Mark Scheme (Results)

Summer 2018

Pearson Edexcel Level 3 GCE
In Physics (9PH0)
Paper 02 Advanced Physics II

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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 schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

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 results.

Question Number	Acceptable answers	Additional guidance	Mark
1	The only correct answer is **B** because the power of a diverging lens is negative, so the total power = 9.4 D – 4.2 D = 5.2 D A is not correct because the total power should be obtained from (9.4 D – 4.2 D), but this is (9.4 D + 4.2 D) C is not correct because this is (4.2 D – 9.4 D) using negative power for a converging lens and positive for a diverging lens where it should be the opposite so that (9.4 D – 4.2 D) is used D is not correct because – 13.6 D = − 9.4 D – 4.2 D, as if both lenses are diverging, which is not the case		**1**
2	The only correct answer is **D** because pressure is proportional to absolute temperature and inversely proportional to volume, so the effect of the volume change is to increase the pressure by 3/2 and the effect of the temperature change is to increase the pressure by 6/5, and 18/10 = 9/5 A is not correct because a pressure of 5/9 *p* would depend on pressure being proportional to volume and inversely proportional to absolute temperature rather than being proportional to absolute temperature and inversely proportional to volume B is not correct because this assumes that pressure is proportional to both volume and absolute temperature, giving an answer of 4/5 *p*, instead of assuming that pressure is proportional to absolute temperature and inversely proportional to volume C is not correct because this assumes that pressure is inversely proportional to both volume and absolute temperature, giving an answer of 5/4 *p*, instead of assuming that pressure is proportional to absolute temperature and inversely proportional to volume		**1**
3	The only correct answer is **B** because the gradient of this graph is change in length ÷ change in force and the change in length is the same as the change in extension, so the gradient is equal to stiffness A is not correct because a graph of extension against force will have a gradient of 1/*k* C is not correct because a graph of stress against strain will have a gradient equal to the Young modulus for the sample D is not correct because a graph of strain versus length is equivalent to a graph of extension versus $(\text{length})^2$, so it does not have a gradient equal to *k*		**1**

4	The only correct answer is **B** because at angles less than or equal to the critical angle not all of the light is reflected internally such that angle of incidence is equal to the angle of reflection A is not correct because total internal reflection occurs at angles greater than the critical angle but at the critical angle the angle of refraction is 90 degrees, so the reflection is not total C is not correct because internal reflection is not total at angles less than the critical angle D is not correct because internal reflection is not total at angles less than the critical angle		**1**
5	The only correct answer is **B** because alpha is the most ionising and gamma is the most penetrating A is not correct because although alpha is the most ionising, gamma and not alpha is the most penetrating C is not correct because alpha, not gamma, is the most ionising and gamma, not alpha is the most penetrating D is not correct because alpha, not gamma is the most ionising, even though gamma is the most penetrating		**1**
6	The only correct answer is **A** because, using Einstein's photoelectric equation, $hf = \varphi + ½\, mv^2_{\text{max}}$, since the work function is constant, an increase in frequency results in an increase in the maximum kinetic energy of the photoelectrons B is not correct because, using Einstein's photoelectric equation, $hf = \varphi + ½\, mv^2_{\text{max}}$, intensity has no effect on the maximum kinetic energy of the photoelectrons, just the rate at which they are emitted C is not correct because , using Einstein's photoelectric equation, $hf = \varphi + ½\, mv^2_{\text{max}}$, and since the work function is equal to (the Planck constant × threshold frequency), a higher threshold frequency will lead to a lower maximum kinetic energy of the photoelectrons D is not correct because, using Einstein's photoelectric equation, $hf = \varphi + ½\, mv^2_{\text{max}}$, a higher work function will lead to a lower maximum kinetic energy of the photoelectrons		**1**

