National
Qualifications

X857/77/01 **Physics**

Marking Instructions

Please note that these marking instructions have not been standardised based on candidate responses. You may therefore need to agree within your centre how to consistently mark an item if a candidate response is not covered by the 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) (http://www.sqa.org.uk/files_ccc/Physicsgeneralmarkingprinciples.pdf) 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 17)

(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 1)

(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 3)

(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 22)

(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 $R = \dfrac{V}{I}$. (GMP 6)

(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 10)

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 $0\cdot\dot{6}$, 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 25)

(k) Where words in the expected responses are underlined, they must be included for the marks to be awarded.

(l) **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.	$V = IR$ $7{\cdot}5 = 1{\cdot}5R$ $R = 5{\cdot}0\ \Omega$	1 mark: relationship 1 mark: substitution 1 mark: correct answer
2.	$5{\cdot}0\ \Omega$	3 marks: correct answer
3.	5·0	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: relationship only
8.	$R = \frac{V}{I} = \_\_\ \Omega$	1 mark: relationship only
9.	$R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = \_\_\ \Omega$	2 marks: relationship and substitution, no final answer
10.	$R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = 4{\cdot}0$	2 marks: relationship and substitution, wrong answer
11.	$R = \frac{V}{I} = \frac{1{\cdot}5}{7{\cdot}5} = 5{\cdot}0\ \Omega$	1 mark: relationship but wrong substitution
12.	$R = \frac{V}{I} = \frac{75}{1{\cdot}5} = 5{\cdot}0\ \Omega$	1 mark: relationship but wrong substitution
13.	$R = \frac{I}{V} = \frac{1{\cdot}5}{7{\cdot}5} = 5{\cdot}0\ \Omega$	0 marks: wrong relationship
14.	$V = IR$ $7{\cdot}5 = 1{\cdot}5 \times R$ $R = 0{\cdot}2\ \Omega$	2 marks: relationship and substitution, arithmetic error
15.	$V = IR$ $R = \frac{I}{V} = \frac{1{\cdot}5}{7{\cdot}5} = 0{\cdot}2\ \Omega$	1 mark: relationship correct but wrong rearrangement of symbols

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)		$a\left(=\dfrac{dv}{dt}\right)=8t-2t^2$ **(1)** $a=8\times 4\cdot 0-2\times 4\cdot 0^2$ **(1)** $a=0\cdot 0\ \text{m s}^{-2}$ **(1)**	3	Accept: 0 ms^{-2} Unit of acceleration required or max 2.
	(b)		$s\left(=\int v.dt\right)=8t+\dfrac{4}{3}t^3-\dfrac{2}{3\times 4}t^4\ (+c)$ **(1)** $s=8\times 4\cdot 0+\dfrac{4}{3}\times 4\cdot 0^3-\dfrac{2}{3\times 4}\times 4\cdot 0^4$ **(1)** $s=75\ \text{m}$ **(1)**	3	Ignore poor form with integration constant/limits. Solution with limits also acceptable. $\left(s=\left(\int_0^{4\cdot 0} v.dt\right)=\int_0^{4\cdot 0}(8+4t^2-\dfrac{2}{3}t^3).dt\right)$ $s=\left[8t-\dfrac{4}{3}t^3-\dfrac{2}{3\times 4}t^4\right]_0^{4\cdot 0}$ (1) $s=(8\times 4\cdot 0+\dfrac{4}{3}\times 4\cdot 0^3-\dfrac{2}{3\times 4}\times 4\cdot 0^4)-0$ (1) $s=75\ \text{m}$ (1) Accept: 70, 74·7, 74·67

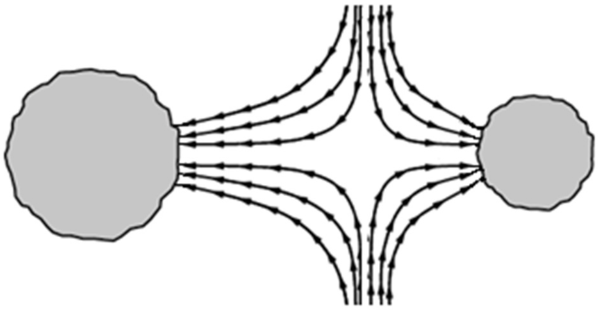
(1)

