National Qualifications 2025

2025 Physics

Higher Paper 2

Question Paper Finalised Marking Instructions

These marking instructions have been prepared by examination teams for use by SQA appointed markers when marking external course assessments.

General marking principles for Physics Higher

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this 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 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.

(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) Where a candidate answers part of a question incorrectly 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)

(e) Award marks 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. (GMP 20)

(f) 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)

(g) Award marks 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). (GMP 19)

(h) Marks are allocated for knowledge of relevant relationships alone. Do not award a mark when a candidate writes down several relationships and does not select the correct one to continue with, for example by substituting values. (GMP 1c)

(i) 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)

(j) 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)

(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.)

(k) 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, 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*, eg 'defraction'
- that might be interpreted as either *fission* or *fusion*, eg 'fussion'

The spelling of these words is similar, but the words have totally different meanings. If the spelling (or handwriting) in an answer makes it difficult for you to interpret a candidate's intention, then do not award the mark. (GMP 22)

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

Standard three marker
The examples over the page set out how to apportion marks to answers requiring calculations. These are the 'standard three marker' type of questions.

Award full marks for a correct answer to a numerical question, even if the steps are not shown explicitly, **unless** it specifically requires evidence of working to be shown.

For some questions requiring numerical calculations, there may be alternative methods (eg alternative relationships) that would lead to a correct answer.

Sometimes, a question requires a calculation that does not fit into the 'standard three marker' type of response. In these cases, the detailed marking instructions will contain guidance for marking the question.

When marking partially correct answers, apportion individual marks as shown over the page.

(I) 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)	(i)	The velocity increases by 1.45 m s^{-1} every second	**1**	Accept: Speed increases by 1.45 m s^{-1} every second. Velocity/speed changes by 1.45 m s^{-1} every second. Rate of change of velocity/speed is 1.45 m s^{-1} every second.
		(ii)	$v^2 = u^2 + 2as$ (1) $8.86^2 = 0^2 + (2 \times 1.45 \times s)$ (1) $s = 27.1$ m (1)	**3**	Accept: 27, 27.07, 27.069 Alternative methods using two relationships: 1 mark for both relationships. 1 mark for both substitutions. 1 mark for final answer.

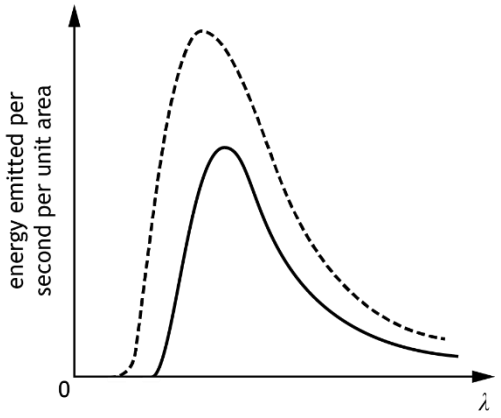
Question			Expected response	Max mark	Additional guidance
1.	(b)		$(W = mg)$ $W = 31 \times 9.8$ (1) Each cable supports $\frac{31 \times 9.8}{4}$ (1) $T \sin 12 = \frac{31 \times 9.8}{4}$ (1) $T = 370$ N (1)	**4**	Accept: 400, 365, 365.3 1 mark for quartering mass/weight/tension/force anywhere. Alternative methods: Each cable supports $\frac{31}{4}$ (1) $(W = mg)$ $W = \frac{31}{4} \times 9.8$ (1) $T \sin 12 = \frac{31}{4} \times 9.8$ (1) $T = 370$ N (1) **OR** $(W = mg)$ $W = 31 \times 9.8$ (1) $T \sin 12 = 31 \times 9.8$ (1) $\left(T = \frac{31 \times 9.8}{\sin 12}\right)$ Tension in each cable $\frac{\left(\frac{31 \times 9.8}{\sin 12}\right)}{4}$ (1) $T = 370$ N (1) Accept methods using $\cos 78$ Do not accept: $F = ma$ $F = mg \sin \theta$ Max 1 mark for quartering.

