National
Qualifications
2024

2024 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.

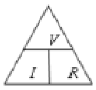
(c) Where a candidate incorrectly answers part of a question and carries the incorrect answer forward in the following part, award marks if the incorrect answer has then been used correctly in the subsequent part or ‘follow-on’. (GMP 16)

(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 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 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 $0{\cdot}\dot{6}$, 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 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

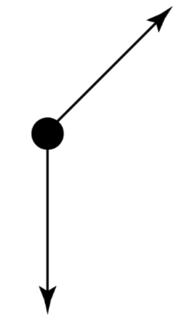
Example question

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.	$V = IR$ $7{\cdot}5 = 1{\cdot}5R$ $R = 5{\cdot}0\ \Omega$	1 mark: relationship 1 mark: substitution 1 mark: correct answer
2.	$5{\cdot}0\ \Omega$	3 marks: correct answer
3.	$5{\cdot}0$	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: 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)		$v = 2.4 + 13t - 0.69t^2$ $a = \frac{dv}{dt} = 13 - 1.38t$ **(1)** at t = 2.0 $a = 13 - (1.38 \times 2.0)$ **(1)** $a = 10\ \text{ms}^{-2}$ **(1)**	**3**	Accept: 10.2, 10.24
	(b)		$s = \left(\int v\,dt =\right)\ 2.4t + \frac{13}{2}t^2 - \frac{0.69}{3}t^3 (+c)$ **(1)** **(at t = 0, s = 0 $\therefore$ c = 0)** $s = (2.4 \times 2.0) + \left(\frac{13}{2} \times 2.0^2\right) - \left(\frac{0.69}{3} \times 2.0^3\right)$ **(1)** $s = 29$ **m** **(1)**	**3**	Accept: 30, 29.0, 28.96 Alternative limits method $\left(s = \int_0^2 (2.4 + 13t - 0.69t^2)\ dt\right)$ $s = \left[2.4t + \frac{13t^2}{2} - \frac{0.69t^3}{3}\right]_0^2$ **(1)** $s = \left(2.4 \times 2.0 + \frac{13 \times 2.0^2}{2} - \frac{0.69 \times 2.0^3}{3}\right)(-0)$ **(1)** $s = 29$ m **(1)**

Question			Expected response	Max mark	Additional guidance
2.	(a)		$v = r\omega$ **(1)** $v = 0.419 \times 3.01$ **(1)** $v = 1.26\ \text{ms}^{-1}$	**2**	SHOW question If final line is missing max 1.
	(b)	(i)		**2**	Accept: mg or W for weight Accept: T for tension 1 mark for each correctly labelled force with correct direction. If centripetal force is shown correctly - ignore If centripetal force is shown incorrectly – max 1 mark Any mention of centrifugal force – award 0 marks
		(ii)	$\left(T\sin\theta = \frac{mv^2}{r}\right.$ and $\left.T\cos\theta = mg\right)$ $\frac{T\sin\theta}{T\cos\theta} = \frac{\left(\frac{mv^2}{r}\right)}{mg}$ **(1,1)** $\tan\theta = \frac{v^2}{gr}$	**2**	Not a standard show question 1 mark for both components of tension 1 mark for dividing Accept: $\left(\tan\theta = \frac{F_c}{W}\right)$ $\tan\theta = \frac{\left(\frac{mv^2}{r}\right)}{mg}$ (1, 1) $\tan\theta = \frac{v^2}{gr}$ 1 mark for both forces F_c and W 1 mark for dividing
		(iii)	$\tan\theta = \frac{v^2}{gr}$ $\tan\theta = \frac{1.26^2}{9.8 \times 0.419}$ **(1)** $\theta = 21°$ **(1)**	**2**	Accept: 20, 21.1, 21.14 Accept answers in radians

Question			Expected response	Max mark	Additional guidance
2.	(c)		θ decreases **(1)** (As $\tan\theta = \frac{v^2}{gr}$) v and r both decrease but <u>v is squared</u>. **(1)**	**2**	MUST JUSTIFY Accept: θ decreases W stays the same and F_c decreases