Question			Expected response	Max mark	Additional guidance
2.	(a)	(i)	$v = r\omega$ $6 \cdot 7 = 0 \cdot 35 \times \omega$ **(1)** $\omega = 19\ \text{rads}^{-1}$ **(1)**	**3**	Accept: 20, 19·1, 19·14.
		(ii)	$\theta = \omega_o t + \frac{1}{2}\alpha t^2$ **(1)** $\theta = 19 \times 5 \cdot 5 + \frac{1}{2} \times -2 \cdot 4 \times 5 \cdot 5^2$ **(1)** $no.\ revolutions = \frac{19 \times 5 \cdot 5 + \frac{1}{2} \times -2 \cdot 4 \times 5 \cdot 5^2}{2\pi}$ **(1)** $no.\ revolutions = 11$ **(1)**	**4**	Or consistent with (a)(i) Independent 1 mark for dividing a value of θ by 2π For alternative methods: 1 mark for **all** relationships 1 mark for **all** substitutions 1 mark for dividing by 2π 1 mark for final answer Use of ω = 0 is incorrect substitution. Accept: 10, 10·9, 10·85
		(iii)	Greater (number of revolutions) **(1)** <u>Smaller angular acceleration</u> (during this 5·5 seconds means the wheel has a greater angular displacement). **(1)**	**2**	**JUSTIFY** For justification, do not accept reduced friction/frictional torque only. <u>Angular acceleration</u> must be specified for the second mark.
	(b)		D. **(1)** Applying the force at a <u>greater distance from the</u> <u>axis of rotation</u> (will generate a greater torque on the flywheel as $\tau = Fr$) **(1)**	**2**	**JUSTIFY** For justification, do not accept greater distance from the centre/middle of the flywheel

Question			Expected response	Max mark	Additional guidance
3.	(a)		$\tau = I\alpha$ **(1)** $6\cdot30\times10^{-3} = I\times0\cdot618$ **(1)** $I = 1\cdot02\times10^{-2}$ kg m^2	**2**	**SHOW** Final answer must be shown or max 1.
	(b)	(i)	The total angular momentum before (an interaction) is equal to the total angular momentum after (an interaction) in the absence of external torque.	**1**	Conservation relationship on its own is insufficient. 'Angular momentum is conserved' award 0.
		(ii)	$I_1\omega_1 = I_2\omega_2$ **(1)** $1\cdot02\times10^{-2}\times7\cdot75 = \left(1\cdot02\times10^{-2} + I_{cube}\right)\times5\cdot74$ **(1)** $I_{cube} = 3\cdot57\times10^{-3}$ kgm^2 **(1)**	**3**	Accept alternative subscripts in the conservation relationship. Accept: 3·6, 3·572. 3·5718
		(iii)	(The angular velocity will be) less (than 5·74) **(1)** since the moment of inertia (of the system) will be greater. **(1)**	**2**	**MUST JUSTIFY** Justification must make reference to moment of inertia. Increased mass alone is insufficient for justification mark.

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>4.</td><td>(a)</td><td>(i)</td><td>The <u>gravitational force</u> acting on a unit mass.</td><td>1</td><td>‘<u>force due to gravity</u>’ acceptable alternative to ‘<u>gravitational force</u>’

‘acting on a mass of 1 kg’ acceptable alternative to ‘acting on a unit mass’</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>1 mark for shape of field and direction of lines.
1 mark for skew (null point closer to smaller asteroid).

</td><td>2</td><td>Independent marks

Field lines should be (approximately) normal to the surface of the asteroids.

Field lines should not cross.

Field lines should not meet at the same point on the surface of the asteroids.</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>Equal to (1)

Since the energy required to move mass between two points in a gravitational field is independent of the path taken. (1)</td><td>2</td><td>JUSTIFY

Accept justification in terms of ‘conservative field’.</td></tr>
<tr><td></td><td>(b)</td><td></td><td>(The clock on the probe runs) faster. (1)

As it is in a weaker gravitational field. (1)</td><td>2</td><td>MUST JUSTIFY
Correct converse statement acceptable.

Statement and justification must be in terms of GR, since GR dominates SR effects in this situation.</td></tr>
<tr><td></td><td>(c)</td><td></td><td>$v=\sqrt{\frac{2GM}{r}}$ (1)
$r=49\cdot8\times1\cdot5\times10^{11}$ (1)
$v=\sqrt{\frac{2\times6\cdot67\times10^{-11}\times2\cdot0\times10^{30}}{49\cdot8\times1\cdot5\times10^{11}}}$ (1)
$v=6\cdot0\times10^{3}\ \text{ms}^{-1}$ (1)</td><td>4</td><td>Independent mark for unit conversion.

