National
Qualifications
2022

2022 Physics

Higher Paper 2

Finalised Marking Instructions

General marking principles for Physics 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.

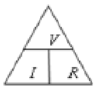
(c) Where a candidate incorrectly answers part of a question and carries the incorrect answer forward in the following part, award marks if the incorrect answer has then been used correctly in the subsequent part or 'follow-on'. (GMP 17)

(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, the mark allocated for stating an appropriate relationship is not awarded. (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 for the relationship, the correct relationship must be stated, for example $V = IR$ or $R = \frac{V}{I}$. (GMP 6)

(i) In rounding to an expected number of significant figures, award the mark for correct answers that have up to two figures more or one figure less than the number in the data with the fewest significant figures. (GMP 10)

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

(j) Award marks where candidates have incorrectly spelled technical terms, provided that responses can be interpreted and understood without any doubt as to the meaning. Where there is ambiguity, do not award the mark. Two specific examples of this would be when the candidate uses a term that might be interpreted as 'reflection', 'refraction' or 'diffraction' (for example 'defraction'), or one that might be interpreted as either 'fission' or 'fusion' (for example 'fussion'). (GMP 25)

(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.

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 "Marking in calculations".

(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) (A)	$u_h = 17.0\cos 24.0$ $u_h = 15.5\ \text{m s}^{-1}$ **(1)**	**1**	Accept: 16, 15.53, 15.530
		(i) (B)	$u_v = 17.0\sin 24.0$ $u_v = 6.91\ \text{m s}^{-1}$ **(1)**	**1**	Accept: 6.9, 6.915, 6.9145
		(ii)	$s = \bar{v}t$ **(1)** $11 = 15.5 \times t$ **(1)** $t = 0.71\ \text{s}$	**2**	**SHOW question** Accept: $s = vt$ $s = ut$ $d = vt$ $d = \bar{v}t$ $s = ut + \frac{1}{2}at^2$ (with $a = 0$) $s = \frac{1}{2}(u+v)t$ (with $u = v$) Alternative method: (as ball is at its maximum height) $v = u + at$ (u and a must have opposite signs)

Question			Expected response	Max mark	Additional guidance
1.		(iii)	$s = ut + \frac{1}{2}at^2$ **(1)** $s = 6.91 \times 0.71 + \frac{1}{2} \times -9.8 \times 0.71^2$ **(1)** $s = 2.4$ m **(1)**	3	**OR** consistent with (a)(i)(B) Accept: 2, 2.44, 2.436 Alternative methods: $v^2 = u^2 + 2as$ $0^2 = 6.91^2 + 2 \times -9.8 \times s$ $s = 2.4$ m Accept: 2, 2.44, 2.436 for this method. $s = \frac{1}{2}(u+v)t$ $s = \frac{1}{2} \times (6.91 + 0) \times 0.71$ $s = 2.5$ m Accept: 2, 2.45, 2.453 for this method.
	(b)		under **(1)** The ball has a smaller (initial) vertical (component of) velocity (so never reaches the same height). **(1)**	2	**JUSTIFY question** Accept: below Accept: speed instead of velocity

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>2.</td><td>(a)</td><td>(i)</td><td>$v^2 = u^2 + 2as$ (1)
$0^2 = 0.78^2 + 2 \times a \times 2.160$ (1)
$a = -0.14$ m s^{-2} (1)</td><td>3</td><td>Accept: -0.1, -0.141, -0.1408

Accept ‘0.14 m s^{-2} to the left’

a must be opposite sign from u and s

Alternative methods:
Both relationships (1)
Both substitutions (1)
Final answer (1)

Do not accept ‘$a = -0.14$ m s^{-2} to the left’</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$F = ma$ (1)
$F = 0.350 \times (-)0.14$ (1)
$F = (-)0.049$ N (1)</td><td>3</td><td>OR consistent with (a)(i)

Accept: 0.05, 0.0490, 0.04900

In <u>this</u> question, ignore negative signs in both the substitution and final answer for force.

Alternative method:
$Fd = \frac{1}{2}mv^2$
$F \times 2.160 = \frac{1}{2} \times 0.350 \times 0.78^2$
$F = 0.049$ N

Both relationships (1)
Both substitutions (1)
Final answer (1)
Accept: 0.05, 0.0493, 0.04929 for <u>this</u> method.</td></tr>
<tr><td></td><td>(b)</td><td></td><td>Mass does not have the largest <u>percentage</u> uncertainty.