Question			Expected response	Max mark	Additional guidance
3.	(a)		$I=\left(\frac{1}{3}ml^2\right)\times 3$ or $I=\left(\frac{1}{3}ml^2\right)$ **(1)** $I=\left(\frac{1}{3}\times 2.0\times 10^4\times 54^2\right)\times 3$ **(1)** $I=5.8\times 10^7$ kg m^2	**2**	SHOW question 1 for relationship 1 for all substitutions, including ×3 ×3 can appear at any stage of the calculation $I_{(blade)}=\left(\frac{1}{3}ml^2\right)$ $I_{(blade)}=\left(\frac{1}{3}\times 2.0\times 10^4\times 54^2\right)$ $I_{(total)}=\left(\frac{1}{3}\times 2.0\times 10^4\times 54^2\right)\times 3$ $I_{(total)}=5.8\times 10^7$ kg m^2
	(b)	(i)	$\omega=\omega_0+\alpha t$ **(1)** $0=3.7+(\alpha\times 550)$ **(1)** $\alpha=-6.7\times 10^{-3}$ rad s^{-2} **(1)**	**3**	Accept: −7, −6.73, −6.727
		(ii)	$\tau=I\alpha$ **(1)** $\tau=5.8\times 10^7\times(-)6.7\times 10^{-3}$ **(1)** $\tau=(-)3.9\times 10^5$ N m **(1)**	**3**	Accept: 4, 3.89, 3.886 Or consistent with (b)(i)
	(c)	(i)	←	**1**	
		(ii)	The mass of the ice is negligible.	**1**	Alternatives: Change in moment of inertia (of the system) is negligible.
	(d)		$P=0.3\rho Av^3$ $P=0.3\times 1.29\times\pi\times 54^2\times 11.5^3$ **(1)** $P=5.4\times 10^6$ W **(1)**	**2**	Accept: 5, 5.39, 5.392

Question			Expected response	Max mark	Additional guidance
4.	(a)		$\frac{GMm}{r^2} = mr\left(\frac{2\pi}{T}\right)^2$ (1) $\frac{6.67\times10^{-11}\times M}{\left(1.2\times10^3\right)^2} = 1.2\times10^3\left(\frac{2\pi}{11.9\times60\times60}\right)^2$ (1) $M = 5.6\times10^{11}$ kg (1)	3	Accept: 6, 5.57, 5.573 $\frac{GMm}{r^2} = mr\omega^2$ and $\omega = \frac{2\pi}{T}$ (1)
	(b)	(i)	$v = \sqrt{\frac{2GM}{r}}$ **(1)** $v = \sqrt{\frac{2\times6.67\times10^{-11}\times5.6\times10^{11}}{1.2\times10^3}}$ **(1)** $v = 0.25$ ms^{-1} **(1)**	3	Accept: 0.2, 0.250, 0.2495 Or consistent with (a)
		(ii)	Gravitational potential energy is less (as $E_p = -\frac{GMm}{r}$) **(1)** r has decreased/Dimorphos is now in a lower orbit **(1)**	2	Accept gravitational potential energy is more negative Any statement about change of mass zero marks.
	(c)		Collision only results in a small deflection. (Large distance required for a change of trajectory greater than the diameter of the Earth).	1	Accept arguments in terms of more time for the deflection to affect the path of the asteroid.

