National
Qualifications
2016

2016 Physics

Advanced Higher

Finalised Marking Instructions

General Marking Principles for Advanced Higher Physics

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in the paper. These principles must be read in conjunction with the detailed marking instructions, which identify the key features required in candidate responses.

(a) Marks for each candidate response must always be assigned in line with these General Marking Principles and the Detailed Marking Instructions for this assessment.

(b) Marking should always be positive. This means that, for each candidate response, marks are accumulated for the demonstration of relevant skills, knowledge and understanding: they are not deducted from a maximum on the basis of errors or omissions.

(c) If a specific candidate response does not seem to be covered by either the principles or detailed Marking Instructions, and you are uncertain how to assess it, you must seek guidance from your Team Leader.

(d) There are no half marks awarded.

(e) Where a wrong answer to part of a question is carried forward and the wrong answer is then used correctly in the following part, the candidate should be given credit for the subsequent part or 'follow on'.

(f) Unless a numerical question specifically requires evidence of working to be shown, full marks should be awarded for a correct final answer (including units if required) on its own

(g) Credit should be given where a diagram or sketch conveys correctly the response required by the question. It will usually require clear and correct labels (or the use of standard symbols).

(h) Marks are provided for knowledge of relevant relationships alone, but when a candidate writes down several relationships and does not select the correct one to continue with, for example by substituting values, no mark can be awarded.

(i) Marks should be awarded for non-standard symbols where the symbols are defined and the relationship is correct, or where the substitution shows that the relationship used is correct. This must be clear and unambiguous.

(j) Where a triangle type "relationship" is written down and then not used or used incorrectly, then any mark for a relationship should not be awarded.

(k) **Significant figures**
Data in question is given to 3 significant figures.
Correct final answer is 8·16 J
Final answer 8·2 J or 8·158 J or 8·1576 J – Award the final mark.
Final answer 8 J or 8·15761 J – Do not award the final mark
Candidates should not be credited for a final answer that includes:

- three or more figures too many
  or
- two or more figures too few, ie accept two more or one fewer

(l) The incorrect spelling of technical terms should usually be ignored and candidates should be awarded the relevant mark, provided that answers can be interpreted and understood without any doubt as to the meaning. Where there is ambiguity, the mark should not be awarded. Two specific examples of this would be when the candidate uses a term that might be interpreted as 'reflection', 'refraction' or 'diffraction' (eg 'defraction') or one that might be interpreted as either 'fission' or 'fusion' (eg 'fussion').

(m) Marks are awarded only for a valid response to the question asked. For example, in response to questions that ask candidates to:

- **describe**, they must provide a statement or structure of characteristics and/or features;
- **determine** or **calculate**, they must determine a number from given facts, figures or information;
- **estimate**, they must determine an approximate value for something;
- **explain**, they must relate cause and effect and/or make relationships between things clear;
- **identify**, **name**, **give**, or **state**, they need only name or present in brief form;
- **justify**, they must give reasons to support their suggestions or conclusions, eg this might be by identifying an appropriate relationship and the effect of changing variables;
- **predict**, they must suggest what may happen based on available information;
- **show that**, they must use physics [and mathematics] to prove something eg a given value – *all steps, including the stated answer, must be shown*;
- **suggest**, they must apply their knowledge and understanding of physics to a new situation. A number of responses are acceptable: marks will be awarded for any suggestions that are supported by knowledge and understanding of physics;
- **use your knowledge of physics or aspect of physics to comment on**, they must apply their skills, knowledge and understanding to respond appropriately to the problem/situation presented (for example by making a statement of principle(s) involved and/or a relationship or equation, and applying these to respond to the problem/situation). They will be rewarded for the breadth and/or depth of their conceptual understanding.