OR

Initial speed has largest <u>percentage</u> uncertainty.</td><td>1</td><td>Accept:
‘%’ for percentage
‘fractional’ for percentage

Absolute uncertainty on its own, (0) marks.</td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
3.	(a)	(i)	$\Delta mv = mv - mu$ **(1)** $\Delta mv = (0.25 \times 1.80) - (0.25 \times 0.40)$ **(1)** $\Delta mv = 0.35$ kg m s^{-1} **(1)**	**3**	Accept: 0.4, 0.350, 0.3500 Accept: $\Delta p = m\Delta v$ $Ft = mv - mu$ $p = mv$ Do not accept: $p = mv - mu$ - 0 marks For alternative methods: Acceptable relationship **(1)** **all** substitutions **including subtraction** **(1)** Final answer **(1)** Sign convention must be consistent within this part of the question. v and u must have same sign. Accept N s
		(ii)	$Ft = mv - mu$ **(1)** $6.25 \times t = 0.35$ **(1)** $t = 0.056$ s **(1)**	**3**	**OR** consistent with (a)(i) Accept: 0.06, 0.0560, 0.05600 Alternative method: $F = ma$ $6.25 = 0.25 \times a$ $v = u + at$ $1.80 = 0.40 + \left(\frac{6.25}{0.25}\right) \times t$ $t = 0.056$ s Both relationships **(1)** Both substitutions **(1)** Final answer **(1)**

Question			Expected response	Max mark	Additional guidance
3.	(b)		(total momentum before = total momentum after) $m_x u_x + m_y u_y = m_x v_x + m_y v_y$ **(1)** $(0.50 \times 0.40) + (0.25 \times 0.40)$ $= (0.50 v_x) + (0.25 \times 1.80)$ **(1)** $v_x = -0.30 \text{ m s}^{-1}$ **(1)** **OR** $(m_x + m_y)u = m_x v_x + m_y v_y$ **(1)** $(0.50 + 0.25) \times 0.40$ $= (0.50 v_x) + (0.25 \times 1.80)$ **(1)** $v_x = -0.30 \text{ ms}^{-1}$ **(1)** (Accept '0.30 m s^{-1} to the left')	**3**	Accept: -0.3, -0.300, -0.3000 Equating the total momenta before and after **(1)** All substitutions **(1)** Final answer **(1)** Sign convention must be consistent. Do not accept: 'v_x = –0.30 m s^{-1} to the left' Alternative methods: $\Delta mv = mv - mu$ $-0.35 = (0.50v) - (0.50 \times 0.40)$ $v = -0.30 \text{ m s}^{-1}$ Δmv and u must have opposite signs $Ft = mv - mu$ -6.25×0.056 $= (0.50v) - (0.50 \times 0.40)$ $v = -0.30 \text{ m s}^{-1}$ F and u must have opposite signs $F = ma$ $-6.25 = 0.50 \times a$ $v = u + at$ $v = 0.40 + \left(\left(\frac{-6.25}{0.5}\right) \times 0.056\right)$ $v = -0.30 \text{ m s}^{-1}$ F and u must have opposite signs Both relationships **(1)** Both substitutions **(1)** Final answer **(1)**

Question			Expected response	Max mark	Additional guidance

3.	(c)		Calculate/compare the <u>total</u> <u>kinetic</u> energy before and (<u>total</u> <u>kinetic</u> energy) after. **(1)**
			
			If (total) kinetic energy before is equal to (total) kinetic energy after, the interaction is elastic. **(1)**
			
			OR
			
			If (total) kinetic energy is conserved, the interaction is elastic.
				2	Accept: E_k for 'kinetic energy'.
					
					Look for a statement relating to calculating/finding the <u>total</u> E_k before and after first, otherwise **(0)** marks.
					
					There must be an indication of total kinetic energy or equivalent term.
					
					Accept:
					Can show by calculation but would still require a statement for the second mark.
					
					Do not accept:
					If (total) kinetic energy is not conserved, the interaction is inelastic, on its own.

