National Qualifications 2025

2025 Physics

National 5

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 National 5 Physics

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.

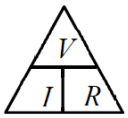
(d) Where a candidate answers part of a question incorrectly and carries the incorrect answer forward in the following part, award marks if the incorrect answer has then been used correctly in the subsequent part or 'follow-on'. (GMP 16)

(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 eg $V = IR$ or $R = \frac{V}{I}$, etc. (GMP 2)

(j) In rounding to an expected number of significant figures, award the mark for correct answers which 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, eg 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, eg 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 your 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. They will gain credit for the breadth and/or depth of their conceptual understanding.

Common issues with candidate responses

When marking National 5 Physics, there are some common issues that arise when considering candidates' answers.

There is often a range of acceptable responses which would sensibly answer a particular question. However, it is often difficult to anticipate all correct or partially correct responses to questions.

The detailed marking instructions contain ideal answers, and examples of other acceptable answers which offer guidance for interpreting candidates' responses. They may also contain advice on answers which are **not** acceptable, or only attract partial marks.

Units

Do not penalise use of upper/lower case when the abbreviated version is given, as long as it can be clearly identified, eg DB, sV, hZ, bq.

However, take care to ensure the unit has the correct prefix, eg for an answer t = 0.005 seconds, t = 5 ms is acceptable but t = 5 Ms is not.

Where a candidate makes multiple unit errors or conversion errors/omissions in any part of a question, penalise once only. For example, when calculating speed from distance and time, and the answer is required to be in m s^{-1}.

If d = 4 km and t = 2 minutes

$$v = \frac{d}{t} \quad \textbf{(1)}$$

$$v = \frac{4\,000\,000}{2} \quad \textbf{(1)}$$

$$v = 2\,000\,000 \quad \textbf{(0)}$$

Although the candidate has made three unit errors, (not correctly converted distance or time and has omitted the final unit), do not award the final mark only.

Some common units often attract incorrect abbreviations in answers to numerical questions.
When the abbreviation can be confused with a different unit then the final mark cannot be awarded, eg sec or secs as an abbreviation for seconds is **not** acceptable.

Common units and abbreviations	
Acceptable unit and abbreviation	*unacceptable version*
second, s	sec, secs
hours, h	hr, hrs
ampere, amp, amps, A, a	
metres per second, m/s, m s^{-1}	mps, m/s^{-1}
metres per second per second, m/s^2, m s^{-2}	m/s/s, mpsps, m/s^{-2}
joules per kilogram per degree celsius, J kg^{-1} $°C^{-1}$, J/kg °C	J/kg/°C

Standard form

Where a candidate fails to express an answer in standard form correctly, treat it as an arithmetic error and do not award the final mark. For example:

For an answer t = 400 000 s, then $t = 4 \times 10^5$ s would be correct but $t = 4^5$ s would be treated as an arithmetic error. (GMP 10)

Incorrect answer carried forward (GMP 16)

Do not apply a further penalty where a candidate carries forward an incorrect answer to part of a question, and uses that incorrect answer correctly:

- within that part of the question, eg from (a)(i) to (a)(ii)
- or to the next part of the question, eg from (a) to (b).

Similarly, if a candidate has selected the wrong value in a question which requires a data value, then award full marks in the subsequent answer for a correct response that uses **either** the candidate's wrong value **or** the correct data value. For example:

(a) State the speed of microwaves in air.
Candidate's answer: *240 m s^{-1}*. This answer would attract zero marks.

(b) Calculate the distance travelled by these microwaves in 0.34 seconds.
The candidate may use **either** the value given in part (a) **or** the correct value for the speed, and could gain full marks if correctly completed.

Where an incorrect answer may be carried forward, this is indicated in the additional guidance column of the detailed marking instructions by the comment 'or consistent with part...'.

Standard three marker

The examples below 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 which 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.