(n) Marking in calculations

Question:

The current in a resistor is 1·5 amperes when the potential difference across it is 7·5 volts. Calculate the resistance of the resistor. (3 marks)

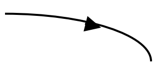
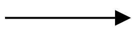
Candidate answer	Mark + Comment
1. $V = IR$	1 mark: formula
$7{\cdot}5 = 1{\cdot}5R$	1 mark: substitution
$R = 5{\cdot}0\ \Omega$	1 mark: correct answer
2. $5{\cdot}0\ \Omega$	3 marks: correct answer
3. $5{\cdot}0$	2 marks: unit missing
4. $4{\cdot}0\ \Omega$	0 marks: no evidence, wrong answer
5. $\_\_\ \Omega$	0 marks: no working or final answer
6. $R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = 4{\cdot}0\ \Omega$	2 marks: arithmetic error
7. $R = \frac{V}{I} = 4{\cdot}0\ \Omega$	1 mark: formula only
8. $R = \frac{V}{I} = \_\_\ \Omega$	1 mark: formula only
9. $R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = \_\_\ \Omega$	2 marks: formula & subs, no final answer
10. $R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = 4{\cdot}0$	2 marks: formula & subs, wrong answer
11. $R = \frac{V}{I} = \frac{1{\cdot}5}{7{\cdot}5} = 5{\cdot}0\ \Omega$	1 mark: formula but wrong substitution
12. $R = \frac{V}{I} = \frac{75}{1{\cdot}5} = 5{\cdot}0\ \Omega$	1 mark: formula but wrong substitution
13. $R = \frac{I}{V} = \frac{7{\cdot}5}{1{\cdot}5} = 5{\cdot}0\ \Omega$	0 marks: wrong formula
14. $V=IR$	2 marks: formula & subs, arithmetic error
$7{\cdot}5 = 1{\cdot}5 \times R$	
$R = 0{\cdot}2\ \Omega$	
15. $V=IR$	
$R = \frac{I}{V} = \frac{1{\cdot}5}{7{\cdot}5} = 0{\cdot}2\ \Omega$	1 mark: formula correct but wrong rearrangement of symbols

Detailed Marking Instructions for each question

Question			Answer	Max Mark	Additional Guidance
1.	(a)		$v = 0\cdot135t^2 + 1\cdot26t$ $a = \frac{dv}{dt} = 0\cdot135 \times 2t + 1\cdot26$ **1** $a = (0\cdot135 \times 2 \times 15\cdot0) + 1\cdot26$ **1** $a = 5\cdot31\ \text{m s}^{-2}$ **1**	**3**	Accept $5\cdot3\ \text{m s}^{-2}$, $5\cdot310\ \text{m s}^{-2}$, $5\cdot3100\ \text{m s}^{-2}$
	(b)		$v = 0\cdot135t^2 + 1\cdot26t$ $s = \int_0^{15\cdot0} v.dt = \left[0\cdot045t^3 + 0\cdot63t^2\right]_0^{15\cdot0}$ **1** $s = (0\cdot045 \times 15\cdot0^3) + (0\cdot63 \times 15\cdot0^2)$ **1** $s = 294\ \text{m}$ **1**	**3**	Accept 290 m, 293·6 m, 293·63 m Constant of integration method acceptable.