7	The only correct answer is **C** emitting an alpha particle decreases the nucleon number by 4 and decreases the proton number by 2 A is not correct because emitting an alpha particle decreases the nucleon number by 4 and decreases the proton number by 2, but here the nucleon number has been increased by 2 and the proton number has been increased by 4 B is not correct because emitting an alpha particle decreases the nucleon number by 4 and decreases the proton number by 2, but here the nucleon number has been increased by 4 and the proton number has been increased by 2 D is not correct because emitting an alpha particle decreases the nucleon number by 4 and decreases the proton number by 2, but here the nucleon number has been decreased by 2 and the proton number has been decreased by 4		**1**
8	The only correct answer is **D** because velocity is equal to the gradient of the displacement-time graph A is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as proportional to −1 times the displacement B is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as −1 times the gradient C is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as proportional to the displacement		**1**
9	The only correct answer is **D** because magnification is numerically equal to image distance divided by object distance A is not correct because magnification is numerically equal to image distance divided by object distance, but this is focal length divided by object distance B is not correct because magnification is numerically equal to image distance divided by object distance, but this is object distance divided by image distance C is not correct because magnification is numerically equal to image distance divided by object distance, but this is object distance divided by focal length		**1**

10	The only correct answer is **C** because the maximum order reached corresponds to the highest integer value less than or equal to line spacing divided by wavelength, which is 4, and there are that many orders either side of the maximum plus a central order A is not correct because the maximum order reached corresponds to the highest integer value less than or equal to line spacing divided by wavelength, which is 4, and there are that many orders either side of the maximum plus a central order, but this answer only gives the number of orders on one side of the central order B is not correct because the maximum order reached corresponds to the highest integer value less than or equal to line spacing divided by wavelength, which is 4, but this order rounds 4.7 to 5 and doesn't consider the central maximum or that there are orders on either side D is not correct because the maximum order reached corresponds to the highest integer value less than or equal to line spacing divided by wavelength, which is 4, but this order rounds 4.7 to 5 and then adds the orders on the other side and the central maximum		**1**

(Total for Multiple Choice Questions = 10 marks)

Question Number	Acceptable answers	Additional guidance	Mark
11(a)	- Equates right hand sides **(1)** - Final E_k formula ($\frac{1}{2} m \langle c^2 \rangle = 3/2\ kT$) and k is constant **(1)**		**2**
11(b)	- Use of $\frac{1}{2} m \langle c^2 \rangle = 3/2\ kT$ **(1)** - with T in Kelvin **(1)** - $\sqrt{\langle c^2 \rangle} = 497\ \text{m s}^{-1}$ **(1)**	Example of calculation $\frac{1}{2} m \langle c^2 \rangle = 3/2\ kT$ $\frac{1}{2} \times 5.0 \times 10^{-26}\ \text{kg} \times \langle c^2 \rangle = 3/2 \times 1.38 \times 10^{-23}\ \text{J K}^{-1} \times 298\ \text{K}$ $\langle c^2 \rangle = 247\ 000\ \text{m}^2\ \text{s}^{-2}$ $\sqrt{\langle c^2 \rangle} = 497\ \text{m s}^{-1}$	**3**

(Total for Question 11 = 5 marks)

Question Number	Acceptable answers		Additional guidance	Mark
12(a)	• Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K • … with sensible temperature expressed in Kelvin • E.g. $\lambda_{max} = 9.89 \times 10^{-6}$ m for 293 K • Value is greater than max wavelength of red light so is in IR region **Or** (if starting from 700 nm) • Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K • $T = 4100$ K • Comparison with stated sensible temperature (°C or K) • Temperature is too high so wavelength greater than max wavelength of red light so is in IR region	**(1)** **(1)** **(1)** **(1)**	Example of calculation $\lambda_{max}T = 2.898 \times 10^{-3}$ m K $\lambda_{max} = 2.898 \times 10^{-3}$ m K / 293 K $\lambda_{max} = 9.89 \times 10^{-6}$ m MP4 consistent with calculation	**4**
12 (b)	• Glass reflects (these wavelengths of) IR radiation • Glass does not transmit (these wavelengths of) IR radiation	**(1)** **(1)**	Accept IR does not pass through glass	**2**

(Total for Question 12 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
13(a)	• Weight and drag force are equal for terminal velocity stated or implied **(1)** • Quotes $F = 6\pi\eta rv$ and $mg = 4(\pi r^3)\rho g/3$ and suitable working to obtain $v = \frac{2g\rho r^2}{9\eta}$ **(1)**		**2**
13(b)	• Use of $v = \frac{2g\rho r^2}{9\eta}$ **(1)** • $v = 760\ (\text{m s}^{-1})$ **(1)**	Example of calculation $v = 2 \times 9.81\ \text{N kg}^{-1} \times 1.0 \times 10^3\ \text{kg m}^{-3}$ $\times (2.5 \times 10^{-3}\ \text{m})^2 / 9 \times 1.8 \times 10^{-5}\ \text{Pa s}$ $v = 757\ \text{m s}^{-1}$	**2**
13(c)	• Measured value much less than calculated value **(1)** **Max 2 from** • The raindrop is moving very fast so Stokes' law does not apply **(1)** • Flow is not laminar so Stokes' law does not apply **(1)** • Raindrops not small so Stokes' law does not apply **(1)** • Raindrops not spherical so Stokes' law does not apply **(1)** • Argument based on increased upward force if upthrust taken into account so it doesn't apply **(1)**		**3**

