Mark Scheme (Final)

October 2020

Pearson Edexcel GCE
In Physics (9PH0)
Paper 3: General and Practical Principles in Physics

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

Autumn 2020
Publications Code 9PH0_03_2010_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Mark scheme notes

Underlying principle

The mark scheme will clearly indicate the concept that is being rewarded, backed up by examples. It is not a set of model answers.

1. Mark scheme format

1.1 You will not see 'wtte' (words to that effect). Alternative correct wording should be credited in every answer unless the MS has specified specific words that must be present. Such words will be indicated by underlining e.g. '<u>resonance</u>'

1.2 Bold lower case will be used for emphasis e.g. '**and'** when two pieces of information are needed for 1 mark.

1.3 Round brackets ( ) indicate words that are not essential e.g. "(hence) distance is increased".

1.4 Square brackets [ ] indicate advice to examiners or examples e.g. [Do not accept gravity] [ecf].

2. Unit error penalties

2.1 A separate mark is not usually given for a unit but a missing or incorrect unit will normally mean that the final calculation mark will not be awarded.

2.2 This does not apply in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.

2.3 The mark will not be awarded for the same missing or incorrect unit only once within one clip in epen.

2.4 Occasionally, it may be decided not to insist on a unit e.g the candidate may be calculating the gradient of a graph, resulting in a unit that is not one that should be known and is complex.

2.5 The mark scheme will indicate if no unit error is to be applied by means of [no ue].

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not be prevent a mark being awarded if the answer given rounds to the answer in the MS.

3.2 Too few significant figures will mean that the final mark cannot be awarded in 'show that' questions where one more significant figure than the value in the question is needed for the candidate to demonstrate the validity of the given answer.

3.3 The use of one significant figure might be inappropriate in the context of the question e.g. reading a value off a graph. If this is the case, there will be a clear indication in the MS.

3.4 The use of g = 10 m s^{-2} or 10 N kg^{-1} instead of 9.81 m s^{-2} or 9.81 N kg^{-1} will mean that one mark will not be awarded. (but not more than once per clip). Accept 9.8 m s^{-2} or 9.8 N kg^{-1}

3.5 In questions assessing practical skills, a specific number of significant figures will be required e.g. determining a constant from the gradient of a graph or in uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations

4.1 Bald (i.e. no working shown) correct answers score full marks unless in a 'show that' question.

4.2 If a 'show that' question is worth 2 marks. then both marks will be available for a reverse working; if it is worth 3 marks then only 2 will be available.

4.3 **use** of the formula means that the candidate demonstrates substitution of physically correct values, although there may be conversion errors e.g. power of 10 error.

4.4 **recall** of the correct formula will be awarded when the formula is seen or implied by substitution.

4.5 The mark scheme will show a correctly worked answer for illustration only.

5.Quality of Written Communication

5.1 Indicated by QoWC in mark scheme. QWC – Work must be clear and organised in a logical manner using technical wording where appropriate.

5.2 Usually it is part of a max mark, the final mark not being awarded unless the QoWC condition has been satisfied.

6.Graphs

6.1 A mark given for axes requires both axes to be labelled with quantities and units, and drawn the correct way round.

6.2 Sometimes a separate mark will be given for units or for each axis if the units are complex. This will be indicated on the mark scheme.

6.3 A mark given for choosing a scale requires that the chosen scale allows all points to be plotted, spreads plotted points over more than half of each axis and is not an awkward scale e.g. multiples of 3, 7 etc.

6.4 Points should be plotted to within 1 mm.

- Check the two points furthest from the best line. If both OK award mark.
- If either is 2 mm out do not award mark.
- If both are 1 mm out do not award mark.
- If either is 1 mm out then check another two and award mark if both of these OK, otherwise no mark.