Question			Answer	Max Mark	Additional Guidance
2.	(a)	(i)	velocity changing or changing direction or an unbalanced force is acting or a centripetal/central/radial force is acting	**1**	
		(ii)	towards the centre	**1**	towards the axis/pole
	(b)	(i) (A)	SHOW QUESTION $\omega = \frac{d\theta}{dt}$ OR $\omega = \frac{\theta}{t}$ **1** $\omega = \frac{1 \cdot 5 \times 2\pi}{2 \cdot 69}$ **1** $\omega = 3 \cdot 5 \text{ rad s}^{-1}$	**2**	$\omega = \frac{v}{r}$ and $v = \frac{d}{t}$ 1 $\omega = \frac{1 \cdot 5 \times 2 \times \pi \times 0 \cdot 48}{2 \cdot 69 \times 0 \cdot 48}$ 1 $\omega = 3 \cdot 5 \text{ rad s}^{-1}$ If final answer not stated, max 1 mark
		(B)	$F = mr\omega^2$ **1** $F = 0 \cdot 059 \times 0 \cdot 48 \times 3 \cdot 5^2$ **1** $F = 0 \cdot 35 \text{ N}$ **1**	**3**	Accept 0·3, 0·347, 0·3469 $F = \frac{mv^2}{r}$ 1 $F = \frac{0 \cdot 059 \times \left(\frac{1 \cdot 5 \times 2 \times \pi \times 0 \cdot 48}{2 \cdot 69}\right)^2}{0 \cdot 48}$ 1 $F = 0 \cdot 35 \text{ N}$ 1
		(C)	$W = mg$ $W = 0 \cdot 059 \times 9 \cdot 8$ **1** $T^2 = 0 \cdot 35^2 + (0 \cdot 059 \times 9 \cdot 8)^2$ **1** $T = 0 \cdot 68 \text{ N}$ **1** 1 mark for calculating weight 1 mark for Pythagorean relationship 1 mark for final answer	**3**	Accept 0·7, 0·676, 0·6759 $W = mg$ $W = 0 \cdot 059 \times 9.8$ 1 $\theta = \tan^{-1}\left(\frac{0 \cdot 35}{0 \cdot 059 \times 9 \cdot 8}\right)$ $\sin\theta = \frac{0 \cdot 35}{T}$ 1 for both $T = 0 \cdot 68 \text{ N}$ 1
		(ii)	In a straight line at a tangent to the circle	**1**	Any parabolic path is not acceptable.

Question			Answer	Max Mark	Additional Guidance
3.	(a)		$v=\sqrt{\frac{2GM}{r}}$ **1** $v=\sqrt{\frac{2\times 6\cdot 67\times 10^{-11}\times 9\cdot 5\times 10^{12}}{2\cdot 1\times 10^{3}}}$ **1** $v=\sqrt{0\cdot 603}$ $v=0\cdot 78\ (\text{m s}^{-1})$ **1** (lander returns to surface as) lander v less than escape velocity of comet **1**	**4**	
	(b)	(i)	SHOW QUESTION $(F_g = W)$ $\frac{GMm}{r^2}=mg$ **1** for both eqns, **1** for equating $g=\frac{GM}{r^2}$ $g=\frac{6\cdot 67\times 10^{-11}\times 9\cdot 5\times 10^{12}}{\left(2\cdot 1\times 10^{3}\right)^{2}}$ **1** $g=1\cdot 4\times 10^{-4}\ \text{N kg}^{-1}$	**3**	Show question, if final line is missing then a maximum of two marks. If the 2nd line is missing then 1 mark maximum for $F_g = W$ $\frac{F}{m}=\frac{GM}{r^2}$ or $g=\frac{GM}{r^2}$ As a starting point, zero marks
		(ii)	Height will be greater **1** Because '*a*' reduces **1** with height **1**	**3**	'Must justify' question Alternative: Assumption that '*a*' is constant is invalid 1 The value for '*a*' is too large 1

Question			Answer	Max Mark	Additional Guidance
4.	(a)		$b = \frac{L}{4\pi r^2}$ **1** $1 \cdot 05 \times 10^{-9} = \frac{L}{4\pi (9 \cdot 94 \times 10^{16})^2}$ **1** $L = 1 \cdot 30 \times 10^{26}$ W **1**	**3**	Accept 1·3, 1·304,1·3037
	(b)		$L = 4\pi r^2 \sigma T^4$ **1** $1 \cdot 30 \times 10^{26} = 4\pi (5 \cdot 10 \times 10^{8})^2 \times$ $5 \cdot 67 \times 10^{-8} \times T^4$ **1** $T = 5150$ K **1**	**3**	Or consistent with (a) Accept 5100, 5146, 5146·4
	(c)		That the star is a black body (emitter/radiator) **OR** the star is spherical/constant radius **OR** the surface temperature of the star is constant/uniform **OR** no energy absorbed between star and Earth	**1**	
5.	(a)	(i)	Frames of reference that are accelerating (with respect to an inertial frame)	**1**	
		(ii)	It is impossible to tell the difference between the effects of gravity and acceleration.	**1**	
	(b)	(i)		**1**	Any convex upward parabola.
		(ii)		**1**	Any straight line.
	(c)		The clock on the surface of the Earth would run more slowly. 1 The (effective) gravitational field for the spacecraft is smaller. 1 Or vice versa.	**2**	

