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Mark Scheme (Results)

Summer 2022

Pearson Edexcel 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.

Question Number	Answers	Mark
1	**The only correct answer is A** ***B*** *is incorrect because the drag force increases as the skydiver falls through the air* ***C*** *is incorrect because the drag force increases as the skydiver falls through the air* ***D*** *is incorrect because the drag force increases as the skydiver falls through the air*	1
2	**The only correct answer is B** ***A*** *is incorrect because the relative refractive index for light travelling from glass to water is required* ***C*** *is incorrect because the relative refractive index for light travelling from glass to water is required* ***D*** *is incorrect because the relative refractive index for light travelling from glass to water is required*	1
3	**The only correct answer is B** ***A*** *is incorrect because amplitude does not affect the diffraction effect* ***C*** *is incorrect because frequency affects the wavelength and hence the diffraction effect* ***D*** *is incorrect because the speed of sound affects the wavelength and hence the diffraction effect*	1
4	**The only correct answer is C** ***A*** *is incorrect because luminosity must have the units of power* ***B*** *is incorrect because luminosity must have the units of power* ***D*** *is incorrect because luminosity must have the units of power*	1
5	**The only correct answer is B** ***A*** *is incorrect because a red giant star has larger surface area but a lower surface temperature than the Sun* ***C*** *is incorrect because a red giant star has larger surface area but a lower surface temperature than the Sun* ***D*** *is incorrect because a red giant star has larger surface area but a lower surface temperature than the Sun*	1
6	**The only correct answer is C** ***A*** *is incorrect because the energy is calculated in eV* ***B*** *is incorrect because the mass and energy conversions are incorrect* ***D*** *is incorrect because the mass conversion is incorrect*	1
7	**The only correct answer is C** ***A*** *is incorrect because the mean kinetic energy is constant at constant temperature* ***B*** *is incorrect because collisions between molecules do not increase the force on the walls of the container* ***D*** *is incorrect because the momentum change depends upon the root mean square speed of the molecules*	1
8	**The only correct answer is D** ***A*** *is incorrect because the angle of incidence must be greater than the critical angle* ***B*** *is incorrect because the angle of incidence must be greater than the critical angle* ***and*** $n_1 < n_2$	1

	C *is incorrect because the light must be incident upon the boundary in the medium with the larger refractive index*	
9	**The only correct answer is C** ***A*** *is incorrect because the focal length of the lens increases* ***B*** *is incorrect because the focal length of the lens increases* ***D*** *is incorrect because lens power is the reciprocal of the focal length*	**1**
10	**The only correct answer is A** ***B*** *is incorrect because an incorrect calibration would give a consistently high or low reading* ***C*** *is incorrect because temperature does not affect the background count rate* ***D*** *is incorrect because a systematic error would be a constant difference between the actual and the recorded count rate*	**1**

(Total for Multiple Choice Questions = 10 marks)

Question Number	Acceptable answers		Additional guidance	Mark
11 (a)	• Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ • … with consistent units for u and f • Use of displacement = $v - f$ • Displacement of lens = 0.07 mm away from sensor	(1) (1) (1) (1)	Example of calculation $\frac{1}{25\times10^{-2}\text{ m}}+\frac{1}{v}=\frac{1}{4.25\times10^{-3}\text{ m}}$ $\therefore \frac{1}{v}=(235.3-4)\text{ m}^{-1}$ $\therefore v=\frac{1}{231.3\text{ m}^{-1}}=4.32\times10^{-3}\text{ m}$ Displacement of lens = (4.32 – 4.25) mm = 0.0735 mm	4
11 (b)	• Lens displacement is so minimal that v doesn't change much **Or** $u >> v$ so Δv doesn't change much **Or** $u >> f$ so displacement doesn't change much **Or** $u >> v$ so v approx. equal to f **Or** most object distances can be considered to be at infinity so will focus at about f	(1)		1

(Total for Question 11 = 5 marks)