Question			Expected response	Max mark	Additional guidance
5.	(a)	(i)	$r_{schwarzchild} = \frac{2GM}{c^2}$ **(1)** $r_{schwarzchild} = \frac{2\times6.67\times10^{-11}\times6.0\times10^{24}}{(3.00\times10^{8})^2}$ **(1)** $r_{schwarzchild} = 8.9\times10^{-3}$ m **(1)**	3	Accept: 9, 8.89, 8.893
		(ii)	$\Delta t = t_G\left(\frac{1}{\sqrt{1-\left(\frac{r_{schwarzchild}}{r}\right)}}-1\right)$ $\Delta t = (24\times60\times60)\times\left(\frac{1}{\sqrt{1-\left(\frac{8.9\times10^{-3}}{6.4\times10^{6}}\right)}}-1\right)$ **(1)** $\Delta t = 6.0\times10^{-5}$ (s) **(1)**	2	Accept: 6, 6.01, 6.007 Or consistent with (a)(i)
	(b)		Clocks on the satellites have to be slowed by 39 μs (per day) **(1)**	1	Accept reduced by 39 μs (per day) Do not accept -39 μs on its own.
	(c)	(i)	$a_r = r\omega^2$ **(1)** $9.8 = \frac{1.8\times10^3}{2}\times\omega^2$ **(1)** $\omega = 0.10$ rad s^{-1} **(1)**	3	0.1, 0.104, 0.1043 Accept: $mr\omega^2 = mg$ as a starting point
		(ii)	(Clock) at the rim (would run slower). **(1)** It experiences a greater <u>acceleration</u> **OR** It experiences the same <u>effect</u> as being in a stronger gravitational field **OR** <u>Equivalent</u> to being in a stronger gravitational field **(1)**	2	MUST JUSTIFY Accept stronger <u>artificial</u> gravity for second mark.

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)	$\frac{P}{A} = \sigma T^4$ **(1)** $\frac{P}{A} = 5.67 \times 10^{-8} \times 2800^4$ **(1)** $\frac{P}{A} = 3.5 \times 10^6\ \text{W m}^{-2}$ **(1)**	**3**	Accept: 3, 3.49, 3.485
		(ii)	$L = 4\pi r^2 \sigma T^4$ **(1)** $4.38 \times 10^{23} = 4\pi \times r^2 \times 5.67 \times 10^{-8} \times 2800^4$ **(1)** $r = 1.0 \times 10^8\ \text{m}$ **(1)**	**3**	Accept: 1, 1.00, 1.000 Or consistent with (a)(i) $\frac{P}{A} = 3.5 \times 10^6 \left(= 5.67 \times 10^{-8} \times 2800^4\right)$
	(b)	(i)	(electron) neutrino Positron	**1**	 Accept: anti-electron
		(ii)	Deuterium only exists for 1 second (before fusing again)	**1**	Accept deuterium only exists for a (very) short time
	(c)		Lifetime is greater than the age of the (observable) Universe	**1**	

Question			Expected response	Max mark	Additional guidance
7.	(a)		Electron diffraction/interference	**1**	Must include experimental evidence rather than just naming an experiment
	(b)	(i)	$\lambda = \frac{h}{p}$ **(1)** $\lambda = \frac{6.63\times10^{-34}}{1.673\times10^{-27}\times1.50\times10^{7}}$ **(1)** $\lambda = 2.64\times10^{-14}$ m **(1)**	**3**	Accept: 2.6, 2.642, 2.6420
		(ii)	(de Broglie) wavelength too small (for wave-like effects) **OR** (de Broglie) wavelength very small (so object behaves like a particle)	**1**	Do not accept: the de Broglie wavelength is smaller than the size of the proton.
	(c)	(i)	$\left(\Delta\lambda = \frac{h}{mc}(1-\cos\theta)\right)$ $\Delta\lambda = (72.5-71.1)\times10^{-12}$ (1) $(72.5-71.1)\times10^{-12} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times3.00\times10^{8}}(1-\cos\theta)$ (1) $\theta = 65.0°$ (1)	**3**	Accept: 65, 64.98, 64.982 (72.5 – 71.1) is an independent mark
		(ii)	Decrease **(1)** $\cos\theta$ has increased **(1)**	**2**	JUSTIFY (θ has decreased, so) $1-\cos\theta$ has decreased Accept justification by calculation