Question			Answer	Max Mark	Additional Guidance
6.			Demonstrates no understanding 0 marks Demonstrates limited understanding 1 marks Demonstrates reasonable understanding 2 marks Demonstrates good understanding 3 marks This is an open-ended question. **1 mark:** The student has demonstrated a limited understanding of the physics involved. The student has made some statement(s) which is/are relevant to the situation, showing that at least a little of the physics within the problem is understood. **2 marks**: The student has demonstrated a reasonable understanding of the physics involved. The student makes some statement(s) which is/are relevant to the situation, showing that the problem is understood. **3 marks:** The maximum available mark would be awarded to a student who has demonstrated a good understanding of the physics involved. The student shows a good comprehension of the physics of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one.	**3**	Open-ended question: a variety of physics arguments can be used to answer this question. Marks are awarded on the basis of whether the answer overall demonstrates "no", "limited", "reasonable" or "good" understanding.

Question			Answer	Max Mark	Additional Guidance
7.	(a)	(i)	$T_K = 15 + 273$ **1** $T_{kelvin} = \frac{b}{\lambda_{peak}}$ $288 = \frac{2\cdot 89x10^{-3}}{\lambda_{peak}}$ **1** $\lambda_{peak} = 1\cdot 0 \times 10^{-5}$ m **1**	**3**	Accept 1, 1·00, 1·003 Also accept 1·0035 Incorrect/no conversion to kelvin - zero marks
		(ii)	Infrared	**1**	Consistent with answer to a(i).
	(b)	(i)	(curve) A **1** Peak at shorter wavelength/higher frequency (as Temperature is higher) **1** **OR** Higher/greater (peak) intensity (as greater energy) **1**	**2**	
		(ii)	curve (approximately) asymptotic to y-axis and decreasing with increased wavelength	**1**	Intercept of y-axis — zero marks

Question			Answer	Max Mark	Additional Guidance
8.	(a)	(i)	$\Delta p_x =$ the uncertainty in the momentum (in the x-direction.)	**1**	
		(ii)	The precise position of a particle/ system and its momentum cannot both be known at the same instant. **1** **OR** If the uncertainty in the location of the particle is reduced, the minimum uncertainty in the momentum of the particle will increase (or vice-versa). **1** **OR** The precise energy and lifetime of a particle cannot both be known at the same instant. **1** **OR** If the uncertainty in the energy of the particle is reduced, the minimum uncertainty in the lifetime of the particle will increase (or vice-versa). **1**	**1**	"At the same instant/ simultaneously" required Confusion of accuracy with precision award zero marks.
	(b)	(i)	$\lambda = \frac{h}{p}$ **1** $\lambda = \frac{6 \cdot 63 \times 10^{-34}}{6 \cdot 5 \times 10^{-24}}$ **1** $\lambda = 1 \cdot 0 \times 10^{-10}$ (m) **1** slit width $0 \cdot 1$ nm used **1**	**4**	
		(ii)	$\Delta x \Delta p_x \geq \frac{h}{4\pi}$ **1** $\Delta x \times 6 \cdot 5 \times 10^{-26} \geq \frac{6 \cdot 63 \times 10^{-34}}{4\pi}$ **1** $\Delta x \geq 8 \cdot 1 \times 10^{-10}$ min uncertainty = $8 \cdot 1 \times 10^{-10}$ m **1**	**3**	Accept 8, 8·12, 8·117
		(iii)	Electron behaves like a wave "Interference" Uncertainty in position is greater than slit separation Electron passes through both slits	**3**	Any three of the statements can be awarded 1 mark each.