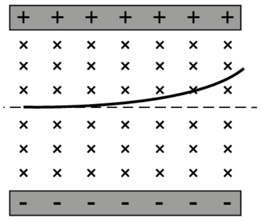
Accept: 6, 5·98, 5·976</td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
5.			**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.

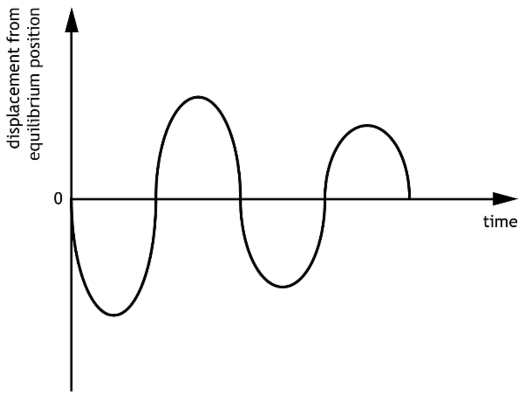
Question			Expected response	Max mark	Additional guidance
6.	(a)		The proton-proton chain.	**1**	Accept 'p-p chain'
	(b)	(i)	$L = 4\pi r^2 \sigma T^4$ **(1)** $L = 4\pi \times \left(8\cdot35\times10^8\right)^2 \times 5\cdot67\times10^{-8} \times (6070)^4$ **(1)** $L = 6\cdot74\times10^{26}$ W **(1)**	**3**	Accept: 6·7, 6·744, 6·7440
		(ii)	$d = 159\times365\cdot25\times24\times60\times60\times3\cdot00\times10^8$ **(1)** $b = \frac{L}{4\pi d^2}$ **(1)** $b = \frac{6\cdot74\times10^{26}}{4\pi\times\left(159\times365\cdot25\times24\times60\times60\times3\cdot00\times10^8\right)^2}$ **(1)** $b = 2\cdot37\times10^{-11}$ Wm^{-2} **(1)**	**4**	Or consistent with (b)(i) Independent mark for unit conversion. Accept use of 365 days. Accept: 2·4, 2·370, 2·3703 (using 365) 2·4, 2·367, 2·3670 (using 365·25)
	(c)	(i)	$T = 3\cdot5$ (days) **(1)** $\omega = \frac{2\pi}{T}$ **(1)** $\omega = \frac{2\pi}{3\cdot5\times24\times60\times60}$ **(1)** $\omega = 2\cdot1\times10^{-5}$ $\left(\text{rads}^{-1}\right)$ **(1)**	**4**	Mark for period from graph independent. Accept T in the range 3·4 - 3·6 days Accept: 2, 2·08, 2·078
		(ii)	$\frac{GMm}{r^2} = mr\omega^2$ **(1)** $\frac{6\cdot67\times10^{-11}\times2\cdot5\times10^{30}\times m}{r^2} = m\times r\times\left(2\cdot1\times10^{-5}\right)^2$ **(1)** $r = 7\cdot2\times10^9$ m **(1)**	**3**	Or consistent with (c)(i) Not a SHOW question, therefore accept if mass cancelled correctly. Accept $\frac{2\pi}{T}$ as an alternative to ω. Accept: 7, 7·23, 7·231.

Question			Expected response	Max mark	Additional guidance
7.	(a)		Compton scattering or Photoelectric effect	1	
	(b)	(i)	$mvr = \frac{nh}{2\pi}$ **(1)** $9 \cdot 11\times10^{-31}\times v\times 2\cdot 12\times10^{-10} = \frac{2\times 6\cdot 63\times10^{-34}}{2\pi}$ **(1)** $v = 1\cdot 09\times10^{6}$ ms^{-1}	2	**SHOW** Final answer must be shown or max 1.
		(ii)	$\lambda = \frac{h}{p}$ **(1)** $\lambda = \frac{6\cdot 63\times10^{-34}}{9\cdot 11\times10^{-31}\times 1\cdot 09\times10^{6}}$ **(1)** $\lambda = 6\cdot 68\times10^{-10}$ m **(1)** Wavelength (comparable to atomic radius so) suitable for demonstrating <u>interference</u> or Wavelength (comparable to atomic radius so) suitable for demonstrating <u>diffraction</u> **(1)**	4	Accept: 6·7, 6·677, 6·6768 Alternative acceptable approach for calculation $\lambda = \frac{2\pi r}{n}$ **(1)** $\lambda = \frac{2\pi\times 2\cdot 12\times10^{-10}}{2}$ **(1)** $\lambda = 6\cdot 66\times10^{-10}$ m **(1)** Accept: 6·7, 6·660, 6·6602
	(c)		$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ $\frac{1}{410\times10^{-9}} = R\times 1^2\left(\frac{1}{2^2} - \frac{1}{6^2}\right)$ **(1)** $R = 1\cdot 1\times10^{7}$ m^{-1} **(1)**	2	Accept:1, 1·10, 1·098

