National
Qualifications
2025

2025 Physics

Advanced Higher

Question Paper Finalised Marking Instructions

General marking principles for Physics Advanced Higher

Always assign marks for each candidate response in line with these marking principles, the Physics: general marking principles (GMPs) (Physics: general marking principles - National 3 to Advanced Higher (sqa.org.uk)) and the detailed marking instructions for this assessment.

(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted from a maximum on the basis of errors or omissions.

(b) 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.

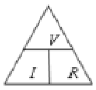
(c) Where a candidate incorrectly answers part of a question and carries the incorrect answer forward in the following part, award marks if the incorrect answer has then been used correctly in the subsequent part or 'follow-on'. (GMP 16)

(d) Award full marks for a correct final answer (including units if required) on its own, unless a numerical question specifically requires evidence of working to be shown, eg in a 'show' question. (GMP 1a)

(e) Award marks where a diagram or sketch correctly conveys the response required by the question. Clear and correct labels (or the use of standard symbols) are usually required for marks to be awarded. (GMP 19)

(f) Award marks for knowledge of relevant relationships alone. When a candidate writes down several relationships and does not select the correct one to continue with, for example by substituting values, do not award a mark. (GMP 1c)

(g) Award marks for the use of 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. (GMP 20)

(h) Do not award marks if a 'magic triangle' (eg) 

is the only statement in a candidate's response. To gain the mark, the correct relationship must be stated, for example $V = IR$ or $R = \frac{V}{I}$. (GMP 2)

(i) In rounding to an expected number of significant figures, award the mark for responses that have up to two figures more or one figure less than the number in the data with the fewest significant figures. (GMP 6)

For example:

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

(Note: the use of a recurrence dot, eg $0.\dot{6}$, would imply an infinite number of significant figures and would therefore not be acceptable).

(j) Award marks where candidates have incorrectly spelled technical terms, provided that responses can be interpreted and understood without any doubt as to the meaning. Where there is ambiguity, do not award the mark. Two specific examples of this would be when the candidate uses a term that might be interpreted as 'reflection', 'refraction' or 'diffraction' (for example 'defraction'), or one that might be interpreted as either 'fission' or 'fusion' (for example 'fussion'). (GMP 22)

(k) **Only award m**arks for a valid response to the question asked. Where candidates are asked to:

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

(l) Marking in calculations

Example 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)

	Example response	Mark and comment
1.	$V = IR$ $7.5 = 1.5R$ $R = 5.0\ \Omega$	1 mark: relationship 1 mark: substitution 1 mark: correct answer
2.	$5.0\ \Omega$	3 marks: correct answer
3.	5.0	2 marks: unit missing
4.	$4.0\ \Omega$	0 marks: no evidence, wrong answer
5.	$\_\_\ \Omega$	0 marks: no working or final answer
6.	$R = \frac{V}{I} = \frac{7.5}{1.5} = 4.0\ \Omega$	2 marks: arithmetic error
7.	$R = \frac{V}{I} = 4.0\ \Omega$	1 mark: relationship only
8.	$R = \frac{V}{I} = \_\_\ \Omega$	1 mark: relationship only
9.	$R = \frac{V}{I} = \frac{7.5}{1.5} = \_\_\ \Omega$	2 marks: relationship and substitution, no final answer
10.	$R = \frac{V}{I} = \frac{7.5}{1.5} = 4.0$	2 marks: relationship and substitution, wrong answer
11.	$R = \frac{V}{I} = \frac{1.5}{7.5} = 5.0\ \Omega$	1 mark: relationship but wrong substitution
12.	$R = \frac{V}{I} = \frac{75}{1.5} = 5.0\ \Omega$	1 mark: relationship but wrong substitution
13.	$R = \frac{I}{V} = \frac{1.5}{7.5} = 5.0\ \Omega$	0 marks: wrong relationship
14.	$V = IR$ $7.5 = 1.5 \times R$ $R = 0.2\ \Omega$	2 marks: relationship and substitution, arithmetic error
15.	$V = IR$ $R = \frac{I}{V} = \frac{1.5}{7.5} = 0.2\ \Omega$	1 mark: relationship correct but wrong rearrangement of symbols