Question			Expected response	Max mark	Additional guidance
8.	(a)	(i)	(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' not acceptable
		(ii)	$F = qvB$ or $F = qvB\sin\theta$ **(1)** $F = 1.60\times10^{-19}\times2.40\times10^{6}\times95.0\times10^{-3}\times\sin55.0$ **(1)** $F = \frac{mv^2}{r}$ or $F = \frac{m(v\sin\theta)^2}{r}$ **(1)** $F = \frac{1.673\times10^{-27}\times(2.40\times10^{6}\times\sin55.0)^2}{r}$ **(1)** $\left(1.60\times10^{-19}\times2.40\times10^{6}\times95.0\times10^{-3}\times\sin55.0 = \frac{1.673\times10^{-27}\times(2.40\times10^{6}\times\sin55.0)^2}{r}\right)$ $r = 0.216$ m **(1)**	**5**	Accept: 0.22, 0.2164, 0.21639 $r = \frac{mv}{qB}$ **(2)** $r = \frac{1.673\times10^{-27}\times2.40\times10^{6}\times\sin55.0}{1.60\times10^{-19}\times95.0\times10^{-3}}$ **(2)** $r = 0.216$ m **(1)**
	(b)		The radius will increase or the pitch will increase **(1)** The magnetic induction has reduced **(1)**	**2**	JUSTIFY

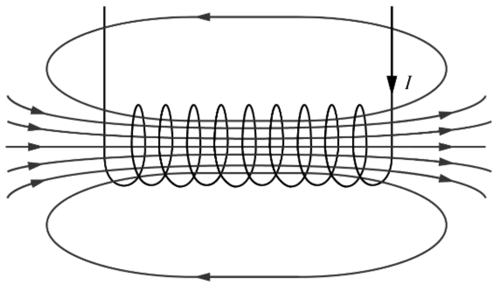
Question			Expected response	Max mark	Additional guidance
9.	(a)		$F = -ky$ **(1)** $(mg = k\Delta y)$ $510 \times 9.8 = (-)8.60 \times 10^4 \times \Delta y$ **(1)** $\Delta y = (-)0.058$ m **(1)**	**3**	Accept: 0.06, 0.0581, 0.05812
	(b)	(i)	$(F = ma\ ,\ F = -ky)$ $ma = -ky$ **(1, 1)** $a = -\omega^2 y$ **(1)** $((-)m\omega^2 y = (-)ky\ )$ $\omega = \sqrt{\frac{k}{m}}$	**3**	Not a standard SHOW question 1 mark for both force relationships 1 mark for equating $a = -\omega^2 y$ on its own 1 mark Final answer not shown max 2 marks
		(ii)	$\omega = \sqrt{\frac{k}{m}}$ $\omega = \sqrt{\frac{8.60 \times 10^4}{510}}$ (1) $\omega = 13$ rads^{-1} (1)	**2**	Accept: 10, 13.0, 12.99
		(iii)	Greater **(1)** The spring constant is greater and the mass remains constant or $\omega \propto \sqrt{k}$ **(1)**	**2**	MUST JUSTIFY Accept justification by calculation
	(c)	(i)	Underdamping	**1**	
		(ii)	Any change that reflects an increase in resistive force: density of oil, area of piston.	**1**	Do not accept increase the resistive force alone.

Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	$v = f\lambda$ **(1)** $\lambda = \frac{1}{0.18}$ (m) **(1)** $v = 9.5 \times \frac{1}{0.18}$ **(1)** $v = 53\ \text{ms}^{-1}$ **(1)**	4	Accept: 50, 52.8, 52.78
		(ii)	$E = kA^2$ **(1)** $\left(1 = k \times \left(1.95 \times 10^{-5}\right)^2\right)$ $\frac{1}{8} = \frac{1}{\left(1.95 \times 10^{-5}\right)^2} \times A^2$ **(1)** $A = 6.89 \times 10^{-6}$ m **(1)**	3	Accept: 6.9, 6.894, 6.8943 Accept: $\frac{E_1}{A_1^2} = \frac{E_2}{A_2^2}$ **(1)** $\frac{1}{\left(1.95 \times 10^{-5}\right)^2} = \frac{0.125}{A_2^2}$ **(1)** $A_2 = 6.89 \times 10^{-6}$ m **(1)**
		(iii)	The energy/amplitude of the wave becomes too small to be detected.	1	Accept: The energy/amplitude of the wave would reduce to zero.
	(b)		$\left(d = vt\right)$ $\Delta t = \frac{0.34}{53} - \frac{0.34}{150}$ **(1),(1)** $\Delta t = 4.1 \times 10^{-3}$ s **(1)**	3	Or consistent with (a)(i) Accept: 4, 4.15, 4.148 (1) for all substitutions (1) for subtraction (1) for final answer