Example of a 'standard three marker' 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)

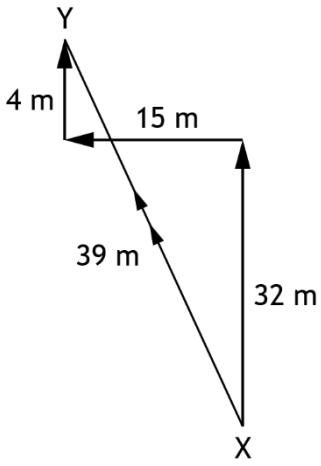
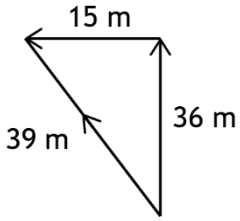
	Example response	Mark and comment
1.	$V = IR$ $7.5 = 1.5R$ $R = 5.0\ \Omega$	1 mark: relationship 1 mark: substitution 1 mark: correct answer
2.	$5.0\ \Omega$	3 marks: correct answer
3.	5.0	2 marks: unit missing
4.	$4.0\ \Omega$	0 marks: no evidence, wrong answer
5.	$\_\_\ \Omega$	0 marks: no working 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

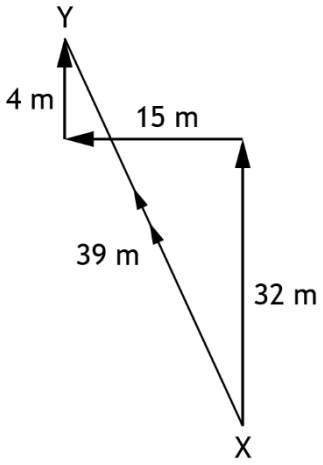
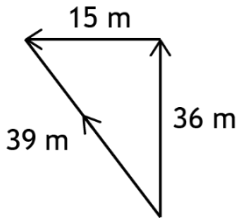
Marking instructions for each question

Section 1

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

Section 2

Question			Expected response	Max mark	Additional guidance
1.	(a)	(i)	**Using Pythagoras:** Resultant^2 = 36^2 + 15^2 **(1)** Resultant = 39 m **(1)** **Using scale diagram:**  OR  Vectors to scale **(1)** Resultant = 39 m **(1)** (allow ± 1 m tolerance)	**2**	Ignore any direction stated in the final answer in this part. If clear arithmetic error shown in 32 + 4 = 36 then MAX (**1**) mark for substitution consistent with arithmetic error. No requirement for arrows to be shown on diagram to calculate the magnitude of displacement. Regardless of method, if a candidate shows a vector diagram (or a representation of a vector diagram ie a triangle with no arrows) **and** the vectors have been added incorrectly, eg head-to-head then MAX (**1**). Accept: 40 39.0 39.00

Question			Expected response	Max mark	Additional guidance
1.	(a)	(ii)	**Using trigonometry:** $\tan\theta = \frac{15}{36}$ **(1)** $(\theta = 23^\circ)$ direction = 337 **(1)** **Using scale diagram:**  OR  Vectors to scale **(1)** Direction = 337 **(1)** (allow ±2° tolerance)	**2**	Or use of resultant value (and appropriate trigonometry) consistent with (a)(i). Regardless of method, if a candidate shows a vector diagram (or a representation of a vector diagram ie a triangle with no arrows) **and** the vectors have been added incorrectly, eg head-to-head then MAX (**1**). **Alternative methods:** $\tan\theta = \frac{36}{15}$ (1) $(\theta = 67^\circ)$ direction = 337 (1) **OR** Can also do using other trig functions, eg $\sin\theta = \frac{15}{39}$ OR $\cos\theta = \frac{36}{39}$ Ignore the degree symbol if the direction is stated as a bearing. Accept: 23° West of North 67° North of West Can obtain first mark for scale diagram method from suitable diagram in part (a)(i) if not drawn in this part. However, the candidate must attempt an answer in this part. Ignore any magnitude stated in the final answer in this part. Do not accept incorrect statements of trig functions at substitution stage, eg $\tan = \frac{15}{36}$ Accept: 20° W of N 340 22·6° W of N 337.4 22·62° W of N 337.38

Question			Expected response		Max mark	Additional guidance
1.	(b)		$s = \overline{v}t$ $39 = \overline{v} \times 55$ $\overline{v} = 0.71$ ms^{-1} at 337	**(1)** **(1)** **(1)**	**3**	Or consistent with (a)(i) and/or (a)(ii). Bar not required above v Accept $d = vt$ provided it is followed by a substitution of the value for displacement. Direction required for final mark. Accept: 0.7 0.709 0.7091
	(c)		$E_w = Fd$ $E_w = 68 \times (32+15+4)$ $E_w = 3500$ J	**(1)** **(1)** **(1)**	**3**	If clear arithmetic error in calculation of total distance, then MAX (2). Accept: 3000 3470 3468