	(d)	(i)	Photovoltaic (effect)	**1**	
		(ii)	Electrons gain/absorb energy from photons/light **(1)** Electrons move from <u>valence band</u> to <u>conduction band</u> **(1)** Electrons move towards n-type semiconductor (producing a potential difference). **(1)**	**3**	Look for reference to both conduction and valence band first, otherwise **(0)** marks. Bands must be named correctly, e.g. do not accept 'valency' or 'conductive'. Third statement is dependent on second statement. The direction the electrons move must be clear.

Question			Expected response	Max mark	Additional guidance
4.			**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
5.	(a)		When moving away from the students: Statement that there are fewer wavefronts per second **OR** The wavefronts are further apart **(1)** When moving towards the students: Statement that there are more wavefronts per second **OR** The wavefronts are closer together **(1)** **OR** diagram showing wavefronts closer together ahead of the buzzer **(1)** and further apart behind it. **(1)** or any similar response	**2**	Look for reference to wavefronts/wavelengths/waves first, otherwise **(0)** marks. In a diagram, there must be an implication of direction of travel.
	(b)	(i)	$z = \frac{\lambda_{\text{observed}} - \lambda_{\text{rest}}}{\lambda_{\text{rest}}}$ **(1)** $z = \frac{610\times10^{-9} - 580\times10^{-9}}{580\times10^{-9}}$ **(1)** $z = 0.052$ **(1)**	**3**	Accept: 0.05, 0.0517, 0.05172 $z = \frac{\lambda_{\text{observed}} - \lambda_{\text{rest}}}{\lambda_{\text{rest}}}$ $z = \frac{610 - 580}{580}$ $z = 0.052$
		(ii)	$z = \frac{v}{c}$ **(1)** $0.052 = \frac{v}{3.00\times10^{8}}$ **(1)** $v = H_0 d$ **(1)** $0.052\times3.00\times10^{8} = 2.3\times10^{-18}\times d$ **(1)** $d = 6.8\times10^{24}\,\text{m}$ **(1)**	**5**	**OR** consistent with (b)(i) Accept: 7, 6.78, 6.783 $z = \frac{v}{c}$ relationship anywhere **(1)** $v = H_0 d$ relationship anywhere **(1)**
	(c)	(i)	$F = G\frac{m_1 m_2}{r^2}$ **(1)** $F = 6.67\times10^{-11}\times\frac{2.19\times10^{30}\times1.80\times10^{30}}{(3.44\times10^{12})^2}$ **(1)** $F = 2.22\times10^{25}\ \text{N}$ **(1)**	**3**	Accept: 2.2, 2.222, 2.2219
		(ii)	(Force is) four (times greater).	**1**	

Question			Expected response	Max mark	Additional guidance
6.	(a)		Meson(s)	**1**	
	(b)	(i)	Anti-up strange	**1**	**Both** required Do not accept: anti anti-strange
		(ii)	Weak (nuclear force)	**1**	
	(c)	(i)	$d = vt$ **(1)** $30.0 = (0.95 \times 3.00 \times 10^8) \times t$ **(1)** $t = 1.05 \times 10^{-7}$ s **(1)**	**3**	Accept: 1.1, 1.053, 1.0526
		(ii)	$l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$ **(1)** $l' = 30.0\sqrt{1-\left(\frac{0.95c}{c}\right)^2}$ **(1)** $l' = 9.37$ m **(1)**	**3**	Accept: 9.4, 9.367, 9.3675 Accept: $l' = 30.0\sqrt{1-(0.95)^2}$
	(d)		For a stationary observer's frame of reference, the mean lifetime of the pion is greater (than 26 ns) **OR** In a pion's frame of reference, the distance is shorter (than 30.0 m).	**1**	The response must involve a statement referring to, or implying, a frame of reference.