Question Number	Acceptable answers		Additional guidance	Mark
12	• Use of $V_{grav} = -\frac{GM}{r}$	**(1)**	Example of calculation $\Delta V_{grav} = -\frac{GM}{r_2} + \frac{GM}{r_1}$ $\Delta V_{grav} = GM\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\Delta V_{grav} = 6.67 \times 10^{-11}$ N m^2 kg^{-2} $\times$ 6.39×10^{23} kg $\left(\frac{1}{(3.39 \times 10^6 + 11.0 \times 10^3)\text{m}} - \frac{1}{(3.39 \times 10^6 + 2.1 \times 10^3)\text{m}}\right)$ $\therefore \Delta V_{grav} = -3.29 \times 10^4$ J kg^{-1} $\therefore \Delta E_{grav} = -3.29 \times 10^4$ J kg^{-2} $\times 1030$ kg $= -3.39 \times 10^7$ J	3
	• Recognises that $\Delta E_{grav} = m \times \Delta V_{grav}$	**(1)**		
	• $\Delta E_{grav} = (-)\ 3.4 \times 10^7$ J	**(1)**		
	OR			
	• Use of $g_{Mars} = -\frac{GM}{r^2}$ with justification that change in g is minimal			
	• Use of $\Delta E_{grav} = m \times g \times \Delta h$			
	• $\Delta E_{grav} = (-)\ 3.4 \times 10^7$ J			

(Total for Question 12 = 3 marks)

Question Number	Acceptable answers		Additional guidance	Mark
13	An explanation that makes reference to the following points: • Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ • (Hence) initial activity of Ac is 50% that of Bi **Or** (Hence) decay constant of Ac is 50% that of Bi • Applies one or two half lives to show fraction of initial activity/number after 10 days for one isotope **Or** Use of exponential decay equation to show fraction of initial activity/number after 10 days for one isotope • Demonstrates quantitatively that both isotopes have the same activity	 **(1)** **(1)** **(1)** **(1)**	<u>Alternative approach:</u> $\lambda_{\text{Ac}} = \frac{\ln 2}{10}$ $A_{\text{Ac}} = \lambda_{\text{Ac}}N = \frac{\ln 2}{10} \times N$ After 10 days $A_{\text{Ac}} = \frac{1}{2} \times \frac{ln2}{10} \times N = \frac{\ln 2}{20} \times N$ $\lambda_{\text{Bi}} = \frac{\ln 2}{5}$ $A_{\text{Bi}} = \lambda_{\text{Bi}}N = \frac{\ln 2}{5} \times N$ After 10 days $A_{\text{Bi}} = \frac{1}{2} \times \frac{1}{2} \times \frac{\ln 2}{5} \times N = \frac{ln2}{20} \times N$ $A_{\text{Ac}} = A_{\text{Bi}}$ **MP2** can be awarded for use of **both** decay constants in exponential decay equations All four marks may be awarded for a full mathematical demonstration, e.g.: $\lambda_{\text{Ac}} = \frac{\ln 2}{10} = 0.0693\ \text{day}^{-1}$ $A_{\text{Ac}} = \lambda_{\text{Ac}}N = 0.0693\ \text{day}^{-1} \times N$ 10 days: $A_{\text{Ac}} = ½ \times 0.0693\ \text{day}^{-1} \times N = 0.0345\ \text{day}^{-1} \times N$ $\lambda_{\text{Bi}} = \frac{\ln 2}{5} = 0.139\ \text{day}^{-1}$ $A_{\text{Bi}} = \lambda_{\text{Bi}}N = 0.139\ \text{day}^{-1} \times N$ 10 days: $A_{\text{Bi}} = ½ \times ½ \times 0.139\ \text{day}^{-1} \times N = 0.0345\ \text{day}^{-1}$ $A_{\text{Ac}} = A_{\text{Bi}}$	4

(Total for Question 13 = 4 marks)

Question Number	Acceptable answers		Additional guidance	Mark
14 (a)	An explanation that makes reference to the following points: • The fractional change in wavelength is proportional to the relative velocity of the source • Hence the change in wavelength is proportional to the wavelength **OR** • $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ and *v* and *c* are the same for all wavelengths **Or** $\frac{\Delta\lambda}{\lambda} = z$ and *z* is constant • change in wavelength is proportional to the wavelength **Or** rearranges, e.g. $\Delta\lambda = x\lambda$ to demonstrate $\Delta\lambda$ is proportional to λ	 **(1)** **(1)** **(1)** **(1)**		2
14 (b)	An explanation that makes reference to the following points: • Estimate λ_{star} (above 7×10^{-7} m) • Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ with 656 nm as denominator • $v = 3.8 \times 10^{7}$ m s^{-1} (range 3.4×10^{7} m s^{-1} to 4.2×10^{7} m s^{-1}) • (Star is) moving away from the Earth **Or (**star is) receding	 **(1)** **(1)** **(1)** **(1)**	Example of calculation $\frac{(7.40 \times 10^{-7} - 6.56 \times 10^{-7})}{6.56 \times 10^{-7}\ m} = \frac{v}{3.00 \times 10^{8}\ m\ s^{-1}}$ $\therefore v = \frac{0.84 \times 10^{-7}\ \text{m}}{6.56 \times 10^{-7}\ \text{m}} \times 3.00 \times 10^{8}\ \text{m s}^{-1}$ $\therefore v = 3.84 \times 10^{7}\ \text{m s}^{-1}$	4

(Total for Question 14 = 6 marks)

Question Number	Acceptable answers		Additional guidance	Mark
15	• Use of $\Delta E = mc\Delta\theta$ • Use of $\Delta E = L\Delta m$ • Apply 5% to calculate energy saved • Use of $P = VI$ **or** Use of $Q = It$ • Use of $P = \frac{W}{t}$ **or** Use of $E = QV$ • 2.69×10^5 J compared with 1.93×10^5 J for energy saved, and concludes claim invalid. **Or** a phone could run for 5 days compared to 7 days and conclusion claim invalid **Or** a phone could run for 433 900 s compared to 604 800 s and conclusion claim invalid	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	<u>Example of calculation:</u> For aluminium when being heated up to m.pt.: $\Delta E = 14 \times 10^{-3}$ kg $\times$ 902 J kg^{-1}K^{-1} $\times$ (660 − 293)K $\Delta E = 4.63 \times 10^3$ J For aluminium when melting: $\Delta E = 14 \times 10^{-3}$ kg $\times$ 396 $\times 10^3$ J kg^{-1} $= 5.54 \times 10^3$ J Energy saved $= \frac{0.95}{0.05} \times$ (4630 + 5540)J Energy saved $= 1.93 \times 10^5$ J $P = 3.7$ V $\times 120 \times 10^{-3}$ A $= 0.444$ W $\Delta E = 0.444$ W $\times 7 \times 24 \times (60 \times 60)$s $= 2.69 \times 10^5$ J	6

(Total for Question 15 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
16 (a)	• Line of best fit drawn **(1)** • Gradient determined **(1)** • Applies eV to J conversion factor **(1)** • $h = 6.62 \times 10^{-34}$ J s (6.4×10^{-34} J s to 6.8×10^{-34} J s) **(1)** MP4 dependent on calculation from graph	Example of calculation Gradient = 4.14×10^{-15} $h = 4.14 \times 10^{-15}$ eV s $\times 1.6 \times 10^{-19}$ J eV^{-1} $h = 6.62 \times 10^{-34}$ J s	4
16 (b)	• x-intercept determined **(1)** • Use of $\phi = h f_0$ **(1)** • ϕ = 2.3 eV, so metal is (probably) caesium (allow ecf for h from (a)) **(1)** **OR** • Reads a pair of co-ordinates from graph • Use of $\phi = h f - E$ • ϕ = 2.3 eV, so metal is (probably) caesium (allow ecf for h from (a))	MP2: allow use of standard value for h **or** value of h determined in (a) Example of calculation $f_0 = 55 \times 10^{13}$ Hz $\phi = 6.62 \times 10^{-34}$ J s $\times 55 \times 10^{13}$ Hz $= 3.64 \times 10^{-19}$ J $\phi = \frac{3.64 \times 10^{-19} \text{J}}{1.6 \times 10^{-19} \text{ J eV}^{-1}} = 2.28$ eV	3

(Total for Question 16 = 7 marks)

Question Number	Acceptable answers	Additional guidance	Mark
17 (a)(i)	• Object/star is at infinity, so (intermediate) image formed at focal length of objective lens **(1)** • (Final image at infinity), so object (intermediate image) must be at focal length of eyepiece lens **(1)** **Or** • Objective lens, $1/v + 1/u = 1/\underline{f}$, and $\underline{u}$ = infinity, so $v = f$ • Eyepiece lens, $1/v + 1/u = 1/f$, $\underline{v}$ = infinity so $u = f$	Appropriate references to parallel rays may be equivalent to object/image at infinity <u>Example</u> Objective: $1/v + 1/u = 1/f$, $u = \infty$, so $1/v + 1/\infty = 1/f$ $1/v + 0 = 1/f$ $v = f$ Eyepiece: $1/v + 1/u = 1/f$, $v = \infty$, so $1/\infty + 1/u = 1/f$ $0 + 1/u = 1/f$ $u = f$ Note: If both lenses are considered, $1/v + 1/u = 1/f$ does not have to be quoted twice	**2**
17 (a)(ii)	• The rays cross over after the objective lens **(1)** **Or** • The objective lens inverts the image **Or** • The image formed by the eyepiece lens is on the same side as its object, so remains the same way up		**1**

17 (b)(i)	**Either** • Use of $n = \frac{c}{v}$ **(1)** • Use of $v = f\lambda$ (with v in coating) **(1)** • Use of path difference = $\frac{\lambda}{2}$ with factor of 2 **(1)** • $d = 9.1 \times 10^{-8}$ m **(1)** **OR** • Use of $v = f\lambda$ (with c in air) • Use of $n = \frac{\lambda_{air}}{\lambda_{\text{coating}}}$ • Use of path difference = $\frac{\lambda}{2}$ with factor of 2 $d = 9.1 \times 10^{-8}$ m	<u>Example of calculation:</u> $v = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{1.38} = 2.17 \times 10^8 \text{ m s}^{-1}$ $\lambda = \frac{2.17 \times 10^8 \text{ m s}^{-1}}{6.00 \times 10^{14} \text{ Hz}} = 3.62 \times 10^{-7} \text{ m}$ $d = \frac{\lambda}{4} = \frac{3.62 \times 10^{-7} \text{ m}}{4} = 9.06 \times 10^{-8} \text{ m}$	**4**
17 (b)(ii)	• Red and blue light do not interfere destructively, so remain in the reflected light **Or** If green light is cancelled/eliminated, then red and blue light will remain in the reflected light. **(1)**		**1**

(Total for Question 17 = 8 marks)

Question Number	Acceptable answers		Additional guidance	Mark
18 (a)(i)	• Use of $\rho = \frac{m}{V}$ with $V = \pi r^2 L$ • $\mu = 1.09 \times 10^{-3}$ (kg m^{-1})(to at least 3 sf)	**(1)** **(1)**	For MP1, accept use of ρA <u>Example of calculation:</u> $\mu = \frac{m}{L} = \frac{V\rho}{L} = \frac{\pi r^2 L\rho}{L} = \pi r^2 \rho$ $\therefore \mu = \pi \left(\frac{1.14 \times 10^{-3}\ \text{m}}{2}\right)^2 \times 1070\ \text{kg m}^{-3}$ $\mu = 1.09 \times 10^{-3}\ \text{kg m}^{-1}$	**2**
18 (a)(ii)	• Use of $L = \frac{\lambda}{2}$ • Use of $v = f\lambda$ • Use of $v = \sqrt{\frac{T}{\mu}}$ • T = 140 N (ecf from (a)(i))	**(1)** **(1)** **(1)** **(1)**	<u>Example of calculation:</u> $\lambda = 2 \times 0.41\ \text{m} = 0.82\ \text{m}$ $v = 440\ \text{Hz} \times 0.82\ \text{m} = 361\ \text{m s}^{-1}$ $361\ \text{m s}^{-1} = \sqrt{\frac{T}{1.09 \times 10^{-3}\ \text{kg m}^{-1}}}$ $\therefore T = (361\ \text{m s}^{-1})^2 \times 1.09 \times 10^{-3}\ \text{kg m}^{-3}$ T = 142 N	**4**
18 (b)	An explanation that makes reference to the following points: • (As the temperature increases,) E decreases • The tension in the string decreases • The wave speed decreases **and** the frequency decreases **Or** Wavelength is constant **and** the frequency decreases	**(1)** **(1)** **(1)**	MP2 accept "the string slackens", accept stress decreases	**3**

(Total for Question 18 = 9 marks)

Question Number	Acceptable answers	Additional guidance	Mark
19 (a)	• Use of $V = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3$ **(1)** • Use of $pV = NkT$ **(1)** • Conversion of temperature to kelvin **(1)** • $N = 6.5 \times 10^{17}$ **(1)**	<u>Example of calculation:</u> $V = \frac{4}{3}\pi(0.080\ \text{m})^3 = 2.14 \times 10^{-3}\ \text{m}^3$ $N = \frac{1.25\ \text{Pa} \times 2.14 \times 10^{-3}\ \text{m}^3}{1.38 \times 10^{-23}\ \text{N m K}^{-1} \times (273 + 25)\text{K}}$ $= 6.50 \times 10^{17}$	**4**
*19 (b)	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning	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.	**6**

IC points	IC mark	Max structure 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

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

IC5 and IC6 can be awarded if suitable equations with terms explained are used

	Indicative content IC1 Electrons in neon atoms/molecules absorb energy due to electron collisions **Or** neon atoms/molecules absorb energy due to electron collisions IC2 Electrons in neon atoms/molecules move to higher energy levels/states **Or** Electrons in neon atoms/molecules are excited **Or** Neon atoms/molecules are excited IC3 A photon is released when an electron drops down energy levels **Or** A photon is released when an atoms/electron de-excites IC4 Electrons/atoms/molecules have discrete energy levels/states IC5 Frequency/wavelength (of emitted photon) is determined by difference in energy levels/states **Or** $E_2 - E_1 = hf$ where is f is frequency IC6 Limited number of possible energy levels/states, and so only certain/particular/specific frequencies/ wavelengths are emitted **Or** Only certain energy changes possible, and so only certain/particular/specific frequencies/ wavelengths are emitted		

(Total for Question 19 = 10 marks)

Question Number	Acceptable answers		Additional guidance	Mark
20 (a)	• Use of $W = mg$ • Use of $\Delta F = k\Delta x$ • Use of $T = 2\pi\sqrt{\frac{m}{k}}$ • Use of $f = \frac{1}{T}$ • f = 1.7 (Hz), so claim is incorrect.	(1) (1) (1) (1) (1)	Example of calculation: $k = \frac{65 \times 10^{-3}\text{kg} \times 9.81\text{ N kg}^{-1}}{0.085\text{ m}} = 7.50\text{ N m}^{-1}$ $T = 2\pi\sqrt{\frac{65 \times 10^{-3}\text{ kg}}{7.50\text{ N m}^{-1}}} = 0.585\text{ s}$ $f = \frac{1}{T} = \frac{1}{0.585\text{ s}} = 1.71\text{ Hz}$	5
20 (b)	• There is damping **Or** resistive forces act on the flamingo • Energy is removed from the oscillating system (and the amplitude decreases)	(1) (1)		2
20 (c)(i)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ • T = 2.24 (s) (at least 3 sf)	(1) (1)	Example of calculation: $T = 2\pi\sqrt{\frac{1.25\text{ m}}{9.81\text{ m s}^{-2}}} = 2.24\text{ s}$	2
20 (c)(ii)	• Use of $\omega = \frac{2\pi}{T}$ • Use of $v = -A\omega\sin\omega t$ • v = 0.21 m s^{-1} (ecf from (i))	(1) (1) (1)	Example of calculation: $\omega = \frac{2\pi}{2.24\text{ s}} = 2.80\text{ rad s}^{-1}$ $v = -7.5 \times 10^{-2}\text{m} \times 2.80\text{ s}^{-1} \times 1 = 0.210\text{ m s}^{-1}$	3

(Total for Question 20 = 12 marks)

Question Number	Acceptable answers	Additional guidance	Mark
21 (a)	• Top line correct (1) • Bottom line correct (1)	Example of calculation: ${}^{87}_{37}\text{Rb} \rightarrow {}^{87}_{38}\text{Sr} + {}^{0}_{-1}\beta^{-} + \bar{\nu}_e$	2
21 (b)	• Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ (1) • Use of $N = N_0 e^{-\lambda t}$ (1) • Use of N_S/N_R to determine N/N_0 (1) • $t = 3.7 \times 10^9$ year (1) • Comparison of their value with corresponding value in question and valid conclusion (1) **Or** • Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ • Use of $N = N_0 e^{-\lambda t}$ • Use of N/N_0 to determine N_S/N_R • $\frac{N_S}{N_R} = 0.066$ if t = age of Earth • Comparison of their value with corresponding value in question and valid conclusion	Example of calculation: $\lambda = \frac{\ln 2}{4.88 \times 10^{10}\ \text{year}} = 1.42 \times 10^{-11}\ \text{year}^{-1}$ $\frac{N_0}{N} = \frac{N_R + N_S}{N_R} = 1 + \frac{N_S}{N_R} = 1.0532$ $1.0532 = e^{1.42\times10^{-11}\ \text{year}^{-1} \times t}$ $\therefore t = \frac{\ln(1.0532)}{1.42 \times 10^{-11}\ \text{year}^{-1}} = 3.65 \times 10^9\ \text{year}$	5
21 (c)	• Because activity is small (and therefore difficult to measure) • **Or** because (significant) change in activity would take a long time (to measure) (1)	For activity accept, e.g. count rate, change in activity, decay rate, change in mass For change in activity accept e.g. number of decays, change in mass, change in N,	1

21 (d)	An explanation that makes reference to the following points: **(1)** **Either** • $t_{1/2}$ is larger, λ will be smaller **(1)** • $N = N_0 e^{-\lambda t}$ so the calculated value of time would be greater MP2 dependent upon MP1 **OR** • If half-life is larger, it would take more time for the ratio $\frac{N_S}{N_R}$ to reach the current value • Hence the rock would be older than originally determined. MP2 dependent upon MP1		**2**

(Total for Question 21 = 10 marks)

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