(Total for Question 13 = 7 marks)

Question Number	Acceptable answers	Additional guidance	Mark
14	• Use of $E_K = p^2 / 2m$ **(1)** • Use of $\lambda = h/p$ **(1)** • $\lambda = 5.0 \times 10^{-11}$ (m) calculated from E_K **Or** $E_K = 9.7 \times 10^{-17}$ (J) calculated from $\lambda = 5.0 \times 10^{-11}$ m **Or** $p = 1.3 \times 10^{-23}$ (kg m s^{-1}) calculated from E_K **and** $p = 1.3 \times 10^{-23}$ (kg m s^{-1}) calculated from $\lambda = 5.0 \times 10^{-11}$ m **(1)** • path difference at X is $\lambda/2$ **Or** path difference at Y is λ **(1)** • (electron) waves at X are in antiphase **Or** (electron) waves at Y are in phase **(1)** • at X destructive interference/superposition takes place **Or** at Y constructive interference/superposition takes place **(1)**	MP1 accept use of $p = mv$ **and** Use of $E_k = ½ mv^2$ MP4 accept (n + ½) λ or n λ respectively Example of calculation $p = \sqrt{(2 \times 9.11 \times 10^{-31} \text{ kg} \times 9.6 \times 10^{-17} \text{ J})}$ $p = 1.32 \times 10^{-23}$ kg m s^{-1} $\lambda = 6.63 \times 10^{-34}$ Js / 1.32×10^{-23} kg m s^{-1} $\lambda = 5.0 \times 10^{-11}$ m	**6**

(Total for Question 14 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
15(a)(i)	• use of $F = Gm_1m_2/r^2$ **and** use of $F = mr\omega^2$ **Or** use of $F = Gm_1m_2/r^2$ **and** use of $F = mv^2/r$ **(1)** • use of $T = 2\pi/\omega$ **Or** use of $T = 2\pi r/v$ **(1)** • $T = 12$ hours **Or** $F = 120$ N by gravitational approach and centripetal force approach **Or** $\omega = 1.45 \times 10^{-4}$ radians s^{-1} by gravitational approach and circular motion approach **Or** height of orbit = 7700 km **(1)** • Comparative statement consistent with their value(s) **(1)**	MP3 and 4 - for force and angular velocity, both approaches required <u>Example of calculation</u> $T^2 = 4\pi^2r^3 / G\ m_1$ $T^2 = 4\pi^2 \times (2\ 430\ 000\ \text{m} + 7\ 690\ 000\ \text{m})^3 / 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 3.30 \times 10^{23}\ \text{kg}$ $T = 43115$ s = 11.98 hours	4
15(a)(ii)	**Max 2** • Allows satellite to get (much) closer to surface **(1)** • So more detailed photographs/scans possible **(1)** **OR** • Allows satellite to spend time further from the surface **(1)** • So prevents exposure to prolonged heat from planet damaging probe **(1)** **OR** • Satellite varies distance from surface **(1)** • So it can take wide-angle and close-up pictures of the planet **(1)**	For each, the second marking point is dependent on the first. Award second marking point for other sensible advantages	2

Question Number	Acceptable Answers	Additional Guidance	Mark
15(b)	• Use of $V_{grav} = - GM/r$ **Or** Use of $E_P = - GMm/r$ with an assumed mass **(1)** • Subtraction of potential at surface from potential at orbital height **Or** Subtraction of potential energy at surface from potential energy at orbital height **(1)** • Use of difference in potential = $E_K/m = ½ v^2$ **Or** Use of difference in potential energy = $E_K = ½ mv^2$ **(1)** • $v = 3948 \text{ m s}^{-1}$ **(1)**	Example of calculation $\Delta V = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 3.30 \times 10^{23} \text{ kg } (1/2.43 \times 10^6 \text{ m} - 1/1.743 \times 10^7 \text{ m}) = 7.795 \times 10^6 \text{ J kg}^{-1}$ $½ mv^2 = 7.795 \times 10^6 \text{ J kg}^{-1} \times m$ Assume 1 kg $v = 3948 \text{ m s}^{-1}$	**4**

