PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 1: WORKING AS A PHYSICIST

SCORE	PERCENTAGE
/715	%

STEMUP

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Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A **ampere**	B,C and D are not base units	**1**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B *is not correct because these are base units of force* C *is not correct because these are not base units* D *is not correct because these are not base units*	kg m s^{-1}	**1**

Q3.

Question number	Acceptable answers	Additional guidance	Mark
(i)	A description that makes reference to the following points: • Record nT (where n is at least 5) **(1)** • Divide measurement by n **(1)**		**2**
(ii)	• Anomalies can be spotted **(1)** • Reduce the effect of random error **(1)**		**2**

Q4.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• BFL is smooth and thin with a definite minimum and minimum is in range 0.26 m – 0.28 m **(1)**		**1**
(ii)	• Values read correctly from candidate's line **(1)** • h to 3 sig fig **and** T to 4 sf **(1)**	Values from their curve to within 1 small square with no unit penalty.	**2**
	A description that makes reference to the following points: • Plot $T^2 h$ against h^2 **(1)** • C is intercept on $T^2 h$ axis **(1)** **OR** C is the value of $T^2 h$ when h^2 is zero **(1)** • Unit is m s^2 **(1)**		**3**

Q5.

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>(i)*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>(i)* (continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.

<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
(i)* (continued)	**Indicative content** • Determine the natural frequency by displacing the tea in the cup and measuring the time for oscillations • Time (5 to 10 or 'suitable number' if test run mentioned) full oscillations and divide by the number • Carry the tea for a known volume of tea for fixed number of steps at a steady pace • Determine the frequency of the gait • Measure the quantity of tea remaining • Repeat for other walking paces		
(ii)	A description that makes reference to the following points: • Plot volume of remaining tea against walking frequency **(1)** • Determine whether there is a relationship between step frequency and spillage **(1)** • If there is, determine whether maximum spillage occurs at or near the natural frequency **(1)**		**3**

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• units eV (energy) base units: kg m^2 s^{-2} **Or** base units of momentum: kg m s^{-1} **(1)** • divide energy by units of speed (c) m s^{-1} gives kg m s^{-1} which are units of momentum Or multiply units of momentum by speed (c) m s^{-1} to give units of energy kg m^2 s^{-2} **(1)**		**2**
(ii)	• resolves a y-component or x-component of electron momentum **(1)** • applies momentum conservation in x-direction or y-direction **(1)** • comparison of total momentum after **Or** momentum of proton after plus comment **(1)** Alternative: • draws a vector triangle	Example of calculation $p_y = 9.1\ (\text{GeV/c})\sin 20 = 3.1\ \text{GeV/c}$ $p_x = 9.1\ (\text{GeV/c})\cos 20 = 8.55\ \text{GeV/c}$ p_x of proton = 20 (GeV/c) - 8.55 (GeV/c) = 11.45 G $p_{\text{proton}} = \sqrt{3.1^2 + 11.45^2}$ = 11.86 GeV/c Alternative: p_y = 9.1 (GeV/c)sin20 = 3.1 GeV/c=11.9(Ø = 15.2 So total p after = 11.9 GeV/c cos 15.2 + 9.1 (GeV/c)cos20	**3**

	• Uses cosine rule • Calculates angle from three sides = 20.4°	= 11.5 + 8.55 = 20.05 GeV/c	
(iii)	• (total) kinetic energy not conserved **(1)**		**1**

Q7.

Question number	Acceptable answers	Additional guidance	Mark
	D		**1**

Q8.

Question Number	Acceptable answers		Additional guidance	Mark
	• Uses V = J/C **Or** V = Nm/C **Or** V = Wb s^{-1}	**(1)**		**(3)**
	• Use of T = N/Cms^{-1} **Or** T = N/Am **Or** T = Wb m^{-2} **Or** Sub of $B=F/IL$ and cancels I's	**(1)**	Example of unit simplification: J/C should equal $\frac{N}{Am} \times A \div m^{-3}Cm$ $= \frac{Nm}{c} = \frac{J}{C}$	
	• Uses units of n = m^{-3} and completes agreement	**(1)**		
	Alternative with base units: • Uses base unit of force = kg m s^{-2} **Or** base unit of energy = kg m^2 s^{-2}	**(1)**		
	• Uses base unit of charge = A s **Or** uses A = Cs^{-1} **Or** Sub of $B=F/IL$ and cancel I's or A's	**(1)**		
	• Uses base units of n = m^{-3} and completes agreement	**(1)**		

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not correct as this is a unit of electric field strength B is not correct as units T m^2 could be used as a unit of flux D is not correct as Wb is a unit of flux		**1**

Q10.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	coulomb, kilogram	**(1)**

Q11.

Question Number	Acceptable answer	Additional guidance	Mark
	A	The only correct answer is **A** because a real image is produced at a distance of 30 cm from the lens B is not the correct answer because the object distance is less than the focal length so the image is virtual C is not the correct answer because diverging lenses produce virtual images with real objects D is not the correct answer because diverging lenses produce virtual images with real objects	**1**

Q12.

Question Number	Answer	Mark
	B	**1**

Q13.

Question Number	Answer	Mark
	D	1

Q14.

Question number	Acceptable answers	Additional guidance	Mark
	• Use of $F = BIl$ or use of $F=Bqv$ **(1)** • Converts N to kg m s^{-2} **(1)**	Example $B = \frac{F[\text{kg m } s^{-2}]}{I[\text{A}]\ l[\text{m}]}$ So units are kg A^{-1} s^{-2}	**2**

Q15.

Question Number	Answer	Mark
	C	1

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • The intercept represents the temperature of the air at which the volume occupied would be zero (1) • This is the absolute zero (of temperature) (1) • Absolute zero is the lowest attainable temperature **Or** absolute zero is the temperature at which the atoms/molecules of the gas have zero kinetic energy (1)	For MP3 accept atoms/molecules stop moving	3
(ii)	**MAX 4** **Resolution:** • It is correct that uncertainties would be reduced by using high resolution instruments (1) • But the instruments are not high resolution (1) • There could be a systematic error (in the measurements) (1) **Graph:** • The points do not lie on a perfect straight line **Or** the true relationship may not linear (1) • Temperature intercept may not be accurate **Or** there may be extrapolation errors (1) • More points are needed **Or** a wider range is needed (1)		4

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Time a number of (complete) oscillations and divide this time by the number of (complete) oscillations **(1)** • This increases the total time recorded **Or** this reduces the effect of reaction time (Dependent on MP1) **(1)** • Time from the mid-point of the oscillation **(1)** • Use a marker to identify the mid-point of the oscillation **Or** pendulum is travelling fastest at the mid-point **(1)** • Each method reduces the (percentage) uncertainty (in the value for T)	Allow: MP1:Use a light gate with a data logger **Or** video oscillation and play back frame by frame MP2: this reduces the effect of reaction time (Dependent on MP1) MP3: accept equilibrium point for mid-point MP5: can't be awarded on its own.	**5**

Q3.

Question Number	Acceptable Answer	Additional Guidance	
(i)	• Wear safety glasses (to protect eyes from breaking wire) **Or** wear suitable footwear (to protect feet from falling masses) **Or** place sand tray under masses (to catch them if they fall)		**1**

Question Number	Acceptable Answer	Additional Guidance	
(ii)	• $\lambda = 2L$ substituted into $v = f\lambda$ **(1)** • v substituted into $v = \sqrt{\frac{T}{\mu}}$ **(1)** • Correct re-arrangement into $y = mx + c$ format **(1)**	$v = f\lambda$ and $\lambda = 2L$ so $v = 2fL$ $v = \sqrt{\frac{T}{\mu}}$, so $4f^2L^2 = \frac{T}{\mu}$ $L^2 = \left(\frac{T}{4\mu}\right).\frac{1}{f^2}$, so gradient is $\frac{T}{4\mu}$	**3**
(iii)	• Gradient calculated **(1)** • Use of gradient = $\frac{T}{4\mu}$ **(1)** • $\mu = 1.8$ (g m^{-1}) **(1)** • SWG consistent with their calculated value of μ (24 swg) **(1)**	Example of calculation gradient = $\frac{(0.043 - 0)\text{m}^2}{(15.0 - 0.0) \times 10^{-6}\text{s}^2} = 2.87 \times 10^3\text{m}^2\text{s}^{-2}$ $\mu = \frac{2.1\text{ kg} \times 9.81\text{ m s}^{-2}}{4 \times 2.87 \times 10^3\text{m}^2\text{s}^{-2}} = 1.79 \times 10^{-3}\text{ kg m}^{-1}$ $\therefore \mu = 1.79\text{ g m}^{-1}$	**4**

Q4.

Question Number	Acceptable Answer	Additional Guidance	
(i)	An explanation that makes reference to the following points: **Either** • Take readings in different positions/orientations along the wire (and calculate a mean) (1) • As wire diameter may not be uniform (1) **OR** • Check (and correct for) for zero error (1) • Zero error reduces the accuracy of the measurement (1) Or Zero error moves the value away from the true value	**Accept:** use ratchet to close up micrometer to avoid squashing the wire MP2 accept cross section for diameter MP2: accept to reduce the effect of random error MP2 accept systematic error not changed by repeat measurements	2

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• discards value for l_3 (1) • l_m=85.7 (cm) (1)	MP2: answer to 1 d.p. only Example of calculation $l_m = \frac{85.5+86.0+85.5}{3} = 85.7$ cm	2
(ii)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ (1) • T=1.86 s (1)	ECF from (i) MP2: accept T = 1.9 s Example of calculation $T = 2\pi\sqrt{\frac{\ell}{g}}$ $= 2\pi \times \sqrt{\frac{0.857\text{ m}}{9.81\text{ m s}^{-2}}} = 1.86$ s	2

Q6.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • Light gates can record short times accurately **(1)** **OR** with smaller uncertainty **(1)** • Because human reaction time is not involved **(1)**		2

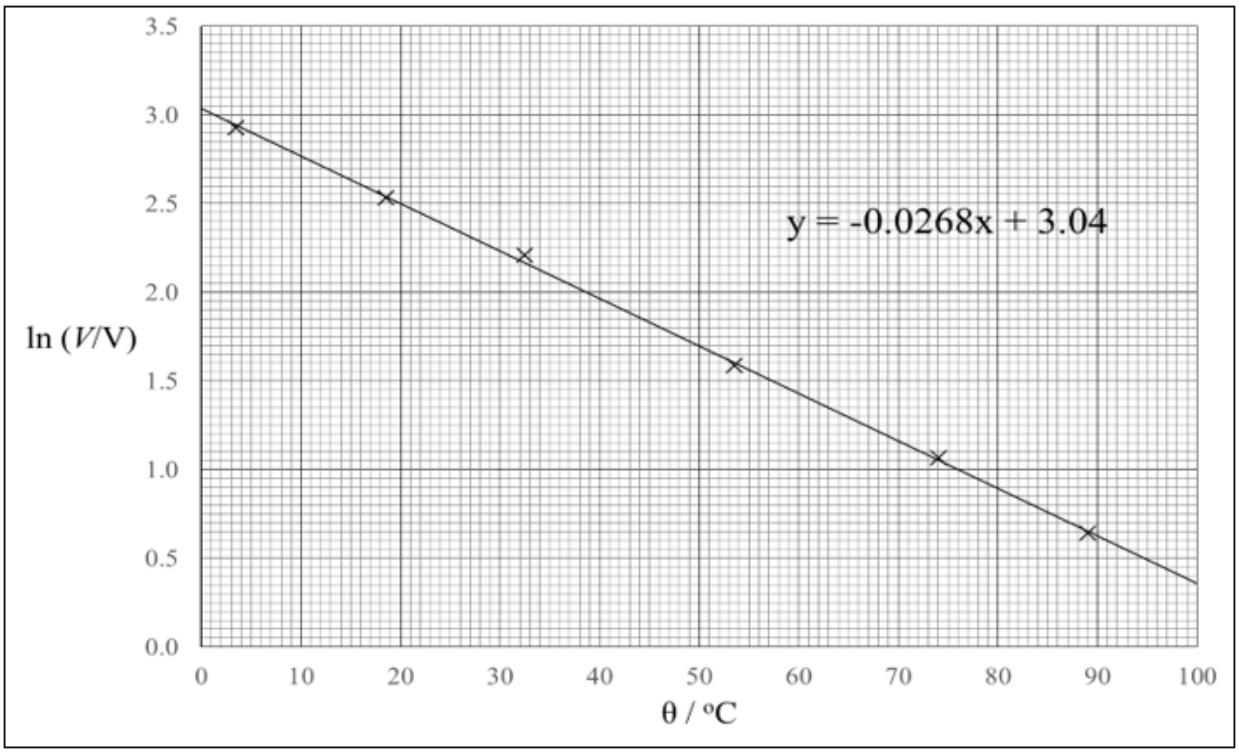
Q7.