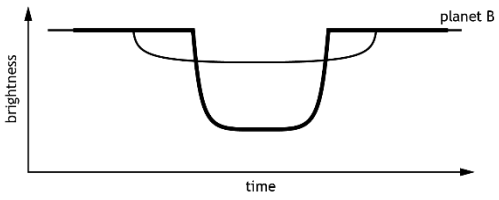
Question			Expected response	Max mark	Additional guidance
2.	(a)		Total momentum before (a collision) is equal to the total momentum after (a collision) in the absence of external forces.	**1**	Do not accept: TMB = TMA. 'An isolated system' is equivalent to the absence of external forces.
	(b)		(total momentum before = total momentum after) $m_P u_P + m_Q u_Q = m_P v_P + m_Q v_Q$ (1) $(0.18 \times 1.20) + (0.24 \times -0.64) = (0.18 \times -0.76) + (0.24 \times v_Q)$ (1) $v_Q = 0.83 \text{ m s}^{-1}$ (1)	**3**	Accept 0.8, 0.830, 0.8300 Equating the total momenta before and after. (1) All substitutions. (1) Final answer. (1) If a direction is stated it must be 'to the right' otherwise MAX 2 marks.
	(c)		$E_k = \frac{1}{2}mv^2$ *before* $E_{k_{before}} = \left(\frac{1}{2} \times 0.18 \times 1.20^2\right) + \left(\frac{1}{2} \times 0.24 \times 0.64^2\right)$ $E_{k_{before}} = 0.18 \text{ J}$ *after* $E_{k_{after}} = \left(\frac{1}{2} \times 0.18 \times 0.76^2\right) + \left(\frac{1}{2} \times 0.24 \times 0.83^2\right)$ $E_{k_{after}} = 0.13 \text{ J}$ The collision is inelastic.	**4**	Or consistent with (b). 1 mark for relationship anywhere. 1 mark for **all** substitutions. 1 mark for **both** total kinetic Energies. 1 mark for correct final statement. Suspend significant figure rule for calculated values of total kinetic energies in this question. Final statement mark only available if calculation for total E_k is attempted.

Question			Expected response	Max mark	Additional guidance
2.	(d)	(i)	$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$ **(1)** $849 = 845 \times \left(\frac{3.40\times10^2}{3.40\times10^2 - v_s}\right)$ **(1)** $v_s = 1.60\ \text{m s}^{-1}$ **(1)**	**3**	Accept: 1.6, 1.602, 1.6019 Accept: $f_o = f_s\left(\frac{v}{v - v_s}\right)$
		(ii)	Statement that there are more wavefronts per second (arriving at the microphone). **OR** The wavefronts (arriving at the microphone) are closer together. **OR** Diagram showing wavefronts closer together ahead of the vehicle and further apart behind it. Or any similar response.	**1**	Look for reference to wavefronts/ wavelengths/waves/crests first, otherwise 0 marks. The wavefronts in front of the vehicle/buzzer are closer together. Do not accept: Any answer that implies that the frequency/wavelength of the sound produced by the buzzer itself is changing. **OR** wavelengths are decreasing on its own.
		(iii)	Move the vehicle/buzzer with a greater speed (towards the student). **OR** Student stands at the middle of the air track (so the vehicle passes the student).	**1**	Do not accept: Moving the microphone. **OR** Changing the frequency of the buzzer. **OR** Visual interpretations e.g. use computer software.

Question			Expected response	Max mark	Additional guidance
3.			**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)		Time dilation	**1**	
	(b)		$t' = \dfrac{t}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$ (1) $t' = \dfrac{245}{\sqrt{1-\left(\dfrac{2.29\times10^8}{3.00\times10^8}\right)^2}}$ (1) $t' = 379$ s (1)	**3**	Accept: 380, 379.3, 379.25 Accept: $t' = \dfrac{245}{\sqrt{1-\left(\dfrac{2.29}{3.00}\right)^2}}$
	(c)		The student is incorrect. **(1)** The train does not travel at relativistic speeds. **(1)**	**2**	**JUSTIFY** Accept: Time dilation is negligible/ insignificant. **OR** No time dilation takes place. Accept: The train is not travelling at a speed close to the speed of light. The effects of special relativity only become significant when the speed $\geq 0.1c$. The train will not reach speeds of this magnitude. Can be justified by calculation. Allow for responses that identify that time dilation does take place but is insignificant, so statement is correct in one aspect.