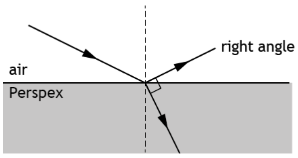
Question			Expected response	Max mark	Additional guidance
8.	(a)		A quantum particle can exist in a position that, according to classical physics, it has insufficient energy to occupy	1	Accept responses in terms of a quantum particle/waveform able to pass through a potential barrier.
	(b)		$\Delta x \Delta p_x \geq \frac{h}{4\pi}$ or $\Delta x \Delta p_{x_{\min}} = \frac{h}{4\pi}$ **(1)** $54\times10^{-15} \times \Delta p_x \geq \frac{6\cdot63\times10^{-34}}{4\pi}$ **(1)** $\Delta p_{x_{\min}} = (\pm)9\cdot8\times10^{-22}$ kgms^{-1} **(1)**	3	Do not accept $\Delta x \Delta p_{x_{\min}} \geq \frac{h}{4\pi}$ Accept: 10, 9·77, 9·770 Do not accept $\Delta p_{x_{\min}} \geq 9\cdot8\times10^{-22}$ kgms^{-1} or $\Delta p_x \geq 9\cdot8\times10^{-22}$ kgms^{-1} or $\Delta p_x = 9\cdot8\times10^{-22}$ kgms^{-1} for the third mark.
	(c)	(i) (A)	$E_k = \frac{1}{2}mv^2$ **(1)** $8\cdot8\times10^6 \times 1\cdot60\times10^{-19}$ $= 0\cdot5\times6\cdot645\times10^{-27}\times v^2$ **(1,1)** $v = 2\cdot1\times10^7$ m s^{-1} **(1)**	4	Independent mark for energy conversion from MeV to J. Accept: 2, 2·06, 2·059
		(B)	$(F = QE$ and $F = qvB)$ $QE = qvB$ **(1),(1)** $v = \frac{E}{B}$	2	**SHOW** 1 for both relationships 1 for equating Accept: qE Final relationship must be shown or max 1.
		(C)	$E = \frac{V}{d}$ **(1)** $v = \frac{E}{B}$ $2\cdot1\times10^7 = \frac{\left(\frac{27\times10^3}{15\times10^{-3}}\right)}{B}$ **(1)** $B = 8\cdot6\times10^{-2}$ T **(1)**	3	Or consistent with (c)(i)(A) Accept 9, 8·57, 8·571
	(c)	(ii)	$r = \frac{qQ}{2\pi\varepsilon_0 mv^2}$ $r = \frac{(3\cdot20\times10^{-19})\times(4\cdot64\times10^{-18})}{2\pi\times8\cdot85\times10^{-12}\times6\cdot645\times10^{-27}\times(2\cdot1\times10^7)^2}$ **(1)** $r = 9\cdot1\times10^{-15}$ m **(1)**	2	Or consistent with (c)(i)(A) Accept $(2\times1\cdot60\times10^{-19})$ and $(29\times1\cdot60\times10^{-19})$ as substitutions for q and Q Accept 9, 9·11, 9·112

Question			Expected response	Max mark	Additional guidance
8.	(d)		Path drawn as an upward curve in B-field **(1)** 	**1**	Ignore any path drawn to the right of the parallel plates.