Question			Answer	Max Mark	Additional Guidance
9.	(a)		SHOW QUESTION $m\frac{v^2}{r} = Bqv(\sin\theta)$ 1 for both relationships 1 for equating $r = \frac{mv}{Bq}$	**2**	If the final line is missing then a maximum of 1 mark can be awarded
	(b)	(i)	$1\cdot50\ (\text{MeV}) = 1\cdot50 \times 10^6 \times 1\cdot60 \times 10^{-19}$ $= 2\cdot40 \times 10^{-13}\ (\text{J})$ **1** $E_k = \frac{1}{2}mv^2$ **1** $2\cdot40\times10^{-13} = 0\cdot5\times3\cdot34\times10^{-27}\times v^2$ **1** $v = 1\cdot20\times10^7\ \text{m s}^{-1}$ **1**	**4**	Accept 1·2, 1·199, 1·1988 No conversion to J - Max 1 mark Calculation of deuteron mass by adding mass of proton and neutron is incorrect - max 2
		(ii)	$r = \frac{mv}{Bq}$ $2\cdot50 = \frac{3\cdot34\times10^{-27}\times1\cdot20\times10^7}{B\times1\cdot60\times10^{-19}}$ **1** $B = 0\cdot100\ \text{T}$ **1**	**2**	Final answer consistent with b(i) Suspend the significant figure rule and accept $0\cdot1$
		(iii)	r will be less **1** $r \propto \frac{m}{q}$ **and** q increases more than m does **1** or q doubles but m × 1·5	**2**	Justification involving an increase in charge without mentioning mass - max 1

Question			Answer	Max Mark	Additional Guidance
10.	(a)	(i)	displacement is proportional to and in the opposite direction to the acceleration	**1**	$F = -ky$ or equivalent
		(ii)	SHOW QUESTION $y = A\cos\omega t$ $\frac{dy}{dt} = -\omega A\sin\omega t$ $\frac{d^2y}{dt^2} = -\omega^2 A\cos\omega t$ **1** $\frac{d^2y}{dt^2} = -\omega^2 y$ **1** $\frac{d^2y}{dt^2} + \omega^2 y = 0$	**2**	If final line not shown then max 1 mark can be awarded Award zero marks if: $\frac{dy}{dt} = \omega A\sin\omega t$ appears First mark can only be awarded if both the first and second differentiations are included.
	(b)	(i)	$T = \frac{12\cdot0}{10}$ **1** $\omega = \frac{2\pi}{T}$ **1** $\omega = \frac{2\pi\times10}{12}$ **1** $\omega = 5\cdot2$ rad s^{-1}	**3**	If final line not shown maximum 2 marks $f = \frac{10}{12}$ 1 $\omega = 2\pi f$ 1 $\omega = \frac{2\pi\times10}{12}$ 1 $\omega = 5\cdot2$ rad s^{-1} **OR** $\theta = 2\pi\times10$ 1 $\omega = \frac{\theta}{t}$ 1 $\omega = \frac{2\pi\times10}{12}$ 1 $\omega = 5\cdot2$ rad s^{-1}
		(ii)	$v = (\pm)\omega\sqrt{A^2 - y^2}$ **1** $v = 5\cdot2\times0\cdot04$ **1** $v = 0\cdot21$ m s^{-1} **1**	**3**	Accept $v_{max} = \omega A$ Accept 0·2, 0·208, 0·2080

