Mark Scheme (Results)

June 2025

Pearson Edexcel GCE
In Physics (9PH0)
Paper 03 General and Practical Principles in Physics

Edexcel and BTEC Qualifications

Summary 2025
Question Paper Log Number P78522A
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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 placing brackets around the unit.

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not 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 be penalised by one mark (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 **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.

4.2 If a ‘show that’ question is worth 2 marks, then both marks will be available for a reverse working. If the question is worth 3 marks then only 2 marks will be available.

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

5. Quality of Written Expression

5.1 Questions that asses the ability to show a coherent and logically structured answer are marked with an asterisk.

5.2 Marks are awarded for indicative content and for how the answer is structured.

5.3 Linkage between ideas, and fully-sustained reasoning is expected.

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.

6.5 For a line mark there must be a thin continuous line which is the best-fit line for the candidate’s results.

Question Number	Acceptable Answer		Additional Guidance	Mark
1(a)	• The ammeter is in series with the bulb and the voltmeter is in parallel with the bulb **Or** Adjusting the variable resistor will vary the current/p.d. • The circuit may not be able to give a full range of applied p.d.s **Or** Reducing the variable resistance will place a p.d. across the bulb much larger than 3 V • Comment on suitability consistent with stated characteristics of circuit	**(1)** **(1)** **(1)**	Allow "the measurements of current and p.d. will be valid"	**3**
1(b)	• Precision is the closeness of agreement (consistency) between (repeated) measurements • As the student has only taken a single value of current, the student cannot say the current is precise • Accuracy is how close the measured value is to the true value • The true value is not known, so the student cannot say the value will be accurate **Or** There may be a systematic error, so the student cannot say the value will be accurate	**(1)** **(1)** **(1)** **(1)**		**4**

(Total for Question 1 = 7 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
2	An explanation that makes reference to the following points: • Microwaves are reflected (from the metal plate) **(1)** • Superposition / interference occurs **Or** A standing wave is produced **(1)** • Maximum (intensity) where waves arrive in phase **Or** minimum (intensity) where waves arrive in antiphase **(1)** • Use of $v = f\lambda$ **(1)** • $\lambda = 2.8$ cm so separation of minima is 1.4 cm ≈ 1.5 cm **(1)**	For "in phase" accept phase difference (2n)π or path difference (2n)λ For "in antiphase" accept phase difference (n+1)π/2 or path difference (n+1)λ/2 May use 1.5 cm to calculate speed and then compare with 3.0×10^8 m s^{-1} or 10.7GHz <u>Example of calculation</u> $\lambda = \frac{v}{f} = \frac{3.0 \times 10^8 \text{ m s}^{-1}}{10.7 \times 10^9 \text{ Hz}} = 0.028 \text{ m}$ $\frac{\lambda}{2} = \frac{2.8 \text{ cm}}{2} = 1.4 \text{ cm}$	5

(Total for Question 2 = 5 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)(i)	An explanation that makes reference to the following points: • The prism and the centre of gravity are at different distances from the pivot **Or** The prism is not at the centre of gravity of the rule **(1)** • So for moments about the pivot to balance the force from the prism must be larger (than the weight of the rule) **(1)**	Allow an explanation based on use of equations. Allow "For the forces to be equal, they would have to be the same distance from the pivot to balance the moments"	**2**
3(a)(ii)	• Use of $F = mg$ **(1)** • Use of moment = Fx **(1)** • Application of principle of moments about the pivot **(1)** • $W = 0.84$ N **(1)**	<u>Example of calculation</u> Force at prism = F $F = (0.1802 \text{ kg} - 0.0255 \text{ kg}) \times 9.81 \text{ N kg}^{-1} = 1.52 \text{ N}$ Taking moments about the pivot point $1.52 \text{ N} \times (30.0 - 5.0) \text{ cm} = W \times (50.0 - 5.0) \text{ cm}$ $\therefore W = \dfrac{1.52 \text{ N} \times 25.0 \text{ cm}}{45.0 \text{ cm}} = 0.84 \text{ N}$	**4**

3(b)	• The distance to the pivot would increase **Or** Percentage uncertainty in distance decreases **(1)** • The force at the prism would decrease **Or** Percentage uncertainty in force/mass increases **(1)** • (As one increases and the other decreases) we cannot be sure how the percentage uncertainty would change **(1)**	Allow "reading on the balance decreases" Dependent upon MP1 and MP2	3