Question			Expected response	Max mark	Additional guidance
9.	(a)		Unbalanced force/acceleration is proportional to, and in the opposite direction to, the displacement (from the rest position)	**1**	Accept $F=-ky$ or equivalent Do not accept 'force is proportional to displacement' without reference to direction.
	(b)		$(y = A\sin\omega t)$ $(v=)\frac{dy}{dt}=\omega A\cos\omega t$ **(1) for both differentiations** $(a=)\frac{d^2y}{dt^2}=-\omega^2 A\sin\omega t$ $F=ma$ **(1)** $F=-m\omega^2 A\sin\omega t$ **(1)** $F=-m\omega^2 y$	**3**	**SHOW** Final relationship must be shown or max 2.
	(c)	(i)	$(F=-m\omega^2 y)$ $F=-ky$ **(1)** $(-)k(y)=(-)m\omega^2(y)$ **(1)** $1\cdot5\times10^2=77\times\omega^2$ **(1)** $\omega=1\cdot4$ rads^{-1}	**3**	**SHOW** Final answer must be shown or max 2.
		(ii)	$v=\pm\omega\sqrt{(A^2-y^2)}$ **(1)** $18=1\cdot4A$ **(1)** $A=13$ m **(1)**	**3**	Accept $v_{max}=\omega A$ as first line. Accept: 10, 12·9, 12·86
		(iii)	$E_p=\frac{1}{2}m\omega^2y^2$ **(1)** $E_p=0\cdot5\times77\times1\cdot4^2\times13^2$ **(1)** $E_p=1\cdot3\times10^4$ J **(1)**	**3**	Or consistent with (c)(ii) Accept: 1, 1·28, 1·275

Question			Expected response	Max mark	Additional guidance
9.	(d)		sine function **(1)** reducing amplitude **(1)** 	2	Displacement must be zero at t=0. Displacement for first half cycle may be positive. Minimum of two cycles must be shown otherwise 0 marks.
	(e)		ω is same **(1)** $ky = m\omega^2 y$ k is the same and m is same (y has no effect). **(1)**	2	**JUSTIFY** Accept 'ω depends on mass and spring constant only, and these haven't changed'.

Question			Expected response	Max mark	Additional guidance
10.	(a)		(Particular thickness will produce) destructive interference of reflected rays (for the specific wavelength of light).	**1**	Accept '(Particular thickness will) maximise the energy transmitted into the glass (for the specific wavelength of light)'.
	(b)	(i)	(Phase change of) π (radians).	**1**	Accept (Phase change of) 180°.
		(ii)	No phase change.	**1**	Accept 0 (radians)/ $0^{(\circ)}$
	(c)	(i)	$d = \dfrac{\lambda}{2n_z}$ $d = \dfrac{660\cdot 0\times 10^{-9}}{2\times 1\cdot 982}$ **(1)** $d = 1\cdot 665\times 10^{-7}$ m **(1)**	**2**	Allow a range for n_z of 1·9815 to 1·9825 Accept: 1·66, 1·6650, 1·66498
		(ii)	The coating is anti-reflecting for red light/red light is transmitted. **(1)** (Some of the) blue and green light/the remainder of the light is reflected, (hence the blue-green appearance). **(1)**	**2**	
	(d)	(i)	$v = f\lambda$ **(1)** $v = 4\cdot 55\times 10^{14}\times 4\cdot 37\times 10^{-7}$ **(1)** $v = 1\cdot 99\times 10^{8}$ ms^{-1} **(1)**	**3**	Accept: 2·0, 1·988, 1·9884
		(ii)	$E = kA^2$ **(1)** $A_2^{\,2} = \dfrac{90\times\left(1\cdot 60\times 10^{3}\right)^2}{100}$ **(1)** $A_2 = 1520$ V m^{-1} **(1)**	**3**	Accept: 1500, 1518, 1517·9

Question			Expected response	Max mark	Additional guidance
11.	(a)		(The electric vector of) light oscillates in a single plane.	**1**	Accept 'vibrates in a single plane' Do not accept: Travels in a single plane/direction Oscillates in one direction
	(b)	(i)	The refracted ray should be at 90° to the reflected ray. 	**1**	No arrow required on the refracted ray but if one is included it must be in the correct direction. Accept a diagram where there is an indication that the angle between the refracted ray and the reflected ray is 90°.
		(ii)	$n = \tan i_p$ **(1)** $1 \cdot 49 = \tan i_p$ **(1)** $i_p = 56 \cdot 1°$ **(1)**	**3**	Accept: 56, 56·13, 56·133
	(c)		The reflected light becomes dimmer (as the analyser approaches Brewster's angle, at which point it is not seen) **(1)** and then becomes brighter (again as it moves away from Brewster's angle) **(1)**	**2**	The response must not indicate a sudden change, otherwise 0 marks.