Question			Answer	Max Mark	Additional Guidance
		(iii)	$E_P = \frac{1}{2} m\omega^2 y^2$ **1** $E_P = \frac{1}{2} \times 1 \cdot 5 \times 5 \cdot 2^2 \times 0 \cdot 04^2$ **1** $E_P = 0 \cdot 032 \text{ J}$ **1**	**3**	Accept 0·03, 0·0324. 0·03245 $E_K = \frac{1}{2} mv^2$ **1** $= 0 \cdot 5 \times 1 \cdot 5 \times 0 \cdot 21^2$ **1** $= 0 \cdot 033 \text{ J}$ **1** Accept 0·03, 0·0331, 0·03308
	(c)	(i)	Any valid method of damping.	**1**	A practical method must be described. For example, place mass in a more viscous medium, increase the surface area of the mass.
		(ii)	amplitude of harmonic wave reducing.	**1**	Graph must show positive and negative amplitude.

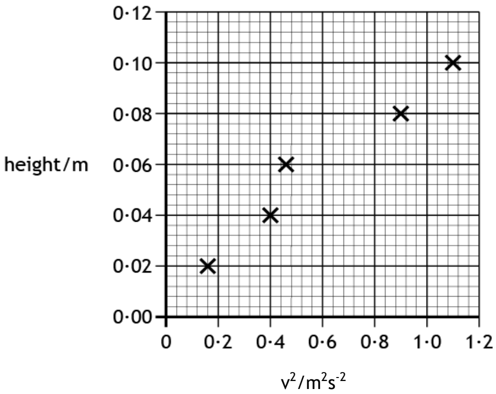
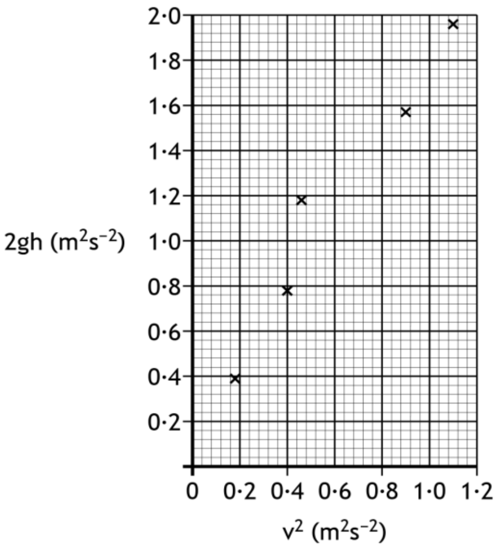
Question			Answer	Max Mark	Additional Guidance
11	(a)		$\frac{1}{\lambda}=0\cdot357$ **1** $\lambda=\frac{1}{0\cdot357}$ $v=f\lambda$ **1** $v=118\times\frac{1}{0\cdot357}$ **1** $v=331\text{ m s}^{-1}$ **1**	4	Accept 330, 330·5, 330·53
	(b)		$E=kA^2$ **1** $\frac{E_1}{A_1^2}=\frac{E_2}{A_2^2}$ $\frac{1}{0\cdot250^2}=\frac{0\cdot5}{A_2^2}$ **1** $A_2=0\cdot177\text{ (m)}$ **1** $y=0\cdot177\sin 2\pi(118t+0\cdot357x)$ **1**	4	$A_1=\sqrt{2}\times A_2$ acceptable method Accept 0·18, 0·1768, 0·17678 Final mark is independent and for: $\sin 2\pi(118t+0\cdot357x)$ $y=0\cdot177\sin(744t+2\cdot24x)$

Question			Answer	Max Mark	Additional Guidance
12.	(a)		(The axes should be arranged) at 90° to each other (eg horizontal and vertical.)	**1**	Perpendicular to each other.
	(b)		The filter for each eye will allow light from one projected image to pass through. **1** while blocking the light from the other projector. **1**	**2**	'only one projected image to pass through to each eye' **2** **OR** 'Light from one projector gets through to one eye. Light from the other projector gets through to the other eye' **2**
	(c)		There will be no change to the brightness. **1** Light from the lamp is unpolarised. **1**	**2**	
	(d)		(As the student rotates the filter,) the image from one projector will decrease in brightness, while the image from the other projector will increase in brightness. (The two images are almost identical). **1**	**1**	