(Total for Question 3 = 9 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
4(a)(i)	• The detector area exposed to γ-radiation is larger in the set-up of Student A • So the count (rate) will be greater (at a given distance from the source) • Hence (the percentage uncertainty will be smaller for) Student A	**(1)** **(1)** **(1)**	<u>Alternative MP1 and MP2</u> • *d* should be measured to the middle of the counter (1) • The error (or uncertainty) in *d* is reduced in set-up of Student A (1) MP3 dependent on MP1 **and** MP2	**3**
4(a)(ii)	An explanation that makes reference to the following points: • Record the background count (rate) and subtract from recorded count (rate) • Gives count (rate) of source only **Or** As background count adds to the count from the source • Record the count for a longer time • As this will increase the total count (at a given distance)	**(1)** **(1)** **(1)** **(1)**	Allow "Adds a systematic error" <u>Alternative MP3 and MP4</u> • Repeat the measurement of the count and calculate a mean (1) • As radioactive decay is random (1)	**4**

4(b)	An explanation that makes reference to the following points: • Place an aluminum sheet between the source and the detector **(1)** • As this will absorb/block the alpha and beta radiation emitted by the source **(1)**	Allow up to 3 mm of lead	**2**

(Total for Question 4 = 9 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(a)	• Use a micrometer screw gauge **(1)** • Check (and correct) for zero error **Or** Use the ratchet on the micrometer **(1)** • Measure diameter at different positions along wire and calculate a mean **Or** Measure diameter at different orientations and calculate a mean **(1)** • Calculate cross sectional area using $\frac{\pi d^2}{4}$ **Or** Calculate radius and then use πr^2 **(1)**	Allow digital calipers not vernier calipers	**4**
5(b)(i)	An explanation that makes reference to the following points: • Electrons collide with (lattice) ion and transfer energy **Or** Current in wire causes temperature of wire to increase **(1)** • So the amplitude of vibration (of the lattice ions) increases **(1)** • Electrons make more frequent collisions (with lattice ions), so the resistance increases **(1)**		**3**

5(b)(ii)	Max **TWO** from: • (For a black body radiator) Stefan(-Boltzmann) law applies **Or** (For a black body radiator) $L = \sigma A T^4$ **(1)** • The rate of energy transfer from the wire is determined by its surface area **(1)** • Increasing the length increases the surface area, so more energy is radiated away (and the temperature does not change) **(1)**		**2**

(Total for Question 5 = 9 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*6</td>
<td>This question assesses a student’s ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.

Indicative content:

IC1 Average kinetic energy of (air) molecules decreases

IC2 So the (mean square) speed/velocity (of air molecules) decreases
Or So the momentum (of air molecules) decreases

IC3 Rate of collision with container walls decreases
Or Momentum change in each collision with container walls decreases

IC4 Rate of change of momentum (with container walls) decreases

IC5 So force (on container walls) decreases

IC6 $P = F/A$ so pressure (exerted by air molecules) decreases</td>
<td>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table></td>
<td>6</td>
</tr>
</table>

(Total for Question 6 = 6 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(a)	• Measure the total thickness of a number of discs (stacked) together **(1)** • Divide by the number of discs (in the stack) to determine the average thickness of one disc **(1)** • Measure the total length of a number of discs lined up together **Or** Measure diameter of a number of discs using vernier calipers **(1)** • Divide by the number of discs to determine the average diameter of one disc **(1)**		**4**