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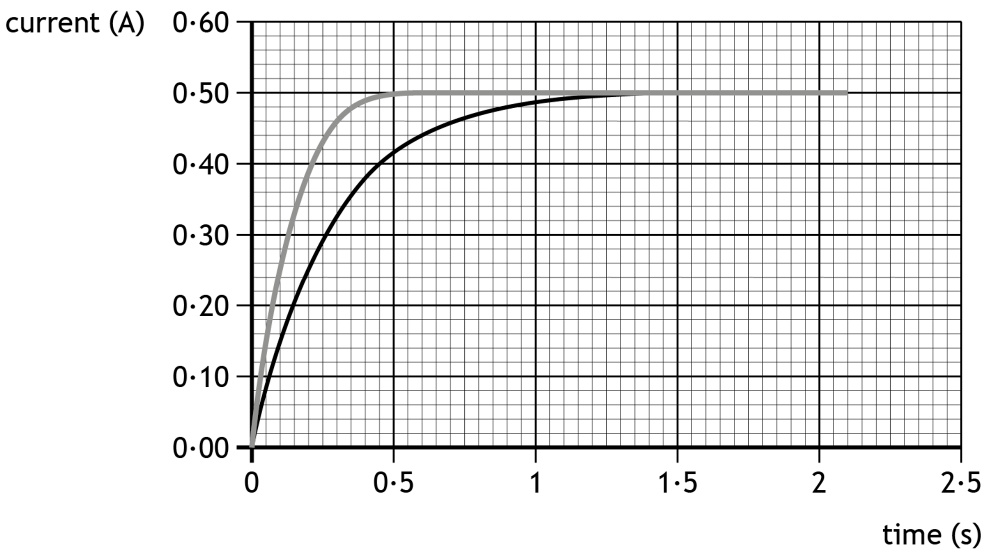
12.			**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, 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
13	(a)		$E=\dfrac{Q}{4\pi\varepsilon_0 r^2}$ **(1)** $(+)144=\dfrac{Q}{4\pi\times 8\cdot 85\times 10^{-12}\times 0\cdot 400^2}$ **(1)** $Q=(+)2\cdot 56\times 10^{-9}\text{C}$ **(1)**	**3**	Accept use of 'k' value (9×10^9 or $8\cdot 99\times 10^9$) Accept: 2·6, 2·562, 2·5623($1/4\pi\varepsilon_0$) 2·6, 2·560, 2·5600 (9×10^9) 2·6, 2·563, 2·5628($8\cdot 99\times 10^9$)
	(b)		$V=\dfrac{Q}{4\pi\varepsilon_0 r}$ **(1)** $V=\dfrac{2\cdot 56\times 10^{-9}}{4\pi\times 8\cdot 85\times 10^{-12}\times 0\cdot 400}$ **(1)** $V=57\cdot 5\text{ V}$ **(1)**	**3**	Or consistent with (a) Accept $V=Er$ $V=144\times 0\cdot 400$ $V=57\cdot 6\text{ V}$ Accept: 58, 57·55, 57·540($1/4\pi\varepsilon_0$) 58, 57·6, 57·560, 57·5600 (9×10^9) 58, 57·54, 57·536($8\cdot 99\times 10^9$)
	(c)		$V=(57\cdot 5-19\cdot 2)$ **(1)** $W=QV$ **(1)** $W=2\cdot 00\times 10^{-12}\times(57\cdot 5-19\cdot 2)$ **(1)** $W=7\cdot 66\times 10^{-11}\text{J}$ **(1)**	**4**	Or consistent with (b) Alternative method: $W=QV$ $W_Y=2\cdot 00\times 10^{-12}\times 57\cdot 5$ $W_X=2\cdot 00\times 10^{-12}\times 19\cdot 2$ $W=(2\cdot 00\times 10^{-12}\times 57\cdot 5)-(2\cdot 00\times 10^{-12}\times 19\cdot 2)$ $W=7\cdot 66\times 10^{-11}\text{J}$ 1 mark for relationship 1 mark for **both** substitutions 1 mark for subtraction 1 mark for final answer Accept: 7·7, 7·660, 7·6600