Marking Instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)		$a\left(=\frac{dv}{dt}\right)=(2\times0.09\times t)-7.0$ (1) $a=(2\times0.09\times15)-7.0$ (1) $a=-4.3\ \text{ms}^{-2}$ (1)	**3**	Accept: -4, -4.30, -4.300 Do not accept: $a=\frac{dv}{dx}$ or $a=\frac{dy}{dx}$
	(b)		$s\left(=\int v\,dt\right)=\frac{0.09t^3}{3}-\frac{7.0t^2}{2}+136t\,(+c)$ (1) (at $t=0, s=0 \therefore c=0$) $t=40$ s (1) $s=\frac{0.09\times40^3}{3}-\frac{7.0\times40^2}{2}+(136\times40)$ (1) $s=1800$ m (1)	**4**	Accept: 2000, 1760 Alternative limits method is acceptable. 1 mark for upper limit 40, 1 mark for integration. $\left(s=\int_0^{40}(0.09t^2-7.0t^2+136)\,dt\right)$ $s=\left[\frac{0.09t^3}{3}-\frac{7.0t^2}{2}+136t\right]_0^{40}$ (1),(1) $s=\left(\frac{0.09\times40^3}{3}-\frac{7.0\times40^2}{2}+136\times40\right)-\left(\frac{0.09\times0^3}{3}-\frac{7.0\times0^2}{2}+136\times0\right)$ (1) $s=1800$ m (1)

Question			Expected response	Max mark	Additional guidance
2.	(a)	(i)	$\omega = \omega_o + \alpha t$ (1) $\omega = (0) + 0.12 \times 34$ (1) $\omega = 4.1\ \text{rad s}^{-1}$ (1)	3	Accept: 4, 4.08, 4.080
		(ii)	$\tau = I\alpha$ (1) $\tau = 2.4 \times 10^4 \times 0.12$ (1) $\tau = 2900\ \text{Nm}$ (1)	3	Accept: 3000, 2880
	(b)		Torque increases (1) as moment of inertia has increased (due to increase in mass). (1)	2	Justify. 'Mass increases' alone, max 1 mark.
	(c)		Friction (between people and wall) no longer balances the weight (of people).	1	'Friction' alone zero marks. Accept: weight now greater than friction.

Question			Expected response	Max mark	Additional guidance
3.	(a)		$\omega = \frac{2\pi}{T}$ (1) $\omega = \frac{2\pi}{1.34}$ (1) $\omega = 4.69 \text{ rad s}^{-1}$	2	SHOW question Final line must be shown or max 1 mark. Alternative starts: $\omega = \frac{d\theta}{dt}, \omega = \frac{\theta}{t}$ $v = r\omega$ and $d = vt$ (1 BOTH equations) **OR** $\omega = 2\pi f$ and $T = \frac{1}{f}$ (1 BOTH equations)
	(b)		$I = \frac{2}{5}mr^2$ (1) $I = \frac{2}{5} \times (2.8 \times 10^{30}) \times (9.74 \times 10^3)^2$ (1) $I = 1.1 \times 10^{38} \text{ kg m}^2$ (1)	3	Accept: 1, 1.06, 1.063
	(c)	(i)	The <u>total</u> angular momentum before (an interaction) is equal to the <u>total</u> angular momentum after (an interaction) in the absence of (net) external torques.	1	
		(ii)	$I_1\omega_1 = I_2\omega_2$ (1) $2.7 \times 10^{42} \times \omega_1 = 1.1 \times 10^{38} \times 4.69$ (1) $\omega_1 = 1.9 \times 10^{-4} \text{ rad s}^{-1}$ (1)	3	Or consistent with (b) Accept: 2, 1.91, 1.911

Question			Expected response	Max mark	Additional guidance
3.	(d)		**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide 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. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	**3**	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