Question Number	Acceptable Answer	Additional Guidance	
(i)	An explanation that makes reference to the following points: • Shows expansion $\ln(V) = \ln(V_0) - b\theta$ **(1)** • Compares with $y = mx + c$ and shows that m is $(-)b$ **(1)**		**2**

Question Number	Acceptable Answer	Additional Guidance	
(ii)	Ln values correct and to 2 or 3 decimal places **(1)** • Labels and unit **(1)** • Scales **(1)** • Plots **(1)** • Line of best fit **(1)**		**5**

θ /°C	V /V	ln (V/V)	ln (V/V)
89.0	1.9	0.642	0.64
74.0	2.9	1.065	1.06
53.5	4.9	1.589	1.59
32.5	9.1	2.208	2.21
18.5	12.6	2.534	2.53
3.5	18.7	2.929	2.93

(iii)	• Gradient determined using large triangle **(1)** • b in range $(0.026 \rightarrow 0.028)$ °C^{-1} to 2 or 3 sf with unit **(1)** • Inverse ln of intercept determined **(1)** • V_0 in range (19 → 22) V **(1)**	MP2: unit can be K^{-1} Example of calculation: $\text{gradient} = \frac{(3.04 - 0.35)}{(0 - 100)} = -0.027\ {}_{\circ}\text{C}_{-1}$ $VV_0 = ee^{3.0}\ \text{V} = 20.1\ \text{V}$	**4**



Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• He should have moved the microphone over more inphase positions (to determine multiple wavelengths) **(1)** • This would reduce the uncertainty in the value (for *d)* (dependent upon MP1) **(1)**	**Alternative:** MP1: move microphone between antiphase positions MP2: as it is easier to judge when waves are in antiphase (peak corresponds to a trough)	**2**

Q9.

Question Number	Acceptable Answer	Additional Guidance
	• The first rubber band is too near the surface of the honey (so the ball won't be at its terminal velocity) **(1)** • There is no method for checking that the ball is falling at terminal velocity (when he times) **(1)**	Accept statements for how procedure could be improved consistent with MP1 and MP2 e.g. there should be multiple bands for timing e.g. they haven't videoed the falling ball

Q10.

Question Number	Acceptable Answer	Additional Guidance	
(i)	• Mean time calculated (1) • Use of $s = ut$ (1) • $u = 0.039$ (m s^{-1}) (1)	Credit individual velocities and then mean velocity being calculated Example of calculation $t_{av} = \frac{6.40 + 6.35 + 6.36 + 6.38)\ s}{4} = 6.37\ s$ $u = \frac{0.25\ \text{m}}{6.37\ s} = 3.92 \times 10^{-2}\ \text{m s}^{-1}$	3
(ii)	• Use of $\eta = \frac{2r^2g(\rho_B - \rho_H)}{9v}$ (1) • $\eta = 10.8$ (Pa s), so it is honey A (1)	Show that value gives 10.5 Pa s 10.7 Pa s if 0.0392 m s^{-1} used Allow ecf from (i) Example of calculation $\eta = \frac{2 \times (5.50 \times 10^{-3})^2 \times 9.81\ \text{m s}^{-2} \times (7750 - 1360)\ \text{kg m}^3}{9 \times 3.9 \times 10^{-2}\ \text{m s}^{-1}}$ $\therefore \eta = 10.8$ Pa s	2

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Counting for 1 minute is too short a time **Or** he should count for at least 3 minutes (1) (1) • He hasn't recorded the background count rate (1) • More than one reading taken and a mean calculated **Or** should have taken more than two readings (to calculate mean)		3

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
	MAX 5 An explanation that makes reference to the following points: • The student has calculated the coun rate rather than the activity of the source **(1)** • The counts haven't been corrected for background (so there is systematic error in his data) **(1)** • The GM tube is too far away from the source **(1)** • α-radiation won't reach the GM-tube as it only has a short range in air **(1)** • Radiation spreads out from the source, so not all the emitted radiation reaches the GM-tube • GM tube won't detect all the gammas which enter it		**5**

Q13.

Question number	Acceptable answers	Additional guidance	Mark
(i)	A description that makes reference to the following points: Circuit diagram showing: • Cell, variable resistor and ammeter in series and voltmeter in parallel with cell **(1)** • Recording pairs of readings of terminal p.d. and current **(1)** • Use the variable resistor to obtain 5 other pairs of readings **(1)**	Should be between 5 and 10 other pairs	**3**
(ii)	A description that makes reference to the following points: • Plot a graph of terminal potential difference on the y-axis and current on the x-axis **(1)** • Intercept on the y-axis equals e.m.f. **(1)** • And gradient = -r **(1)**		**3**

Q14.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points: • total resistance of strand decreases (1) • this increases the current in the strand <u>OR</u> remaining bulbs are brighter (1) • greater power / energy consumption with blown bulbs <u>OR</u> reduces the life of the remaining bulbs (1)		**(3)**

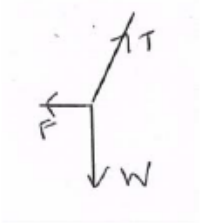
Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• use of $V = IR$ and addition of resistances in series to determine current in strand with 5 blown bulbs (1) <u>OR</u> use of $V = IR$ and addition of resistances in series to determine current in healthy strands <u>OR</u> use of resistance in parallel and series to determine total resistance • $I = 2.9$ A (1) • 2.9 A < 3 A so fuse does not blow (1)	<u>Example of calculation:</u> Total current = sum of current in the four healthy strands + current in the unhealthy strand $I = 4\left(\frac{230\text{ V}}{50\times 8.0\ \Omega}\right) + \left(\frac{230\text{ V}}{(45\times 8.0\ \Omega)+(5\times 3.0\ \Omega)}\right)$ $I = 2.9$ A Allow credit for a consistent conclusion from an incorrect calculation of current	**(3)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(i)	• use a micrometer	(1)		
	• $A = \pi\left(\frac{d}{2}\right)^2$ <u>OR</u> $A = \pi r^2$ and $r = \frac{d}{2}$	(1)		
	• repeats readings in different planes/positions	(1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• current directly proportional to cross-sectional area		**(1)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(iii)	• calculates area = $0.13\ (\text{mm}^2)$	**(1)**	<u>Example of calculation:</u> $A = \pi\left(\frac{0.4\ \text{mm}}{2}\right)^2 = 0.13\ \text{mm}^2$	
	• use of $y = mx + c$	**(1)**		
	• I = 2.8 A	**(1)**	$I = \frac{1.28\ \text{A} \times 0.13\ \text{mm}^2}{0.06\ \text{mm}^2} = 2.8\ \text{A}$	
	• 2.8 A < 3 A so the wire is suitable to use as a fuse wire	**(1)**	Wire is suitable as I < 3 A Allow credit for a consistent conclusion from an incorrect calculation of current Accept converse working to find diameter of 3 A fuse wire	**(4)**

Q15.

Question Number	Answer		Mark
(a)(i)	*W*/*mg* and *T* correct *F*/*E*/ electric force correct Example of diagram  	(1) (1)	2
(a)(ii)	See $T\cos\theta = W$ See $T\sin\theta = F$ **Or** Draws a correct triangle of forces Correctly labels θ (if a triangle is drawn it must be a closed polygon with correctly orientated direction of arrows)	(1) (1) (1) (1)	2
(b)(i)	Records 1pair of values from graph Records 2nd pair of values from graph Use of $F\,r^2$ Shows that $F_1r_1^2 = F_2r_2^2$ (accept answers with or without the powers of ten included) Example of answer Ignoring powers of 10 115 N × 20^2 m^2 = 46000 51 N × 30^2 m^2 = 45900	(1) (1) (1) (1)	4
(b)(ii)	Uses constant from (b) ignoring powers of ten errors **Or** uses a pair of values from graph Use of $F = kQ_1Q_2/r^2$ with 1.6×10^{-19} C $Q = 7.2 \times 10^{-9}$ C Example of answer 100 Q^2 = 46000 × 10^{-9} N m^2 / 8.99 × 10^9 N m^2 C^{-2} $Q^2 = 5.12 \times 10^{-17}$ C^2 $Q = 7.2 \times 10^{-9}$ C	(1) (1) (1)	3
	Total for question		**11**

Q16.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Data not recorded to the same sf/dp • Positions of mass holder not recorded	(1) (1)		2

Q17.

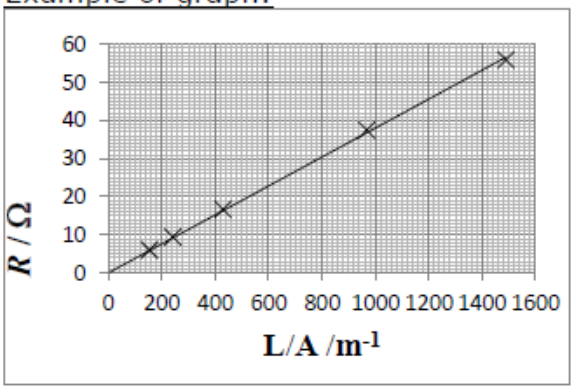
Question number	Acceptable answers	Additional guidance	Mark
(a)	Any three from: • Inconsistent precision for extension **(1)** • Lack of precision on mass, should be shown to 3 DP **(1)** • No evidence of repeat readings **(1) OR** there should be more readings to compensate for repeat readings being inappropriate **(1)** • Inconsistent intervals between readings **(1)**	Uncertainty suggested by 1 sf is far greater than that expected in practice	**3**

Question number	Acceptable answers	Additional guidance	Mark
(b)	A description that makes reference to two of the following points: • use of ficidual mark **(1)** • eye close to liquorice lace to avoid parallax errors **(1)** • Fixed metre rule close to lace **(1)** • Use of set square to ensure rule vertical **(1)**		**2**

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• all *I* values should be recorded to the same number of decimal places **(1)** **Or** all *I* values should be recorded to the same resolution	Do not accept same number of significant figures	**1**

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• axes and labels (1) • suitable scale (1) • all points plotted correctly (1) • line of best fit drawn (1)	Example of graph:  	**(4)**
(a)(ii)	• attempt to measure gradient using large triangle (1) • ρ = (0.035 – 0.041) Ωm to 2 sf (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	Two problems identified with solutions from: • taking only one reading could produce an unreliable result (1) • so take repeat readings of length and diameter (1) • metre ruler cannot be used to measure the diameter with sufficient precision (1) OR metre rule can only measure diameter at ends of cylinder • so use Vernier callipers instead (1) • comment about non-uniform shape (1) • so take repeat readings at different positions/ orientations (1)	Accept micrometer giving precision of 0.01 mm for diameter	**(4)**

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• laser light should not be aimed directly into the eye (1) • as concentrated beam can cause damage to the retina (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	EITHER • all x values should be recorded to the same number of decimal places, so x_2 and x_4 are incorrectly recorded (1) OR • all processed data should be recorded to the same number of significant figures, so sin θ for x_1 is incorrectly recorded	Do not award repeat readings, not appropriate in this experiment	**(1)**
(b)(ii)	• use of $\tan\theta = \frac{x}{D}$ [θ = 22.9°] (1) • $\sin\theta$ = 0.390 (1)	Example of calculation: $\tan\theta = \frac{0.741}{1.75} = 0.423$ $\therefore \theta = 22.9°$ $\therefore \sin\theta = 0.3899$	**(2)**
(b)(iii)	point plotted correctly and best straight line drawn through points (1)		**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)	• $\sin\theta = \frac{n\lambda}{d}$, so gradient = $\frac{\lambda}{d}$ (1) • gradient = 0.194 (1) • use of d = 1/number of lines per mm (1) • d = 3.33 × 10^{-6} (m) (1) • λ = 6.5 × 10^{-7} m (1)	Example of calculation: $d = \frac{1}{3\times10^{5}\,\text{m}^{-1}} = 3.33\times10^{-6}\,\text{m}$ $\lambda = 3.33\times10^{-6}\,\text{m}\times0.194$ $= 6.47\times10^{-7}\,\text{m}$	**(5)**

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Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An answer that makes reference to two of the following pairs: • use a Vernier scale to record *x* (1) • so that data to the nearest 0.1 cm could be obtained to reduce the percentage uncertainty (1) • use a larger grating to screen distance (1) • so that all *x* values would be greater to reduce the percentage uncertainty (1) • measure from nth order on one side to nth order on the other side (1) • so that the distance measured is larger hence reducing the percentage uncertainty in x (1) • use a grating with more lines per mm (1) • so that values of *x* will be greater to reduce the percentage uncertainty (1)	Do not award repeat readings, not appropriate in this experiment	**(4)**

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • The time interval is very short **(1)** • the idea of a high sample rate (with the datalogger) **(1)** **Or** (Percentage) uncertainty in measurement would be small (when using the datalogger).	MP2 examples: time interval between measurements is small Many recordings/sec	**2**

Q2.