For a line mark there must be a thin continuous line which is the best fit line for the candidate's resuts

Question Number	Acceptable Answer	Additional Guidance	Mark
1	An explanation that makes reference to the following points: • High precision means a small spread of values **(1)** • High accuracy means close to the true value **(1)** Any **TWO** from: • A is precise but not accurate (as there is a small spread but displaced from the centre of the target) **(1)** • B is both accurate and precise (as there is a small spread centred on the target) **(1)** • C is neither accurate nor precise (as there is a large spread displaced from the centre of the target) **(1)** • D is accurate but not precise (as there is a moderate spread centred on the target) **(1)**	Credit MP1/MP2 if the explanation of high accuracy/precision is made by reference to a relevant part of the diagram.	**4**

(Total for Question 1 = 4 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
2(a)(i)	An explanation that makes reference to the following points: • Identify when the distance fallen between frames has become constant **(1)** • Measure the distance fallen over a number of frames **Or** measure the distance fallen between frames a number of times and calculate an average distance **(1)** • Calculate terminal velocity by dividing the distance fallen by the time taken **(1)** • Use $\frac{1}{60}$ s as time between frames. **(1)**	MP3: Allow reference to $v = \frac{s}{t}$ to calculate terminal velocity	**4**
2(a)(ii)	An explanation that makes reference to the following points: • There may be parallax error in reading the ball position **(1)** **Or** the metre rule may not be vertical • Recorded distance may be greater than actual distance, so calculated terminal velocity would be greater than true value. **(1)** **OR** **(1)** • The frame rate may be not be 60 s^{-1} • Time between frames may be less than 1/60 s, so calculated terminal velocity may be greater than true value **(1)**	Recorded distance may be less than actual distance, so terminal velocity would be less than true value Time between frames may be more than 1/60 s, so calculated terminal velocity may be less than true value	**2**

2(b)	An explanation that makes reference to the following points: • With a phone camera there won't be reaction time errors (when starting and stopping the stopwatch) **Or** with a phone camera the recording can be replayed (a number of times) **(1)** • So the uncertainty in the measured times will be reduced **Or** this may lead to a more accurate value/time/velocity **(1)**		**2**

(Total for Question 2 = 8 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)	Any **TWO** from: • Should have used (a fiducial mark as) a reference point **(1)** • Should have timed from the equilibrium position of the bob **Or** Shouldn't time from the maximum displaced position of the bob **(1)** • Only timed one oscillation **Or** should have times more than one oscillation **(1)** • Should have allowed the pendulum to swing to and fro a few times before starting to time (as the first swing may be different from the others) **(1)**	Accept centre/vertical/undisplaced position for equilibrium position	**2**
3(b)	• Determination of gradient **(1)** • Re-arrangement of $T = 2\pi\sqrt{\frac{l}{g}}$ **(1)** • Algebra to show $T^2 = -\frac{4\pi^2}{g}d + \frac{4\pi^2}{g}h$ **(1)** • Gradient = $(-)\frac{4\pi^2}{g}$ **(1)** • g = 9.6 m s^{-2} [accept 9.5 → 9.7 m s^{-2}] **(1)**	$T^2 = \frac{4\pi^2}{g}l$ $T^2 = \frac{4\pi^2}{g}(h-d)$ $T^2 = -\frac{4\pi^2}{g}d + \frac{4\pi^2}{g}h$ <u>Example of calculation</u> $\text{gradient} = \frac{(12.1-9.2)\ \text{s}^2}{(0.00-0.70)\ \text{m}} = -4.1\ \text{s}^2\text{m}^{-1}$ $\therefore g = \frac{4\pi^2}{4.1\ \text{s}^2\text{m}^{-1}} = 9.6\ \text{m s}^{-2}$	**5**

(Total for Question 3 = 7 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
*4	See below	See below	6

Acceptable Answer

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content:

- IC1 The rate of decay depends upon the number of unstable nuclei in the sample ($A = -\lambda N$)
- IC2 Radium has a large half-life, so unstable nuclei are present in the sample for a long time
- IC3 When a nucleus decays there is a (small) decrease in mass Δm
- IC4 Energy is released according to $\Delta E = c^2 \Delta m$
- IC5 Δm is small but c is large, so a significant amount of energy is released
- IC6 Energy released by the decay becomes kinetic energy of the atoms in the sample (hence sample is above the temperature of the surroundings

