two independent coils labelled X and Y. [1]
M2 Alternating power supply/signal generator connected to coil X in a workable circuit. [1]
M3 Coil Y connected to voltmeter/c.r.o. in a workable circuit. [1]
M4 Use c.r.o. to determine period/frequency or read off signal generator. [1]
M5 Method to keep current constant in coil X: adjust signal generator/use of rheostat. [1]

Method of analysis (2 marks)

A1 Plot a graph of *V* against *f*. [1]
A2 Relationship valid if straight line through origin [1]

Safety considerations (1 mark)

S1 Reference to hot coils – switch off when not in use/use gloves/do not touch coils. Must refer to hot coils. [1]

Additional detail (4 marks)

D1/2/3/4 Relevant points might include [4]

1. Use large current in coil X/large number of coils on coil Y (to increase emf).
2. Use iron core (to increase emf).
3. Detail on measuring emf e.g. height × *y*-gain.
4. Avoid other alternating magnetic fields.
5. Detail on measuring frequency from c.r.o. to determine period and hence *f*.
6. Use of ammeter/c.r.o. and resistor to check current is constant
7. Use insulated wire for coils.
8. Keep coil Y and coil X in the same relative positions.

Do not allow vague computer methods.

[Total: 15]

2 Analysis, conclusions and evaluation (15 marks)

Part	Mark	Expected Answer	Additional Guidance
(a)	A1	Gradient = *b* *y*-intercept = lg *a*	Allow log *a* but not ln *a*
(b)	T1 T2	1.9777 | 0.292 or 0.2923 1.9294 | 0.265 or 0.2648 1.8751 | 0.241 or 0.2405 1.8129 | 0.210 or 0.2095 1.7404 | 0.170 or 0.1703 1.6532 | 0.127 or 0.1271	T1 for lg *l* column – ignore rounding errors; min 2 dp. T2 for lg *T* column – must be values given A mixture is allowed
	U1	From ± 0.004 or ± 0.005 to ± 0.006 or ± 0.007	Allow more than one significant figure.
(c) (i)	G1	Six points plotted correctly	Must be within half a small square; penalise ≥ half a small square. Penalise 'blobs' ≥ half a small square. Ecf allowed from table.
	U2	Error bars in lg (*T*/s) plotted correctly.	All error bars must be plotted. Check first and last point. Must be accurate within half a small square; penalise ≥ half a small square.
(ii)	G2	Line of best fit	If points are plotted correctly then lower end of line should pass between (1.65, 0.124) and (1.65, 0.128) **and** upper end of line should pass between (2.00, 0.300) and (2.00, 0.306). Allow ecf from points plotted incorrectly; five trend plots needed – examiner judgement.
	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through <u>all</u> the error bars.	Line should be clearly labelled or dashed. Should pass from top of top error bar to bottom of bottom error bar **or** bottom of top error bar to top of bottom error bar. Mark scored only if all error bars are plotted.
(iii)	C1	Gradient of best fit line	The triangle used should be at least half the length of the drawn line. Check the read offs. Work to half a small square; penalise ≥ half a small square.
	U3	Uncertainty in gradient	Method of determining absolute uncertainty Difference in worst gradient and gradient.
(iv)	C2	*y*-intercept	Must be negative. Check substitution of point from line into *c* = *y* – *mx*. Allow ecf from **(c)(iii)**.

	U4	Uncertainty in *y*-intercept	Method of determining absolute uncertainty Difference in worst *y*-intercept and *y*-intercept. Do not allow ecf from false origin read-off (FOX). Allow ecf from **(c)(iv)**.
(d)	C3	$a = 10^{y \text{ intercept}}$	*y*-intercept must be used. Expect an answer of about 0.19. If FOX expect answer of about 1.3.
	C4	*b* = gradient and in the range 0.495 to 0.520 and to 2 or 3 sf	Allow 0.50 to 0.52 to 2 sf Penalise 1 sf or ≥4 sf
	U5	Absolute uncertainty in *a* and *b*	Difference in *a* and worst *a*. Uncertainty in *b* should be the same as the uncertainty in the gradient.

[Total: 15]

Uncertainties in Question 2

(c) (iii) Gradient [U3]

1. Uncertainty = gradient of line of best fit – gradient of worst acceptable line
2. Uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)

(c) (iv) [U4]

1. Uncertainty = *y*-intercept of line of best fit – *y*-intercept of worst acceptable line
2. Uncertainty = ½ (*y*-intercept of steepest worst line – *y*-intercept of shallowest worst line)

(d) [U5]

1. Uncertainty = $10^{\text{best } y \text{ intercept}} - 10^{\text{worst } y \text{ intercept}}$

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Additional detail (4 marks)

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[Total: 15]

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	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through all the error bars.	Line should be clearly labelled or dashed. Should pass from top of top error bar to bottom of bottom error bar **or** bottom of top error bar to top of bottom error bar. Mark scored only if all error bars are plotted.
(iii)	C1	Gradient of best fit line	The triangle used should be at least half the length of the drawn line. Check the read offs. Work to half a small square; penalise ≥ half a small square.
	U3	Uncertainty in gradient	Method of determining absolute uncertainty Difference in worst gradient and gradient.
(iv)	C2	*y*-intercept	Must be negative. Check substitution of point from line into $c = y - mx$. Allow ecf from **(c)(iii)**.