Question			Expected response	Max mark	Additional guidance
2.	(a)	(i)	$W = mg$ **(1)** $W = 1.43 \times 10^6 \times 9.8$ **(1)** $W = 1.4 \times 10^7$ N **(1)**	**3**	Accept: 1×10^7 1.40×10^7 1.401×10^7
		(ii)	$F = 2.28 \times 10^7 - 1.4 \times 10^7$ **(1)** $F = ma$ **(1)** $(2.28 \times 10^7 - 1.4 \times 10^7) = 1.43 \times 10^6 \times a$ **(1)** $a = 6.2$ ms^{-2} **(1)**	**4**	Or consistent with (a)(i). Calculation of unbalanced force may be implied by correct substitution. If no attempt to calculate the unbalanced force, then MAX (1) for the relationship. If clear arithmetic error in calculation of unbalanced force, then MAX (3). Accept: 6 6.15 6.154
	(b)	(i)	friction/air resistance (1)  weight (1)	**2**	(1) for each force correctly labelled with corresponding direction. Accept if arrows do not touch the section. Accept: 'force due to gravity'. 'gravitational pull'. 'pull of gravity'. Do not accept: 'upward force' alone. 'upthrust'. 'wind resistance'. 'gravitational field strength' alone. 'gravity' alone. 'gravity/weight'. Ignore horizontal forces. Where a candidate has identified more than two vertical forces, apply +/- rule for other vertical forces.

Question			Expected response	Max mark	Additional guidance
2.	(b)	(ii)	Air resistance/friction is increased (by parachute). **(1)** producing an unbalanced force (upwards). **(1)**	**2**	Independent marks. Accept: 'upward force increases'. 'drag increases'. Accept: 'upward force is greater than downward force'. 'friction is greater than weight'.
		(iii)	9300 N **(1)** Constant velocity (means that forces must be balanced/equal and opposite). **(1)**	**2**	**MUST JUSTIFY** Accept: 'constant speed'. 'it has reached terminal velocity'.

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)		It experiences a (gravitational) slingshot/catapult (from Mars) **(1)** (causing) an increase in its speed/velocity/kinetic energy. **(1)**	**2**	Independent marks. Accept a description of the gravitational slingshot/catapult. Accept: (causing it to) accelerate.
	(b)	(i)	(The unbalanced force) is applied over an extended/long period of time.	**1**	
		(ii)	(As the spacecraft moves away from the Sun the solar cells) receive less light/energy (from the Sun).	**1**	Accept: 'receives less solar energy'. 'receives less solar power'. 'less power from the Sun'. Accept: in case the spacecraft is in the shade of/behind planets/moons. Do not accept an indication that there is no light/energy (from the Sun). Do not accept a response in terms of 'greater distance from the Sun' alone.
	(c)	(i)	$\left(\text{period} = \frac{56}{41}\right)$ $\text{period} = 1.4 \text{ days}$	**1**	Accept: 1 day. 1.37 days. 1.366 days. Accept correct answer given in other units of time.
		(ii)	(The orbital period) decreases.	**1**	Do not accept answers in terms of speed alone. Ignore any extraneous information.

Question			Expected response	Max mark	Additional guidance
5.	(a)		The metal dishes become positively charged/have the same charge (as the dome). **OR** Like/similar/same charges repel.	**1**	
	(b)	(i)	$Q = It$ **(1)** $2.50\times10^{-6} = I\times0.80\times10^{-3}$ **(1)** $I = 3.1\times10^{-3}$ A **(1)**	**3**	Accept: 3×10^{-3} 3.13×10^{-3} 3.125×10^{-3}
		(ii)	$\left(\text{number of electrons} = \frac{2.50\times10^{-6}}{1.60\times10^{-19}}\right)$ $= 1.56\times10^{13}$ **(1)**	**1**	Accept: 1.6×10^{13} 1.563×10^{13} 1.5625×10^{13}