Additional Guidance

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The table shows how the marks should be awarded for indicative content and structure and lines of reasoning.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5–4	3
3–2	2
1	1
0	0

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

IC2: accept idea that it takes a long time to decay for "unstable nuclei are present…or a long period of time"

IC3 accept a reference to binding energy increasing

(Total for Question 4 = 6 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
5(a)	• use of $Q = It$ • use of $V = \frac{W}{Q}$ • W = 5.1 × 10^8 J	(1) (1) (1)	Allow calculations based on power i.e. $VI = \frac{W}{t}$ <u>Example of calculation:</u> $Q = It$=25 ×10^3A ×7.5 ×10^{-3}s=188 C $W = QV$=188 C × 2.7 × 10^6V = 5.08 ×10^8 J	3
5(b)	• Use of $A = \frac{\pi d^2}{4}$ Or use of πr^2 • Use of $R = \frac{\rho l}{A}$ • Calculates $l - 1.5$ • Height = 27.1 m so it is not taller than 30 m **OR** • Use of $A = \frac{\pi d^2}{4}$ Or use of πr^2 • Calculate wire length wire for 30 m statue [l = 31.5 m] • Use of $R = \frac{\rho l}{A}$ • R = 4.7 × 10^{-3} Ω (> 4.3 × 10^{-3} Ω) so statue is not taller than 30 m	(1) (1) (1) (1)	<u>Example of calculation:</u> $A = \frac{\pi d^2}{4} = \frac{\pi \times (1.2\times10^{-2}\text{m})^2}{4}$ = 1.13×10^{-4}m^2 $l = \frac{RA}{\rho} = \frac{4.3 \times 10^{-3}\Omega \times 1.13 \times 10^{-4}\text{m}^2}{1.7 \times 10^{-8}\ \Omega\ \text{m}}$ = 28.6 m Height = 28.6 m – 1.5 m = 27.1 m	4
5(c)	• So that the lightning makes contact with the conductor rather than the statue	(1)		1

(Total for Question 5 = 8 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
6(a)	• Series circuit with power supply, heater and ammeter. • Voltmeter connected in parallel with heater	**(1)** **(1)**		**2**
6(b)	• Use of $P = VI$ • Calculation of gradient • Gradient = $\frac{\Delta m}{\Delta t}$ • Use of $\Delta E = mL$ and $P = \frac{\Delta E}{\Delta t}$ • $L = 2.30 \times 10^6$ (J kg^{-1}) • Comparison of calculated value for L with values in table and appropriate conclusion. • But not all of the energy supplied to the liquid will be used to boil the liquid **Or** thermal energy will be transferred to surroundings	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	For MP2 and MP3 credit Δm read from graph and used with corresponding Δt value For MP3 and MP4, credit $L = \frac{VI}{\text{gradient}}$ Answers in the range $(2.26 - 2.34) \times 10^6$ J kg^{-1} <u>Example of calculation</u>: grad= $\frac{(211\text{-}155)\times 10^{-3}\text{ kg}}{(0\text{-}600)\text{ s}} = 9.33 \times 10^{-5}$ kg s^{-1} $\therefore \frac{\Delta m}{\Delta t} = 9.33 \times 10^{-5}$ kg s^{-1} $P = 20.5\text{ V} \times 10.5\text{ A} = 215\text{ W}$ $\therefore L = \frac{215\text{ W}}{9.33 \times 10^{-5}\text{kg s}^{-1}} = 2.30 \times 10^6$ J kg^{-1}	**7**

6(c)	• Use lagging to insulate the container from the surroundings **(1)** • So that a greater proportion of the energy supplied is used to boil the liquid **(1)** **Or** • Use a heater with a higher electrical power **(1)** • So that a shorter time is needed to boil the liquid **(1)**	Accept “to minimise heat loss to the surroundings”	**2**