Question number	Acceptable answers	Additional guidance	Mark
	• Diameter is only half a division on the scale **(1) OR** diameter is measured to only 1 sf **(1)** • Hence there is a large percentage uncertainty in measurement of diameter of oil drop **(1)** • Since the volume of the drop is calculated by taking (diameter)^3, the percentage uncertainty in volume becomes very large (3 × % uncertainty in diameter) **(1)** • Suggestion for improvement: use a larger oil drop, use a (vernier) scale capable of reading to nearest 0.1 mm, project image of droplet to larger size **(1)** • Drop will not spread out as an exactly circular area, so diameter reading may be inaccurate **(1)** • Suggestion for improvement: the diameter of spread-out oil drop should be taken a number of times across a number of different directions and a mean calculated **(1)**	Allow for identification of any other valid problems and improvements based on good physics, for example place metre rule across tray so that it is close to the surface.	**6**

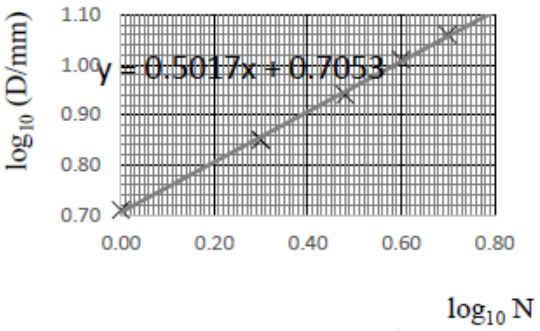
Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	**MAX 3** • There is an inconsistent number of decimal places (1) • No evidence of repeats (1) • Range is too small (1) • Not enough readings between 24 °C and 60 °C (1) • Four (pairs of) readings are not enough (1)		3
(ii)	An explanation that makes reference to the following points: • The (trapped) air may not have been at the temperature of the water (1) • Because water temperature may not be uniform **Or** because transfer of thermal energy through the glass takes time (1) • The volume of the (trapped) air column may not be proportional to the length of the column (1) • Because the bore of the glass tube may not have been uniform (1) • The temperature / length may be read incorrectly (1) • Because there may be a parallax error when reading the temperature or length of the trapped air column (1)	Mark any two pairs	4
(iii)	**Any two from:** • Stir water in beaker (1) • Use digital thermometer **Or** temp sensor & data logger (1) • Put thermometer close to tube (1) • Let tube reach thermal equilibrium before taking readings (1) • Use thermostatically controlled water bath (1) • Take reading in line with scale (1)		2

Q4.

Question Number	Acceptable Answer	Additional Guidance Whole question to be clipped together to allow full ECF	Mark
(i)	• Micrometer (screw gauge) **Or** digital calipers (1) • Because the measured value indicates a resolution of 0.01 mm (1)		2
(ii)	• % uncertainty = 0.2 % (1)	Example of calculation: $\%\ \text{uncertainty} = \frac{0.005\ \text{mm}}{2.52\ \text{mm}} \times 100\ \% = 0.20\ \%$	1
(iii)	• % uncertainty = 1.6 % (1)	Example of calculation: $\%\ \text{uncertainty} = \frac{0.5\ \text{g}}{32.0\ \text{g}} \times 100\ \% = 1.56\ \%$	1
(iv)	• % uncertainty = 2.7 % [1 or 2 sf] (1) **Allow ECF from (a)(ii), (bii) and (b)(iii)**	Example of calculation: % uncertainty = 0.7 % + 1.6 % + (2 × 0.2 %) = 2.7 %	1
(v)	• Use of $V = L \times \frac{\pi d^2}{4}$ (1) • Use of $\rho = \frac{m}{V}$ (1) • Uncertainty in density = 200 kg m^{-3} (1) • So maximum density is 7600 kg m^{-3} which is lower than the standard value **Or** comment consistent with their calculated value (1) **Allow ECF from (a)(iii) and (b)(iv)**	Example of calculation: $V = 0.866\ m \times \frac{\pi(2.52\times10^{-3})^2}{4} = 4.32\times10^{-6}\ \text{m}^3$ $\rho = \frac{3.20\times10^{-2}\ \text{kg}}{4.32\times10^{-6}\ \text{m}^3} = 7400\ \text{kg m}^{-3}$ Uncertainty in $\rho = \pm(7400\ \text{kg m}^{-3} \times \frac{2.7}{100})$ $= 200\ \text{kg m}^{-3}$	4

Q5.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td></td>
<td>
• Log values calculated in table (1)
• Axes correctly labelled (1)
• Suitable scales (1)
• All points plotted correctly (1)
• Line of best fit drawn (1)
• Determine gradient using large triangle (1)
• Intercept read from graph (1)
• $p = 5.0 - 5.2$ (mm) (1)
Or $p = (5.0 - 5.2) \times 10^{-3}$ (m)
$q = 0.5$
</td>
<td>
Accept $\log_{10}$ or ln ($\log_e$)
<table>
<tr><th>$\log_{10}$ (D/mm)</th><th>$\log_{10}$ N</th></tr>
<tr><td>0.710</td><td>0.000</td></tr>
<tr><td>0.850</td><td>0.301</td></tr>
<tr><td>0.940</td><td>0.477</td></tr>
<tr><td>1.01</td><td>0.602</td></tr>
<tr><td>1.06</td><td>0.699</td></tr>
</table>
<table>
<tr><th>ln (D/mm)</th><th>ln N</th></tr>
<tr><td>1.64</td><td>0.000</td></tr>
<tr><td>1.96</td><td>0.693</td></tr>
<tr><td>2.16</td><td>1.10</td></tr>
<tr><td>2.33</td><td>1.39</td></tr>
<tr><td>2.44</td><td>1.61</td></tr>
</table>


</td>
<td>8</td>
</tr>
</table>

Q6.

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td></td>
<td>
A description that makes reference to the following points:
• Refer to $v^2 = u^2 + 2as$ (1)
• Where s is height reached, v is zero, $a = -g$ (1)
• So $u = \sqrt{2gs}$ (1)
</td>
<td>Allow argument $½\ mv^2 = mgh$ to get the same results.</td>
<td>3</td>
</tr>
<tr>
<td>(ii)</td>
<td>
• Air resistance will act on the popper… (1)
• …As a decelerating force (1) OR… dissipating energy (1)
• So the initial speed will be lower than in the absence of air resistance, so the suggestion is not correct (1)
</td>
<td></td>
<td>3</td>
</tr>
</table>

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Precision refers to the spread of values (so the reference to precision is incorrect) **(1)** • Accuracy refers to how close the value is to the true value **(1)** • The resolution (of the balance) is 0.01 g **Or** the uncertainty (of the readings) is (half of) 0.01 g **(1)** • Repeating the measurement doesn't reduce the effect of random error **(1)**		**4**
	Or Repeating the measurement and calculating a mean reduces the effect of random error		

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Use a micrometer to measure y and/or z **(1)** • Use Vernier/digital calipers to measure x and/or **(1)** • Mass of slide(s) measured using (top pan) balance/scales **(1)** • Repeat and determine mean for at least one measurement **(1)**	**(Part (a) and (b) to be marked holistically** **MP1** accept digital calipers for a single slide Accept Vernier calipers if it is clear that the thickness of a number of slides is being measured. To award both MP1 & 2, *x*, *y* & *z* must all be referred to. MP4 can be awarded for a reference to averaging any of the measurements.	**4**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	Check zero error on micrometer/callipers/balance **Or** measure *x*/*y*/*z* of slide in different places **Or** measure thickness/mass of multiple slides **(1)**	Accept 'tare' for zero error check on balance	**1**

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Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Measure the thickness of a stack of slides and divide by number of slides **(1)** • the uncertainty would be the same but the measurement would be larger (so the percentage uncertainty would be less) **(1)**		**2**

Q10.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $\ln 2 = \lambda t_{1/2}$ • $\lambda = 4.92 \times 10^{-18}$ (s^{-1})	(1) (1)	Example of calculation $\lambda = \ln 2 / 1.41 \times 10^{17}$ s $= 4.92 \times 10^{-18}$ s^{-1}	2
(ii)	• Calculate rate = counts / time • Subtract background radiation • Use of $A = -\lambda N$ • Calculates $N \times$ atomic mass • Calculates percentage by mass • Answer = 0.17% (ecf for λ from (a)(i))	(1) (1) (1) (1) (1) (1)	Example of calculation background rate = 525 / (10 × 60) s = 0.875 s^{-1} vase count rate = 3623 / (5 × 60) s = 12.077 s^{-1} corrected rate = 11.2 s^{-1} for whole vase = 11.2 s^{-1} × 0.0177 m^2 / 6.36×10^{-5} m^2 = 3117 s^{-1} N = 3117 / 4.91×10^{-18} s^{-1} = 6.348×10^{20} Mass = $6.348 \times 10^{20} \times 238 \times 1.66 \times 10^{-27}$ kg = 2.51×10^{-4} kg Percentage = 2.51×10^{-4} kg × 100 / 0.149 = 0.17%	6
(iii)	**Max 2** from: • Alpha particles could have been absorbed by the glass • Alpha particles will be emitted in all directions, not just towards the detector • Some alpha particles could have been detected from other parts of the vase • The count could include radiation from decay products	(1) (1) (1) (1) (1)		2
	• Some alpha particles could be absorbed by the GM tube window			

Q11.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• Correct time(s) read from graph • Use of $v = \frac{s}{t}$ • $v = 5900$ ($m s^{-1}$)	(1) (1) (1)	Example of calculation: $t = (1400 - 1000) \times 10^{-6}$ s $v = \frac{2L}{t} = \frac{2 \times 1.18 \text{ m}}{400 \times 10^{-6} \text{ s}} = 5900 \text{ m s}^{-1}$	3

Question Number	Acceptable Answer		Additional Guidance	Mark
(ii)	• Substitution into $E = v^2\rho$ ecf from (b)(i)	(1)	MP2 accept N m^{-2} for units 'show that value' gives $E = 2.8 \times 10^{11}$ Pa	
	• $E = 2.7 \times 10^{11}$ Pa	(1)	Example of calculation: $E = v^2\rho = (5900\,\text{m s}^{-1})^2 \times 7850\,\text{kg m}^{-3}$ $\therefore E = 2.73 \times 10^{11}\,\text{Pa}$	2

Q12.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• Mean straight line with positive intercept on the y-axis	(1)		1

Question Number	Acceptable Answer		Additional Guidance	Mark
(ii)	• $C = \dfrac{K}{4\pi d^2}$ used to show $\dfrac{1}{\sqrt{C}} \propto d$ **Or** identifies gradient as $\sqrt{\dfrac{4\pi}{K}}$ which is constant	(1)		
	• Since graph is a straight line, data is consistent with this	(1)		
	• However, line doesn't pass through the origin	(1)		
	• This indicates a <u>systematic</u> error in measuring the distance	(1)		4

Q13.

Question Number	Acceptable Answer		Additional Guidance	
	An explanation that makes reference to the following points: • Shows expansion $\ln \Delta\theta = \ln \Delta\theta_o - bt$ • Compares with $y = mx + c$ and states that the gradient is b (which is constant)	(1) (1)		2

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• subtracts background from counts in 60 s (1) • use of half life × λ = ln 2 (1) • use of $A = A_0\, e^{-\lambda t}$ (1) • correct logarithmic conversion (1) • year = 1987 (1)	<u>Example of calculation:</u> 12227 - 22 = 12205 322 - 15 = 307 $307 = 12205 \times e^{-\ln 2t/5.3\ y}$ ln 307 = ln 12205 - ln2 × t / 5.3 y t = 28 years Year = 2015 - 28 = 1987	**(5)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	An explanation that makes reference to one of the following pairs: • if the measurement in 2015 were at a larger distance than X, the count rate would be less (1) • the source would appear to be older than it really is (1) <u>OR</u> • 307 is a relatively small count (1) • the equations apply for large numbers of decays therefore you cannot be sure of the accuracy of the age (1) <u>OR</u> • if the sensitivity of the GM tube were greater in 2015, the count rate would be larger (1) • the source would appear to be younger than it really is (1)	Allow reverse arguments	**(2)**

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• Use of $P = VI$ (1) • $P = 1900$ W (1.9 kW) (1)	Example of calculation $P = 230\ \text{V} \times 8.20\ \text{A} = 1890\ \text{W}$	2
(a)(ii)	• Use of $\Delta E = mc\Delta\vartheta$ • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • $\Delta t = 112$ s or 113 s [106 s or 107 s if show that value used] (1) ECF from (a)(i) (1)	Example of calculation $\Delta E = 0.655\ \text{kg} \times 4190\ \text{J kg}^{-1}\text{K}^{-1} \times (100 - 22.5)\text{K}$ $\Delta E = 2.13 \times 10^5\ \text{J}$ $\Delta t = \frac{2.13 \times 10^5\text{J}}{1890\ \text{W}} = 112.5\ \text{s}$	3

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• After a short time of boiling in the flask, all the apparatus would be at 100 °C. **Or** so energy is not being used to heat up the flask **Or** so steam won't condense in the flask (1)		1
(b)(ii)	• Use of $\Delta E = mL$ (1) • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • 1720 W (1.72 kW) (1)	Example of calculation $\frac{\Delta m}{\Delta t} = \frac{95 \times 10^{-3}\ \text{kg}}{125\ \text{s}}$ $= 7.6 \times 10^{-4}\ \text{kg s}^{-1}$ $\frac{\Delta E}{\Delta t} = 7.6 \times 10^{-4}\ \text{kg s}^{-1} \times 2.26 \times 10^6\text{J kg}^{-1}$ $P = 1720\ \text{J s}^{-1}$	3
(b)(iii)	• Comparison of answer to (a)(i) with answer to (b)(ii) (1) • Not all of the energy from the heater is used to turn water from liquid state into vapour (1) **Or** energy is being used to heat the heat exchanger (1) **Or** not all the steam condenses in the heat exchanger • Some energy is transferred to the surroundings	e.g. rate at which thermal energy is supplied to the water in the flask is greater than rate at which thermal energy is removed from the water in the heat exchanger. If answer for (b)(ii) is bigger than 2 kW,1 mark for correct comparison can be scored.	3

Q16.