Question			Expected response	Max mark	Additional guidance
6.	(a)		ammeter in series with resistor R (1) voltmeter in parallel with resistor R (1)	**2**	MAX (1) mark if circuit is not a functioning circuit (eg not complete, connections would not allow correct measurements to be taken, or open switch). Accept multiple ammeters/voltmeters, providing they are positioned appropriately.
	(b)		gradient $= \frac{3.0-0.2}{0.05-0}$ $(=56)$ **(1)** resistance $= 56\ \Omega$ **(1)**	**2**	Can use any other points on the line. Substitution of any valid pair of points from the line into gradient formula. (1) Value for resistance. (1) Do not accept a value calculated using a single point on the line (0) For any value for resistance stated on its own, without any working, accept a value within the range: 54.5 – 57.5 Ω. Accept 1-4 significant figures in final answer.
	(c)		(Resistance is) changing/ not constant/increasing.	**1**	Accept: 'non-ohmic'.

Question			Expected response	Max mark	Additional guidance
7.	(a)		If one of the spotlights develops a fault, the rest will stay on. **(1)** **OR** So, all the spotlights operate at the correct voltage/voltage across each branch (of the circuit) is 12 V. **(1)**	**1**	Accept: 'LED' or 'light'. Do not accept: 'independent switching'. 'same voltage' alone. 'same brightness' alone. 'same current'.
	(b)		$P = IV$ **(1)** $(4.8 \times 4) = I \times 12$ **(1)** $I = 1.6$ A **(1)**	**3**	Accept: 2 1.60 1.600 **Alternative method 1:** $P = IV$ (1) $4.8 = I \times 12$ $I = 0.4$ A $I_{total} = 0.4 \times 4$ (1) $I_{total} = 1.6$ A (1) **Alternative method 2:** $P = \frac{V^2}{R}$ $(4.8 \times 4) = \frac{12^2}{R}$ $R = 7.5\ \Omega$ $V = IR$ (1) both relationships $12 = I \times 7.5$ (1) all substitutions $I = 1.6$ A (1) **Alternative method 3:** $P = \frac{V^2}{R}$ $(4.8 \times 4) = \frac{12^2}{R}$ $R = 7.5\ \Omega$ $P = I^2R$ (1) both relationships $(4.8 \times 4) = I^2 \times 7.5$ (1) all substitutions $I = 1.6$ A (1)
	(c)	(i)	MOSFET	**1**	Accept: 'transistor' in place of MOSFET. Do not accept: 'npn transistor' or 'pnp transistor'.

Question			Expected response	Max mark	Additional guidance
7.	(c)	(ii)	(As light level decreases), the resistance of the LDR increases. **(1)** The voltage across the LDR increases. **(1)** (When voltage across the LDR reaches a certain value) the MOSFET switches on. **(1)**	**3**	Independent marks. Accept 'X' or 'transistor' in place of MOSFET. Accept naming of component X consistent with part (c)(i). Accept MOSFET conducts/saturates/activates. Ignore any value for switching voltage stated.

Question			Expected response	Max mark	Additional guidance
8.			**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			Answer	Max mark	Additional guidance
9.	(a)	(i)	$E_h = cm\Delta T$ **(1)** $= 4180 \times 0.38 \times (22 - 0)$ **(1)** $= 35\,000$ J **(1)**	**3**	Calculation of temperature change may be implied by correct substitution of 22. Accept: (0 – 22) for temperature change. Ignore minus sign in final answer. Accept: 30 000 34 900 34 940
		(ii)	$P = \frac{E}{t}$ **(1)** $120 = \frac{35000}{t}$ **(1)** $t = 290$ s **(1)**	**3**	Or consistent with a(i). Ignore negative value in substitution of energy, but not in final value of time. Accept: 300 292 291.7
		(iii)	Put a lid on/insulate (the machine).	**1**	Do not accept: 'use a heat shield'. 'place it in a colder environment'. Do not accept if candidate states that improvement would reduce heat loss to the surroundings.
	(b)		$E_h = ml$ **(1)** $15.3 \times 10^3 = m \times 3.34 \times 10^5$ **(1)** $m = 0.0458$ kg **(1)**	**3**	Accept: 0.046 0.045 81 0.045 808