(Total for Question 6 = 11 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
7(a)	An explanation that makes reference to the following points: • The potential difference creates an electric field • An (electric) field/force does work on the electrons (increasing their kinetic energy) **Or** an (electric) field/force accelerates the electrons (increasing their velocity)	(1) (1)		2
7(b)(i)	• (Perpendicularly) out of the page • The force is perpendicular to the magnetic field and the direction of (conventional) current **Or** an application of Fleming's Left-Hand Rule	(1) (1)	Accept movement of electrons for current	2
7(b)(ii)	An explanation that makes reference to the following points: • There would be a force (of constant magnitude) on the electron perpendicular to its direction of motion • Causing an acceleration towards the centre of a circle	(1) (1)	Accept reference to centripetal force for MP1	2
7(c)(i)	• Use of $F = BQv$ and $F = EQ$ • Algebra to show $v = \frac{E}{B}$	(1) (1)		2
7(c)(ii)	• Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ • Use of $v = \frac{E}{B}$ • $\frac{e}{m}$=1.7×10^{11}C kg^{-1}	(1) (1) (1)	<u>Example of calculation:</u> $v = \frac{E}{B} = \frac{1.4 \times 10^4\ \text{V m}^{-1}}{1.5 \times 10^{-3}\ \text{T}}$ $\frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{\left(9.33 \times 10^6\ \text{m s}^{-1}\right)^2}{2 \times 250\ \text{V}} = 1.74 \times 10^{11}\ \text{C kg}^{-1}$	3

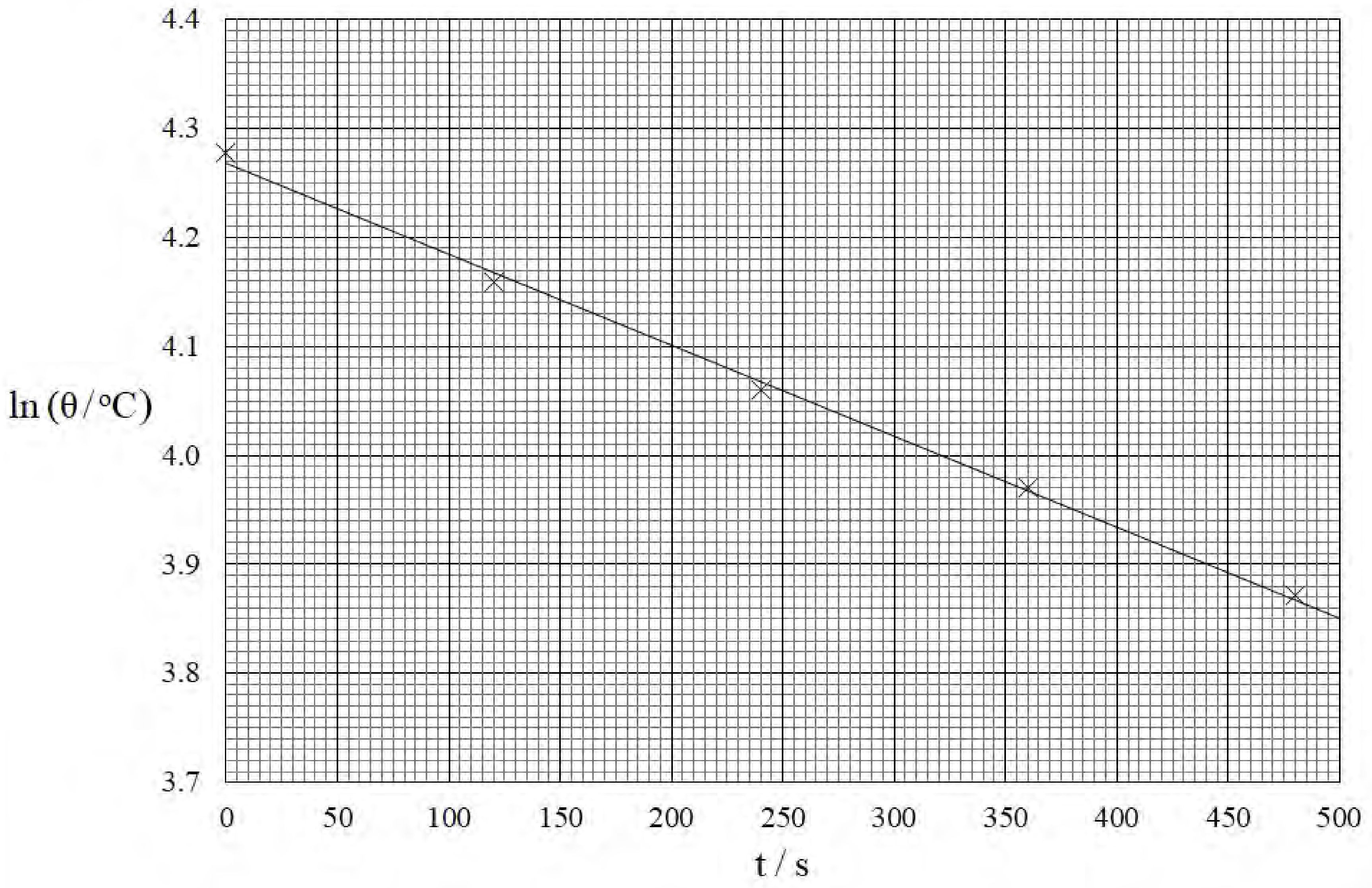
7(d)	• The hydrogen ion must be (about 2000 times) more massive than the electron **Or** the electron must be (about 2000 times) less massive than the hydrogen ion **(1)**	Accept “proton” for “hydrogen ion”	**1**