	U4	Uncertainty in *y*-intercept	Method of determining absolute uncertainty Difference in worst *y*-intercept and *y*-intercept. Do not allow ecf from false origin read-off (FOX). Allow ecf from **(c)(iv)**.
(d)	C3	$a = 10^{y \text{ intercept}}$	*y*-intercept must be used. Expect an answer of about 0.19. If FOX expect answer of about 1.3.
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1. Uncertainty = *y*-intercept of line of best fit – *y*-intercept of worst acceptable line

2. Uncertainty = ½ (*y*-intercept of steepest worst line – *y*-intercept of shallowest worst line)

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UNIVERSITY of CAMBRIDGE
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1 **Planning (15 marks)**

Defining the problem (3 marks)

P1 *c*, *d* or *A* is the independent variable and *R* is the dependent variable or vary *c*, *d* or *A* and measure *R*. [1]

P2 If *c* varied then (*t* and) *d* or *A* kept constant, if *d* varied then (*t* and) *c* or *A* kept constant, if *A* varied then *c* or *d* kept constant. [1]

P3 Keep temperature <u>constant</u>. [1]

Methods of data collection (5 marks)

M1 Circuit diagram to measure resistance. [1]

M2 Use micrometer screw gauge to measure *d* or *t*. (Allow digital or vernier callipers) [1]

M3 Measure *c* with a ruler/metre rule. [1]

M4 Method of making contact with the strip e.g. use electrodes of at least same dimension as *c* or *d* or *t* or conducting paint methods. Do not allow crocodile clips, unless it is clear that the whole area of the end of the strip is covered. [1]

M5 Method to determine resistance. [1]

Method of analysis (2 marks)

A1 Plot a graph of *R* against *c*, 1/*d* or 1/*A* depending on orientation. Other alternatives possible, e.g. *R* against 1/*c* depending on orientation [1]

A2 Must be consistent with A1: $\rho = A \times$ gradient or $t \times$ gradient/c [1]
Other alternatives possible, e.g. $\rho = d \times$ gradient/t

Safety considerations (1 mark)

S1 Reference sharp edges or cutting metals, e.g. wear gloves. [1]

Additional detail (4 marks)

D1/2/3/4 Relevant points might include [4]

1. Insulate aluminium strip
2. Take many readings of *t* or *d* and average
3. Use a protective resistor/circuit designed to reduce current
4. Rearrange equation to determine graph using *c*, *d* and *t* or A
5. Determine typical resistance of aluminium strip
6. Likely meter range of ammeter/voltmeter/ohmmeter
7. Detail on cutting strip e.g. mark using set square

Do not allow vague computer methods.

[Total: 15]

2 Analysis, conclusions and evaluation (15 marks)

Part	Mark	Expected Answer	Additional Guidance
(a)	A1	$\frac{t}{C}$	Must be negative. Allow $\frac{15}{C}$.
(b)	T1 T2	150 – 1.28 or 1.281 100 – 1.61 or 1.609 66.7 – 1.86 or 1.856 50.0 – 1.97 or 1.974 33.3 – 2.08 or 2.079	T1 for 1/*R* column – ignore sf and rounding errors T2 for ln (*V*/V) column – must be values given A mixture is allowed
	U1	From ± 0.05 or ± 0.06 to ± 0.02 or ± 0.03	Allow more than one significant figure.
(c) (i)	G1	Five points plotted correctly	Must be within half a small square; penalise ≥ half a small square. Ecf allowed from table. Penalise 'blobs' ≥ half a small square.
	U2	Error bars in ln(*V*/V) plotted correctly.	All plots to have error bars; penalise ≥ half a small square. Check first and last point. Must be accurate within half a small square.
(ii)	G2	Line of best fit	If points are plotted correctly then upper end of line should pass between (20, 2.16) and (20, 2.18) **and** lower end of line should pass between (160, 1.20) and (160, 1.225). Allow ecf from points plotted incorrectly – examiner judgement.
	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through <u>all</u> the error bars.	Line should be clearly labelled or dashed. Should pass from top of top error bar to bottom of bottom error bar **or** bottom of top error bar to top of bottom error bar. Mark scored only if all error bars are plotted.
(iii)	C1	Gradient of best fit line Must be negative	The triangle used should be at least half the length of the drawn line. Check the read offs. Work to half a small square; penalise ≥ half a small square. Do not penalise POT.
	U3	Uncertainty in gradient	Method of determining absolute uncertainty. Difference in worst gradient and gradient.
(d) (i)	C2	*C* = –15/gradient	Gradient must be used. Allow ecf from **(c)(iii)**. Do not penalise POT.
	C3	2.14×10^{3} F to 2.24×10^{3} F <u>and</u> to 2 or 3 sf	Must be in range – penalise POT. Allow equivalent unit including s Ω^{1}, C V^{1}, A s V^{1}

(ii)	U4	Determines % uncertainty in *C*	Uses worst gradient or worst calculated *C* value. Do not check calculation.
(e)	C4	Determines *R* correctly	Expect to see an answer about 3000 Ω. *R* = 6.514/candidate's *C*; allow ecf from **(d)(i)**
	U5	Determines absolute uncertainty	Determines worst value of *R* or **(d)(ii)** × *R*

[Total: 15]

Uncertainties in Question 2

(c) (iii) Gradient [U3]

1. Uncertainty = gradient of line of best fit – gradient of worst acceptable line
2. Uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)

(d) (ii) [U4]

1. Works out worst *C* then determines % uncertainty
2. Works out percentage uncertainty in gradient

(e) [U5]

1. Works out worst *R* then determines difference
2. $\Delta R = \left(\dfrac{\Delta \text{gradient}}{\text{gradient}}\right) R = \left(\dfrac{\Delta C}{C}\right) R$