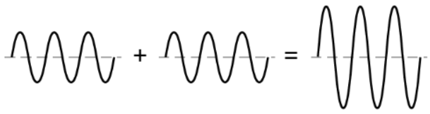
Question			Expected response	Max mark	Additional guidance
6.	(e)		**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type 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
7.	(a)		Protons are (positively) charged **(1)** Protons experience a <u>force</u> (in the electric field) **(1)**	**2**	Must state protons are charged otherwise, maximum **(1)** mark. Any mention of protons being negatively charged or uncharged - award **(0)** marks. Charged particles experience a <u>force</u>, on its own, award **(1)** mark.
	(b)	(i)	$E_k = \frac{1}{2}mv^2$ **(1)** $E_k = \frac{1}{2} \times 1.673 \times 10^{-27} \times (3.8 \times 10^5)^2$ **(1)** $E_k = 1.2 \times 10^{-16}$ J	**2**	**SHOW question**
		(ii)	$W = QV$ **(1)** $W = 1.60 \times 10^{-19} \times 2.8 \times 10^3$ **(1)** $W = 4.5 \times 10^{-16}$ J **(1)**	**3**	Accept: 4, 4.48, 4.480
		(iii)	$E_k = 1.2 \times 10^{-16} + 4.5 \times 10^{-16}$ **(1)** $(E_k = 5.7 \times 10^{-16}$ J$)$ $E_k = \frac{1}{2}mv^2$ **(1)** $(1.2 \times 10^{-16} + 4.5 \times 10^{-16})$ $= \frac{1}{2} \times 1.673 \times 10^{-27} \times v^2$ **(1)** $v = 8.3 \times 10^5$ m s^{-1} **(1)**	**4**	**OR** consistent with (b)(ii) Accept: 8, 8.25, 8.255 $E_k = \frac{1}{2}mv^2$ anywhere **(1)** Must attempt addition of kinetic energy and work done, otherwise maximum **(1)** mark. Demonstrated arithmetic mistake can be carried forward through the response. If using 4.48×10^{-16} (J), accept: 8, 8.2, 8.24, 8.240
	(c)		No effect **(1)** Work done is the same OR <u>gain in</u> kinetic energy is the same **(1)**	**2**	**MUST JUSTIFY** Look for this statement first - if incorrect or missing then **(0)** marks. charge and potential difference are unchanged, on its own, is insufficient for second mark. Any mention of magnetic field/force on its own is insufficient for second mark.

Question			Expected response	Max mark	Additional guidance
8.	(a)	(i)	$\left(A=\pi r^2\right)$ $A=\pi\times(15\times10^{-3})^2$ **(1)** $I=\frac{P}{A}$ **(1)** $17=\frac{P}{\pi\times(15\times10^{-3})^2}$ **(1)** $P=0.012\ \text{W}$ **(1)**	**4**	Accept: 0.01, 0.0120, 0.01202 The use of 3.14 is acceptable for π. For use of 3.14, accept: P = 0.01201 $I=\frac{P}{A}$ anywhere **(1)** If no attempt to calculate area, maximum **(1)** mark for irradiance relationship.
		(ii)	(Experimental setup is) not a point source **OR** Parallel beam so the irradiance does not change with distance.	**1**	Accept: The beam of light does not diverge Sodium lamp is not a point source, on its own - award **(0)** marks.
	(b)	(i)	Lower (energy level)	**1**	
		(ii)	$v=f\lambda$ **(1)** $3.00\times10^8=f\times589.0\times10^{-9}$ **(1)** $E=hf$ **(1)** $E=6.63\times10^{-34}\times\left(\frac{3.00\times10^8}{589.0\times10^{-9}}\right)$ **(1)** $E=3.38\times10^{-19}\ \text{J}$ **(1)**	**5**	Accept: 3.4, 3.377, 3.3769 Accept: $\Delta E=hf$ OR $E_2-E_1=hf$ $v=f\lambda$ anywhere **(1)** $E=hf$ anywhere **(1)** Alternative method: $(\Delta)E=\frac{hc}{\lambda}$ OR $E_2-E_1=\frac{hc}{\lambda}$ Combined relationship **(2)** Substitution for c and λ **(1)** Substitution for h **(1)** Final answer **(1)**

Question			Expected response	Max mark	Additional guidance
8.	(b)	(iii)	There are more electrons (per second) making the transition for the 589.0 nm line. **(1)** Meaning more photons (per second) are emitted. **(1)** **OR** There are fewer electrons (per second) making the transition for the 589.6 nm line. **(1)** Meaning fewer photons (per second) are emitted. **(1)**	**2**	Do not accept greater brightness due to greater frequency/energy of the photons.