7(b)	• Uses $V = \pi r^2 t$ **(1)** • Use of $\rho = \frac{m}{V}$ **(1)** • $\rho = 1.1 \times 10^4\ \text{kg m}^{-3}$ **(1)** • Uses % uncertainty in mass **or** diameter **or** thickness **(1)** • Uses 2 × % U in diameter **(1)** • % U in density = 10 % **(1)**	<u>Example of calculation</u> $V = \pi\left(\frac{5.2 \times 10^{-2}\ \text{m}}{2}\right)^2 \times 1.9 \times 10^{-3}\ \text{m} = 4.04 \times 10^{-6}\ \text{m}^3$ $\rho = \frac{42.5 \times 10^{-3}\ \text{kg}}{4.04 \times 10^{-6}\ \text{m}^3} = 1.05 \times 10^4\ \text{kg m}^{-3}$ For mass % U $= \frac{0.5\ \text{g}}{42.5\ \text{g}} \times 100\% = 1.2\ \%$ For diameter % U $= \frac{0.1\ \text{cm}}{5.2\ \text{cm}} \times 100\% = 1.9\ \%$ For thickness % U $= \frac{0.1\ \text{mm}}{1.9\ \text{mm}} \times 100\% = 5.3\ \%$ % U in density $= 1.2\ \% + (2 \times 1.9\ \%) + 5.3\ \% = 10.3\ \%$ <u>Alternative MP4 and MP5</u> • Uses absolute uncertainties to calculate upper or lower limit • Uses half range •	6

(Total for Question 7 = 10 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
8(a)	• Uses $V = \frac{4}{3}\pi r^3$ • Use of $\rho = \frac{m}{V}$ • Use of $W = mg$ to calculate upthrust • Use of $F = 6\pi\eta r v$ • $v = 1.8 \times 10^{-3}$ m s^{-1}	**(1)** **(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> $V = \frac{4}{3}\pi \times (6.8 \times 10^{-3}\text{ m})^3 = 1.32 \times 10^{-6}\text{ m}^3$ $m = \rho V = 925\text{ kg m}^{-3} \times 1.32 \times 10^{-6}\text{ m}^3 = 1.22 \times 10^{-3}\text{ kg}$ upthrust $= 1.22 \times 10^{-3}\text{ kg} \times 9.81\text{ N kg}^{-1} = 1.20 \times 10^{-2}\text{ N}$ $v = \dfrac{1.20 \times 10^{-2}\text{ N}}{6\pi \times 52.6\text{ Pa s} \times 0.68 \times 10^{-2}\text{ m}} = 1.77 \times 10^{-3}\text{ m s}^{-1}$	**5**
8(b)(i)	An explanation that makes reference to the following points: **EITHER** • Shows expansion $\log\eta = B\log T + \log A$ • Compares with $y = mx + c$ **and** states that gradient is B (which is a constant) **OR** • Shows expansion $\log\eta = \log A + B\log T$ • Compares with $y = c + mx$ **and** states that gradient is B (which is a constant)	 **(1)** **(1)** **(1)** **(1)**	 Do not accept m for gradient MP2 dependent on MP1 Do not accept m for gradient MP2 dependent on MP1	**2**

<table>
<tr>
<td>8(b)(ii)</td>
<td>

- Log values correct and consistent to 3 decimal places (1)
- Axis labels y as log (η / mPa s), x as log (T / K) (1)
- Scales (1)
- Plots (1)
- Line of best fit (1)

</td>
<td>

Accept correct and consistent to 2 decimal places
[Each column is internally consistent]

T / K	η / mPa s	log T	log T	log η	log η
123	4.60	2.090	2.09	0.663	0.66
173	6.00	2.238	2.24	0.778	0.78
273	8.30	2.436	2.44	0.919	0.92
373	10.4	2.572	2.57	1.017	1.02
473	12.0	2.675	2.67	1.079	1.08

</td>
<td>5</td>
</tr>
<tr>
<td>8(b)(iii)</td>
<td>

- Gradient determined using large triangle (1)
- $B = 0.68 \rightarrow 0.75$ to 2 or 3 sf (1)
- Inverse log of intercept determined (1)
- $A = 0.12 \rightarrow 0.18$ ignore unit (1)