Question			Answer	Max Mark	Additional Guidance
13	(a)		SHOW QUESTION $V = \frac{1}{4\pi\varepsilon_o}\frac{Q_1}{r}$ **1** $V = \frac{1}{4\pi \times 8 \cdot 85 \times 10^{-12}}\frac{12 \times 10^{-9}}{0 \cdot 30}$ **1** $V = (+)360\ \text{V}$	2	$V = k\frac{Q_1}{r}$ **1** $V = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{0 \cdot 30}$ **1** **OR** $V = \frac{12 \times 10^{-9}}{1 \cdot 1 \times 10^{-10} \times 0 \cdot 30}$ $V = (+)360\ \text{V}$ If either a value for k or ε_0 is not given, then a maximum of 1 mark can be awarded. If the final line is missing then a maximum of 1 mark can be awarded
	(b)	(i)	V = -360 (V) **1** $V = \frac{1}{4\pi\varepsilon_o}\frac{Q_2}{r}$ $-360 = \frac{Q_2}{4\pi \times 8 \cdot 85 \times 10^{-12} \times 0 \cdot 40}$ **1** $Q_2 = -1 \cdot 6 \times 10^{-8}\ \text{C}$ **1**	3	Accept 2, 1·60, 1·601 Use of 9×10^9 acceptable Accept 2, 1·60, 1·600 Use of ratio method acceptable. Must start with $V_1 + V_2 = 0$ or equivalent. V = +360V – zero marks
		(ii)	$E_1 = \frac{1}{4\pi\varepsilon_o}\frac{Q_1}{r^2}$ **1** $E_1 = \frac{1}{4\pi \times 8 \cdot 85 \times 10^{-12}}\frac{12 \times 10^{-9}}{0 \cdot 30^2}$ **1** $E_1 = 1200\ (\text{N C}^{-1}\ \textit{to right})$ $E_2 = \frac{1}{4\pi \times 8 \cdot 85 \times 10^{-12}}\frac{1 \cdot 6 \times 10^{-8}}{0 \cdot 40^2}$ **1** $E_2 = 900\ (\text{N C}^{-1}\ \text{to right})$ $\textit{Total} = 2100\ \text{N C}^{-1}\ (\text{to right})$ **1**	4	Accept 2000, 2098 Allow correct answer or consistent with b(i).
		(iii)	Shape of attractive field, including correct direction **1** Skew in correct position **1**	2	Field consistent with (b) (i)

Question			Answer	Max Mark	Additional Guidance
14.	(a)		$B = \frac{\mu_o I}{2\pi r}$ **1** $B = 5\times10^{-6} = \frac{4\pi\times10^{-7}\times I}{2\pi\times0\cdot1}$ **1** $I = 2\cdot5$ A **1**	**3**	Accept 3, 2·50, 2·500
	(b)	(i)	ignore calibration (less than 1/3) $\%\text{unc} = 0\cdot002/0\cdot1\times100 = 2\%$ **1**	**1**	Accept 2·1% if calibration not ignored. (Accept 2%, 2·06%, 2.062%)
		(ii)	reading $5 = 0\cdot1/5\times100 = 2\%$ **1** total%=√(reading%^{2}+calibration%^{2}) **1** total % = √(1·5^2 + 2^2) = 2·5% **1**	**3**	Accept 3%, 2·50%, 2·500%
		(iii)	total % = √(2^2 + 2·5^2)=√10·25% **1** abs u/c= $\frac{\sqrt{10\cdot25}}{100}$ × 2·5 = 0·08 A **1**	**2**	Accept 0·1, 0·080, 0·0800 Consistent with b(i) and (ii).
	(c)		Uncertainty in measuring exact distance from wire to position of sensor.	**1**	