Question			Expected response	Max mark	Additional guidance
4.	(a)	(i)	$v_{esc} = \sqrt{\frac{2GM}{r}}$ (1) $v_{esc} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{6.4 \times 10^{6} + 3.6 \times 10^{5}}}$ (1) $v_{esc} = 1.1 \times 10^{4}\ \text{ms}^{-1}$ (1)	3	Accept: 1, 1.09, 1.088
		(ii)	Allows spacecraft to leave Earth's gravitational field.	1	To ensure the spacecraft is not trapped in the Earth's gravitational field. Do not accept 'gravitational pull'. Any reference to orbit alone – zero marks
	(b)		$\Delta v = \frac{2ugr}{gr + u^2}$ $\Delta v = \frac{2 \times 1.7 \times 10^{4} \times 9.8 \times (6.4 \times 10^{6} + 3.6 \times 10^{5})}{9.8 \times (6.4 \times 10^{6} + 3.6 \times 10^{5}) + (1.7 \times 10^{4})^{2}}$ (1) $v = \left(\frac{2 \times 1.7 \times 10^{4} \times 9.8 \times (6.4 \times 10^{6} + 3.6 \times 10^{5})}{9.8 \times (6.4 \times 10^{6} + 3.6 \times 10^{5}) + (1.7 \times 10^{4})^{2}} \right) + 1.7 \times 10^{4}$ (1) $v = 2.3 \times 10^{4}\ \text{ms}^{-1}$ (1)	3	Accept: 2, 2.33, 2.334
	(c)		The rate (at which time passes on the spacecraft clock) increases (as the spacecraft moves away from Earth) (1) The gravitational field strength decreases (1)	2	Explanation in terms of Special Relativity alone, max 1 mark. Do not accept: 'time passes faster' without reference to the rate at which time passes.

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>5.</td><td>(a)</td><td></td><td>$L = 4\pi r^2 \sigma T^4$ (1)
$9.4\times10^{24} = 4\pi\times\left(5.6\times10^{6}\right)^2\times5.67\times10^{-8}\times T^4$ (1)
$T = 2.5\times10^4$ K (1)</td><td>3</td><td>Accept: 3, 2.55, 2.547</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>$b = \dfrac{L}{4\pi d^2}$ (1)
$5.8\times10^{-8} = \dfrac{L}{4\pi\times\left(8.0\times10^{18}\right)^2}$ (1)
$L = 4.7\times10^{31}$ W</td><td>2</td><td>SHOW question

Final line must be shown, if not max 1 mark.</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Greater than (1)

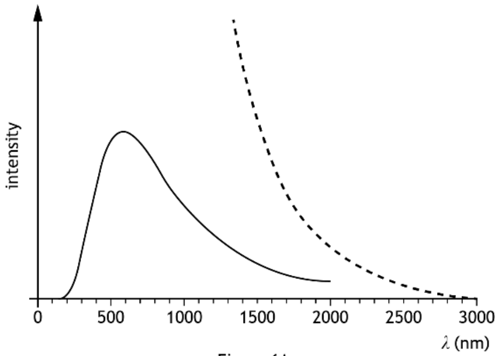
Betelgeuse has (a similar luminosity and) a lower surface temperature (so radius must be greater) and $L = 4\pi r^2 \sigma T^4$ (1)</td><td>2</td><td>Justify

$L \propto r^2 T^4$ acceptable.

Justification in terms of area or $\dfrac{P}{A} = \sigma T^4$ alone is insufficient.</td></tr>
<tr><td></td><td>(c)</td><td></td><td><table><tr><th>Star</th><th>Spectrum</th></tr><tr><td>Betelgeuse</td><td>C</td></tr><tr><td>Rigel</td><td>A</td></tr><tr><td>Sirius B</td><td>B</td></tr><tr><td>Sun</td><td>D</td></tr></table></td><td>3</td><td>All correct award 3 marks.