Question Number	Acceptable Answer	Additional Guidance Whole question to be clipped together to allow full ECF	Mark
(i)	• Calculation of mean value (1) • Use of $l = \pi w$ (1) • l = 48.1 mm (3 sf) (1)	Example of calculation: $w = \frac{(15.3+15.2+15.4+15.3)}{4} = 15.3$ mm $l = \pi \times 15.3$ mm $= 48.1$ mm	3
(ii)	• Calculation of half range **Or** greatest deviation from mean (1) • % uncertainty = 0.7 % **Allow ECF from (a)(i)** (1)	Example of calculation: Half range value $= \frac{15.4 \text{ mm} - 15.2 \text{ mm}}{2} = 0.1$ mm $\therefore$ % uncertainty $= \frac{0.1 \text{ mm}}{15.3 \text{ mm}} \times 100\ \% = 0.65\ \%$	2
(iii)	• Use of $L = Nl$ with N = 16 **or** 18 (1) • L = 866 mm [0.866 m] **Allow ECF from (a)(i)** (1)	Example of calculation: $L = 18 \times 48.1$ mm $= 866$ mm	2

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Micrometer (screw gauge) (1)	Accept digital calipers	1

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • With a phone camera there won't be reaction time errors (when starting and stopping the stopwatch) **Or** with a phone camera the recording can be replayed (a number of times) (1) • So the uncertainty in the measured times will be reduced **Or** this may lead to a more accurate value/time/velocity (1)		2

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• By lagging the flask (to reduce energy transfer to the surroundings) (1)		1

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	**Either** • The GM-tube has a low efficiency for γ-ray detection (1) **Or** there is an increased area exposed to γ-rays • (So) placing the tube side on to the radiation would increase the count rate (1) **Or** • The γ-radiation could be detected anywhere inside the GM-tube (1) • So placing the tube side on to the radiation would reduce the uncertainty in the distance measurement (1)	For low efficiency, accept GM tube poor at detecting γ-rays.	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• Record the count (at least) twice and then determine an average count rate **Or** record the count for a much longer time (1) • This reduces the effect of (random) errors in the measurement of the count rate (1)		2

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points: • total resistance of strand decreases (1) • this increases the current in the strand <u>OR</u> remaining bulbs are brighter (1) • greater power / energy consumption with blown bulbs <u>OR</u> reduces the life of the remaining bulbs (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• use of $V = IR$ and addition of resistances in series to determine current in strand with 5 blown bulbs (1) <u>OR</u> use of $V = IR$ and addition of resistances in series to determine current in healthy strands <u>OR</u> use of resistance in parallel and series to determine total resistance • $I = 2.9$ A (1) • 2.9 A < 3 A so fuse does not blow (1)	<u>Example of calculation:</u> Total current = sum of current in the four healthy strands + current in the unhealthy strand $I = 4\left(\frac{230\text{ V}}{50\times 8.0\ \Omega}\right) + \left(\frac{230\text{ V}}{(45\times 8.0\ \Omega)+(5\times 3.0\ \Omega)}\right)$ $I = 2.9$ A Allow credit for a consistent conclusion from an incorrect calculation of current	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(i)	• use a micrometer (1) • $A = \pi\left(\frac{d}{2}\right)^2$ OR $A = \pi r^2$ and $r = \frac{d}{2}$ (1) • repeats readings in different planes/positions (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• current directly proportional to cross-sectional area		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(iii)	• calculates area = $0.13\ (\text{mm}^2)$ **(1)** • use of $y = mx + c$ **(1)** • I = 2.8 A **(1)** • 2.8 A < 3 A so the wire is suitable to use as a fuse wire **(1)**	Example of calculation: $A = \pi\left(\frac{0.4\ \text{mm}}{2}\right)^2 = 0.13\ \text{mm}^2$ $I = \frac{1.28\ \text{A} \times 0.13\ \text{mm}^2}{0.06\ \text{mm}^2} = 2.8\ \text{A}$ Wire is suitable as I < 3 A Allow credit for a consistent conclusion from an incorrect calculation of current Accept converse working to find diameter of 3 A fuse wire	**(4)**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ratio of atoms and atoms per g **(1)** • Number of nuclei = 2.9×10^{17} **(1)**	$N = 0.3\ \text{g} \times 8.1 \times 10^{21}\ \text{g}^{-1} \times 0.012/100 = 2.9 \times 10^{17}$	**2**

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• use of ln 2 = $\lambda t_{1/2}$	(1)	ln 2 = $\lambda \times 1.25 \times 10^9$ years = $\lambda \times (1.25 \times 10^9 \times 365 \times 24 \times 60 \times 60)$ s $\lambda = 1.76 \times 10^{-17}$ s^{-1} $A = 1.76 \times 10^{-17}$ s^{-1} × 2.9×10^{17} = 5.1 Bq	3
	• use of activity = λN (ecf from (b)(i))	(1)		
	• activity = 5.1 (Bq) (use of show that value gives 5.3 Bq)	(1)		

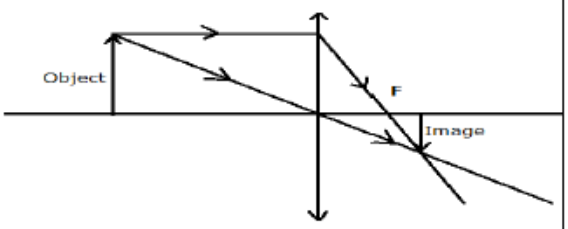
Question Number	Acceptable answers		Additional guidance	Mark
(iii)	• use of count rate = (counts – background counts) / time	(1)	**MP3** can only be awarded if Activity from (ii) is used. A clear comparison with the corresponding value must be made e.g. percentage = 0.8 % which is < 7.5 % so not efficient **Or** detects 176 but should detect 379 counts in 10 min, so not efficient **Or** should detect a rate of at least 0.63 Bq, so not efficient Example of calculation Recorded count rate = (176 - 150) ÷ 600 s = 0.04 Bq 0.04 Bq × 100 ÷ 5.1 Bq = 0.78 % (ecf from (b)(ii) for MP3)	3
	• calculates percentage of activity from (b)(ii) **Or** applies 7.5% to activity from (b)(ii)	(1)		
	• Comparative statement consistent with their values	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(iv)	**Max two from**			2
	• emissions are in all directions	(1)		
	• some emitted particles may be absorbed by the material in the sample	(1)		
	• some emitted particles may be absorbed by the window	(1)		
	• some emitted particles pass (right) through detector	(1)		

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K (1) • … with sensible temperature expressed in Kelvin (1) • E.g. $\lambda_{max} = 9.89 \times 10^{-6}$ m for 293 K (1) • Value is greater than max wavelength of red light so is in IR region (1) **Or** (if starting from 700 nm) • Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K • $T = 4100$ K • Comparison with stated sensible temperature (°C or K) • Temperature is too high so wavelength greater than max wavelength of red light so is in IR region	Example of calculation $\lambda_{max}T = 2.898 \times 10^{-3}$ m K $\lambda_{max} = 2.898 \times 10^{-3}$ m K / 293 K $\lambda_{max} = 9.89 \times 10^{-6}$ m MP4 consistent with calculation	4

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of a correct ray (1) • use of second correct ray (1) • indicates image formed where rays cross (1) • image drawn is real, inverted and diminished (1)	Correct rays are: Ray through the principal focus and parallel to the principal axis Ray parallel to principal axis then through the principal focus Ray through the optical centre of the lens Example of diagram:  	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• use of $1/f = 1/v + 1/u$ (1) for u estimate 4 – 10 mm • use of $P = 1/f$ (1) • P = (120 D to 230 D) (1)	Example of calculation: Assuming the thickness of 8 mm: $1/f = 1/0.008 + 1/0.045$ $P = 1/f$ P = 147 D Full credit for any thicknesses in range 4 – 10 mm	**(3)**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	D In the dark the resistance of the LDR will be very large so practically all the potential difference of 6V will be across it.	a little below 6 V	**1**
	A assumes the resistance of the LDR decreases to almost zero B assumes the resistance of the LDR decreases a little C assumes the resistance of the LDR increases a little		

Q6.

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>* (continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • As parachute opens (at B) the upwards force increases • Along BC the velocity is decreasing at a non-constant rate • The drag is greater than weight (negative gradient) • The drag is decreasing (curved line) • Eventually the drag force balances the weight • No acceleration so line is horizontal		

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Accuracy is (a measure of) how close a measured/calculated value is to the true value **(1)** • Precision is (a measure of) the consistency of values obtained by repeated measurements **(1)**		2

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • High precision means a small spread of values (1) • High accuracy means close to the true value (1) Any **TWO** from: • A is precise but not accurate (as there is a small spread but displaced from the centre of the target) (1) • B is both accurate and precise (as there is a small spread centred on the target) (1) • C is neither accurate nor precise (as there is a large spread displaced from the centre of the target) (1) • D is accurate but not precise (as there is a moderate spread centred on the target) (1)	Credit MP1/MP2 if the explanation of high accuracy/precision is made by reference to a relevant part of the diagram.	**4**

Q3.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • Light gates can record short times accurately **(1)** **OR** with smaller uncertainty **(1)** • Because human reaction time is not involved **(1)**		**2**

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Counting for 1 minute is too short a time **Or** he should count for at least 3 minutes (1) (1) • He hasn't recorded the background count rate (1) • More than one reading taken and a mean calculated **Or** should have taken more than two readings (to calculate mean)		3

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
	MAX 5 An explanation that makes reference to the following points: • The student has calculated the coun rate rather than the activity of the source (1) (1) • The counts haven't been corrected for background (so there is systematic error in his data) (1) (1) • The GM tube is too far away from the source (1) • α-radiation won't reach the GM-tube as it only has a short range in air (1) • Radiation spreads out from the source, so not all the emitted radiation reaches the GM-tube • GM tube won't detect all the gammas which enter it		5

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of half resolution to calculate % uncertainty (1) (1) • % uncertainty in $V = 3 \times$ % uncertainty in r (1) • % uncertainty in ρ = (% uncertainty in m + % uncertainty in V) (1) (1) • Use of % uncertainty to calculate upper value of density (1) • Upper value of density 2596 (kg m^{-3}) [2616 (kg m^{-3}) if "show that" value used] • Glass is in the range and Quartz isn't, so it may not be genuine Allow use of half resolution in either r or m to calculate minimum V and maximum m and then calculate maximum ρ for MP1 → MP4 ECF from (a)	% uncertainty in $r = \frac{0.005\text{ cm}}{5.06\text{ cm}} \times 100\ \% = 0.10\ \%$ % uncertainty in $m = \frac{0.5\text{ g}}{175\text{ g}} \times 100\ \% = 0.29\ \%$ % uncertainty in $\rho = (3 \times 0.1\%) + 0.29\% = 0.59\%$ Range $= \pm\frac{0.6}{100} \times 2580\text{ kg m}^{-3} = \pm 15.5\text{ kg m}^{-3}$ Density range = 2565 → 2596 kg m^{-3}	6

Q7.

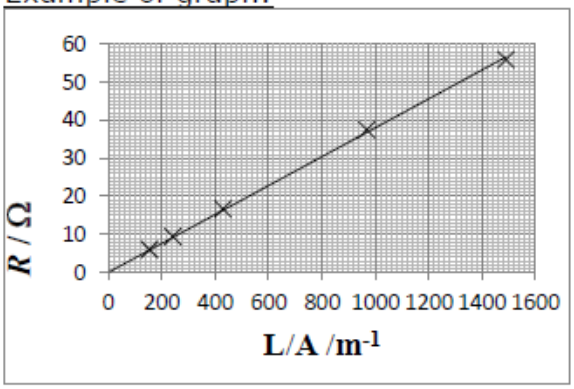
Question Number	Acceptable Answer	Additional Guidance	Mark
	MAX 3 • Voltmeter must measure alternating p.d.s (1) **Or** voltmeter would indicate zero for a.c. (1) • A.C. voltmeter would give an r.m.s. p.d. directly (1) • Voltmeter may draw current and affect the circuit it was connected to (1) **Or** oscilloscope would have little effect on the circuit it was connected to (1) • Accuracy would depend upon the calibration of the voltmeter • A (digital) voltmeter would give better resolution than measuring trace height on an oscilloscope.	Accept "voltmeter reading would change too fast to measure"	3

Q8.