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<td>

<u>Example of calculation</u>

Gradient = $B = \frac{1.105-0.675}{2.70-2.10} = 0.717$

$\log A = \log\eta - B\log T = 1.105 - 0.717 \times 2.7 = -0.831$

$A = 10^{-0.831} = 0.148$

MP3: Allow intercept from false origin

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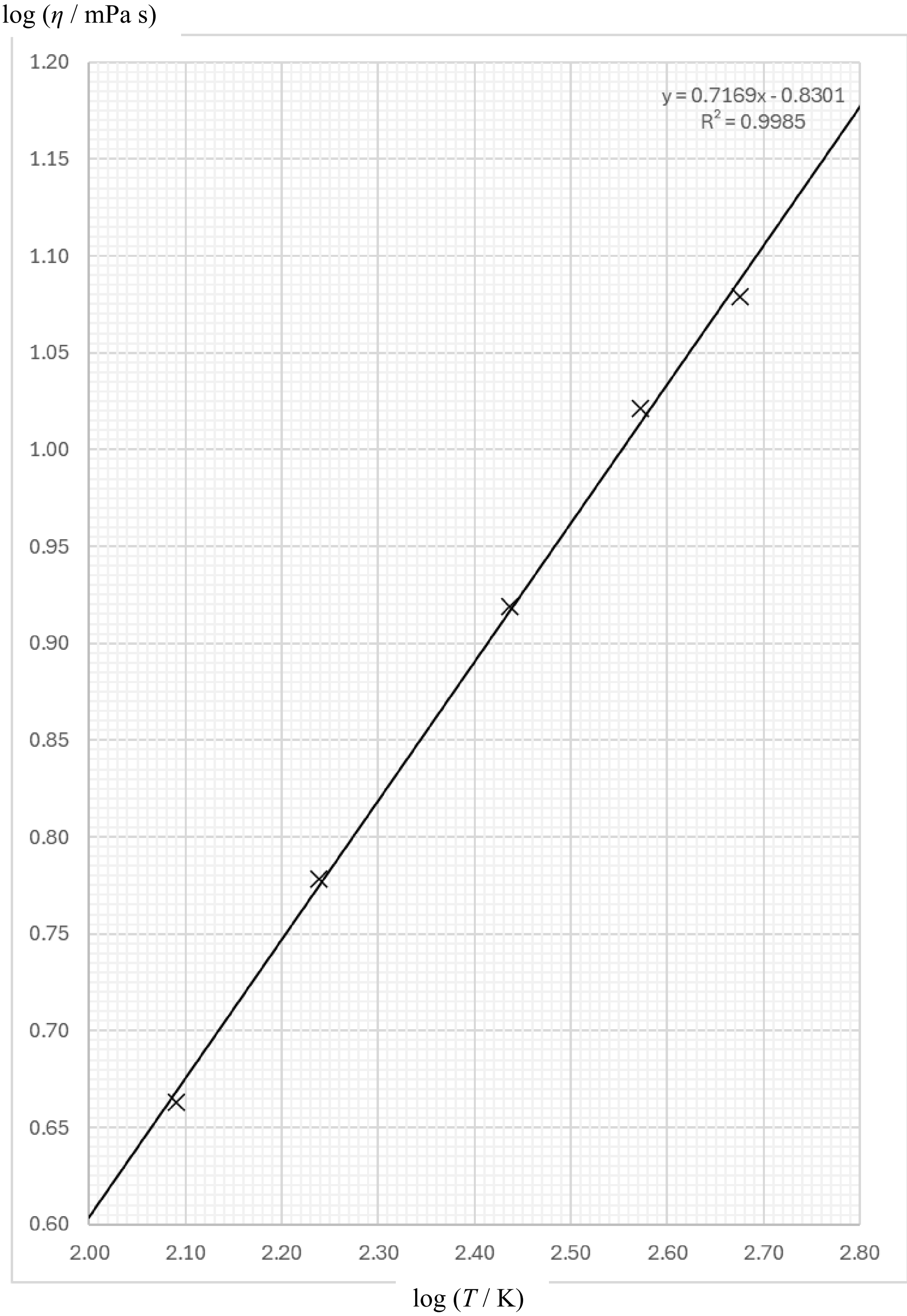
<td>4</td>
</tr>
</table>

(Total for Question 8 = 16 marks)


log (η / mPa s)
y = 0.7169x - 0.8301
R^2 = 0.9985
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
2.00
2.10
2.20
2.30
2.40
2.50
2.60
2.70
2.80
log (T / K)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(a)(i)	An explanation that makes reference to the following points: • Use a (fiducial) marker **(1)** • Placed at the equilibrium position (of cantilever) **(1)** • (This will reduce timing errors) as end of cantilever is moving fastest at the equilibrium position **(1)**		**3**
9(a)(ii)	An explanation that makes reference to the following points: • Time a larger number of oscillations **(1)** • This will increase the total time recorded **(1)**		**2**

