National
Qualifications
SPECIMEN ONLY

S857/76/12

Physics
Paper 1 — Multiple choice

Date — Not applicable

Duration — 45 minutes

Total marks — 25

Attempt ALL questions.

You may use a calculator.

Instructions for the completion of Paper 1 are given on *page 02* of your answer booklet S857/76/02.

Record your answers on the answer grid on *page 03* of your answer booklet.

Reference may be made to the data sheet on *page 02* of this question paper and to the relationships sheet S857/76/22.

Space for rough work is provided at the end of this booklet.

Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

S8577612

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \text{J s}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\ \text{C}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \text{kg}$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \text{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\ \text{m s}^{-2}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \text{kg}$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\ \text{s}^{-1}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 }	Infrared
	10 590 }	
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting point*/K	*Boiling point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

Marking instructions for each question

Question	Answer	Max mark
1.	C	1
2.	A	1
3.	B	1
4.	C	1
5.	C	1
6.	C	1
7.	B	1
8.	B	1
9.	C	1
10.	B	1
11.	D	1
12.	D	1
13.	B	1
14.	E	1
15.	D	1
16.	A	1
17.	E	1
18.	C	1
19.	D	1
20.	C	1
21.	E	1
22.	A	1
23.	A	1
24.	E	1
25.	D	1

[END OF SPECIMEN MARKING INSTRUCTIONS]

National
Qualifications
SPECIMEN ONLY

S857/76/01

Physics
Paper 2

Marking Instructions

These marking instructions have been provided to show how SQA would mark this specimen question paper.

SQA
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General marking principles for Physics Higher

Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

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

(b) If a 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) Do not award half marks.

(d) 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.

(e) Unless a numerical question specifically requires evidence of working to be shown, award full marks for a correct final answer (including units if required) on its own.

(f) Award marks for a diagram or sketch that 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.

(g) 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.

(h) 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.

(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 $R = \frac{V}{I}$.

(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.

(k) 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').

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

- **identify**, **name**, **give**, or **state**, they must 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 gain marks for the breadth and/or depth of their conceptual understanding.

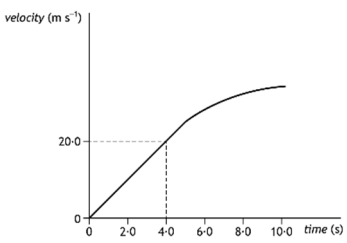
(m) Marking in calculations

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

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)		$v = u + at$ **(1)** $20{\cdot}0 = 0 + a \times 4{\cdot}0$ **(1)** $a = 5{\cdot}0 \text{ m s}^{-2}$ **(1)**	**3**	Accept 5, 5·00, 5·000
	(b)		motorcycle $s = \text{area under graph}$ **(1)** $s = \frac{1}{2} \times 4{\cdot}0 \times 20{\cdot}0$ **(1)** car $s = \text{area under graph}$ $s = 4{\cdot}0 \times 15{\cdot}0$ **(1)** $s_{between} = (4{\cdot}0 \times 15{\cdot}0) - (\frac{1}{2} \times 4{\cdot}0 \times 20{\cdot}0)$ $s_{between} = 20 \text{ m}$ **(1)**	**4**	Accept 20·0, 20·00 Alternative method motorcycle $s = ut + \frac{1}{2}at^2$ $s = \frac{1}{2} \times 5{\cdot}0 \times 4{\cdot}0^2$ car $d = \bar{v}t$ $d = 15 \times 4{\cdot}0$ 1 mark for both relationships 1 mark for each substitution 1 mark for final answer
	(c)	(i)	$F = ma$ **(1)** $F = 290 \times 5{\cdot}0$ **(1)** $F = F_{Driving} - F_{Friction}$ $(290 \times 5{\cdot}0) = 1800 - F_{Friction}$ **(1)** $F_{Friction} = 350 \text{ N}$ **(1)**	**4**	Or consistent with (a) Accept 400, 350·0, 350·00
		(ii)	Frictional force /friction/drag/air resistance increases with speed **(1)** Driving force must be increased to ensure a constant unbalanced force **(1)**	**2**	
	(d)		 graph curves (gradually, away from velocity axis) after 5 s	**1**	Line can level out, but not curve downwards.

Question			Expected response	Max mark	Additional guidance
2.			Estimate of car mass (500 kg < mass < 3000 kg) **(1)** Estimate of car speed (20 m s^{-1} < speed < 70 m s^{-1}) **(1)** $E_k = \frac{1}{2}mv^2$ **(1)** Final answer **(1)**	**4**	Both estimates must be within the given tolerances in order to access the final 1 mark.