Question number	Acceptable answers	Additional guidance	Mark
(a)	Any three from: • Inconsistent precision for extension **(1)** • Lack of precision on mass, should be shown to 3 DP **(1)** • No evidence of repeat readings **(1) OR** there should be more readings to compensate for repeat readings being inappropriate **(1)** • Inconsistent intervals between readings **(1)**	Uncertainty suggested by 1 sf is far greater than that expected in practice	**3**

Question number	Acceptable answers	Additional guidance	Mark
(b)	A description that makes reference to two of the following points: • use of ficidual mark **(1)** • eye close to liquorice lace to avoid parallax errors **(1)** • Fixed metre rule close to lace **(1)** • Use of set square to ensure rule vertical **(1)**		**2**

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• axes and labels (1) • suitable scale (1) • all points plotted correctly (1) • line of best fit drawn (1)	Example of graph: 	**(4)**
(a)(ii)	• attempt to measure gradient using large triangle (1) • ρ = (0.035 – 0.041) Ωm to 2 sf (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	Two problems identified with solutions from: • taking only one reading could produce an unreliable result (1) • so take repeat readings of length and diameter (1) • metre ruler cannot be used to measure the diameter with sufficient precision (1) OR metre rule can only measure diameter at ends of cylinder • so use Vernier callipers instead (1) • comment about non-uniform shape (1) • so take repeat readings at different positions/ orientations (1)	Accept micrometer giving precision of 0.01 mm for diameter	**(4)**

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• laser light should not be aimed directly into the eye (1) • as concentrated beam can cause damage to the retina (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	EITHER • all x values should be recorded to the same number of decimal places, so x_2 and x_4 are incorrectly recorded (1) OR • all processed data should be recorded to the same number of significant figures, so sin θ for x_1 is incorrectly recorded	Do not award repeat readings, not appropriate in this experiment	**(1)**
(b)(ii)	• use of $\tan\theta = \frac{x}{D}$ [θ = 22.9°] (1) • $\sin\theta$ = 0.390 (1)	Example of calculation: $\tan\theta = \frac{0.741}{1.75} = 0.423$ $\therefore \theta = 22.9°$ $\therefore \sin\theta = 0.3899$	**(2)**
(b)(iii)	point plotted correctly and best straight line drawn through points (1)		**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)	• $\sin\theta = \frac{n\lambda}{d}$, so gradient = $\frac{\lambda}{d}$ (1) • gradient = 0.194 (1) • use of d = 1/number of lines per mm (1) • d = 3.33 × 10^{-6} (m) (1) • λ = 6.5 × 10^{-7} m (1)	Example of calculation: $d = \frac{1}{3\times10^{5}\,\text{m}^{-1}} = 3.33\times10^{-6}\,\text{m}$ $\lambda = 3.33\times10^{-6}\,\text{m}\times0.194$ $= 6.47\times10^{-7}\,\text{m}$	**(5)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An answer that makes reference to two of the following pairs: • use a Vernier scale to record *x* (1) • so that data to the nearest 0.1 cm could be obtained to reduce the percentage uncertainty (1) • use a larger grating to screen distance (1) • so that all *x* values would be greater to reduce the percentage uncertainty (1) • measure from nth order on one side to nth order on the other side (1) • so that the distance measured is larger hence reducing the percentage uncertainty in x (1) • use a grating with more lines per mm (1) • so that values of *x* will be greater to reduce the percentage uncertainty (1)	Do not award repeat readings, not appropriate in this experiment	**(4)**

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• The data has to be collected over a long period of time **(1)**		1

Q12.

Question Number		Additional Guidance	Mark
	• An error is the difference between the (measured) result and the true value (1) • An uncertainty is the interval/range in which the (true) value can be considered to lie (1)	Accept calculated/their for measured result/value Accept theoretical/actual value for true value	2

Q13.

Question Number	Acceptable Answer	Additional Guidance Whole question to be clipped together to allow full ECF	Mark
(i)	• Micrometer (screw gauge) **Or** digital calipers (1) • Because the measured value indicates a resolution of 0.01 mm (1)		2
(ii)	• % uncertainty = 0.2 % (1)	Example of calculation: $\%\ \text{uncertainty} = \frac{0.005\ \text{mm}}{2.52\ \text{mm}} \times 100\ \% = 0.20\ \%$	1
(iii)	• % uncertainty = 1.6 % (1)	Example of calculation: $\%\ \text{uncertainty} = \frac{0.5\ \text{g}}{32.0\ \text{g}} \times 100\ \% = 1.56\ \%$	1
(iv)	• % uncertainty = 2.7 % [1 or 2 sf] (1) **Allow ECF from (a)(ii), (bii) and (b)(iii)**	Example of calculation: % uncertainty = 0.7 % + 1.6 % + (2 × 0.2 %) = 2.7 %	1
(v)	• Use of $V = L \times \frac{\pi d^2}{4}$ (1) • Use of $\rho = \frac{m}{v}$ (1) • Uncertainty in density = 200 kg m^{-3} (1) • So maximum density is 7600 kg m^{-3} which is lower than the standard value **Or** comment consistent with their calculated value (1) **Allow ECF from (a)(iii) and (b)(iv)**	Example of calculation: $V = 0.866\ m \times \frac{\pi(2.52\times10^{-3})^2}{4} = 4.32\times10^{-6}\ \text{m}^3$ $\rho = \frac{3.20\times10^{-2}\ \text{kg}}{4.32\times10^{-6}\ \text{m}^3} = 7400\ \text{kg m}^{-3}$ Uncertainty in $\rho = \pm(7400\ \text{kg m}^{-3} \times \frac{2.7}{100})$ $= 200\ \text{kg m}^{-3}$	4

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Repeat readings can give very similar measurements so value precise **(1)** • Value is not accurate because of a systematic error **(1)**	In MP2 accept zero error or calibration or parallax error for systematic error	2

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	**MAX 3** • There is an inconsistent number of decimal places (1) • No evidence of repeats (1) • Range is too small (1) • Not enough readings between 24 °C and 60 °C (1) • Four (pairs of) readings are not enough (1)		3
(ii)	An explanation that makes reference to the following points: • The (trapped) air may not have been at the temperature of the water (1) • Because water temperature may not be uniform **Or** because transfer of thermal energy through the glass takes time (1) • The volume of the (trapped) air column may not be proportional to the length of the column (1) • Because the bore of the glass tube may not have been uniform (1) • The temperature / length may be read incorrectly (1) • Because there may be a parallax error when reading the temperature or length of the trapped air column (1)	Mark any two pairs	4
(iii)	**Any two from:** • Stir water in beaker (1) • Use digital thermometer **Or** temp sensor & data logger (1) • Put thermometer close to tube (1) • Let tube reach thermal equilibrium before taking readings (1) • Use thermostatically controlled water bath (1) • Take reading in line with scale (1)		2

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• use of $s = ut + \frac{1}{2}at^2$ (1) • a = 7.4 m s^{-2} (1)	Example of calculation: $s = ut + \frac{1}{2}at^2 \quad \therefore a = \frac{2 \times 0.75\text{m}}{(0.45\text{s})^2} = 7.41\text{ms}^{-2}$	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
* **(b)**	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5 - 4 / 3 3 - 2 / 2	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	

1	1
0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning	
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	(1) (1) (1)
Answer is partially structured with some linkages and lines of reasoning	1	(1)
Answer has no linkages between	0	(1)

	points and is unstructured		

Indicative content:

- when the magnet falls there is a rate of change of magnetic flux linked with the tube
- the change in flux linkage for the copper tube induces an emf (Faraday's law)
- the induced emf causes a current to flow in the tube
- the induced emf (and current) are in such a direction as the oppose the change in flux linkage (Lenz's law)
- a force is exerted on the magnet opposing its motion
- plastic is not a conductor so no current is induced, shorter time to fall through the tube so teacher is correct

(6)

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	An explanation that makes reference to the following:			
	• the slit will limit the size of the induced current	(1)		
	• hence a smaller force will oppose the motion of the magnet	(1)		
	• so the time taken to fall will be less	(1)		**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	An explanation that makes reference to the following: • manual timing will be affected by reaction time (1) • the shorter the time being measured the greater the effect that reaction time will have (1)		**(2)**

Q17.

Question number	Acceptable answers	Additional guidance	Mark
	• Diameter is only half a division on the scale **(1) OR** diameter is measured to only 1 sf **(1)** • Hence there is a large percentage uncertainty in measurement of diameter of oil drop **(1)** • Since the volume of the drop is calculated by taking (diameter)^3, the percentage uncertainty in volume becomes very large (3 × % uncertainty in diameter) **(1)** • Suggestion for improvement: use a larger oil drop, use a (vernier) scale capable of reading to nearest 0.1 mm, project image of droplet to larger size **(1)** • Drop will not spread out as an exactly circular area, so diameter reading may be inaccurate **(1)** • Suggestion for improvement: the diameter of spread-out oil drop should be taken a number of times across a number of different directions and a mean calculated **(1)**	Allow for identification of any other valid problems and improvements based on good physics, for example place metre rule across tray so that it is close to the surface.	**6**

Q18.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• The measurement of resistance has an uncertainty of 0.6 %	(1)	MP1 accept use of 0.05 giving 0.3 % Example of calculation: Uncertainty in $R = \frac{0.1\Omega}{18.2\Omega} \times 100\% = 0.55\%$ Uncertainty in $L = \frac{0.05\,\text{m}}{1.25\,\text{m}} \times 100\% = 4.0\%$ Uncertainty in $d = \frac{0.01\,\text{m}}{0.27\,\text{m}} \times 100\% = 3.7\%$	4
	• The measurement of the length has an uncertainty of 4 %	(1)		
	• The measurement of the diameter has an uncertainty of 4 %	(1)		
	• The % uncertainty in diameter is doubled giving the greatest amount of uncertainty into the value for the resistivity	(1)		

Q19.

Question Number	Acceptable Answer		Additional Guidance	Mark
	An explanation that makes reference to the following points: • Uncertainty in each reading = 0.05 cm	(1)	Example of calculation: % uncertainty= $\frac{0.1\text{ cm}}{(17.5\text{-}5.0)\text{ cm}} \times 100\,\% = 0.8\,\%$ Accept statement that uncertainty in $r = 0.1$ cm for MP2	3
	• Uncertainty in r is 2 × uncertainty in each reading	(1)		
	• Hence percentage uncertainty = 0.8 %	(1)		

Q20.

Question Number		Additional Guidance	Mark
	Any **two** valid reasons that relate to • the instrument being used to make the measurement (1) • the way in which the measurement is made (1) • the quantity measured not being constant	Examples: resolution of instrument, zero error, parallax error, reaction time Vague statements that there will be random errors or there might be systematic errors not acceptable.	2

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Mark Scheme

Q1.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• (±) 0.005 cm	(1)		1
(ii)	• Use of 2 × uncertainty • 0.07 % [1 or 2 sf] ECF answer from (a)(i)	(1) (1)	Example of calculation % uncertainty in h = $\frac{2 \times 0.005\text{cm}}{(27.10 - 12.00\text{cm})} \times 100\%$ % uncertainty in h = 0.066 %	2
(iii)	MAX 2 • No units given for $1/r$ in table • $1/r$ recorded to more significant figures than r • h recorded to an inconsistent number of decimal places • raw data for h not shown	(1) (1) (1) (1)		2

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• absolute uncertainty in position × 2 (1) • % uncertainty = 0.2 % (1)	Example of calculation Absolute uncertainty = 2 × 0.005 mm = 0.01 mm $\therefore$% uncertainty= $\frac{0.01\text{ mm}}{5.13\text{ mm}} \times 100\% = 0.2\,\%$	2
(ii)	• The edges of the dark circle are not clearly defined (1)	Accept: the rings are not perfect circles	1

Q3.

Question number	Acceptable answers	Additional guidance	Mark
	• Sensible estimate of uncertainties from readings given **(1)** • Adds percentage uncertainties **(1)** • Hence calculates uncertainty in speed **(1)** • Candidate's conclusion must be supported by their estimate of the uncertainties **(1)**	Example of calculation: %U in L is (0.1/25.6) x 100 % = 0.4 % %U in F is (1/320) x 100 % = 0.3 % %U in speed is 0.7 % 328 x 0.007 = 2 Speed = 328 ± 2 All three results are within the calculated uncertainty so concludes student B is correct	4

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• (Take readings at) different places/positions (1) • (Take readings at) different orientations/angles (1) • Calculate a mean/average value (1)		3

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• There will be variations in positioning the (jaws of the) micrometer. **Or** There will be variations in the length of the tube (at different points around the circumference of the tube) **(1)**	(Accept any reasonable practical physics alternative)	1

Q6.

Question number	Acceptable answers	Additional guidance	Mark
	• Calculates B x r **(1)** • Calculate the percentage uncertainty **(1)** • Suitable comment on difference from expectation **(1)** • Weak conclusion because only three readings **(1) OR** no repeats **(1) OR** limited range **(1)**	Example of calculation: %U = (0.06/5.01) x 100% = 1.2%	4

Radius /cm	Magnetic flux density/mT	
8.0	0.63	5.04
9.5	0.52	4.94
11.0	0.46	5.06

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	MAX 3 A comment that makes reference to the following points: (1) • High precision means a small spread of values (1) • High accuracy means close to the true value (1) • The student is actually referring to the resolution of the balance (1) • (The student should have stated) there was a low uncertainty in the value of the force **Or** a high resolution doesn't guarantee accuracy/precision		3

Q8.