Question			Expected response	Max mark	Additional guidance
5.	(a)		$\left(\frac{210000}{2290}\right) = 92$ (1) (Surface temperature of Star 2 is) 2 (orders of magnitude) greater. **OR** Surface temperature of Star 1 is 2 orders of magnitude smaller. **(1)**	**2**	Accept: $\left(\frac{2.1\times10^5}{2.29\times10^3}\right) = 92$ **OR** $\left(\frac{10^5}{10^3}\right) = 10^2$ (1) Accept: '2 greater' on its own. (2) Do not accept: '2 <u>times</u> greater' on its own. (0) Care should be taken where candidates answer by the reciprocal method – 2 marks are still available. $\left(\frac{2.29\times10^3}{2.1\times10^5}\right) = 0.011$ (1) Comparison statement. (1)
	(b)	(i)		**2**	Peak wavelength less. (1) Line added should always be above original line. (1)
		(ii)	Lower (surface) temperature. **OR** (The radiation from star 1) has a longer <u>peak</u> wavelength (than the Sun).	**1**	Accept: Less hot or cooler. Accept: A <u>peak</u> wavelength closer to red.

Question			Expected response	Max mark	Additional guidance
5.	(c)	(i)	$F = G\frac{m_1 m_2}{r^2}$ (1) $F = 6.67\times10^{-11}\times\frac{6.09\times10^{24}\times1.77\times10^{29}}{\left(1.81\times10^{11}\right)^2}$ (1) $F = 2.19\times10^{21}$ N (1)	**3**	Accept: 2.2, 2.195, 2.1946
		(ii)	Force is less/ $\frac{3}{4}$ **(1)** Three times the mass gives three times the force. **(1)** Doubling the distance gives quarter of the force. **(1)**	**3**	**JUSTIFY** Look for this statement first – if incorrect or missing then 0 marks. Correct statement. (1) Do not accept: decrease by $\frac{3}{4}$ Numerator three times bigger. (1) Denominator four times bigger. (1) Can justify by calculation Correct substitution. (1) Correct numerical final answer (1) $\left(1.65\times10^{21}\text{ N}\right)$ Accept: 1.6, 1.646, 1.6460
		(iii)		**2**	**INDEPENDENT MARKS** Drop from same initial brightness is greater. (1) Transit time is shorter. (1) Accept "double or multiple dips"; however if multiple dips are shown, transit times and dips must look consistent.

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)	(Some) mass (is lost and) converted to energy.	**1**	There must be an indication of mass being converted (or an equivalent term) to energy eg transformed, becomes, changed to. Do not accept: transferred. Mass is lost on its own (0) Mass defect is wrong physics (0)
		(ii)	Mass before $= 4.0028\times10^{-25}$ (kg) Mass after $= 3.9363\times10^{-25} + 6.6447\times10^{-27}$ Mass after $= 4.002747\times10^{-25}$ (kg) Mass lost $= 5.3\times10^{-30}$ (kg) (1) $E = mc^2$ (1) $E = 5.3\times10^{-30}\times\left(3.00\times10^{8}\right)^2$ (1) $E = 4.77\times10^{-13}$ J (1)	**4**	Accept: 4.8, 4.770, 4.7700 Check for correct substitutions of values in calculation of mass lost. If values are incorrect, maximum 1 mark for relationship, even if final answer is correct. $E = mc^2$ anywhere, 1 mark. If masses before and after not substituted to full significant figures as given in the table, then maximum 1 mark for relationship. Ignore inappropriate reference to mass defect. Arithmetic mistake can be carried forward through the response.
	(b)	(i)	Nitrogen	**1**	Accept: N or $^{14}_{7}\mathrm{N}$
		(ii)	An (anti)neutrino is emitted. **OR** An extra particle is emitted.	**1**	Accept: Beta decay is evidence for (the existence of) the neutrino.