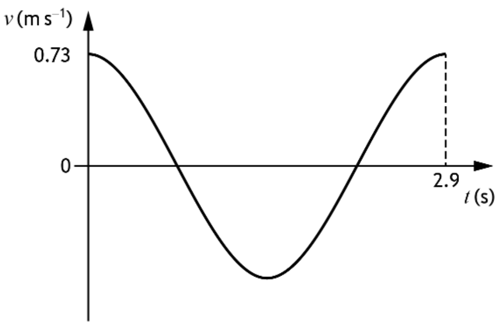
Two or three correct award 2 marks.

One correct award 1 mark.</td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)	(The) Ultraviolet Catastrophe	**1**	Accept UV for Ultraviolet. Accept 'Rayleigh-Jeans Law'.
		(ii)	 Figure 6A	**1**	Line asymptotic to y-axis. Line must be above or on the line shown on the original figure.
	(b)	(i)	340 K	**1**	Accept 67 °C. 335-345 K acceptable.
		(ii)	$\frac{P}{A} = \sigma T^4$ (1) $\frac{P}{A} = 5.67 \times 10^{-8} \times 340^4$ (1) $\frac{P}{A} = 760\ \text{W m}^{-2}$ (1)	**3**	Or consistent with (b)(i). Accept: 800, 758, 757.7
		(iii)	The object is not a (perfect) black-body radiator.	**1**	
	(c)	(i)	$\lambda = \frac{h}{p}$ (1) $5.6 \times 10^{-6} = \frac{6.63 \times 10^{-34}}{p}$ (1) $p = 1.2 \times 10^{-28}\ \text{kg m s}^{-1}$ (1)	**3**	Accept: 1, 1.18, 1.184
		(ii)	The photon can be considered as a particle.	**1**	Do not accept 'the photon has (rest) mass'.

Question			Expected response	Max mark	Additional guidance
7.	(a)		The Sun/stars/black holes.	**1**	Do not accept 'solar wind'.
	(b)		(Component of) the velocity parallel to the (magnetic) field is constant/ results in no (unbalanced) force/ is unaffected by the (magnetic) field. (1) (Component of) the velocity perpendicular to the (magnetic) field results in circular motion/ central force. (1)	**2**	Independent marks 'Horizontal component', 'vertical component' alone not acceptable.
	(c)	(i)	$\left(\begin{array}{l} W = QV \\ W = 1.60 \times 10^{-19} \times 5.56 \times 10^{9} \end{array}\right)$ $W = 8.90 \times 10^{-10}$ (J)	**1**	Unit not required. Accept: 8.9, 8.896, 8.8960 Do not accept substitution of -1.6×10^{-19}
		(ii)	$\Delta E \Delta t \geq \frac{h}{4\pi}$ (1) $4.55 \times 10^{-31} \times \Delta t \geq \frac{6.63 \times 10^{-34}}{4\pi}$ (1) $\Delta t = 1.16 \times 10^{-4}$ s (1)	**3**	Do not accept as starting point: $\Delta E \Delta t = \frac{h}{4\pi}$ Do not accept as final answer: $\Delta t \geq 1.16 \times 10^{-4}$ s Accept: 1.2, 1.160, 1.1596

Question			Expected response	Max mark	Additional guidance
8.			**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide 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. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	3	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