Question			Expected response	Max mark	Additional guidance
3.	(a)	(i)	$v^2 = u^2 + 2as$ **(1)** $v^2 = 0 + 2\times 9{\cdot}8\times 2{\cdot}0$ **(1)** $v = 6{\cdot}3$ m s^{-1} OR $(m)gh = \frac{1}{2}(m)v^2$ **(1)** $(42)\times 9{\cdot}8\times 2{\cdot}0 = \frac{1}{2}(42)v^2$ **(1)** $v = 6{\cdot}3$ m s^{-1}	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
		(ii)	$\Delta p = mv - mu$ **(1)** $\Delta p = (42\times(5{\cdot}3)) - (42\times(-6{\cdot}3))$ **(1)** $\Delta p = 490$ kg m s^{-1} **(1)**	**3**	Accept 500, 487, 487·2 Accept alternative direction convention.
		(iii)	$Ft = mv - mu$ **(1)** $F\times 0{\cdot}50 = 490$ **(1)** $F = 980$ N **(1)**	**3**	Or consistent with (a)(ii) Accept 1000, 980·0
	(b)		Tension (in rope) now has a horizontal component **(1)** Vertical component of tension (in rope) is unchanged **(1)**	**2**	Independent marks Statements must refer to forces on rope.

Question			Expected response	Max mark	Additional guidance
4.	(a)		$d = \bar{v}t$ **(1)** $d = (3{\cdot}00\times10^{8}\times0{\cdot}995)\times2{\cdot}2\times10^{-6}$ **(1)** $d = 660$ m	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
	(b)		$t' = \dfrac{t}{\sqrt{1-\left(\dfrac{v}{c}\right)^{2}}}$ **(1)** $t' = \dfrac{2{\cdot}2\times10^{-6}}{\sqrt{1-\left(\dfrac{0{\cdot}995}{1}\right)^{2}}}$ **(1)** $t' = 2{\cdot}2\times10^{-5}$ s **(1)**	**3**	Accept 2, 2·20, 2·203
	(c)		The mean lifetime of the muon is greater for an observer in Earth's frame of reference OR The mean distance travelled by a muon is shorter in the muon's frame of reference	**1**	

Question			Expected response	Max mark	Additional guidance
5.	(a)	(i)	The galaxy is moving away from Earth **(1)** The apparent wavelengths of the lines of the hydrogen spectrum from the galaxy have increased **(1)** OR The apparent frequencies of the lines of the hydrogen spectrum from the galaxy are less than the corresponding frequencies from the laboratory source OR The frequency of the light from the galaxy has shifted towards the red end of the spectrum OR Observed light from the galaxy shows redshift	**2**	
		(ii)	$z = \frac{(\lambda_{obs} - \lambda_{rest})}{\lambda_{rest}}$ **(1)** $z = \frac{(676\times10^{-9} - 656\times10^{-9})}{656\times10^{-9}}$ **(1)** $z = \frac{v}{c}$ **(1)** $\frac{(676\times10^{-9} - 656\times10^{-9})}{656\times10^{-9}} = \frac{v}{3{\cdot}00\times10^{8}}$ **(1)** $v = 9{\cdot}15\times10^{6}$ m s^{-1} **(1)**	**5**	Accept 9·1,9·146,9·1463
	(b)		$v = H_0 d$ **(1)** $1{\cdot}2\times10^{7} = 2{\cdot}3\times10^{-18}\times d$ **(1)** $d = 5{\cdot}2\times10^{24}$ m **(1)**	**3**	Accept 5, 5·22, 5·217

Question			Expected response	Max mark	Additional guidance
5.	(c)		**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 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 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 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)	(i)	$W = QV$ **(1)** $W = 1{\cdot}60\times10^{-19}\times3{\cdot}5\times10^{4}$ **(1)** $W = 5{\cdot}6\times10^{-15}$ J	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
		(ii)	E_k at R $E_k = \frac{1}{2}mv^2$ **(1)** $E_k = 0{\cdot}5\times1{\cdot}673\times10^{-27}\times(1{\cdot}2\times10^{6})^2$ **(1)** E_k at S $E_k = \frac{1}{2}mv^2$ $\left[0{\cdot}5\times1{\cdot}673\times10^{-27}\times(1{\cdot}2\times10^{6})^2\right]$ $+5{\cdot}6\times10^{-15}$ $= 0{\cdot}5\times1{\cdot}673\times10^{-27}\times v^2$ addition **(1)** substitution **(1)** $v = 2{\cdot}9\times10^{6}$ m s^{-1} **(1)**	**5**	Accept 3,2·85,2·852
	(b)	(i)	To ensure the (accelerating) force is in the same direction OR To ensure the protons accelerate in the same direction OR To ensure that the direction of the electric field is correct when the proton passes through a tube	**1**	
	(b)	(ii)	Alternating voltage has a constant frequency (rather than a frequency that changes) OR As speed of proton increases, they travel further in the same time	**1**	
	(c)		Downwards	**1**	