Question			Answer	Max Mark	Additional Guidance
15.	(a)	(i)	$gradient = \frac{8 \cdot 3 \times 10^{-10}}{10^3}$ $= 8 \cdot 3 \times 10^{-13}$ **1** -------------------------------- $gradient = \varepsilon_0 A$ **1** $8 \cdot 3 \times 10^{-13} = \varepsilon_0 \times 9 \cdot 0 \times 10^{-2}$ $\varepsilon_0 = 9 \cdot 2 \times 10^{-12}$ F m^{-1} **1**	**3**	Accept 9, 9·22, 9·222 If gradient calculated using two points from best fit line, full credit possible.
		(ii)	$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ **1** $c = \frac{1}{\sqrt{9 \cdot 2 \times 10^{-12} \times 4\pi \times 10^{-7}}}$ **1** $c = 2 \cdot 9 \times 10^8$ m s^{-1} **1**	**3**	Accept 3, 2·94, 2·941 Or consistent with (a)(i)
	(b)		Systematic uncertainty specific to capacitance or spacing measurement	**1**	Systematic uncertainty: Large % uncertainty in smallest values of d Stray capacitance Dip in plates/non uniform plate separation. Insufficient/poor choice of range. 'Systematic uncertainty' on its own – 0 marks

Question			Answer	Max Mark	Additional Guidance
16.	(a)		$I=\frac{2}{5}mr^2$ **1** $I=\frac{2}{5}\times3\cdot8\times0\cdot053^2$ **1** $I=4\cdot3\times10^{-3}\ \text{kg m}^2$ **1**	**3**	Accept 4, 4·27, 4·270
	(b)	(i)	Labelling & scales **1** Plotting **1** best fit line **1** ½ box tolerance applies for plotting	**3**	If rogue point not ignored, do not award the mark for best fit line, unless incorrect plotting does not expose a rogue point.  

Question			Answer	Max Mark	Additional Guidance
		(ii)	*gradient* = 1·73 or consistent with candidate's best fit line. 1 --- $2gh=\left(\frac{I}{mr^2}+1\right)v^2$ $\frac{2gh}{v^2}=\left(\frac{I}{mr^2}+1\right)$ $1\cdot 73=\left(\frac{I}{3\cdot 8\times 0\cdot 053^2}+1\right)$ **1** $I=7\cdot 8\times 10^{-3}\text{ kg m}^2$ **1**	**3**	The gradient should be calculated using points from the candidate's best fit line to access the first mark. $\frac{h}{v^2}=\frac{1}{2g}\left(\frac{I}{mr^2}+1\right)$ $0\cdot 088=\frac{1}{2\times 9\cdot 8}\left(\frac{I}{3\cdot 8\times 0\cdot 053^2}+1\right)$ **1** $I=7\cdot 74\times 10^{-3}\text{kg m}^2$ 1

Question			Answer	Max Mark	Additional Guidance
	(c)		Demonstrates no understanding 0 marks Demonstrates limited understanding 1 marks Demonstrates reasonable understanding 2 marks Demonstrates good understanding 3 marks This is an open-ended question. **1 mark:** The student has demonstrated a limited understanding of the physics involved. The student has made some statement(s) which is/are relevant to the situation, showing that at least a little of the physics within the problem is understood. **2 marks**: The student has demonstrated a reasonable understanding of the physics involved. The student makes some statement(s) which is/are relevant to the situation, showing that the problem is understood. **3 marks:** The maximum available mark would be awarded to a student who has demonstrated a good understanding of the physics involved. The student shows a good comprehension of the physics of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one.	**3**	Open-ended question: a variety of physics arguments can be used to answer this question. Marks are awarded on the basis of whether the answer overall demonstrates "no", "limited", "reasonable" or "good" understanding.

[END OF MARKING INSTRUCTIONS]