Question			Expected response	Max mark	Additional guidance
9.	(a)		(f_0 =) 7.0×10^{14} Hz	**1**	Accept: 7×10^{14} Hz Accept: 6.9×10^{14} - 7.1×10^{14} Hz
	(b)		$E = hf_0$ **(1)** $E = 6.63 \times 10^{-34} \times 7.0 \times 10^{14}$ **(1)** $E = 4.6 \times 10^{-19}$ (J) **(1)** Calcium/Ca **(1)**	**4**	**OR** consistent with (a) Accept: 5, 4.64, 4.641 If calcium is correctly identified with <u>no</u> calculation, maximum **(1)** mark. If there is a calculation with a value consistent with (a), then the metal chosen must be consistent with their calculation. If this calculated value does not match a value in the table, then maximum **(3)** marks. A unit is not required but, if a unit is given, it must be correct. If a candidate completes a calculation but does <u>not</u> go on to identify a metal, then a unit is required. In this question, if an incorrect metal or no metal identified, maximum **(3)** marks. Accept: $E = hf$ Alternative method: $E = hf_0$ **(1)** $4.6 \times 10^{-19} = 6.63 \times 10^{-34} \times f_0$ **(1)** $f_0 = 6.9 \times 10^{14}$ (Hz) **(1)** Therefore calcium **(1)** Accept: 7, 6.94, 6.938 Where more than one calculation is shown all substitutions must be correct for substitution mark, and all calculated values must be correct for calculated value mark. Accept: $E_k = hf - hf_o$ **(1)** Substituted values must be consistent with the line or the table, depending on the method chosen.

Question			Expected response	Max mark	Additional guidance
10.	(a)		(The sound waves from the loudspeakers have a) constant phase relationship (and have the same frequency, wavelength, and velocity).	**1**	Accept: constant phase difference 'In phase' is not sufficient.
	(b)		Waves <u>meet</u> in phase. **OR** Crest <u>meets</u> crest. **OR** Trough <u>meets</u> trough. **OR** Path difference = $m\lambda$	**1**	Accept: peak for crest. Can be shown by diagram e.g.  Diagram must imply addition of two waves in phase. Do not accept: 'join' or 'merge' alone.
	(c)		path difference = mλ **(1)** path difference = 3×0.400 **(1)** path difference = $L_2P - L_1P$ $(3 \times 0.400) = 6.00 - L_1P$ **(1)** L_1P = 4.80 m **(1)**	**4**	Accept: 4.8, 4.800, 4.8000 **OR** $L_2P - L_1P$ = mλ $6.00 - L_1P = 3 \times 0.400$ L_1P = 4.80 m An indication that path difference = m λ **(1)** Substitution for m and λ **(1)** Equate path difference to 6 - L_1P **(1)** Final answer **(1)**
	(d)		Destructive (interference)	**1**	Do not accept: deconstructive

Question			Expected response	Max mark	Additional guidance
11.	(a)		$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $1.47 = \frac{\sin\theta_1}{\sin 37.0}$ **(1)** $\theta_1 = 62.2°$ **(1)**	**3**	Accept: 62, 62.21, 62.211 Accept: $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$ (1) $\frac{1.47}{1} = \frac{\sin\theta_1}{\sin 37.0}$ (1) $\theta_1 = 62.2°$ (1)
	(b)		$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{1.47}$ **(1)** $\theta_c = 42.9°$ **(1)**	**3**	Accept: 43, 42.86, 42.865
	(c)		(point) P **(1)** The (absolute) refractive index of the vegetable oil (for this light) is the same as the (absolute) refractive index of the glass (therefore there is no refraction/change in speed/ wavelength/direction). **(1)**	**2**	Look for this statement **first** – if incorrect or missing then (**0**) marks. Indication of point P being selected on the diagram can be accepted as an alternative for a statement. Accept: The refractive indices/indexes are the same. The refractive index is the same. The (value of) refractive index has not changed.