Question			Expected response	Max mark	Additional guidance
6.	(c)	(i)	Fundamental particles are not composed of other particles.	**1**	Accept: Fundamental particles cannot be 'broken down' into other/smaller particles. **OR** Fundamental particles cannot be 'broken down' any further.
		(ii)	Baryon(s)	**1**	
		(iii)	$+\frac{2}{3}(e)-\frac{1}{3}(e)+\left(\frac{2}{3}(e)-\frac{2}{3}(e)\right)+s=0$ (1) $s=-\frac{1}{3}e$ (1) $\left(+\frac{2}{3}(e)\right)+\left(-\frac{1}{3}(e)\right)+\left[\left(+\frac{2}{3}(e)\right)+\left(-\frac{2}{3}(e)\right)\right]+s=0$ (1) $s=-\frac{1}{3}e$ (1)	**2**	Accept: 5.33×10^{-20} C $-\frac{1}{3}$ on its own, maximum 1 mark. Allow imprecise working leading to a correct final answer for this question.

Question			Expected response	Max mark	Additional guidance
7.	(a)		The power per unit area (incident on a surface).	**1**	Accept: power per square metre. power per metre squared. power per m^2. Do not accept: watts per square metre.
	(b)		$198.4 \times 0.200^2 = 7.94$ $49.6 \times 0.400^2 = 7.94$ $22.0 \times 0.600^2 = 7.92$ $12.4 \times 0.800^2 = 7.94$ (2) statement of $I \times d^2 = \text{constant}$ **OR** $I \propto \frac{1}{d^2}$ (1)	**3**	If only 3 sets of data used correctly then maximum 2 marks. If only 2 sets of data used correctly then maximum 1 mark (for relationship). If only 1 set of data used correctly, award 0 marks. Must be clear how the candidate has used the data to obtain the relationship. Suspend significant figure rule for calculated values of constant in this question. Accept: $I \times d^2 = 7.9$ Unit is not required but if stated needs to be correct. In this case watts, W. The 'statement' mark is only available if consistent with the calculations shown. $I_1 d_1^2 = I_2 d_2^2$ is insufficient on its own for statement of relationship. $I \times d^2 = k$ is insufficient on its own for statement of relationship. Graphical method: Graph drawn correctly. (1) Line of best fit through origin. (1) Statement of relationship. (1) A sketch graph is not acceptable.

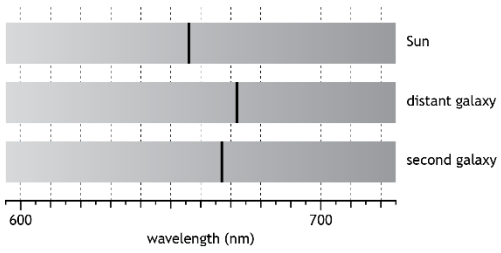
Question			Expected response	Max mark	Additional guidance
7.	(c)		Any two from: Smaller lamp / use point source. Black cloth on bench / wear black clothing. Greater range of distances. Smaller increments of distance. Account for background light level eg Subtract background light level, Tare/zero the light meter.	**2**	Do not accept: 'repeat measurements and calculate the mean'. Do not accept: do it in a darkened room. **OR** any suggestion about making the room darker. ± rule applies for surplus responses (GMP 21).
	(d)	(i)	$\left(r = 5.00\times10^{-4}\right)$ $(A = \pi r^2)$ $A = \pi \times (5.00\times10^{-4})^2$ (1) $I = \frac{P}{A}$ (1) $1.51\times10^{3} = \frac{P}{\pi \times (5.00\times10^{-4})^2}$ (1) $P = 1.19\times10^{-3}$ W (1)	**4**	Accept: 1.2, 1.186, 1.1860 The use of 3.14 is acceptable for π. For use of 3.14, accept: P = 1.185, 1.1854 $I = \frac{P}{A}$ anywhere, 1 mark. If no attempt to calculate area, maximum 1 mark for irradiance relationship.
		(ii)	Laser is not a point source. **OR** Light from the laser does not conform to the inverse square law. **OR** Laser beam does not diverge.	**1**	Accept: The beam of light does not spread out. **OR** The beam of light covers same area. Do not accept: 'irradiance doesn't change with distance' on its own.