9(b)	• Calculation of average time (period) **(1)** • Use of $T^2 \propto \frac{ML^3}{E}$ **(1)** • Calculates $\frac{E_1}{E_2}$ **(1)** • Calculates $\frac{E_{\text{spruce}}}{E_{\text{cedar}}}$ **(1)** • $\frac{E_1}{E_2}$ =1.22 **and** $\frac{E_{\text{spruce}}}{E_{\text{cedar}}} = 1.25$ **(1)** • As 1.22 is close to 1.25, the metre rule must be made from spruce **and** half-metre rule from cedar **Or** Conclusion based on comparison of calculated values from using calculated ratio **(1)**	<u>Example of calculation</u> $T_1 = \frac{14.69\text{ s} + 14.64\text{ s} + 14.76\text{ s})/3}{5} = 2.94\text{ s}$ $T_2 = \frac{5.33\text{ s} + 5.40\text{ s} + 5.24\text{ s})/3}{5} = 1.06\text{ s}$ $\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{L_1}{L_2}\right)^3 \times \frac{E_2}{E_1} \quad \therefore \frac{E_1}{E_2} = \left(\frac{L_1}{L_2}\right)^3 \times \left(\frac{T_2}{T_1}\right)^2$ $\therefore \frac{E_1}{E_2} = \left(\frac{0.95\text{ m}}{0.45\text{ m}}\right)^3 \times \left(\frac{1.06\text{ s}}{2.94\text{ s}}\right)^2 = 1.22$ $\frac{E_{\text{spruce}}}{E_{\text{cedar}}} = \frac{9.6\text{ GPa}}{7.7\text{ GPa}} = 1.25$ <u>Alternative MP4 and MP5</u> • Calculates $E_{\text{cedar}} \times \frac{E_1}{E_2} = E_{\text{spruce}}$ • $\frac{E_1}{E_2}$ =1.22 **and** $E_{\text{spruce}} = 9.5$ (or $E_{\text{cedar}} = 7.9$)	**6**

(Total for Question 9 = 11 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
10(a)	• Use of $P = \frac{V^2}{R}$ • P = 48.2 (W)	**(1)** **(1)**	<u>Example of calculation</u> $P = \frac{(8.5\text{ V})^2}{1.5\ \Omega} = 48.2\text{ W}$ Bald answer of 48.2 can score MP2 only Bald answer of 48 scores 0	**2**
10(b)	• Use of $\rho = \frac{m}{V}$ • Use of $\Delta E = mc\Delta\theta$ • Use of $P = \frac{\Delta W}{\Delta t}$ • Time = 128 s (ecf from (a))	**(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> $m = 1.25 \times 10^{-4}\text{ m}^3 \times 1050\text{ kg m}^{-3} = 0.131\text{ kg}$ $t = \frac{0.131\text{ kg} \times 3930\text{ J kg}^{-1}\text{ K}^{-1} \times 12\text{ K}}{48.2\text{ W}} = 128\text{ s}$ Allow 130s Show that value gives 129 s	**4**

10(c)	• (Connect oscilloscope to the a.c. supply and) adjust time base so that a complete wave can be seen on the screen **(1)** • Measure the (horizontal) distance from peak to peak **(1)** • Use the time base setting × distance between peaks (to determine the time for one cycle) **(1)** • Use $f = \frac{1}{T}$ to calculate the supply frequency **(1)** • Use the voltage sensitivity and amplitude (of a peak to determine the peak p.d.) **(1)** • Use $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$ (to calculate the r.m.s. p.d. and compare with the voltmeter reading) **(1)**	Accept several complete cycles for MP1, but in that case require measurement across several cycles for MP2.	**6**

(Total for Question 10 = 12 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
11(a)(i)	An explanation that makes reference to the following points: • The velocity/momentum increases as the energy of the protons increases **(1)** • $r = \frac{p}{Bq}$ **and** $p=mv$ so the magnetic flux density must increase (to keep r constant). **Or** $r = \frac{p}{Bq}$ **and** $E_k = \frac{p^2}{2m}$ so the magnetic flux density must increase (to keep r constant). **Or** $F = \frac{mv^2}{r}$ **and** $F = Bqv$ so the magnetic flux density must increase (to keep r constant) **(1)**		**2**