Question			Expected response	Max mark	Additional guidance
12.	(a)		The energy gained by/supplied to 1 coulomb (of charge passing through the battery).	**1**	Accept: 'number of joules' for energy Accept: 'unit charge' for 1 coulomb.
	(b)	(i)	6.0 V	**1**	Accept: 6 V Accept: 5.95 - 6.05 V
		(ii)	$\left(m = \dfrac{y_2 - y_1}{x_2 - x_1}\right)$ $m = \dfrac{2.0 - 4.0}{0.50 - 0.25}$ **(1)** $m = -8.0$ **(1)** $(m = -r)$ $r = 8.0\ \Omega$ **(1)**	**3**	Accept: 8, 8.00, 8.000 Gradient = *r* is wrong physics, award **(0)** marks. substitution of any valid pair of points into gradient formula **(1)** accept any point on a correctly extrapolated line e.g. (0.00,6.0) calculated value of gradient **(1)** Alternative method: $E = V + Ir$ **(1)** $6.0 = 2.0 + 0.50 \times r$ **(1)** $r = 8.0\ \Omega$ **(1)** If using this method, must use data from the line. **Or** value of E consistent with (b)(i)
	(c)		Open the switch, and take the reading on the <u>voltmeter</u> (which is the EMF)	**1**	Accept: reading on the <u>voltmeter</u> for an open circuit **OR** reading on <u>voltmeter</u> before closing switch
	(d)		(As resistance decreases,) current increases **(1)** Lost volts increases, (terminal potential difference decreases) **(1)**	**2**	If there is wrong physics in the answer, award **(0)** marks.
	(e)		The line drawn can be extrapolated to intercept y-axis at less than 6.0 V **(1)** Passably straight line of same gradient **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
13.	(a)		(Close the switch and) take readings on voltmeter at (regular) time intervals **(1)** Plot a graph of voltage against time **(1)**	**2**	
	(b)	(i)	$E = \frac{1}{2}CV^2$ **(1)** $E = \frac{1}{2} \times 47 \times 10^{-6} \times 12^2$ **(1)** $E = 3.4 \times 10^{-3}$ J **(1)**	**3**	Accept: 3, 3.38, 3.384 Alternative methods: Both relationships **(1)** Both substitutions **(1)** Final answer **(1)**
		(ii)	Increase the supply voltage	**1**	Must clearly indicate the supply voltage is increased/greater. If a value is given for the supply voltage then it must be greater than 12 V and less than or equal to 15 V. Accept: 'increase the voltage supplied to the circuit'. 'increase the voltage supplied to the capacitor'. Do not accept: 'increase the voltage across the capacitor' on its own. Do not accept: any implication of power supply being replaced by another power supply.

Question			Expected response	Max mark	Additional guidance
14.	(a)		Appropriate labels and units **(1)** Suitable scales **(1)** Plotting and line of best fit **(1)**	**3**	Allow for axes starting at zero, or broken axes, or at an appropriate value. Accuracy of plotting should be easily checkable with the scale chosen. An origin is not essential and can be implied by a suitable linear scale. If the origin is shown, the scale must either be continuous or the axis must be 'broken'. Otherwise maximum **(2)** marks. An appropriate scale must be linear over the range of the data. Accept: graph of L against T^2.
	(b)		$\left(m = \frac{y_2 - y_1}{x_2 - x_1}\right)$ $m = \frac{4-2}{0.96-0.48}$ (for example) **(1)** $m = 4.2\ (\text{s}^2\ \text{m}^{-1})$ **(1)**	**2**	**<u>Must</u>** be consistent with graph drawn for (a). Candidates are asked to calculate the gradient of **<u>their graph</u>.** Tolerance required depending upon best fit line drawn by the candidate. If candidates use values from the table, these points must lie on **<u>their line</u>**. 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.	(c)		$(\frac{T^2}{L}=\frac{4\pi^2}{g}=\text{gradient})$ $\frac{4\pi^2}{g}=4.2$ **(1)** $g=9.4\ \text{N kg}^{-1}$ **(1)**	**2**	<u>**Must be**</u> consistent with (b) <u>**Must**</u> substitute the gradient of <u>**their graph**</u>, and not a single data point. If a single data point is substituted into in the calculation, award **(0)** marks. The use of 3.14 is acceptable for π. Accept m s^{-2}. If a candidate has plotted L against T^2, this becomes $(\frac{L}{T^2}=\frac{g}{4\pi^2}=\text{gradient})$ $\frac{g}{4\pi^2}=0.24$ **(1)** $g=9.5\ \text{N kg}^{-1}$ **(1)**

[END OF MARKING INSTRUCTIONS]