(Total for Question 7 = 12 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th></th><th>Additional Guidance</th><th></th></tr>
<tr><td>8(a)</td><td>An explanation that makes reference to the following points:
• Shows expansion ln $\Delta\theta = \ln \Delta\theta_o - bt$
• Compares with $y = mx + c$ and states that the gradient is b (which is constant)</td><td>(1)
(1)</td><td></td><td>2</td></tr>
<tr><td>8(b)(i)</td><td>• ln values correct (at least 2 dec.places)
• Labels and unit
• Scales
• Plots
• Line of best fit</td><td>(1)
(1)
(1)
(1)
(1)</td><td><table><tr><th>Δθ / ^{o}C</th><th>ln (Δθ / ^{0}C)</th></tr><tr><td>72</td><td>4.277</td></tr><tr><td>64</td><td>4.159</td></tr><tr><td>58</td><td>4.060</td></tr><tr><td>53</td><td>3.970</td></tr><tr><td>48</td><td>3.871</td></tr></table></td><td>5</td></tr>
<tr><td>8(b)(ii)</td><td>• Determines gradient using large triangle
• $b = 8 \times 10^{-4} \rightarrow 9 \times 10^{-4}$ (2 or 3 sf)
• Units s^{-1}</td><td>(1)
(1)
(1)</td><td><u>Example of calculation:</u>
$m = \frac{4.27 - 3.85}{(0 - 500)\ \mathrm{s}} = 8.4 \times 10^{-4}\ \mathrm{s}^{-1}$</td><td>3</td></tr>
</table>

8(c)	**MAX 3 from** • Dataloggers are useful when data changes over a very short (or very long) time scale • Dataloggers are useful when a number of quantities are being measured simultaneously • A comment on the time between temperature readings in this experiment. • It takes longer for the liquid in glass thermometer to respond to temperature changes than the temperature sensor • There may be parallax error in reading from the liquid in glass thermometer • Conclusion consistent with discussion of suitability of using a data logger	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**		**4**

(Total for Question 8 = 14 marks



4.4
4.3
4.2
4.1
ln (θ / °C)
4.0
3.9
3.8
3.7
0
50
100
150
200
250
300
350
400
450
500
t / s

Question Number	Acceptable Answer	Additional Guidance	Mark

9(a)

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content:

- IC1 Alternating p.d. causes an alternating current in the coil
- IC2 Current carrying conductor in a magnetic field experiences a force
- IC3 Current is alternating, so force changes direction with current (same frequency)
  Or the alternating current drives the cone at the frequency of the p.d.
- IC4 The loudspeaker forces the box into oscillation
- IC5 (At certain frequencies) the frequency of oscillation equals the natural frequency of oscillation of the air in the box
- IC6 Maximum energy is transferred and the amplitude of vibration of the box increases