Question			Expected response	Max mark	Additional guidance
8.	(a)		Each photon has a fixed/discrete amount of energy. **OR** Each photon removes one electron.	**1**	Some indication of quantisation of energy.
	(b)	(i)	The minimum energy required for (photo)electron(s) to be emitted/ejected.	**1**	Accept: The minimum energy required for photoemission (of electrons). Accept: least/lowest/smallest. Do not accept: minimum energy of light without mention of photon.
		(ii)	$E_k = hf - hf_0$ (1) $E_k = \left(6.63\times10^{-34}\times1.30\times10^{15}\right) - 5.89\times10^{-19}$ (1) $E_k = 2.73\times10^{-19}$ J (1)	**3**	Accept: 2.7, 2.729, 2.7290 Alternative method: $E = hf$ (1) $E = 6.63\times10^{-34}\times1.30\times10^{15}$ $E_k = \left(6.63\times10^{-34}\times1.30\times10^{15}\right) - 5.89\times10^{-19}$ (1) $E_k = 2.73\times10^{-19}$ J (1) $E = hf$ on its own (0) marks.
		(iii)	No effect (on the maximum kinetic energy). **(1)** Each photon incident on the metal plate has the same energy as before. **(1)**	**2**	**MUST JUSTIFY** Accept: no change (to the maximum kinetic energy). Accept: $E = hf$ is unchanged.

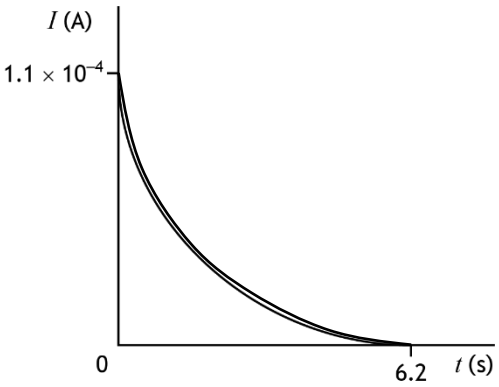
Question			Expected response	Max mark	Additional guidance
9.	(a)		Path difference (at the central maximum) is zero for each wavelength. **(1)** All wavelengths combine (to give white light). **OR** Constructive interference occurs for each wavelength. **(1)**	**2**	**INDEPENDENT MARKS** Accept: Path difference (at the central maximum) is the same for all wavelengths. Accept: frequency/colour for wavelength, for this question.
	(b)		$d \sin\theta = m\lambda$ **(1)** $\frac{1}{1000\,000} \times \sin\theta = 1 \times 412 \times 10^{-9}$ **(1)** $\theta = 24.3°$ **(1)**	**3**	Accept: 24, 24.33, 24.331 Accept: $d \sin\theta = m\lambda$ **(1)** $\frac{1 \times 10^{-3}}{1000} \times \sin\theta = 1 \times 412 \times 10^{-9}$ **(1)** $\theta = 24.3°$ **(1)**
	(c)		Greater (%) absorption at red and blue/violet ends of the spectrum. **(1)** Smaller (%) absorption of green light. **(1)**	**2**	**INDEPENDENT MARKS** Smaller (%) transmission at red and blue/violet ends of the spectrum. **(1)** Greater (%) green light is transmitted/passes through. **(1)** Effect on red and blue light. (**1**) Effect on green light. (**1**) Do not accept: any discussion of appearing green due to reflection, on its own. The question is asking about the transmitted light. Do not accept: any implication of total absorption or total transmission.

Question			Expected response	Max mark	Additional guidance
9.	(d)		Slit separation d of new grating is greater than the previous grating. **(1)** Spectrum is narrower. **OR** Colours in the spectrum are closer together. **OR** It is more difficult to place the spectrophotometer in one colour of light. **(1)**	**2**	**INDEPENDENT MARKS** Do not accept: fewer lines per millimetre on its own. Accept: angle of dispersion is smaller. Do not accept: $\sin\theta$ or θ is smaller on its own. **OR** maxima less spaced out on its own. May be answered with the aid of a labelled diagram.