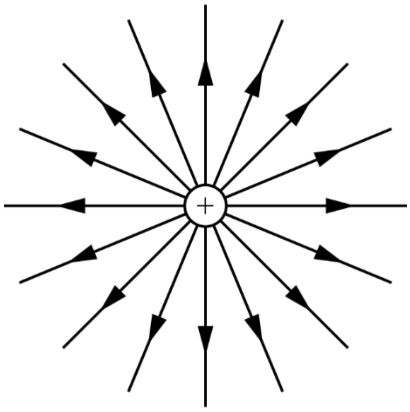
Question			Expected response	Max mark	Additional guidance
9.	(a)		$\tau = Fr$ (1) $\tau = 19 \times 9.8 \times 1.8$ (1) $19 \times 9.8 \times 1.8 = F \times 2.3$ (1) $F = 150$ N (1)	4	Accept: 100, 146, 145.7 $F_1 r_1 = F_2 r_2$ acceptable starting point.
	(b)	(i)	$v =$ or $\frac{dy}{dt} = 2.2 \times 0.33 \cos 2.2t$ and $a =$ or $\frac{d^2y}{dt^2} = -2.2^2 \times 0.33 \sin 2.2t$ (1) $a =$ or $\frac{d^2y}{dt^2} = -2.2^2 y$ (1) (since the equation is in the form) $a = -\omega^2 y$ (the vertical displacement is consistent with SHM). (1)	3	Non-standard SHOW. First mark is for BOTH differentiations performed correctly. Second mark is for the substitution of y back into second differential (including correct treatment of negatives). Numerical constant may be evaluated without penalty. Statement regarding significance of equation required for third mark. Any differentiation with respect to x, award 0 marks.
		(ii)	$\omega = \frac{2\pi}{T}$ (1) $2.2 = \frac{2\pi}{T}$ (1) $T = 2.9$ s (1)	3	Accept: 3, 2.86, 2.856
		(iii)	$v = \pm\omega\sqrt{(A^2 - y^2)}$ (1) $v = (\pm)2.2 \times \sqrt{(0.33^2 - 0^2)}$ (1) $v = (\pm)0.73$ m s^{-1} (1)	3	Accept: 0.7, 0.726, 0.7260 Accept $v = \pm\omega A$ as a starting point.
		(iv)		3	Minimum one full period of sin or cos curve, else 0 marks. 1 mark for cos curve (positive or negative). 1 mark for 2.9 s on time axis. 1 mark for 0.73 m s^{-1} on velocity axis or consistent with (b) parts (ii) and (iii). Sine curve max 2 marks.

Question			Expected response	Max mark	Additional guidance
9.	(c)		The force/acceleration is no longer directly proportional to the displacement (from equilibrium).	**1**	$F \neq -ky$ $a \neq -ky$

Question			Expected response	Max mark	Additional guidance
10.	(a)		The wave is a sound wave. (1) $v = f\lambda$ (1) $v = 3.94\times10^{4}\times8.63\times10^{-3}$ $v = 340\ (\text{ms}^{-1})$ (1)	**3**	Must Justify by calculation. Suspend sig fig rule.
	(b)		$E = kA^2$ or $\frac{E_1}{A_1^2} = \frac{E_2}{A_2^2}$ (1) $\frac{100}{(7.17\times10^{-5})^2} = \frac{40}{A_2^2}$ (1) $(A_2 = 4.53\times10^{-5}\,(\text{m}))$ $y = 4.53\times10^{-5}\sin 2\pi\left(3.94\times10^{4}t + \frac{x}{8.63\times10^{-3}}\right)$ (1), (1)	**4**	Accept: 4.5, 4.535, 4.5347 Final mark for + sign in relationship is independent.
	(c)		At high enough frequencies the reactance/impedance of the capacitor is low. **OR** At lower frequencies the reactance/impedance of the capacitor is too high.	**1**	Do not accept any explanation relating to resistance.

Question			Expected response	Max mark	Additional guidance
11.	(a)	(i)	(When) two <u>coherent</u> waves meet <u>in-phase</u>.	**1**	Both conditions must be stated. Accept: 'path difference $= m\lambda$' in place of 'in-phase' 'constant phase relationship' in place of 'coherent'.
		(ii)	A maximum reading is displayed on the meter.	**1**	
		(iii)	$\Delta x = \frac{\lambda D}{d}$ (1) $470\times10^{-3} = \frac{\lambda\times720\times10^{-3}}{42\times10^{-3}}$ (1) $\lambda = 0.027$ m (1)	**3**	Accept: 0.03, 0.0274, 0.02742
	(b)	(i) A	π (rad)	**1**	Unit not required but, if given, must be correct.
		(i) B	π (rad)	**1**	Unit not required but, if given, must be correct.
		(ii)	$\left(\begin{array}{l} opd = n\times gpd \\ gpd = 2d \\ opd = 2nd \\ opd = \left(m+\frac{1}{2}\right)\lambda \end{array}\right)$ $2nd = \left(m+\frac{1}{2}\right)\lambda$ (1) $m = 0$ (1) $d = \frac{\lambda}{4n}$	**2**	Use of (minus formula) and m = 1 is acceptable. $2nd = \frac{\lambda}{2}$ (1), (1) $d = \frac{\lambda}{4n}$
	(c)	(i)	$\left(d = \frac{\lambda}{4n}\right)$ $d = \frac{633\times10^{-9}}{4\times1.31}$ (1) $d = 1.21\times10^{-7}$ m (1)	**2**	Accept: 1.2, 1.208, 1.2080
		(ii)	It is impossible to make a layer of ice so thin (in a school).	**1**	Or consistent with (c)(i)