(Total for Question 15 = 10 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*16(a)</td>
<td>
<p>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p>
<p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p>
<p>The following table shows how the marks should be awarded for indicative content.</p>
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td><td>Max linkage mark available</td><td>Max final mark</td></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>
<p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p>
</td>
<td>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td>3</td>
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</table>

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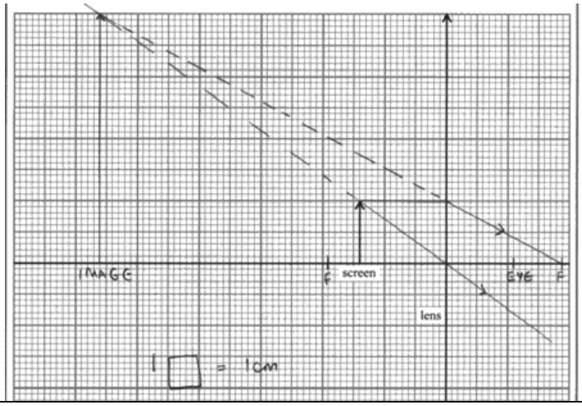
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured 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>
Indicative content
• he pendulums have the same length, so they have the same time period/frequency
• he first pendulum causes forced oscillations of the second pendulum
• The driving frequency equals the natural frequency
• Resonance occurs, so there is maximum transfer of energy so the amplitude increases until all energy is transferred
• The second pendulum then acts as a driver for the first pendulum **Or** the process repeats with energy transfer from B to A
• When the lengths differ the driving frequency is not the natural frequency of the second pendulum so little energy transfer occurs
</td>
<td></td>
<td></td>
</tr>
<tr>
<td>**16(b)(i)**</td>
<td>• Pendulum A is π/2 ahead of pendulum B **(1)**</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>**16(b)(ii)**</td>
<td>• $T = 1.2$ s from graph **(1)**
• Use of $T = 2\pi\sqrt{(l/g)}$ **(1)**
• $l = 0.36$ m **(1)**</td>
<td>$T = 3.0$ s / 2.5 oscillations
$1.2 \text{ s} = 2\pi\sqrt{(l/9.81 \text{ N kg}^{-1})}$
$l = 0.36$ m</td>
<td>3</td>
</tr>
</table>

(Total for Question 16 = 10 marks

Question Number	Acceptable answers	Additional guidance	Mark
17(a)	• Two rays correctly drawn including extrapolation **(1)** • Completes diagram with image at 10.6 cm (range 9.0 cm to 12.0 cm) **(1)** • Magnification = 3.8 (3.5 to 4.0) **(1)** • Conclusion consistent with values for distance and *M* **(1)**	Acceptable rays: • from arrowhead on object through the optical centre of the lens • from arrowhead on object parallel to the axis up to the lens and then through the principal focus on the other side • from the principal focus on the same side and through the arrowhead on the object to the lens and then parallel to the axis <u>Example of calculation</u> *M* = image size / object size (accept use of distances) = 8.0 cm / 2.0 cm = 4.0 	**4**

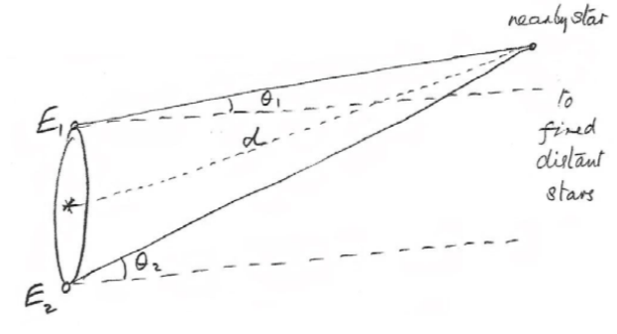
Question Number	Acceptable Answers		Additional Guidance	Mark
17 (b)(i)	- use of $n_1 \sin i_1 = n_2 \sin i_2$ - with angle of incidence in plastic = 28° - angle of deviation = angle of refraction – angle of incidence - angle of deviation = 16°	**(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> $n_1 \sin i_1 = n_2 \sin i_2$ $1.47 \sin (90° - 62°) = 1.00 \sin i_2$ $i_2 = 43.6°$ angle of deviation = 44° − 28° = 16°	**4**
17 (b)(ii)	- Going from the centre of the lens towards the edge the angle of incidence in the plastic increases - The angle of deviation increases - (So) all rays cross (the axis) at the principal focus	**(1)** **(1)** **(1)**	Accept focal point for principal focus	**3**