Question			Expected response	Max mark	Additional guidance
10.	(a)		Photons of particular/some/certain energies/frequencies/wavelengths are absorbed. **(1)** in its/the Sun's (upper/outer) atmosphere/outer layers. **(1)**	**2**	Accept: Particular/some/certain frequencies/wavelengths of light/radiation are absorbed. Accept: gases or suitable named gases in place of atmosphere, but not elements or atoms on their own. Do not accept: 'in the atmosphere' – it is too vague.
	(b)	(i)	486 nm	**1**	Accept: 4.86×10^{-7} m 486×10^{-9} m
		(ii)	$v = f\lambda$ (1) $3.00\times10^{8} = f \times 486\times10^{-9}$ (1) $f = 6.17\times10^{14}$ Hz (1)	**3**	Or consistent with b(i) Accept: 6.2, 6.173, 6.1728
		(iii) (A)	$E = hf$ (1) $E = 6.63\times10^{-34}\times6.17\times10^{14}$ (1) $E = 4.09\times10^{-19}$ J (1)	**3**	Or consistent with b(ii) Accept: 4.1, 4.091, 4.0907 Accept: $E_2 - E_1 = hf$ $\Delta E = hf$
		(iii) (B)	E_1 to E_3	**1**	Or consistent with (b)(iii)(A). Accept: (Electron transition) to E_3 Accept: $E_1 \rightarrow E_3$ Between E_1 and E_3 Direction must be correct. Accept: correct transition indicated on energy level diagram. Do not accept: E_1 – E_3 'E_1 and E_3' on its own. Between E_3 and E_1

Question			Expected response	Max mark	Additional guidance
10.	(c)	(i)	$z = \frac{\lambda_o - \lambda_r}{\lambda_r}$ (1) $z = \frac{672\times10^{-9} - 656\times10^{-9}}{656\times10^{-9}}$ (1) $z = \frac{v}{c}$ (1) $\frac{672\times10^{-9} - 656\times10^{-9}}{656\times10^{-9}} = \frac{v}{3.00\times10^{8}}$ (1) $v = 7.32\times10^{6}\ \text{ms}^{-1}$ (1)	**5**	Accept: 7.3, 7.317, 7.3171 $z = \frac{\lambda_o - \lambda_r}{\lambda_r}$ anywhere, 1 mark. Accept: 672 and 656 $z = \frac{v}{c}$ anywhere, 1 mark substitution of 3.00×10^8 **(1)** Alternative method: $\frac{\lambda_o - \lambda_r}{\lambda_r} = \frac{v}{c}$ $\frac{672-656}{656} = \frac{v}{3.00\times10^{8}}$ $v = 7.32\times10^{6}\ \text{ms}^{-1}$ Equating formula, **(2)** Substitution of λ_r and λ_o **(1)** Substitution of c **(1)** Final answer **(1)**
		(ii)		**1**	Or consistent with (c)(i). Line drawn should be between the Sun and distant galaxy lines. (667 nm). Note: If value to (c)(i) is less than 4.88×10^6 m s^{-1} then line can be anywhere to the right of distant galaxy line.
	(d)		Dark energy	**1**	

Question			Expected response	Max mark	Additional guidance
11.	(a)		$V = IR$ (1) $6.0 = 2.0\times10^{-3}\times R_T$ (1) $R = \left(\frac{6.0}{2.0\times10^{-3}}\right) - 1.8\times10^{3}$ (1) $R = 1.2\times10^{3}\ \Omega$ (1)	**4**	Accept: 1, 1.20, 1.200 Alternative method using $V = IR$ twice: Relationship **(1)** Substitution to find voltage across 1.8 kΩ **(1)** Substitution to find R **(1)** Correct final answer **(1)**
	(b)		$T = 4\times5.0\times10^{-3}\ (\text{s})$ (1) $T = \frac{1}{f}$ (1) $4\times5.0\times10^{-3} = \frac{1}{f}$ (1) $f = 50$ Hz	**3**	**SHOW question** Accept: $f = \frac{N}{t}$ Accept: $T = \frac{1}{f}$ (1) $4\times5.0\times10^{-3} = \frac{1}{f}$ (2) $f = 50$ Hz
	(c)		(Amplitude) increases **(1)** Total resistance of the circuit decreases. **OR** Current (in R) increases. **(1)** Voltage across R increases. **(1)**	**3**	**MUST JUSTIFY.** Resistance of parallel part of circuit decreases. **OR** voltage across parallel part of circuit decreases. Do not accept: Voltage through/in … Current across … 0 marks