Question			Expected response	Max mark	Additional guidance
11.	(a)		Helium-neon laser **(1)** Longest wavelength and $\Delta x = \frac{\lambda D}{d}$, D and d are constant **OR** Longest wavelength and $\Delta x \propto \lambda$ **(1)**	**2**	JUSTIFY
	(b)	(i)	$\Delta x = \frac{0.191}{12}$ **(1)** $\Delta x = \frac{\lambda D}{d}$ **(1)** $\frac{0.191}{12} = \frac{\lambda \times 3.15}{1.00 \times 10^{-4}}$ **(1)** $\lambda = 5.05 \times 10^{-7}$ m **(1)**	**4**	Accept: 5.1, 5.053, 5.0529 First mark independent
		(ii)	Measurement of separation of the fringes is too small. **OR** Measurement of slits to screen distance too large. **OR** Measurement of slit separation too small.	**1**	
	(c)	(i)	(The multiple tracks on the CD result in multiple) <u>coherent</u> sources of light (multiple reflections) **(1)** (Bright spots are where) the light meets <u>in phase</u> (to give constructive interference). **(1)**	**2**	Accept: division of wavefront in place of coherent Independent marks
		(ii) (A)	Reduce the (percentage/fractional) uncertainty in the measurements (of x and/or h) **OR** Reduces the (percentage/fractional) uncertainty in the separation of the tracks.	**1**	Do not accept reduces the scale reading uncertainty. Do not accept reduces the absolute uncertainty in the measurement.
		(ii) (B)	Dimmer spots, wider spots, fewer spots on the screen	**1**	

Question			Expected response	Max mark	Additional guidance
12.	(a)		Polaroid sheet/analyser (in front of screen) **(1)** (Observation of) light intensity change when the polaroid sheet / analyser is rotated **(1)**	**2**	If mention of two polaroid sheets (both polariser and analyser) – zero marks.
	(b)		**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)	(i)	(The electrical) force acting on a unit positive charge.	**1**	
		(ii)	$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ **(1)** $E = \dfrac{-4.5\times10^{-9}}{4\pi\times8.85\times10^{-12}\times0.088^2}$ **(1)** $E = -5.2\times10^3\ \text{NC}^{-1}$ **(1)**	**3**	Accept: -5, -5.23, -5.225 Using 9×10^9 gives -5.230
	(b)	(i)	$\left(E_T = \sqrt{E_1^2 + E_2^2}\right)$ $E_T = \sqrt{\left(-5.2\times10^3\right)^2 + \left(-5.2\times10^3\right)^2}$ **(1)** $E_T = 7.4\times10^3\ \text{NC}^{-1}$ **(1)**	**2**	Accept: 7, 7.35, 7.354 Or consistent with (a)(ii) Accept alternative methods using trigonometry.
		(ii)	(Vertically) down the page	**1**	Do not accept down/downwards on its own
	(c)	(i)	$W = QV$ **(1)** $W = (-)4.5\times10^{-9}\times(-)325$ **(1)** $(eV) = \dfrac{W}{1.60\times10^{-19}}$ $(eV) = \dfrac{4.5\times10^{-9}\times325}{1.60\times10^{-19}}$ **(1)** $(eV) = 9.1\times10^{12}$ (electron volts) **(1)**	**4**	Accept: 9, 9.14, 9.141
		(ii)	The starting position for Q_2 was not at the zero of electric potential.	**1**	Accept: Q_2 did not come from infinity.