Question			Expected response	Max mark	Additional guidance
14.	(a)		Into the page.	**1**	Do not accept 'down'.
	(b)	(i)	$(F = qvB)$ $\left(F = \frac{mv^2}{r}\right)$ $\frac{mv^2}{r} = qvB$ **(1),(1)** $v = \frac{qBr}{m}$	**2**	**SHOW** 1 for both relationships 1 for equating Alternative method $(F = qvB)$ $(F = mr\omega^2)$ $(v = r\omega)$ $mr\left(\frac{v}{r}\right)^2 = qvB$ $v = \frac{qBr}{m}$ 1 mark for **all** relationships 1 mark for substitution for ω and equating Final relationship must be shown or max 1.
		(ii)	$v = \frac{qBr}{m}$ $v = \frac{1 \cdot 60 \times 10^{-19} \times 0 \cdot 714 \times 0 \cdot 105}{1 \cdot 673 \times 10^{-27}}$ **(1)** $v = 7 \cdot 17 \times 10^6 \text{ ms}^{-1}$ **(1)**	**2**	Accept: 7·2, 7·170, 7·1700
	(c)		The direction of (electrical) force acting on the proton must change (every time the proton crosses the gap).	**1**	Accept The proton travels in opposite directions (every time the proton crosses the gap).

Question			Expected response		Max mark	Additional guidance
15.	(a)	(i)	Changing current produces a changing magnetic field, (which induces a back EMF across the inductor)		1	
		(ii)	$\frac{dI}{dt} = 1 \cdot 73$	(1)	4	Accept use of gradient calculated for tangent (Acceptable range 1·70-1·75)
			$\varepsilon = -L\frac{dI}{dt}$	(1)		
			$-4 \cdot 0 = -L \times 1 \cdot 73$	(1)		
			$L = 2 \cdot 3$ H	(1)		Accept: 2, 2·31, 2·312
		(iii)	$(V = IR)$		4	Or consistent with (a)(ii)
			$3 \cdot 2 = I \times 8 \cdot 0$	(1)		
			$E = \frac{1}{2}LI^2$	(1)		
			$E = \frac{1}{2} \times 2 \cdot 3 \times \left(\frac{3 \cdot 2}{8 \cdot 0}\right)^2$	(1)		
			$E = 0 \cdot 18$ J	(1)		Accept: 0·2, 0·184, 0·1840
	(b)				2	
			1 mark for curve showing shorter time to I_{max} 1 mark for I_{max} = 0·50 A			Do not penalise if the line extends beyond 2·0 s.

Question			Expected response	Max mark	Additional guidance
16.	(a)	(i)	$\left(T^2 = \frac{4\pi^2}{g}L\right)$ $m = \frac{4\pi^2}{g}$ **(1)** $3\cdot53 = \frac{4\pi^2}{g}$ **(1)** $g = 11\cdot2\ \text{Nkg}^{-1}$ **(1)**	**3**	Accept use of gradient calculated for the line of best fit. (Acceptable range 3·40-3·60) Accept: 11, 11·18, 11·184
		(ii)	$\left(\frac{\Delta g}{g} = \frac{\Delta m}{m}\right)$ $\frac{\Delta g}{11\cdot2} = \frac{0\cdot69}{3\cdot53}$ **(1)** $\Delta g = 2\ \text{Nkg}^{-1}$ **(1)**	**2**	Or consistent with (a)(i) Accept the use of percentage uncertainties Suspend significant figures rule. Accept 3 N kg^{-1}
		(iii)	Uncertainty in gradient takes into account the uncertainties in length and period	**1**	Accept the suggestion that the uncertainty in the gradient incorporates/amalgamates/combines the uncertainties in length and period.
	(b)		Any two suggestions from: Measure length to centre of mass of bob **(1)** Time over multiple swings (and find mean value of T) **(1)** Increase range of lengths **(1)** Increase number of lengths **(1)** Reduce the angle of swing **(1)** Automatic timing **(1)**	**2**	Do not accept the suggestion of improving precision of instrumentation. Do not accept 'repeat measurements' alone
	(c)		<u>T measurement</u> (consistently too large) **OR** <u>L measurement</u> (consistently too small)	**1**	

[END OF MARKING INSTRUCTIONS]

The following table provides information on each question including: Course content being assessed,Skills assessed (see Physics Understanding Standards materials for a definition of each code); Maximum Mark; A-type marks.