Question			Expected response	Max mark	Additional guidance
12.	(a)		(The electric field vector) oscillates (or vibrates) in one plane only.	**1**	Do not accept: 'travels' instead of 'oscillates' 'direction' instead of plane 'axis' instead of plane.
	(b)	(i)	$n = \tan i_p$ (1) $i_p = \frac{110}{2}$ (1) $n = \tan\left(\frac{110}{2}\right)$ (1) $n = 1.4$ (1)	**4**	Independent mark for halving 110° for Brewster angle. Accept: 1, 1.43, 1.428
		(ii)	Background light from other sources. **OR** Imperfections on the surface of the prism.	**1**	Do not accept 'not fully polarised'. Accept: systematic uncertainty in the light meter.

Question			Expected response	Max mark	Additional guidance
13.	(a)			**1**	Field lines should be evenly spaced around the charge. Field lines should be passably straight. Field lines should be touching the charge. Minimum number of field lines is five.
	(b)		$E=\dfrac{Q}{4\pi\varepsilon_0 r^2}$ (1) $E=\dfrac{12\times10^{-9}}{4\pi\times8.85\times10^{-12}\times0.15^2}$ (1) $E=4800\ \text{NC}^{-1}$	**2**	SHOW question $E=k\dfrac{Q}{r^2}$ (1) $E=9\times10^9\times\dfrac{12\times10^{-9}}{0.15^2}$ (1) $E=4800\ \text{NC}^{-1}$ Final line must be shown or max 1 mark.
	(c)	(i)	$F=mg\tan\theta$ (1) $F=16\times10^{-3}\times9.8\times\tan5.0$ (1) $F=1.4\times10^{-2}\ \text{N}$ (1)	**3**	Accept 1, 1.37, 1.372
		(ii)	$F=EQ$ (1) $1.4\times10^{-2}=4800\times Q$ (1) $Q=2.9\times10^{-6}\ \text{C}$ (1)	**3**	Or consistent with (c)(i) Accept: 3, 2.92, 2.917 $F=\dfrac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$ $1.4\times10^{-2}=\dfrac{12\times10^{-9}\times Q_2}{4\pi\times8.85\times10^{-12}\times0.15^2}$ $Q_2=2.9\times10^{-6}\ \text{C}$
	(d)		The angle will be less. (1) r^2 term greater influence than Q (1)	**2**	Justify Can justify by calculation of force.

Question			Expected response	Max mark	Additional guidance
14.	(a)	(i)	$\left(F_B = qvB\right)$ $\left(F_E = QE\right)$ $qvB = QE$ (1, 1) $v = \dfrac{E}{B}$	**2**	SHOW question 1 mark for both relationships. 1 mark for equating. Final line must be shown or max 1 mark.
		(ii)	$E = \dfrac{V}{d}$ (1) $\left(v = \dfrac{E}{B}\right)$ $v = \dfrac{\left(\dfrac{4.80\times10^3}{10.0\times10^{-3}}\right)}{225\times10^{-3}}$ (1) $v = 2.13\times10^6\ \text{ms}^{-1}$ (1)	**3**	Accept 2.1, 2.133, 2.1333
		(iii)	Velocity is dependent on E and B only.	**1**	Velocity is independent of mass and charge.
	(b)		$r = \dfrac{mv}{qB}$ $r_{2_H} = \dfrac{3.34\times10^{-27}\times2.13\times10^6}{1.60\times10^{-19}\times0.65}$ (1) $r_{3_H} = \dfrac{5.01\times10^{-27}\times2.13\times10^6}{1.60\times10^{-19}\times0.65}$ (1) $\Delta x = 2\times\left(\left(\dfrac{5.01\times10^{-27}\times2.13\times10^6}{1.60\times10^{-19}\times0.65}\right)-\left(\dfrac{3.34\times10^{-27}\times2.13\times10^6}{1.60\times10^{-19}\times0.65}\right)\right)$ (1) $\Delta x = 0.068$ m (1)	**4**	Accept 0.07, 0.0684, 0.06841 Or consistent with (a)(ii)
	(c)		Radii (of curvature) increase (1) Velocity of ions increases (1)	**2**	Justify