Question			Expected response	Max mark	Additional guidance
10.	(a)		The (air) particles collide with the walls (of the syringe).	**1**	Ignore any extraneous information. Accept 'atoms'/'molecules' in place of 'particles'.
	(b)	(i)	Suitable scales, labels, and units. **(1)** All points plotted accurately to ±half a division. **(1)** Best fit straight line. **(1)**	**3**	A non-linear scale on either axis prevents access to any marks. (0) Allow broken axes from origin (with or without symbol), but scale must be linear across data range. Axes can be transposed. A bar chart/histogram can obtain MAX (1) for scales, labels, and units.
		(ii)	(Pressure is) inversely proportional (to volume). **OR** Pressure is directly proportional to 1/volume.	**1**	**Must** be consistent with line candidate has drawn. If the candidate has not shown a best fit straight line in (b)(i) this mark cannot be accessed. If the candidate has used a non-linear scale in (b)(i) this mark cannot be accessed. Accept: $p \propto \frac{1}{V}$ **OR** $pV = constant$ Pressure is proportional to $\frac{1}{V}$ There is a linear relationship between pressure and $\frac{1}{V}$ Allow ±one division tolerance for line passing through origin (or would pass through origin if extrapolated) for a statement of inverse or direct proportion. Do not accept: 'as volume decreases pressure increases'.

Question			Expected response	Max mark	Additional guidance
10.	(b)	(iii)	From graph: ($\frac{1}{V}$ =) 0.23 **(1)** volume = 4.3 ml **(1)**	**2**	**Must** be consistent with the line the candidate has drawn. Ignore any units after the selected value of $1/V$ If the candidate has not shown a curve or line in (b)(i) these marks cannot be accessed. If the candidate has used a non-linear scale in (b)(i) these marks cannot be accessed. Accept 1-4 significant figures.
	(c)		Repeat (measurements) and average. **OR** Repeat (measurements) to identify outliers/rogue points. **OR** Increase the range of volumes. **OR** Increase the number of different volumes.	**1**	Do not accept: 'repeat measurements' alone. 'more readings' alone. Do not accept responses in terms of accuracy or precision. Apply +/- rule for surplus answers.

Question			Expected response	Max mark	Additional guidance
11.	(a)		(Particle) vibrations/oscillations are at 90°/right angles/perpendicular to the direction of energy transfer. **OR** (Particle) vibrations/oscillations are at 90°/right angles/perpendicular to the direction the wave is travelling.	**1**	Accept: 'particles move up and down' to indicate a vibration/oscillation 'disturbance' to indicate a vibration/oscillation. Do not accept: 'particles move perpendicular…'.
	(b)	(i)	$f = \frac{N}{t}$ **(1)** $f = \frac{500}{(30 \times 60)}$ **(1)** $f = 0.28$ Hz	**2**	**'Show' question** Must state relationship or (0) marks. Calculation can be carried out in steps, but all steps must be shown for the substitution mark to be awarded (ie 30 × 60). Final answer of 0.28 Hz, including unit, must be shown or MAX (1). **Alternative method:** $f = \frac{1}{T}$ (1) $f = \frac{1}{\frac{(30 \times 60)}{500}}$ (1) $f = 0.28$ Hz For the second mark to be awarded it must be shown how the period is calculated.
		(ii)	$d = \bar{v}t$ **(1)** $160 = \bar{v} \times 32$ **(1)** $\bar{v} = 5.0$ ms^{-1} **(1)**	**3**	Bar not required above v. Accept: 5 5.00 5.000
		(iii)	$v = f\lambda$ **(1)** $5.0 = 0.28 \times \lambda$ **(1)** $\lambda = 18$ m **(1)**	**3**	Or consistent with (b)(ii) Accept: 20 17.9 17.86