Question	Part	Course content	Skills assessed	Maximum mark	A-type marks
1	(a)	Rotational motion and astrophysics- kinematic relationships	K3	3	
	(b)	Rotational motion and astrophysics- kinematic relationships	K3	3	
2	(a)(i)	Rotational motion and astrophysics- angular motion	K3	3	
	(a)(ii)	Rotational motion and astrophysics- angular motion	K3	3	1
			S4	1	1
	(a)(iii)	Rotational motion and astrophysics- angular motion	S6	2	1
	(b)	Rotational motion and astrophysics- rotational dynamics	K2	2	1
3	(a)	Rotational motion and astrophysics- rotational dynamics	K3	2	
	(b)(i)	Rotational motion and astrophysics- rotational dynamics	K1	1	
	(b)(ii)	Rotational motion and astrophysics- rotational dynamics	K3	3	
	(b)(iii)	Rotational motion and astrophysics- rotational dynamics	K2	2	2
4	(a)(i)	Rotational motion and astrophysics- gravitation	K1	1	
	(a)(ii)	Rotational motion and astrophysics- gravitation	S3	2	2
	(a)(iii)	Rotational motion and astrophysics- gravitation	K2	2	1
	(b)	Rotational motion and astrophysics- general relativity	K2	2	2
	(c)	Rotational motion and astrophysics- gravitation	S4	1	
			K3	3	
5		Rotational motion and astrophysics- general relativity	K2	3	2
6	(a)	Rotational motion and astrophysics- stellar physics	K1	1	
	(b)(i)	Rotational motion and astrophysics- stellar physics	K3	3	
	(b)(ii)	Rotational motion and astrophysics- stellar physics	S4	1	
			K3	3	
	(c)(i)	Rotational motion and astrophysics- angular motion	S2	1	1
			K3	3	2
	(c)(ii)	Rotational motion and astrophysics- gravitation	K3	3	
7	(a)	Quanta and waves - introduction to quantum theory	K1	1	
	(b)(i)	Quanta and waves - introduction to quantum theory	K3	2	
	(b)(ii)	Quanta and waves - introduction to quantum theory	K3	3	
			K2	1	1
	(c)	Quanta and waves - introduction to quantum theory	S4	2	2
8	(a)	Quanta and waves - introduction to quantum theory	K1	1	
	(b)	Quanta and waves - introduction to quantum theory	K3	3	
	(c)(i)(A)	Electromagnetism - fields	S4	1	
			K3	3	
	(c)(i)(B)	Quanta and waves - particles from space	K3	2	

Question	Part	Course content	Skills assessed	Maximum mark	A-type marks
	(c)(i)(C)	Electromagnetism - fields	K3	3	2
	(c)(ii)	Electromagnetism - fields	S4	2	
	(d)	Quanta and waves - particles from space	S6	1	1
9	(a)	Quanta and waves - simple harmonic motion	K1	1	
	(b)	Quanta and waves - simple harmonic motion	K3	3	1
	(c)(i)	Quanta and waves - simple harmonic motion	K3	3	
	(c)(ii)	Quanta and waves - simple harmonic motion	K3	3	
	(c)(iii)	Quanta and waves - simple harmonic motion	K3	3	
	(d)	Quanta and waves - simple harmonic motion	S3	2	1
	(e)	Quanta and waves - simple harmonic motion	S6	2	1
10	(a)	Quanta and waves - interference	K2	1	1
	(b)(i)	Quanta and waves - interference	K1	1	
	(b)(ii)	Quanta and waves - interference	K1	1	
	(c)(i)	Quanta and waves - interference	S4	2	
	(c)(ii)	Quanta and waves - interference	K2	2	2
	(d)(i)	Quanta and waves - waves	S2	1	
			K3	2	
	(d)(ii)	Quanta and waves - waves	K3	3	2
11	(a)	Quanta and waves - polarisation	K1	1	
	(b)(I)	Quanta and waves - polarisation	S3	1	
	(b)(ii)	Quanta and waves - polarisation	K3	3	
	(c)	Quanta and waves - polarisation	K2	2	
12		Uncertainties	K2	3	2
13	(a)	Electromagnetism - fields	K3	3	
	(b)	Electromagnetism - fields	K3	3	
	(c)	Electromagnetism - fields	S4	1	1
			K3	3	2
14	(a)	Electromagnetism - fields	S6	1	
	(b)(i)	Electromagnetism - fields	K3	2	
	(b)(ii)	Electromagnetism - fields	K3	2	
	(c)	Electromagnetism - fields	K2	1	1
15	(a)(i)	Electromagnetism - circuits	K2	1	1
	(a)(ii)	Electromagnetism - circuits	S2	1	
			K3	3	
	(a)(iii)	Electromagnetism - circuits	K3	4	3
	(b)	Electromagnetism - circuits	S3	2	1
16	(a)(i)	Data analysis	S4	3	
	(a)(ii)	Uncertainties	S2	1	
			K3	1	
	(a)(iii)	Data analysis	K2	1	1
	(b)	Evaluation and significance of experimental uncertainties	S7	2	2
	(c)	Uncertainties	S7	1	1