Question Number	Acceptable Answer	Additional Guidance Whole question to be clipped together to allow full ECF	Mark
(i)	• Calculation of mean value (1) • Use of $l = \pi w$ (1) • $l = 48.1$ mm (3 sf) (1)	Example of calculation: $w = \frac{(15.3+15.2+15.4+15.3)}{4} = 15.3$ mm $l = \pi \times 15.3$ mm $= 48.1$ mm	3
(ii)	• Calculation of half range **Or** greatest deviation from mean (1) • % uncertainty = 0.7 % **Allow ECF from (a)(i)** (1)	Example of calculation: Half range value $= \frac{15.4 \text{ mm} - 15.2 \text{ mm}}{2} = 0.1$ mm $\therefore$ % uncertainty $= \frac{0.1 \text{ mm}}{15.3 \text{ mm}} \times 100\ \% = 0.65\ \%$	2
(iii)	• Use of $L = Nl$ with $N = 16$ or 18 (1) • $L = 866$ mm [0.866 m] **Allow ECF from (a)(i)** (1)	Example of calculation: $L = 18 \times 48.1$ mm $= 866$ mm	2

Q9.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>(a)(i)</td><td>Max 2
Inconsistent number of significant figures or decimal places
Or results recorded to different precision /resolution (1)
No repeat readings (1)
More readings needed up to <u>1.5</u> cm (1)</td><td>2</td></tr>
<tr><td>(a)(ii)(1)</td><td>Attempt to use Vr= constant (1)
Correctly finds two values of Vr from values in table and makes comment
Or uses Vr value with another r or V to confirm corresponding value and makes comment (1)

<u>Example of calculation</u>

<table><tr><th>r/cm</th><th>V/V</th><th>rV/ cmV</th></tr><tr><td>1.0</td><td>0.725</td><td>0.725</td></tr><tr><td>1.5</td><td>0.483</td><td>0.725</td></tr><tr><td>2.0</td><td>0.363</td><td>0.726</td></tr><tr><td>2.5</td><td>0.29</td><td>0.725</td></tr><tr><td>3.0</td><td>0.242</td><td>0.726</td></tr><tr><td>3.5</td><td>0.21</td><td>0.735</td></tr></table></td><td>2</td></tr>
<tr><td>(a)(ii)(2)</td><td>The graph would be a straight line graph through the origin. (1)
(accept a sketch of a straight line graph going through the origin graph)</td><td>1</td></tr>
<tr><td>(b)(i)</td><td>An e.m.f. is (induced) when there is a changing (magnetic) field/flux. (1)

Because the <u>current</u> is constant there is a constant magnetic field. Or Because the <u>current</u> is constant there isn't a changing magnetic field. (1)</td><td>2</td></tr>
<tr><td>(b)(ii)</td><td>Movement of either the coil or the wire (1)
Use an alternating current/signal/supply/AC (1)
Switch the current on/off Or change current e.g. use of variable resistor (1)</td><td>3</td></tr>
<tr><td></td><td>Total for question</td><td>10</td></tr>
</table>

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• Use of $P = VI$ (1) • $P = 1900$ W (1.9 kW) (1)	Example of calculation $P = 230\text{ V} \times 8.20\text{ A} = 1890\text{ W}$	2
(a)(ii)	• Use of $\Delta E = mc\Delta\vartheta$ • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • $\Delta t = 112$ s or 113 s [106 s or 107 s if show that value used] (1) ECF from (a)(i) (1)	Example of calculation $\Delta E = 0.655\text{ kg} \times 4190\text{ J kg}^{-1}\text{K}^{-1} \times (100 - 22.5)\text{K}$ $\Delta E = 2.13 \times 10^5\text{ J}$ $\Delta t = \frac{2.13 \times 10^5\text{J}}{1890\text{ W}} = 112.5\text{ s}$	3

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• After a short time of boiling in the flask, all the apparatus would be at 100 °C. **Or** so energy is not being used to heat up the flask **Or** so steam won't condense in the flask (1)		1
(b)(ii)	• Use of $\Delta E = mL$ (1) • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • 1720 W (1.72 kW) (1)	Example of calculation $\frac{\Delta m}{\Delta t} = \frac{95 \times 10^{-3}\text{ kg}}{125\text{ s}}$ $= 7.6 \times 10^{-4}\text{ kg s}^{-1}$ $\frac{\Delta E}{\Delta t} = 7.6 \times 10^{-4}\text{ kg s}^{-1} \times 2.26 \times 10^6\text{J kg}^{-1}$ $P = 1720\text{ J s}^{-1}$	3
(b)(iii)	• Comparison of answer to (a)(i) with answer to (b)(ii) (1) • Not all of the energy from the heater is used to turn water from liquid state into vapour (1) **Or** energy is being used to heat the heat exchanger (1) **Or** not all the steam condenses in the heat exchanger • Some energy is transferred to the surroundings	e.g. rate at which thermal energy is supplied to the water in the flask is greater than rate at which thermal energy is removed from the water in the heat exchanger. If answer for (b)(ii) is bigger than 2 kW,1 mark for correct comparison can be scored.	3

Q11.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• To reduce the effect of random errors	(1)		1
(ii)	• Use of data to calculate mean value • Use of half range **Or** Use of greatest deviation from mean • % uncertainty in range 5 % to 6% consistent with student's working (1 or 2 SF)	(1) (1) (1)	Example of calculation: $\omega_{av}=\frac{(0.112+0.116+0.118+0.123+0.125)}{5}$ $= 0.119 \text{ rad s}^{-1}$ Half range value $=\frac{0.125 \text{ mm} - 0.112 \text{ mm}}{2} = 0.0065$ $\therefore$ % uncertainty $= \frac{0.0065 \text{ mm}}{0.119 \text{ mm}} \times 100\ \% = 5.5\ \%$ Use of greatest deviation from mean gives 5.9 %	3
(iii)	• % uncertainty in ω is doubled • Add % uncertainty in r • % uncertainty = 11 % to 13% consistent with student's working (2 or 3 SF)(ecf from (b)(ii))	(1) (1) (1)	Don't penalise sf in both (ii) **and** (iii) Example of calculation: % uncertainty = 5% + 5% + 1% = 11%	3

Q12.

Question Number	Acceptable Answer		Additional Guidance	Mark
	% uncertainty calculated for d or t % uncertainty calculated for cross sectional area Uncertainty in volume = (±) 4% [accept 4.0%]	(1) (1) (1)	Example of calculation uncertainty in $d = \frac{0.1 \text{ mm}}{13 \text{ mm}} \times 100\% = 0.77\%$ $\therefore$ uncertainty in $A = 2 \times 0.77\% = 1.5\%$ uncertainty in $t = \frac{0.05 \text{ mm}}{2 \text{ mm}} \times 100\% = 2.5\%$ $\therefore$ uncertainty in $V = 1.5\% + 2.5\% = 4.0\ \%$	3

Q13.

Question Number	Acceptable Answer		Additional Guidance	Mark
	Use of $V = \pi r^2 t$	(1)	Example of calculation $V = \pi r^2 t = \pi\left(\frac{1.3\times10^{-2}\ \text{m}}{2}\right)^2 \times 2 \times 10^{-3}\text{m}$ $\therefore V = 2.65\times10^{-7}\text{m}^3$ $m = \rho V = 7900\ \text{kg m}^{-3} \times 2.65\times10^{-7}\text{m}^3$ $\therefore m = 2.10\times10^{-3}\text{kg}$ $\frac{0.1\ \text{g}}{M} = 0.5\%$ $\therefore M = \frac{0.1\ \text{g}}{0.5/100} = 20\ \text{g}$ $\therefore$ number of discs $= \frac{20\ \text{g}}{2.10\ \text{g}} = 9.5$	4
	Use of $\rho = \frac{m}{V}$ to find m	(1)		
	Use of 0.5% to find total mass needed	(1)		
	Number of discs = 10	(1)		

Q14.

Question Number	Acceptable answers		Additional guidance	Mark
	• (Faint and difficult to see, so may not be seen at the correct p.d. and) recorded p.d. could be too high	(1)		3
	• (Range of frequencies could mean light is seen before the light at the stated frequency and) recorded p.d. could be too low	(1)		
	• Discussion of these points, e.g. opposite effects, could cancel or could be systematic errors and not affect gradient	(1)		

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• reference point so that reliable timings can be made (1) • end of metre rule will be travelling fastest at its equilibrium position (so uncertainty is determining when rule is at this position is least) (1)		**(2)**
(a)(ii)	• calculate average time period for each ruler [T_1 = 0.962 s, T_2 = 1.072 s] (1) • use of $T^2 \propto \frac{ML^3}{E}$ (1) • $\frac{E_2}{E_1} = 0.80$ (1)	Example of calculation: $T_1 = \frac{19.3\text{s} + 19.1\text{s} + 19.3\text{s}}{60} = 0.962\text{s}$ $T_2 = \frac{21.3\text{s} + 21.5\text{s} + 21.5\text{s}}{60} = 1.07\text{s}$ $T^2 \propto \frac{ML^3}{E} \therefore \frac{E_1}{E_2} = \frac{T_2^2}{T_1^2}$ $\frac{E_2}{E_1} = \frac{T_1^2}{T_2^2} = \left(\frac{0.962\text{s}}{1.07\text{s}}\right)^2 = 0.804$	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	T^2 on y-axis and L^3 on x-axis (or vice versa)		**(1)**
(b)(ii)	An explanation that makes reference to the following: • $T^2 = \frac{KML^3}{E}$, so gradient will be $\frac{KM}{E}$ (if T^2 plotted against L^3) (1) • $\therefore E = \frac{KM}{\text{gradient}}$, if K is known E can be determined (1)	If axes reversed in (b)(i), gradient = E/KM for full credit	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An explanation that makes reference to the following: • time a larger number of oscillations (1) • as the greater the total time the smaller the % uncertainty (1)		**(2)**

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• calculates mean value of time (1) • use of $s = ut + \frac{1}{2}at^2$ (1) • a = 9.5 m s^{-2} to 2/3 sf (1)	Example of calculation: Average time, t_{av} = (0.45 s +0.51 s + 0.43 s)/3 = 0.46 s $s = ut + \frac{1}{2}at^2 \quad \therefore a = \frac{2 \times 1.00\,\text{m}}{(0.46\,\text{s})^2} = 9.45\,\text{m s}^{-2}$	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• calculates % uncertainty in t using range / half-range **Or** calculates uncertainty in s using precision of instrument (1) • doubles uncertainty in t (1) • uncertainty in a = 18 % (1)	Example of calculation: Uncertainty in t = (0.04/0.46) × 100% = 8.7 % Uncertainty in t^2 = 2 × 8.7 % = 17.4 % Uncertainty in s = (0.01/1.00)× 100 % = 1 % Uncertainty in g = 18.4 %	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• % uncertainty in t would decrease (1) • longer times identified as key factor in reducing uncertainty in value obtained for *g* (1)		**(2)**

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Measured diameter in multiple places / orientations **and** calculate a mean **(1)** • Calculating a mean reduces the effect of random error **(1)**	Treat references to resolution of instrument and thickness of wire as neutral	**2**

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • Identify when the distance fallen between frames has become constant (1) • Measure the distance fallen over a number of frames **Or** measure the distance fallen between frames a number of times and calculate an average distance (1) • Calculate terminal velocity by dividing the distance fallen by the time taken (1) • Use $\frac{1}{60}$ s as time between frames. (1)	MP3: Allow reference to $v = \frac{s}{t}$ to calculate terminal velocity	4
(ii)	An explanation that makes reference to the following points: • There may be parallax error in reading the ball position (1) **Or** the metre rule may not be vertical • Recorded distance may be greater than actual distance, so calculated terminal velocity would be greater than true value. (1)	Recorded distance may be less than actual distance, so terminal velocity would be less than true value	
	OR • The frame rate may be not be 60 s^{-1} (1) • Time between frames may be less than 1/60 s, so calculated terminal velocity may be greater than true value (1)	Time between frames may be more than 1/60 s, so calculated terminal velocity may be less than true value	2

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Systematic (error) (1)		1

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Line of best fit drawn • Value of $1/r$ calculated • $h = 13.8$ cm	Example of calulation $\frac{1}{r} = \frac{1}{0.11\ \text{mm}} = 9.1\ \text{mm}^{-1}$	3
(ii)	• There are only 4 points, which isn't enough to form a firm conclusion (1) • The range of the points is insufficient to form a firm conclusion (no data between 0.0 and 6.0 on x-axis) (1) **Either** • $h = \frac{k}{r}$ suggests a straight line through the origin (1) • the points plotted do lie in a straight line (1) **Or** • $h = \frac{k}{r}$ suggests hr is a constant (1) • This is approximately true (k ≈ 1.5)	Credit there may be systematic error in h causing the points to be displaced	4

Mark Scheme

Q1.

Question number	Acceptable answers	Additional guidance	Mark
(a)	Any three from: • Inconsistent precision for extension **(1)** • Lack of precision on mass, should be shown to 3 DP **(1)** • No evidence of repeat readings **(1) OR** there should be more readings to compensate for repeat readings being inappropriate **(1)** • Inconsistent intervals between readings **(1)**	Uncertainty suggested by 1 sf is far greater than that expected in practice	**3**

Question number	Acceptable answers	Additional guidance	Mark
(b)	A description that makes reference to two of the following points: • use of ficidual mark **(1)** • eye close to liquorice lace to avoid parallax errors **(1)** • Fixed metre rule close to lace **(1)** • Use of set square to ensure rule vertical **(1)**		**2**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	For the proton beam • Proton beam deposits more energy in tumour than the X-rays (1) • Proton beam results in less energy absorbed by surrounding tissue compared to X-rays (1)	Accept converse statement for both marks related to X-rays	**2**

Q3.

Question Number	Acceptable Answers	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5 - 4 / 3 3 - 2 / 2 1 / 1 0 / 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

(6)

Indicative content

- the capacitor can be charged to a higher p.d. than that of the battery
- storing larger amount of energy on capacitor as predicted by $E = \frac{1}{2} CV^2$
- with a low resistance in the bulb the capacitor discharges rapidly
- this produces enough power, $P = W/t$ to produce the flash
- use of $T = RC$ to estimate a value for T (1 ms)
- comparison of time constant with 4 ms

Example of calculation:
$T = 6\ \Omega \times 185\ \mu\text{F} = 1.1\ \text{ms}$
Accept $5T > 4\ \text{ms}$

Q4.