Question			Expected response	Max mark	Additional guidance
12.	(a)		1.1×10^{-4} on the y-axis **(1)** Graph shape **(1)** Reaches zero at 6.2 **(1)** 	**3**	Accept: 1, 1.07, 1.071 Line crossing x-axis – maximum **(2)** Line crossing y-axis – maximum **(2)** Line must be a curve to award the second mark. **If** an acceptable value for initial current is shown, then the line must start at this value to be awarded the 'graph shape' mark. Line must tend towards the time axis to gain the second mark.
	(b)	(i)	Decreasing (the resistance). **(1)** The current would decrease during charging so the resistance must be decreased to compensate. **(1)**	**2**	**JUSTIFY** Accept: The voltage across R would decrease during charging so the resistance must be decreased to compensate. 2nd mark is for indicating what would happen if you didn't adjust the resistance. eg to prevent the current from decreasing
		(ii)	$Q = It$ (1) $Q = 15 \times 10^{-6} \times 28$ (1) $Q = 4.2 \times 10^{-4}$ C (1)	**3**	Accept: 4, 4.20, 4.200
		(iii)	$C = \frac{Q}{V}$ (1) $C = \frac{4.2 \times 10^{-4}}{9.0}$ (1) $C = 4.7 \times 10^{-5}$ F (1)	**3**	Or consistent with (b)(ii) Accept: 5, 4.67, 4.667

Question			Expected response	Max mark	Additional guidance
13.			**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
14.	(a)	(i)	Axes appropriately labelled (quantity and units) and axes linearly scaled. **(1)** [Allow for axes starting at zero or broken axes or an appropriate value]. Data points plotted accurately. **(1)** Appropriate line of best-fit. **(1)**	**3**	If the origin is shown the scale must either be continuous, or the axis must be 'broken'. Otherwise, maximum 2 marks. If non-linear scale is used over the range of the data on either axis eg values from the table are used as the scale points, (0) marks. Do not penalise if candidates plot e against F. Accuracy of plotting should be easily checkable with the scale chosen. An appropriate scale to allow the accuracy of plotting to be checked must be linear over the range of the data.

Question			Expected response	Max mark	Additional guidance
14.	(a)	(ii)	Choosing 2 points on their line. **(1)** Calculate gradient. **(1)** (min 1 sig fig, max 4 sig figs). (Gradient works out as approx. 3.3×10^3).	**2**	**Must** be consistent with graph drawn for (a)(i). Candidates are asked to calculate the gradient of **their line of best fit**. If relationship to calculate gradient is stated incorrectly (0) marks, eg $\frac{y^2 - y^1}{x^2 - x^1}$. If candidates use values from the table, these points must lie on **their line**. If $(\times 10^{-3})$ is not accounted for in the final answer, maximum 1 mark unless this being omitted is consistent with the graph drawn in (a)(i). A unit is not required in the final answer, but if stated it must be correct. If candidate has a non-linear scale over the range of the values used in the substitution, **(0)** marks. If candidate has drawn a 'dot to dot' graph or no line, **(0)** marks.

Question			Expected response	Max mark	Additional guidance
14.	(a)	(iii)	$\left(gradient = \frac{EA}{L} \right)$ $3.3 \times 10^{3} = \frac{E \times 5.9 \times 10^{-8}}{1.500}$ (1) $E = 8.4 \times 10^{10}$ Pa (1)	**2**	**Must be** consistent with (a)(ii). **Must** substitute the gradient of **their line of best fit**, and not a single data point. If a single data point is substituted into in the calculation, award (0) marks. Accept: correct alternative units. If candidate has plotted extension against force, the formula becomes $\left(gradient = \frac{L}{EA} \right)$ $3.3 \times 10^{-4} = \frac{1.500}{E \times 5.9 \times 10^{-8}}$ (1) $E = 8.4 \times 10^{10}$ Pa (1)
	(b)		There is (a non-zero) y-intercept. **OR** the line of best fit does not go through the origin.	**1**	

[END OF MARKING INSTRUCTIONS]