Question			Expected response	Max mark	Additional guidance
15.	(a)	(i)	Changing current produces a changing magnetic field. (1) This induces a back EMF in the inductor which opposes the change in current. (1)	**2**	Independent marks.
		(ii)	$\mathcal{E} = -L\frac{dI}{dt}$ (1) $-6.0 = -L \times 3.4$ (1) $L = 1.8$ H (1)	**3**	Accept 2, 1.76, 1.765 Accept: $\mathcal{E} = -L\frac{dI}{dt}$ (1) $6.0 = L \times 3.4$ (1) $L = 1.8$ H (1)
		(iii)	$E = \frac{1}{2}LI^2$ (1) $E = \frac{1}{2} \times 1.8 \times 5.0^2$ (1) $E = 23$ J (1)	**3**	Accept 20, 22.5, 22.50 Or consistent with (a)(ii)
	(b)		Time will be less (1) The (self-) inductance has decreased. (1)	**2**	Justify question Rate of change of current increases.
	(c)		$\left(Q = \frac{\omega L}{R}\right)$ $44.2 = \frac{\omega \times 2.4 \times 10^{-3}}{8.0}$ (1) $\omega = 2\pi f$ (1) $\left(\frac{44.2 \times 8.0}{2.4 \times 10^{-3}} = 2\pi f\right)$ $f = 2.3 \times 10^4$ Hz (1)	**3**	Accept 2, 2.34, 2.345 $\omega = 2\pi f$ independent mark.

Question			Expected response	Max mark	Additional guidance
16.	(a)		$E = gradient \times \dfrac{L^3}{3I}$ (1) $E = 564.00 \times \dfrac{0.90^3}{3 \times 7.2 \times 10^{-10}}$ (1) $E = 1.9 \times 10^{11}$ Pa (1)	**3**	Accept 2, 1.90, 1.904
	(b)	(i)	$\dfrac{\Delta W}{W} = \sqrt{\left(\dfrac{\Delta X}{X}\right)^2 + \left(\dfrac{\Delta Y}{Y}\right)^2 + \left(\dfrac{\Delta Z}{Z}\right)^2}$ $\left(\dfrac{\Delta E}{E} = \sqrt{\left(\dfrac{\Delta grad}{grad}\right)^2 + \left[3 \times \left(\dfrac{\Delta L}{L}\right)\right]^2 + \left(\dfrac{\Delta I}{I}\right)^2}\right)$ $\dfrac{\Delta E}{1.9 \times 10^{11}} = \sqrt{\left(\dfrac{8.47}{564.00}\right)^2 + \left[3 \times \left(\dfrac{0.005}{0.90}\right)\right]^2 + \left(\dfrac{0.01 \times 10^{-10}}{7.20 \times 10^{-10}}\right)^2}$ $\Delta E = 0.04 \times 10^{11}$ Pa	**4**	Accept % method 1 relationship 1 tripling %ΔL 1 all subs 1 final answer Suspend significant figures rule Allow 'rule of 3' for ΔI Accept: 0.043, 0.0427, 0.04271
		(ii)	The force measurement could be consistently too high. **OR** The displacement measurement could be consistently too low.	**1**	

[END OF MARKING INSTRUCTIONS]