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>(a)(i)</td><td>Max 2
Inconsistent number of significant figures or decimal places
Or results recorded to different precision /resolution
No repeat readings
More readings needed up to <u>1.5</u> cm</td><td>(1)
(1)
(1)</td><td>2</td></tr>
<tr><td>(a)(ii)(1)</td><td>Attempt to use Vr= constant
Correctly finds two values of Vr from values in table and makes comment
Or uses Vr value with another r or V to confirm corresponding value and makes comment

<u>Example of calculation</u>

<table><tr><th>r/cm</th><th>V/V</th><th>rV/ cmV</th></tr><tr><td>1.0</td><td>0.725</td><td>0.725</td></tr><tr><td>1.5</td><td>0.483</td><td>0.725</td></tr><tr><td>2.0</td><td>0.363</td><td>0.726</td></tr><tr><td>2.5</td><td>0.29</td><td>0.725</td></tr><tr><td>3.0</td><td>0.242</td><td>0.726</td></tr><tr><td>3.5</td><td>0.21</td><td>0.735</td></tr></table></td><td>(1)

(1)</td><td>2</td></tr>
<tr><td>(a)(ii)(2)</td><td>The graph would be a straight line graph through the origin.
(accept a sketch of a straight line graph going through the origin graph)</td><td>(1)</td><td>1</td></tr>
<tr><td>(b)(i)</td><td>An e.m.f. is (induced) when there is a changing (magnetic) field/flux.

Because the <u>current</u> is constant there is a constant magnetic field. Or Because the <u>current</u> is constant there isn't a changing magnetic field.</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td>(b)(ii)</td><td>Movement of either the coil or the wire
Use an alternating current/signal/supply/AC
Switch the current on/off Or change current e.g. use of variable resistor</td><td>(1)
(1)
(1)</td><td>3</td></tr>
<tr><td></td><td>Total for question</td><td></td><td>10</td></tr>
</table>

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $W = VIt$ (1) • use of $\Delta E = mc\Delta\theta$ (1) • use of efficiency = useful power output / total power input (1) • efficiency = 0.90 Or 90% (1)	Example of calculation: W = 247 V × 11.8 A × 172 s = 501 000 J ΔE = 1.20 kg × 4180 J kg^{-1} K^{-1} × (101 - 11) K = 451 000 J Efficiency = 451 000 / 501 000 = 0.90	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• calculates area of sphere of radius 30 cm = 1.13 m^2 (1) • use of $I = P/A$ (1) • use of $W = Pt$ (1) • W = 2.0 J (1)	Example of calculation: Area = 4π × (0.3 m)^2 = 1.13 m^2 P = 10.5 × 10^{-3} W m $^{-2}$ × 1.13 m^2 = 1.19 × 10^{-2} W W = 1.19 × 10^{-2} W × 172 s = 2.0 J	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	An explanation that makes reference to the following: • the quiet boil electric kettle is more efficient, but only by 3% which isn't 'much' (1) • the energy transferred by sound is very small, so it is not the reason for the difference (1)	Allow 1 mark if the student gives a comment that the uncertainties are too high to draw a valid conclusion without reference to the data in the question, the candidate's calculations may be awarded one mark	**(2)**

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • Radiation is absorbed/scattered passing through the atmosphere. (1) • Radiation is reflected from the top of the atmosphere (1) • Only half of the Earth's surface has radiation from the Sun incident on it at any one instant. (1) • The intensity of radiation (normal to the surface) is greater at the equator than at the poles. (1)		4

(ii)	• Use of $A=4\pi r^2$ (1) • Use of efficiency= $\frac{\text{useful power output}}{\text{total power input}}$ (1) • Use of $I=\frac{P}{A}$ (1) • % of surface needed is 0.0005%, so claim is not valid (1) [Accept reverse calculation to show power generated by cells over 0.5% of the Earth would generate 1.06×10^5 GW]	<u>Example of calculation:</u> $A=\frac{P}{I}$ $=\frac{100\times10^9\ \text{W}}{0.25\times164\ \text{W m}^{-2}}=2.44\times10^9\text{m}^2$ $A=4\pi\times(6.4\times10^6\ \text{m})^2$ $=5.15\times10^{14}\text{m}^2$ % needed = $\frac{2.44\times10^9\text{m}^2}{5.15\times10^{14}\ \text{m}^2}\times100\%=0.00047\ \%$	4

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• so the proportion of unstable nuclei does not change significantly over time **Or** activity does not change significantly over time (1)		1

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	Maximum 3 marks • There cannot be a p.d. across his body (1) • Electric field strength inside cage is zero (1) • As no potential gradient (1) • Current/electrons/charge would conduct through suit **Or** the current would not pass through body (1)	Accept reference to Faraday cage for MP2	3max

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• laser light should not be aimed directly into the eye (1) • as concentrated beam can cause damage to the retina (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	EITHER • all x values should be recorded to the same number of decimal places, so x_2 and x_4 are incorrectly recorded (1) OR • all processed data should be recorded to the same number of significant figures, so sin θ for x_1 is incorrectly recorded	Do not award repeat readings, not appropriate in this experiment	**(1)**
(b)(ii)	• use of $\tan\theta = \frac{x}{D}$ [θ = 22.9°] (1) • $\sin\theta$ = 0.390 (1)	Example of calculation: $\tan\theta = \frac{0.741}{1.75} = 0.423$ $\therefore \theta = 22.9°$ $\therefore \sin\theta = 0.3899$	**(2)**
(b)(iii)	point plotted correctly and best straight line drawn through points (1)		**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)	• $\sin\theta = \frac{n\lambda}{d}$, so gradient = $\frac{\lambda}{d}$ (1) • gradient = 0.194 (1) • use of d = 1/number of lines per mm (1) • d = 3.33 × 10^{-6} (m) (1) • λ = 6.5 × 10^{-7} m (1)	Example of calculation: $d = \frac{1}{3\times10^{5}\,\text{m}^{-1}} = 3.33\times10^{-6}\,\text{m}$ $\lambda = 3.33\times10^{-6}\,\text{m}\times0.194$ $= 6.47\times10^{-7}\,\text{m}$	**(5)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An answer that makes reference to two of the following pairs: • use a Vernier scale to record *x* (1) • so that data to the nearest 0.1 cm could be obtained to reduce the percentage uncertainty (1) • use a larger grating to screen distance (1) • so that all *x* values would be greater to reduce the percentage uncertainty (1) • measure from nth order on one side to nth order on the other side (1) • so that the distance measured is larger hence reducing the percentage uncertainty in x (1) • use a grating with more lines per mm (1) • so that values of *x* will be greater to reduce the percentage uncertainty (1)	Do not award repeat readings, not appropriate in this experiment	**(4)**

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• use of $F = Gm_1m_2/r^2$ **and** use of $F = mr\omega^2$ **Or** use of $F = Gm_1m_2/r^2$ **and** use of $F = mv^2/r$	(1)	MP3 and 4 - for force and angular velocity, both approaches required Example of calculation $T^2 = 4\pi^2r^3 / G m_1$	4
	• use of $T = 2\pi/\omega$ **Or** use of $T = 2\pi r/v$	(1)	$T^2 = 4\pi^2 \times (2\,430\,000\text{ m} + 7\,690\,000\text{ m})^3 / 6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 3.30 \times 10^{23}\text{ kg}$	
	• $T = 12$ hours **Or** $F = 120$ N by gravitational approach and centripetal force approach **Or** $\omega = 1.45 \times 10^{-4}$ radians s^{-1} by gravitational approach and circular motion approach **Or** height of orbit = 7700 km	(1)	$T = 43115$ s = 11.98 hours	
	• Comparative statement consistent with their value(s)	(1)		
(ii)	**Max 2** • Allows satellite to get (much) closer to surface	(1)	For each, the second marking point is dependent on the first. Award second marking point for other sensible advantages	2
	• So more detailed photographs/scans possible	(1)		
	OR			
	• Allows satellite to spend time further from the surface	(1)		
	• So prevents exposure to prolonged heat from planet damaging probe	(1)		
	OR			
	• Satellite varies distance from surface	(1)		
	• So it can take wide-angle and close-up pictures of the planet	(1)		

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	Max 2 • normal car would have much more mass (1) • too much area of solar cell needed so impractical (1) • going uphill would need far more power (1)		2

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	Any two from: • Cost of treatment reduced in the long-term (1) • Better chances of success compared with previous treatment (1) • Fewer side effects compared to previous **Or** patient recover more quickly (1)		2

Q7.

Question Number	Answer		Mark
(a)(i)	Use of $\lambda t_{1/2} = \ln 2$	(1)	
	$\lambda = 5.8 \times 10^{-8}$ (s^{-1})	(1)	
	Use of $\frac{\Delta N}{\Delta t} = -\lambda N$	(1)	
	$\frac{\Delta N}{\Delta t} = (-)1.5\times10^{8}$ Bq [accept s^{-1} **Or** counts s^{-1}]	(1)	**4**
	Example of calculation $\lambda = \frac{0.693}{(138\times24\times3600)s} = 5.81\times10^{-8}s^{-1}$ $\frac{\Delta N}{\Delta t} = -5.81\times10^{-8}s^{-1}\times2.54\times10^{15} = -1.48\times10^{8}$ Bq		
(a)(ii)	Use of $N = N_0 e^{-\lambda t}$	(1)	
	Fraction of nuclei remaining = 0.90	(1)	
	10% of nuclei have decayed [accept 0.1 **Or** 1/10]	(1)	**3**
	Example of calculation t = 21 × 24 × 3600 s = 1 814 400 s $\frac{N}{N_0} = e^{-5.81\times10^{-8}s^{-1}\times1.81\times10^{6}s}$ $\frac{N}{N_0} = e^{-0.105} = 0.900$ Fraction decayed = 1- 0.9 = 0.1		

(b)	Idea that α-particles are not able to penetrate the (dead layer of) skin (from outside the body)	(1)	
	Damage/danger if energy is transferred to cells/DNA **Or** damage/danger to cells/DNA due to ionisation	(1)	**2**
(c)(i)	$^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}\alpha$		
	Top line correct	(1)	
	Bottom line correct	(1)	**2**
(c)(ii)	So that momentum is conserved	(1)	**1**
(d)	Spontaneous means that the decay cannot be influenced by any external factors.	(1)	
	Random means that we cannot identify which atom/nucleus will (be the next to) decay **Or** we cannot identify when an individual atom/nucleus will decay **Or** we cannot state exactly how many atoms/nuclei will decay in a set time **Or** we can only estimate the fraction of the total number that will decay in the next time interval	(1)	**2**

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(e)	Idea that traces of the isotope will be excreted from the body (and deposited in the surroundings) (1) Idea that the half life is long enough for the activity to be detectable for a long time (1)	**2**
	Total for question	**16**

Q8.

Question Number	Answer	Mark
(a)	A radioactive atom has an unstable nucleus **(1)** which emits α, β, or γ radiation [at least one of α β γ named] **(1)**	**2**
(b)	$C \rightarrow {}^{11}_{5}B + {}^{0}_{1}e^{+} + \nu_e$ Top line correct **(1)** Bottom line correct **(1)**	**2**
(c)	Attempt at mass diference calculation **(1)** Attempt at conversion from (M)eV to J **(1)** $\Delta E = 1.4 \times 10^{-13}$ (J) **(1)** Example of calculation: $\Delta E = 10\,253.6 - 10252.2\text{-}0.5 = 0.889$ MeV $\Delta E = 0.889 \text{ MeV} \times 1.6 \times 10^{-13} \text{ J MeV}^{-1} = 1.42 \times 10^{-13}$ J	**3**
(d)	The idea that the sample will not produce radiation for very long (because carbon-11 has a relatively short half-life) **(1)** β particles are not very ionising **Or** positrons are not very ionising **Or** boron is safe in small amounts **(1)**	**2**
(e)	Use of $\lambda t_{1/2} = \ln 2$ **(1)** $(\lambda = 5.68 \times 10^{-4} \text{ s}^{-1})$ Use of $A = A_0 e^{-\lambda t}$ **(1)** Use $A = 1.58 \times 10^{6}$ Bq in $A = A_0 e^{-\lambda t}$ **(1)** $A_0 = 1.2 \times 10^{7}$ Bq **(1)** Example of calculation: $\lambda = \frac{0.693}{1220 \text{ s}} = 5.68 \times 10^{-4} \text{ s}^{-1}$ $1.58 \times 10^{6} \text{ Bq} = A_0 e^{-5.68 \times 10^{-4} \text{ s}^{-1} \times 60 \times 60 \text{ s}}$ $A_0 = 1.22 \times 10^{7}$ Bq	**4**
	Total for question	**13**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	An explanation that makes reference to the following: • use a GM tube and counter to measure the number of counts in a known time (1) • place a piece of aluminium a few mm thick between the source and the detector (1) • α and β will not penetrate aluminium but γ will (1) • so the source that is unchanged is Co 60 and the one with a decreased count is Ra 226 (1)	Answers may refer to the use of a ratemeter instead of a counter	
	<u>OR</u> use a GM tube and counter to measure the number of counts in a known time • place a strong magnet near the source (1) • α and β will be deviated but γ will not (1) • so the source that is unchanged is Co 60 and the one with a decreased count is Ra 226 (1)		**(4)**

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	An explanation that makes reference to a precaution and the reason for it • make sure the source remains at a distance of at least 30 cm from your body to minimise exposure	(1)		
	OR make sure the source is always pointed away from you to minimise exposure	(1)		
	OR only use one source at a time to minimise exposure	(1)		
	• the sources emit ionising radiation which can be harmful to your cells	(1)		**(2)**

Q10.