Question			Expected response	Max mark	Additional guidance
7.	(a)		Fundamental particles cannot be subdivided	**1**	
	(b)		$-\frac{1}{3}e$	**1**	
	(c)		The strong force (associated with the gluon) has a short range. **(1)** The gravitational force (requires a force mediating particle that) has infinite range. **(1)**	**2**	
	(d)		(The strong force is) 13 (orders of magnitude) greater (than the weak force)	**1**	
	(e)		beta decay	**1**	

Question			Expected response	Max mark	Additional guidance
8.	(a)		mass loss $m = (4 \times 1{\cdot}673 \times 10^{-27}) - 6{\cdot}646 \times 10^{-27}$ **(1)** $E = mc^2$ **(1)** $E = ((4 \times 1{\cdot}673 \times 10^{-27}) - (6{\cdot}646 \times 10^{-27})) \times (3{\cdot}00 \times 10^{8})^2$ **(1)** $E = 4{\cdot}14 \times 10^{-12}$ J **(1)**	**4**	Accept 4·1, 4·140, 4·1400
	(b)		0·20 kg hydrogen has $\frac{0{\cdot}20}{1{\cdot}673 \times 10^{-27}}$ $(= 1{\cdot}195 \times 10^{26}$ atoms) **(1)** provides $\frac{1{\cdot}195 \times 10^{26}}{4} = 0{\cdot}2989 \times 10^{26}$ reactions **(1)** releases $0{\cdot}2989 \times 10^{26} \times 4{\cdot}14 \times 10^{-12}$ $= 1{\cdot}2 \times 10^{14}$ J **(1)**	**3**	Accept 1, 1·24,1·237 Multiplying the number of hydrogen nuclei by the energy for each reaction is wrong physics.
	(c)		The particles involved in fusion reactions must be at a high temperature	**1**	

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>9.</td><td>(a)</td><td></td><td>Irradiance is the power incident per unit area</td><td>1</td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td>Graphical method

Correct quantities on axes
(I and $1/d^2$) (1)

Accuracy of plotting and line of best fit (1)

Statement of relationship (1)

Do not award statement mark if less than three points plotted accurately.</td><td>3</td><td>ALTERNATIVE METHOD

<table><tr><td>d</td><td>0·200</td><td>0·300</td><td>0·400</td><td>0·500</td></tr><tr><td>I</td><td>672</td><td>302</td><td>170</td><td>110</td></tr><tr><td>Id^2</td><td>26·9</td><td>27·2</td><td>27·2</td><td>27·5</td></tr></table>
AND
Within the limits of experimental uncertainty, Id^2 is constant and so $I \alpha 1/d^2$.

Award 3 marks where all four calculated values in the table are correct and the final statement is correct.
Award 2 marks where all four calculated values in the table are correct and the final statement is incorrect or omitted.
Award 2 marks where three calculations in the table are correct and the final statement is correct.
Award 1 mark where three calculations in the table are correct and the final statement is incorrect or omitted.
Award 0 marks where fewer than three calculations are correct (a relationship cannot be stated from only two values or fewer).</td></tr>
<tr><td></td><td>(c)</td><td></td><td>(Black cloth) prevents reflections</td><td>1</td><td></td></tr>
<tr><td></td><td>(d)</td><td></td><td>The laser is not a point source
OR
Light from the laser does not conform to the inverse square law
OR
Laser beam does not spread out</td><td>1</td><td></td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	$v = f\lambda$ **(1)** $3{\cdot}00\times10^{8} = f\times525\times10^{-9}$ **(1)** $E = hf$ **(1)** $E = 6{\cdot}63\times10^{-34}\times\left(\frac{3{\cdot}00\times10^{8}}{525\times10^{-9}}\right)$ **(1)** $E = 3{\cdot}79\times10^{-19}$ J	**4**	SHOW question. A maximum of 3 marks is available if the final line is not shown.
		(ii)	$(E_k = 3{\cdot}79\times10^{-19} - 2{\cdot}24\times10^{-19})$ $E_k = 1{\cdot}55\times10^{-19}$ J	**1**	
	(b)	(i)	Photons with frequency below f_0 do not have enough energy to release electrons	**1**	
		(ii)	$E = hf_0$ **(1)** $2{\cdot}24\times10^{-19} = \left(6{\cdot}63\times10^{-34}\right)\times f_0$ **(1)** $f_0 = 3{\cdot}38\times10^{14}$ Hz **(1)**	**3**	Accept 3·4, 3·379, 3·3786