(Total for Question 17 = 11 marks)

Question Number	Acceptable answers		Additional guidance	Mark
18(a)(i)	- Use of $\lambda t_{½} = \ln 2$ - Use of $dN/dt = -\lambda N$ - $N = 9.5 \times 10^{10}$	**(1)** **(1)** **(1)**	$\lambda \times (1600 \times 365 \times 24 \times 60 \times 60)$ s = ln 2 $\lambda = 1.37 \times 10^{-11}$ s^{-1} 1.3 Bq = 1.37×10^{-11} s$^{-1} \times N$ $N = 9.46 \times 10^{10}$	**3**
18(a)(ii)	- Use of $A = A_0$ e$^{-\lambda t}$ - Use of ln$A$ = ln$A_0 - \lambda t$ or equivalent - $t = 8.58 \times 10^{10}$ s = 2700 years	**(1)** **(1)** **(1)**	ecf λ calculated in (i) ln 0.4 = ln1.3 –1.37×10^{-11} s$^{-1} \times t$ $t = 8.58 \times 10^{10}$ s = 2721 years	**3**
18(b)	- attempt to determine mass difference between radium and radon-plus-alpha - conversion to kg - Use of $\Delta E = c^2\Delta m$ - Use of 1.6×10^{-19} factor - Answer = 4.87 (MeV)	**(1)** **(1)** **(1)** **(1)** **(1)**	Δm = 225.97713u – (221.97040u + 4.00151 u) = 5.22×10^{-3} u = $5.22 \times 10^{-3} \times 1.66 \times 10^{-27}$ kg = 8.67×10^{-30} kg $\Delta E = c^2\Delta m = (3 \times 10^8$ m s$^{-1})^2 \times 8.67 \times 10^{-30}$ kg = 7.80×10^{-13} J ΔE in MeV = 7.80×10^{-13} J ÷ 1.6×10^{-19} C = 4.87 MeV	**5**

(Total for Question 18 = 11 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
19(a)(i)	• use of $I = L / 4\pi d^2$ **(1)** • $L = 6.53 \times 10^{23}$ W **(1)** • = 0.17% of Sun **(1)**	Example of calculation $3.25 \times 10^{-11}\ \text{W m}^{-2} = L / 4\pi(4.00 \times 10^{16}\ \text{m})^2$ $L = 6.53 \times 10^{23}$ W $6.53 \times 10^{23}\ \text{W} / 3.85 \times 10^{26}\ \text{W} = 0.17\%$	3
19(a)(ii)	• use of $L = \sigma A T^4$ **(1)** • $T = 3124$ (K) **(1)** • Statement relating calculated values of T and L to main sequence on H-R diagram **(1)**	Example of calculation $6.53 \times 10^{23}\ \text{W} = 5.67 \times 10^{-8}\ \text{W m}^{-2}\,\text{K}^{-4} \times 4\pi\,(9.81 \times 10^{7}\ \text{m})^2 \times T^4$ $T = 3124$ K	3
19(b)	• atoms/electrons have fixed/discrete/specific energy levels **(1)** • electrons get excited by absorbing photons **(1)** • energy of photon absorbed = difference in energy levels **(1)** • only certain transitions possible, so only certain photon energies absorbed so only certain frequencies missing **(1)** • the set of frequencies absorbed depends on the element **(1)**	Answers in terms of emission spectrum can be awarded MP1, 4 and 5	5
19(c)	• The star is viewed from two positions at 6 month intervals **Or** The star is viewed from opposite ends of its orbit diameter about the Sun **(1)** • The change in angle/position of the star against backdrop of fixed stars is measured **(1)**	Marks may be obtained from suitably annotated diagrams e.g MP1 and MP2:	**3**

	• Trigonometry is used to calculate the distance to the star [Do not accept Pythagoras] **Or** The diameter/radius of the Earth's orbit about the Sun must be known	**(1)**		

(Total for Question 19 = 14 marks)

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