11(a)(ii)	• Radius calculated **(1)** • Use of $F = \frac{mv^2}{r}$ **(1)** • Use of $F = Bqv$ **(1)** • $B = 7.3 \times 10^{-5}$ T **(1)**	Allow use of $p = mv$ for MP2 and use of $r = \frac{p}{Bq}$ for MP3 <u>Example of calculation</u> $r = \frac{\text{circumference}}{2\pi} = \frac{27 \times 10^3\ \text{m}}{2\pi} = 4.30 \times 10^3\ \text{m}$ $F = \frac{1.67 \times 10^{-27}\ \text{kg} \times (3.0 \times 10^7\ \text{m s}^{-1})^2}{4.30 \times 10^3\ \text{m}} = 3.50 \times 10^{-16}\ \text{N}$ $B = \frac{3.50 \times 10^{-16}\ \text{N}}{1.6 \times 10^{-19}\ \text{C} \times 3.0 \times 10^7\ \text{m s}^{-1}} = 7.28 \times 10^{-5}\ \text{T}$	**4**
11(a)(iii)	• Conversion to joule **(1)** • Use of $\Delta E = c^2 \Delta m$ **(1)** • $m = 2.4 \times 10^{-23}$ (kg) **(1)**	<u>Example of calculation</u> $E = 13\,600 \times 10^9\ \text{eV} \times 1.6 \times 10^{-19}\ \text{J eV}^{-1} = 2.18 \times 10^{-6}\ \text{J}$ $m = \frac{2.18 \times 10^{-6}\ \text{J}}{(3.0 \times 10^8\ \text{m s}^{-1})^2} = 2.42 \times 10^{-23}\ \text{kg}$	**3**

***11(b)**

This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning

Indicative content:

- IC1 In a fixed target collision there is momentum before the collision so there is momentum after the collision
- IC2 So particle(s) created must have some kinetic energy
- IC3 So not all kinetic energy converted to mass
- IC4 In a colliding beam experiment total initial momentum is zero (if the colliding particles have the same mass and speed)
- IC5 Momentum after the collision will be zero
- IC6 So (almost) all of the kinetic energy is converted to mass

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.

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

Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning.

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

6

(Total for Question 11 = 15 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
12(a)(i)	An explanation that makes reference to the following points: • t_1 is not significantly different from the other times **Or** t_1 is only 0.6% different from t_{mean} **Or** there is not enough data to show that t_1 is anomalous **(1)** • So the student who says that all the data should be used is correct **(1)**	MP2 dependent upon MP1	**2**
12(a)(ii)	• Mean t calculated **(1)** • Uses half range **Or** Uses furthest from mean **(1)** • % U = 0.4 % given to 1 or 2 sig figs only **(1)** 0.5% using furthest from mean	Example of calculation $t_{\text{mean}} = \dfrac{7.85\text{ s} + 7.81\text{ s} + 7.79\text{ s} + 7.80\text{ s}}{4} = 7.81\text{ s}$ Half range = $\frac{7.85\text{ s} - 7.79\text{ s}}{2} = 0.03\text{ s}$ % U = $\frac{0.03\text{ s}}{7.81\text{ s}} \times 100\% = 0.38\ \%$	**3**
12(a)(iii)	• Height of cylinder **Or** Length of cylinder **(1)**		**1**

12(b)(i)	• Use of $v^2 = u^2 + 2as$ **(1)** • v = 3.8 m s^{-1} **(1)**	<u>Example of calculation</u> $v^2 = u^2 + 2as$ $\therefore v = \sqrt{2 \times 9.81 \text{ m s}^{-2} \times 0.75 \text{ m}} = 3.84 \text{ m s}^{-1}$	**2**
12(b)(ii)	An explanation that makes reference to the following points: • The cylinder is travelling (very) quickly (when it reaches the light gate) **(1)** • Therefore the time taken for the cylinder to pass through the light gate is (very) short **(1)** • Using the light gate and a data logger there is minimal effect from reaction time **Or** Difficult/impossible to press stopwatch button again after such a short time **(1)**		**3**

(Total for Question 12 = 11 marks)

TOTAL FOR PAPER = 120 MARKS

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