Question			Expected response	Max mark	Additional guidance
10.	(c)		**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 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 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 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
11.	(a)		Bright fringes are produced by waves meeting in phase/crest to crest/trough to trough	**1**	
	(b)	(i)	$\Delta x = \frac{\lambda D}{d}$ $\frac{9{\cdot}5\times10^{-3}}{4} = \frac{633\times10^{-9}\times0{\cdot}750}{d}$ division by 4 **(1)** substitutions **(1)** $d = 2{\cdot}0\times10^{-4}$ m **(1)**	**3**	Accept 2,2·00,1·999 The mark for dividing by 4 is independent
		(ii)	$\%uncertainty\Delta x = \frac{0{\cdot}2\times10^{-3}\times100}{9{\cdot}5\times10^{-3}} = 2{\cdot}1\%$ **(1)** $\%uncertaintyD = \frac{0{\cdot}001\times100}{0{\cdot}750} = 0{\cdot}13\%$ **(1)** Improve precision in measurement of Δx **(1)**	**3**	
	(c)		Green light has a shorter wavelength **(1)** Fringes are closer together **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
12.	(a)		$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $n = \frac{\sin(51{\cdot}4)}{\sin(36{\cdot}0)}$ **(1)** $n = 1{\cdot}33$	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
	(b)	(i)	(Critical angle is) the angle of incidence that produces an angle of refraction of 90°	**1**	
		(ii)	$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{1{\cdot}33}$ **(1)** $\theta_c = 48{\cdot}8^\circ$ **(1)**	**3**	Accept 49, 48·75, 48·753

Question			Expected response	Max mark	Additional guidance
13.	(a)	(i)	2·5 Ω	**1**	
		(ii)	$E = \frac{y_2 - y_1}{x_2 - x_1}$ $E = \frac{11 - 0}{0{\cdot}80 - 0{\cdot}15}$ substitution of two points on line **(1)** $E = 17$ V **(1)**	**2**	Or consistent with data points chosen
	(b)		$V = IR$ **(1)** $17 = I \times 2{\cdot}5$ **(1)** $I = 6{\cdot}8$ A **(1)**	**3**	Or consistent with (a)(i) and (a)(ii)

Question			Expected response	Max mark	Additional guidance
14.	(a)		$V = IR$ **(1)** $12 = 3{\cdot}0\times10^{-5}\times R$ **(1)** $R = 4{\cdot}0\times10^{5}\ \Omega$ **(1)**	**3**	Accept 4, 4·00, 4·000
	(b)	(i)	$Q = It$ **(1)** $Q = 3{\cdot}0\times10^{-5}\times25$ **(1)** $Q = 7{\cdot}5\times10^{-4}$ C **(1)**	**3**	Accept 8, 7·50, 7·500
		(ii)	$C = \frac{Q}{V}$ **(1)** $220\times10^{-6} = \frac{7{\cdot}5\times10^{-4}}{V}$ **(1)** $V = 3{\cdot}4$ (V) **(1)** Therefore voltage across resistor is $12 - 3{\cdot}4 = 8{\cdot}6$ V **(1)**	**4**	Or consistent with (b)(i) Accept 9, 8·59, 8·591

Question			Expected response	Max mark	Additional guidance
15.	(a)		Material 2	**1**	
	(b)		(Voltage applied causes) electrons to move towards conduction band of p-type **(1)** Electrons move/drop from conduction band to valence band **(1)** Photon emitted (when electron drops) **(1)**	**3**	If candidate does not refer to either conduction band or valence band, award 0 marks. Bands must be named correctly in first two marking points ie not valency or conductive. Award 0 marks for any answer using recombination of holes and electrons **on its own**, with no reference to band theory. The final mark is dependent upon having at least one of the first two statements correct.

Question			Expected response	Max mark	Additional guidance
16.	(a)		Suitable scales with labels on axes (quantity and unit) **(1)** Points plotted accurately **(1)** Acceptable line(curve) of best fit **(1)**	**3**	
	(b)		7·5 mm ±1mm	**1**	Or consistent with graph drawn
	(c)		Repeat measurements **(1)** Smaller steps/divisions/intervals in radius (around the 75% value or equivalent) **(1)**	**2**	

[END OF SPECIMEN MARKING INSTRUCTIONS]