Additional Guidance

This question assesses a student's ability to show a coherent and logic structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The table shows how the marks should be awarded for indicative cont and structure and lines of reasoning.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5–4	3
3–2	2
1	1
0	0

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Alternative to first 3 indicative content points:

- IC1 Current in coil causes a magnetic field
- IC2 Current is alternating so field changes direction with current (same frequency)
- IC3 Field interacts with permanent magnet's field so coil experiences oscillating force

- IC6 Resonance occurs and the amplitude of vibration of the box increases

Mark: 6

9(b)(i)	• A standing wave is set up in the tube **Or** interference (of sound waves) takes place in the tube **(1)** • Where constructive interference occurs the amplitude is a maximum **Or** at antinodes the amplitude is a maximum **(1)** • Where destructive interference occurs the amplitude is a minimum **Or** at nodes the amplitude is zero/minimum **(1)** • Sand is displaced from points of max amplitude to points of min amplitude **Or** sand is displaced from antinodes to nodes **(1)**		**4**
9(b)(ii)	• Measure over at least 3 heaps **(1)** • Divide by the number of gaps between the heaps **(1)** • Repeat measurement and calculate average **(1)**	i.e at least 2 gaps	**3**
9(b)(iii)	• Use of $d = \frac{\lambda}{2}$ **(1)** • Use of $v = f\lambda$ **(1)** • v = 330 (m s^{-1}) and a comment on consistency with 340 m s^{-1} **(1)**	<u>Example of calculation:</u> $\lambda = 2d = 2 \times 5.1 \times 10^{-2}$ m = 0.102 m $v = 3.25 \times 10^3$ Hz × 0.102 m = 332 m s^{-1}	**3**

(Total for Question 9 = 16 marks)

Question Number	Acceptable Answer		Additional Guidance Whole question to be clipped together to allow full ECF	Mark
10(a)(i)	• Calculation of mean value • Use of $l = \pi w$ • l= 48.1 mm (3 sf)	(1) (1) (1)	Example of calculation: $w = \frac{(15.3+15.2+15.4+15.3)}{4} = 15.3$ mm $l = \pi \times 15.3$ mm$=48.1$ mm	3
10(a)(ii)	• Calculation of half range **Or** greatest deviation from mean • % uncertainty = 0.7 % **Allow ECF from (a)(i)**	(1) (1)	Example of calculation: Half range value = $\frac{15.4\text{ mm} - 15.2\text{ mm}}{2} = 0.1$ mm ∴ % uncertainty= $\frac{0.1\text{ mm}}{15.3\text{ mm}} \times 100\ \% = 0.65\ \%$	2
10(a)(iii)	• Use of $L = Nl$ with N = 16 **or** 18 • L = 866 mm [0.866 m] **Allow ECF from (a)(i)**	(1) (1)	Example of calculation: $L = 18 \times 48.1$ mm $= 866$ mm	2
10(b)(i)	• Micrometer (screw gauge) **Or** digital calipers • Because the measured value indicates a resolution of 0.01 mm	(1) (1)		2
10(b)(ii)	• % uncertainty = 0.2 %	(1)	Example of calculation: % uncertainty= $\frac{0.005\text{ mm}}{2.52\text{ mm}} \times 100\ \% = 0.20\ \%$	1
10(b)(iii)	• % uncertainty = 1.6 %	(1)	Example of calculation: % uncertainty= $\frac{0.5\text{ g}}{32.0\text{ g}} \times 100\ \% = 1.56\ \%$	1
10(b)(iv)	• % uncertainty = 2.7 % [1 or 2 sf] **Allow ECF from (a)(ii), (bii) and (b)(iii)**	(1)	Example of calculation: % uncertainty = 0.7 % + 1.6 % + (2 × 0.2 %) = 2.7 %	1