Question Number	Answer		Mark
(a)	Activity is the rate of decay of (unstable) nuclei **Or** activity is the number of (unstable) nuclei that decay in unit time	**(1)**	1

(b)(i)	Background radiation/count will increase the recorded count **Or** background count must be subtracted from the recorded count **Or** background radiation contributes systematic error to the count [Do not accept "to correct for background radiation"]	**(1)**	**1**
(b)(ii)	Radioactive decay is a random process (so count for a fixed period will vary) [Ignore references to spontaneous, accurate, reliable] Idea that repeating enables a mean/average value to be calculated	**(1)** **(1)**	**2**
(b)(iii)	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ Use of $A = A_0 e^{-\lambda t}$ [allow 2.5 Bq for A_0 here; allow use of $N = N_0 e^{-\lambda t}$] $A = 0.47$ Bq [Allow calculation of number of half lives elapsed and use of $A = A_0\left(\frac{1}{2}\right)^{t/t_{1/2}}$ for mp1 and mp2] <u>Example of calculation:</u> $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{8.0\,\text{d}} = 0.0866\,\text{d}^{-1}$ $A = A_0 e^{-\lambda t} = 6.38 \times \text{e}^{-0.0866\,\text{d}^{-1} \times 30\,\text{d}} = 6.38\,\text{Bq} \times 0.074 = 0.47\,\text{Bq}$	**(1)** **(1)** **(1)**	**3**
(b)(iv)	Idea that people have to be close to or ingest seaweed for any degree of risk **Or** β particles are moderately ionising **Or** β particles can enter body through the skin The half-life is short **Or** after a month the activity has decayed to negligible levels **Or** the radioisotope doesn't remain in the seaweed for very long	**(1)** **(1)**	**2**
	Total for Question		**9**

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Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • Use of $P = P_1 + P_2 = 5\text{D}$ therefore use one lens with power of 2 (D) and one with power of 3 (D) (1)	Example of Calculation $v = 0.5 \times 0.6\text{ m} = 0.3\text{ m}$ $\frac{1}{f} = \frac{1}{0.6\text{ m}} + \frac{1}{0.3\text{ m}}$ $f = 0.2\text{ m}$ $P = 1/0.2\text{ m} = 5\text{D}$	4

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• V at top/start = 0V **Or** recognition "potential divider" **Or** V increases (by implication) **Or** V at bottom = 1.5V (1) • Two sections of wire act as series resistors **Or** $R=\rho l/A$ **Or** comment about R proportional to length **Or** $\frac{V}{1.5} = \frac{R}{R_T}$ (1) • potential difference proportional to length of wire (1)	**Alternative MS** Constant Current (I) in wire (1) p.d. across section of wire $=Ir$ between A and loop (1) Increases from 0V to 1.5V linearly (1)	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• Tangent drawn at 1.5 s (1) • Scales p.d. to give distance (1) • Gradient determined using a base of triangle of at least 1.0 s **Or** use of $s = \frac{(u+v)}{2}t$ **and** correct V read from graph (1) (1) • velocity = 1.0 m s^{-1} – 1.3 m s^{-1}	Example of calculation Gradient $= \frac{1.1\text{V} - 0.2\text{V}}{1.0\text{s}} = 0.9\text{Vs}^{-1}$ As 1.5 V represents 2.00 m $v = 0.9\text{ Vs}^{-1} \times \frac{2.00\text{m}}{1.5\text{V}} = 1.2\text{ ms}^{-1}$	4

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of $v = u + at$	(1)	Example of calculation $1.5\,\text{ms}^{-1} = 1.2\,\text{m s}^{-1} + \text{a} \times 0.5\,\text{s}$ $a = \frac{0.3\,\text{m s}^{-1}}{0.5} = 0.6\,\text{m s}^{-2}$ $0.6\,\text{m s}^{-2} = 9.81\,\text{m s}^{-2} \sin\theta$ $\theta = 3.6°$	4
	• Use of $a = g\sin\theta$	(1)		
	• Calculates a value for a, θ or v (using a SUVAT AND $a = g\sin\theta$)	(1)		
	• Valid comparison of their calculated quantity and the stated quoted uncertainty.	(1)		

Q3.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• The replacement charger will still have to supply the same charge (6510 C)	(1)	MP1: may be awarded for use of 6510 C in a calculation for MP2	4
	• The replacement charging plug takes more time to charge **Or** the old charging plug takes less time to charge	(1)	MP2 calculation to support this using t = Q/I Or if the phone uses 1A the time to charge will be the same	
	• Replacement charging plug uses a lower current therefore reduces heating effect	(1)		
	• The phone may try and draw a current of 1 A which may damage the charging plug	(1)		

Q4.

Question Number	Answer		Mark
(a)	Resistivity is a property of a material **Or** is constant for a material Resistance is a property of a wire/component/object **Or** Resistance depends on dimensions of a wire/component/object	(1) (1)	2
* (b)	*Circuit diagram* Wire and a power supply (accept resistor symbol for wire) Ammeter in series and voltmeter in parallel with wire (an Ohmmeter across a wire with no supply scores 2 marks, an Ohmmeter across a wire with a supply scores 0 marks.) (QWC- Work must be clear and organised in a logical manner using technical wording where appropriate.) *Quantities measured* Current and potential difference **Or** resistance (consistent with diagram) Length of wire Diameter/thickness of wire (not area or radius) *Graph* Graph of R against l **Or** graph of V against l (for constant I) **Or** Graph of R against l/A **Or** Graph of RA against l (this mark is only awarded for a graph including different values of length) *Determination of resistivity* Determine the gradient of a relevant graph (allow for a graph of V against I) $A = \pi d^2/4$ **Or** $A = \pi r^2$ Correct processing to find ρ consistent with the graph (if no gradient, award final mark for statement that $\rho=RA/l$, ρ must be the subject)	(1) (1) (1) (1) (1) (1) (1) (1) (1)	9

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• As the speed increases, drag increases (1) • There is greater fuel consumption to maintain a higher constant speed **Or** the fuel economy reduces at higher speeds to maintain a constant speed (1) • Statement linking fuel economy to engine efficiency (1)	MP1: accept 'air resistance' for 'drag' MP3 e.g. The efficiency of the engine may increase (with speed) but the fuel economy decreases **Or** you can't compare efficiency which is a ratio with fuel consumption/economy which is a volume	3

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V = IR$ (1) • Use of $R = \rho l/A$ (1) • (Min) resistivity = 160 (Ω m) **Or** (max) resistivity = 730 (Ω m) (1) • Compacted clay pathways **and** limestone are present in the soil (1)	Example of calculation $R_{min} = \frac{1.8\ V}{9.5 \times 10^{-8}\ A} = 189.5\ \Omega$ $R_{max} = \frac{8.0\ V}{9.5 \times 10^{-8}\ A} = 842.1\ \Omega$ $\rho_{min} = \frac{RA}{l} = \frac{189.5\ \Omega \times 0.650\ m^2}{0.75\ m} = 164.2$ Ω m $\rho_{max} = \frac{RA}{l} = \frac{842.1\ \Omega \times 0.650\ m^2}{0.75\ m} = 729.8$ Ω m conclusion to be consistent with calculated values	4

Q7.

Question Number	Answer		Mark
(a)(i)	Use of $\lambda t_{1/2} = \ln 2$	(1)	
	$\lambda = 5.8 \times 10^{-8}$ (s^{-1})	(1)	
	Use of $\frac{\Delta N}{\Delta t} = -\lambda N$	(1)	
	$\frac{\Delta N}{\Delta t} = (-)1.5\times10^{8}$ Bq [accept s^{-1} **Or** counts s^{-1}]	(1)	**4**
	Example of calculation $\lambda = \frac{0.693}{(138\times24\times3600)s} = 5.81\times10^{-8}s^{-1}$ $\frac{\Delta N}{\Delta t} = -5.81\times10^{-8}s^{-1}\times2.54\times10^{15} = -1.48\times10^{8}$ Bq		
(a)(ii)	Use of $N = N_0 e^{-\lambda t}$	(1)	
	Fraction of nuclei remaining = 0.90	(1)	
	10% of nuclei have decayed [accept 0.1 **Or** 1/10]	(1)	**3**
	Example of calculation t = 21 × 24 × 3600 s = 1 814 400 s $\frac{N}{N_0} = e^{-5.81\times10^{-8}s^{-1}\times1.81\times10^{6}s}$ $\frac{N}{N_0} = e^{-0.105} = 0.900$ Fraction decayed = 1- 0.9 = 0.1		

(b)	Idea that α-particles are not able to penetrate the (dead layer of) skin (from outside the body)	(1)	
	Damage/danger if energy is transferred to cells/DNA **Or** damage/danger to cells/DNA due to ionisation	(1)	**2**
(c)(i)	$^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}\alpha$		
	Top line correct	(1)	
	Bottom line correct	(1)	**2**
(c)(ii)	So that momentum is conserved	(1)	**1**
(d)	Spontaneous means that the decay cannot be influenced by any external factors.	(1)	
	Random means that we cannot identify which atom/nucleus will (be the next to) decay **Or** we cannot identify when an individual atom/nucleus will decay **Or** we cannot state exactly how many atoms/nuclei will decay in a set time **Or** we can only estimate the fraction of the total number that will decay in the next time interval	(1)	**2**

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(e)	Idea that traces of the isotope will be excreted from the body (and deposited in the surroundings) (1) Idea that the half life is long enough for the activity to be detectable for a long time (1)	**2**
	Total for question	**16**

Q8.

Question Number	Answer	Mark
(a)	A radioactive atom has an unstable nucleus **(1)** which emits α, β, or γ radiation [at least one of α β γ named] **(1)**	**2**
(b)	$C \rightarrow {}^{11}_{5}B + {}^{0}_{1}e^{+} + \nu_e$ Top line correct **(1)** Bottom line correct **(1)**	**2**
(c)	Attempt at mass diference calculation **(1)** Attempt at conversion from (M)eV to J **(1)** $\Delta E = 1.4 \times 10^{-13}$ (J) **(1)** Example of calculation: $\Delta E = 10\,253.6 - 10252.2\text{-}0.5 = 0.889$ MeV $\Delta E = 0.889 \text{ MeV} \times 1.6 \times 10^{-13} \text{ J MeV}^{-1} = 1.42 \times 10^{-13}$ J	**3**
(d)	The idea that the sample will not produce radiation for very long (because carbon-11 has a relatively short half-life) **(1)** β particles are not very ionising **Or** positrons are not very ionising **Or** boron is safe in small amounts **(1)**	**2**
(e)	Use of $\lambda t_{1/2} = \ln 2$ **(1)** $(\lambda = 5.68 \times 10^{-4} \text{ s}^{-1})$ Use of $A = A_0 e^{-\lambda t}$ **(1)** Use $A = 1.58 \times 10^{6}$ Bq in $A = A_0 e^{-\lambda t}$ **(1)** $A_0 = 1.2 \times 10^{7}$ Bq **(1)** Example of calculation: $\lambda = \frac{0.693}{1220 \text{ s}} = 5.68 \times 10^{-4} \text{ s}^{-1}$ $1.58 \times 10^{6} \text{ Bq} = A_0 e^{-5.68 \times 10^{-4} \text{ s}^{-1} \times 60 \times 60 \text{ s}}$ $A_0 = 1.22 \times 10^{7}$ Bq	**4**
	Total for question	**13**

Q9.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• as the lift accelerates the accelerating force is equal to $T–mg$ **Or** $T - mg = ma$ **Or** $T = mg + ma$	(1)	Accept force provided by motor for the tension in the lift cable (T)	
	• greater power when accelerating because there is a resultant/accelerating force.	(1)	Accept **correct** references to frictional force (not air resistance) e.g. for MP1 $T - mg -$ frictional force $= ma$	
	• lower power when at constant velocity as just need to overcome weight (of lift and passengers)	(1)		
	• greater power as the number of passengers increases because **weight** (of lift + passengers) increases (as well as the accelerating force)	(1)		**(4)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to **four** of the following: <u>Disadvantages</u> because it doesn't take into account: • mass of passengers **Or** variations in load (1) • additional power needed to accelerate lift (1) • assumes full power used all the time (1) • efficiency of the motor (1) • suitable reference to other energy consumption such as lighting or opening/closing doors (1) • lift usage would decrease/change if there is more than one lift (1)	To award all 4 marks at least one mark must be awarded for the discussion of an advantage Allow credit for a correct equivalent point provided it has a physics basis	**(4)**

	<u>Advantages</u> because: • can give a basic comparison between motors (1) • energy estimate will take into account the height of the building (1) • gives a value for operational energy use (1)		

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Must give at least one benefit to obtain full marks **Risks** • Increased speed produces increased kinetic energy so more energy to dissipate in a collision **(1) OR** collisions more likely to result in injury **(1) OR** collisions more likely to cause damage to vehicle/property **(1)** • Human reaction time unchanged so thinking distance is larger at higher speed **(1)** • Greater likelihood of colliding with stationary traffic **(1) OR** Greater hazard to stationary vehicles **(1) OR** maintenance crews on the hard shoulder **(1)** • Road surfaces need to be better maintained **(1)** **Benefits** • Shorter journey times **(1)** • Cars on road for shorter time leading to less congestion **(1)**	Allow credit for correct equivalent points provided they have a physics basis.	**4**