Question			Expected response	Max mark	Additional guidance
14.	(a)			2	1 mark for shape 1 mark for direction
	(b)		$\left(B = \dfrac{\mu_0 INR^2}{2\left(R^2 + x^2\right)^{\frac{3}{2}}}\right)$ $B = \dfrac{4\pi \times 10^{-7} \times 3.5 \times 64 \times (120 \times 10^{-3})^2}{2\left((120 \times 10^{-3})^2 + 0^2\right)^{\frac{3}{2}}}$ **(1)** $B = 1.2 \times 10^{-3}$ T **(1)**	2	Accept: 1, 1.17, 1.173 Substitution of x = 0 not required for first mark
	(c)	(i)	(In a ferromagnetic material) the magnetic dipoles/domains (in the material) can be made to align, (resulting in the material becoming magnetised).	1	
		(ii)	Iron (or nickel or cobalt)	1	Any other ferromagnetic material is acceptable, such as steel or neodymium
		(iii)	The field lines will be more densely/ tightly packed together **OR** there will be more of them.	1	

Question			Expected response	Max mark	Additional guidance
15.			**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
16.	(a)	(i)	Five (time constants)	1	
		(ii)	$\tau = RC$ **(1)** $\frac{1.0\times10^{-3}}{5} = R\times220\times10^{-9}$ **(1)** $R = 9.1\times10^{2}\ \Omega$ **(1)**	3	Accept: 9, 9.09, 9.091 Or consistent with (a)(i)
	(b)		Equal to. **(1)** $(\tau = RC)$ and R and C are unchanged **(1)**	2	MUST JUSTIFY Accept: The time constant for the circuit is independent of the potential difference of the power supply.
	(c)	(i)	The opposition of a capacitor to changing current.	1	Accept: the opposition of a capacitor to AC Do not accept change in direction or change in magnitude on its own
		(ii)	$X_C = \frac{1}{2\pi fC}$ **(1)** $X_C = \frac{1}{2\pi\times77\times220\times10^{-9}}$ **(1)** $X_C = 9.4\times10^{3}\ \Omega$ **(1)**	3	Accept: 9, 9.40, 9.395

Question			Expected response	Max mark	Additional guidance
17.	(a)	(i)	$\left(\bar{t} = \frac{(16.09+16.26+16.15+16.48+16.22)}{5}\right)$ $\bar{t} = 16.24\,(\text{s})$ $\left(\bar{T} = \frac{\bar{t}}{10}\right)$ $\bar{T} = 1.624$ s **(1)**	**1**	Accept: 1.62
		(ii)	$\Delta t = \frac{(16.48-16.09)}{5}$ **(1)** $\left(\begin{array}{l} \Delta t = 0.078\ (\text{s}) \\ \frac{\Delta T}{T} = \frac{\Delta t}{t} \\ \frac{\Delta T}{1.624} = \frac{0.078}{16.24} \end{array}\right)$ $\Delta T = 0.008$ s **(1)**	**2**	Suspend sig figs rules Or consistent with (a) (i) Accept: 0.01, 0.0078 $\Delta t = \frac{(1.648-1.609)}{5}$ wrong physics zero marks.
	(b)		Acceptable substitutions into gradient relationship. **(1)** $\left(m = \frac{4\pi^2}{g}\right)$ $4.14 = \frac{4\pi^2}{g}$ **(1)** $g = 9.54\ \text{ms}^{-2}$ **(1)**	**3**	Or consistent with points chosen from the line Evidence of data extracted from the graph must be shown Use of single point only – award 0 marks.
	(c)		The uncertainties (in the experiment) are very small and hence the experiment is precise. **(1)** The value obtained in the experiment doesn't agree with the accepted value (for acceleration due to gravity) and hence is not accurate. **(1)**	**2**	Or consistent with (b) Independent marks. Accept: points all close to the line of best fit for precision

[END OF MARKING INSTRUCTIONS]