Question			Expected response	Max mark	Additional guidance
12.	(a)	(i)	$d = vt$ **(1)** $20\,200 \times 10^3 = 3.0 \times 10^8 \times t$ **(1)** $t = 0.067$ s	**2**	**'Show' question.** Must state relationship or (0) marks. Final answer of 0.067 s, including unit, must be shown or MAX (1). Accept use of $D=ST$ relationship, provided use of S for speed is clarified by substitutions.
		(ii)	It is not geostationary. **(1)** It does not have an (orbital) period of 24 hours. **OR** It is not at an (orbital) altitude of 36 000 km. **(1)**	**2**	**MUST JUSTIFY.** Accept converse justification (eg geostationary satellites have an orbital period of 24 hours).
	(b)	(i)	CCD **OR** photodiode **OR** phototransistor	**1**	Accept: LDR. thermistor. thermocouple. Do not accept: IR/infrared camera. photographic film. (black-bulb) thermometer. thermogram. Apply +/- rule for surplus answers.
		(ii)	$v = f\lambda$ **(1)** $3.0 \times 10^8 = f \times 904 \times 10^{-9}$ **(1)** $f = 3.3 \times 10^{14}$ Hz **(1)**	3	Accept: 3×10^{14} 3.32×10^{14} 3.319×10^{14}
		(iii)	$d = vt$ **(1)** $d = 3.0 \times 10^8 \times 1.2 \times 10^{-6}$ **(1)** $\text{distance} = \frac{3.0 \times 10^8 \times 1.2 \times 10^{-6}}{2}$ **(1)** $= 180$ m **(1)**	4	Accept: 200 180.0 **Alternative method:** $\text{time} = \frac{1.2 \times 10^{-6}}{2}$ (1) $d = vt$ (1) $d = 3.0 \times 10^8 \times \frac{1.2 \times 10^{-6}}{2}$ (1) $d = 180$ m (1)

Question			Expected response	Max mark	Additional guidance
13.	(a)		X: (angle of) incidence Y: (angle of) refraction	**1**	Both required. Do not accept: 'ray of incidence'. 'ray of refraction'.
	(b)		Refraction takes place. **OR** There is a change in speed. **OR** The ray is moving from a less (optically) dense into a more (optically) dense medium. **(1)** The angle of incidence is greater than 0° **(1)**	**2**	Independent marks. Accept: There is a change in wavelength. Do not award first mark if candidate states there is a change in frequency. Do not award first mark if candidate indicates there is an increase in speed. Accept: 'The incident ray is not along the normal' for the second mark.
	(c)		Appropriate change in direction away from normal.	**1**	Line must be passably straight.

Question			Expected response	Max mark	Additional guidance
14.	(a)		Alpha and beta are unable to reach the detector. **OR** (Only) gamma will reach the detector.	**1**	Accept response in terms of ability to penetrate the ground/layers/ etc. Accept response in terms of what would/would not be absorbed by ground/layers/etc.
	(b)	(i)	Time for activity to (decrease by) half. **OR** Time for half the nuclei to decay.	**1**	Do not accept: Time for radiation/radioactivity/ count rate to half.
		(ii)	sodium-24 **(1)** it is a gamma emitter **and** has a suitable half-life **(1)**	**2**	**MUST JUSTIFY.** Accept for justification: bismuth-204 is a beta emitter only. barium-133 half-life too long. barium-137m half-life too short. Must have all three.
	(c)	(i)	150 s	**1**	±10 s
		(ii)	50 kBq	**1**	Accept any single value between 40 kBq and 60 kBq inclusive.

Question			Expected response	Max mark	Additional guidance
15.	(a)	(i)	$H = Dw_r$ **(1)** $0.25\times10^{-6} = D\times1$ **(1)** $D = 2.5\times10^{-7}$ Gy **(1)**	**3**	Accept: 3×10^{-7} 2.50×10^{-7} 2.500×10^{-7}
		(ii)	$D = \frac{E}{m}$ **(1)** $2.5\times10^{-7} = \frac{E}{64}$ **(1)** $E = 1.6\times10^{-5}$ J **(1)**	**3**	Or consistent with (a)(i). Accept: 2×10^{-5} 1.60×10^{-5} 1.600×10^{-5}
	(b)		When an (uncharged) atom gains or loses/gains/loses an electron/ electrons.	**1**	
	(c)		Limit the time near machine. **OR** Keep distance from machine. **OR** Stand behind shielding.	**1**	Do not accept: 'wear a film badge'. Only accept protective clothing if clarified (eg lead apron). Apply +/- rule for surplus answers.

[END OF MARKING INSTRUCTIONS]