10(b)(v)	• Use of V = $L \times \frac{\pi d^2}{4}$ **(1)** • Use of $\rho = \frac{m}{V}$ **(1)** • Uncertainty in density = 200 kg m^{-3} **(1)** • So maximum density is 7600 kg m^{-3} which is lower than the standard value **Or** comment consistent with their calculated value **(1)** **Allow ECF from (a)(iii) and (b)(iv)**	<u>Example of calculation:</u> V = 0.866 $m \times \frac{\pi(2.52\times10^{-3})^2}{4}$ = 4.32× 10^{-6} m^3 $\rho = \frac{3.20\times10^{-2}\text{ kg}}{4.32\times10^{-6}\text{m}^3}$ =7400 kg m^{-3} Uncertainty in ρ = $\pm$(7400 kg m^{-3} $\times \frac{2.7}{100}$) = 200 kg m^{-3}	4

(Total for Question 10 = 16 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
11(a)	• Use of $L = 4\pi r^2 \sigma T^4$ **(1)** • Use of $I = \frac{L}{4\pi d^2}$ **(1)** • $I = 1.37$ (kW m^{-2}) **(1)** • This is less than 2 (kW m^{-2}) and so the claim is false. **(1)**	<u>Example of calculation:</u> $L = 4\pi(6.96\times10^{8}\,\text{m})^2 \times 5.67\times10^{-8}\,\text{W m}^{-2}\text{K}^{-4}(5790\ \text{K})^4$ $L = 3.88 \times 10^{26}$ W $I = \frac{3.88\times10^{26}\,\text{W}}{4\pi(1.50\times10^{11}\,\text{m})^2} = 1372\ \text{W m}^{-2}$	**4**
11(b)(i)	An explanation that makes reference to the following points: • Radiation is absorbed/scattered passing through the atmosphere. **(1)** • Radiation is reflected from the top of the atmosphere **(1)** • Only half of the Earth's surface has radiation from the Sun incident on it at any one instant. **(1)** • The intensity of radiation (normal to the surface) is greater at the equator than at the poles. **(1)**		**4**
11(b)(ii)	• Use of $A = 4\pi r^2$ **(1)** • Use of efficiency$= \frac{\text{useful power output}}{\text{total power input}}$ **(1)** • Use of $I = \frac{P}{A}$ **(1)** • % of surface needed is 0.0005%, so claim is not valid **(1)** [Accept reverse calculation to show power generated by cells over 0.5% of the Earth would generate 1.06×10^5 GW]	<u>Example of calculation:</u> $A = \frac{P}{I} = \frac{100\times10^{9}\ \text{W}}{0.25\times164\ \text{W m}^{-2}} = 2.44\times10^{9}\,\text{m}^2$ $A = 4\pi \times (6.4 \times 10^{6}\ \text{m})^2 = 5.15\times10^{14}\,\text{m}^2$ % needed $= \frac{2.44\times10^{9}\,\text{m}^2}{5.15\times10^{14}\ \text{m}^2} \times 100\% = 0.00047\ \%$	**4**

11(c)(i)	• Satellite would always be above the same point on the Earth's surface **(1)** • So that contact/communication with the space station would be maintained at all times **(1)**		**2**
11(c)(ii)	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$ **(1)** Use of $\omega = 2\pi/T$ **(1)** $r = 4.23 \times 10^7$ m **(1)** $h = 3.6 \times 10^7$ m **(1)** **OR** Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$ **(1)** Use of $v = 2\pi r/T$ **(1)** $r = 4.23 \times 10^7$ m **(1)** $h = 3.6 \times 10^7$ m **(1)**	<u>Example of calculation:</u> $m\omega^2 r = \frac{GMm}{r^2}$ $\therefore \left(\frac{2\pi}{T}\right)^2 = \frac{GM}{r^3}$ $\therefore r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$ $r = \sqrt[3]{\frac{6.67\times10^{11}\text{N m}^2\text{ kg}^2\times6.00\times10^{24}\text{kg}\times(8.64\times10^4\text{s})^2}{4\pi^2}}$ $r = 4.23 \times 10^7$m $h = r - R_E = 4.23\times10^7\text{ m} - 6.4\times10^6\text{ m} = 3.59\times10^7\text{ m}$	**4**

(Total for Question 11 = 18 marks)

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom