Pearson Edexcel

Mark Scheme (Results)

January 2025

Pearson Edexcel International Advanced Level in Physics (WPH15)
Paper 01 Thermodynamics, Radiation, Oscillations and Cosmology

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January 2025
Question Paper Log Number P78479A
Publications Code WPH15_01_2501_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. 'resonance'

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.

Question Number	Answer	Mark
1	**C is the correct answer (diameter increases and surface temperature decreases)** A is not correct because diameter increases B is not correct because diameter increases and surface temperature decreases D is not correct because surface temperature decreases	**1**
2	**D is the correct answer (these materials deform plastically)** A is not correct because this will not absorb energy from the oscillation B is not correct because this will not absorb energy from the oscillation C is not correct because this will absorb and then return energy to the oscillation	**1**
3	**C is the correct answer (both fields can produce repulsive forces)** A is not correct because both fields are radial B is not correct because both fields can exert attractive forces D is not correct because both fields obey an inverse square law for force	**1**
4	**B is the correct answer (P is the least stable and Q is the most stable)** A is not correct because Q is more stable than R C is not correct because Q is the most stable and P the least stable D is not correct because P is less stable than Q	**1**
5	**C is the correct answer (the distance between the Sun and the Earth)** A is not correct because this is the unknown distance B is not correct because this does not affect the star's apparent displacement D is not correct because this does not affect the star's apparent displacement	**1**
6	**A is the correct answer (1/4)** B is not correct because $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ C is not correct because $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ D is not correct because $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	**1**
7	**D is the correct answer (7.1 *T*)** A is not correct **because** age of universe $= \frac{1}{H_0}$ B is not correct **because** age of universe $= \frac{1}{H_0}$ C is not correct **because** age of universe $= \frac{1}{H_0}$	**1**
8	**D is the correct answer (amplitude of oscillation decreased more slowly)** A is not correct because the frequency has not decreased B is not correct because the period has not increased C is not correct because initially the pendulum has more energy	**1**
9	**B is the correct answer (gravitational force between Earth and Moon decreases and gravitational potential energy of Moon increases)** A is not correct because gravitational potential energy (GPE) increases C is not correct because gravitational force decreases and GPE increases D is not correct because gravitational force decreases	**1**
10	**D is the correct answer (s.h.c. of solid = s.h.c. of gas)** A is not correct because gradient for solid is greater than gradient for liquid B is not correct because gradient for solid is equal to gradient for gas C is not correct because gradient for solid is greater than gradient for liquid	**1**

Question Number	Answer		Mark
11	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ [Allow use of this equation to calculate a ratio of periods] Original mass subtracted from new mass [Allow (0.35 + *m*) substituted into equation for period] Mass added = 0.16 kg <u>Example of calculation</u> $0.95\text{ s} = 2\pi\sqrt{\frac{0.35\text{ kg}}{k}}$ $\therefore k = \frac{4\pi^2 \times 0.35\text{ kg}}{(0.95\text{ s})^2} = 15.3\text{ N m}^{-1}$ $1.15\text{ s} = 2\pi\sqrt{\frac{m}{15.3\text{ N m}^{-1}}}$ $\therefore m = \frac{(1.15\text{ s})^2 \times 15.3\text{ N m}^{-1}}{4\pi^2} = 0.512\text{ kg}$ Mass added = 0.512 kg – 0.35 kg = 0.162 kg	**(1)** **(1)** **(1)**	3
	Total for question 11		**3**

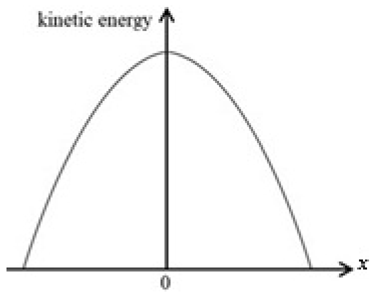
Question Number	Answer		Mark
12	Value of V and corresponding value of r read from graph	(1)	
	Use of $V = -\frac{GM}{r}$	(1)	
	$M = 6.0 \times 10^{24}$ (kg) [at least 2 sig fig]	(1)	3
	Example of calculation 1.0×10^7 J kg^{-1}, 0.40×10^8 m $M = \frac{1.0 \times 10^7 \text{ J kg}^{-1} \times 0.4 \times 10^8 \text{ m}}{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}} = 5.997 \times 10^{24}$ kg		
	Total for question 12		**3**

Question Number	Answer		Mark
13(a)	Use of $\Delta E = mL$	**(1)**	
	Use of $P = \frac{E}{t}$	**(1)**	
	Use of efficiency $= \frac{\text{useful power output}}{\text{total power input}}$	**(1)**	
	Efficiency = 0.65 [65%]	**(1)**	**4**
	<u>Example of calculation</u> $P = \frac{mL}{t} = \frac{0.65\text{ kg} \times 2.26 \times 10^6\text{ J kg}^{-1}}{1250\text{ s}} = 1175\text{ W}$ efficiency $= \frac{1175\text{ W}}{1800\text{ W}} = 0.653$		
13(b)	**EITHER**		
	Less steam escapes [Allow less evaporation occurs]	**(1)**	
	(So) less energy transfer to the surroundings	**(1)**	
	OR		
	Steam condenses at the lid	**(1)**	
	(So latent heat of vaporisation) energy is returned to the pan / water	**(1)**	**2**
	Total for question 13		**6**

Question Number	Answer		Mark
14(a)	Gravitational force equated to centripetal force	**(1)**	
	Use of $\omega = \frac{2\pi}{T}$ **Or** Use of $v = \frac{2\pi r}{T}$	**(1)**	
	$M = 2.0 \times 10^{30}$ (kg)	**(1)**	**3**
	<u>Example of calculation</u> $\omega = \frac{2\pi}{365 \times 3.15 \times 10^{7}\ \text{s}} = 1.99 \times 10^{-7}\ \text{rad s}^{-1}$ $m\omega^2 r = \frac{GMm}{r^2}$ $M = \frac{\omega^2 r^3}{G} = \frac{(1.99 \times 10^{-7}\ \text{rad s}^{-1})^2 \times (1.49 \times 10^{11}\ \text{m})^3}{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}}$ $\therefore M = 1.96 \times 10^{30}$ kg		
14(b)	**EITHER**		
	Use of $g = \frac{GM}{r^2}$	**(1)**	
	Ratio of field strengths = 27.6	**(1)**	
	Comparison of calculated ratio (of field strengths) with 28 and consistent conclusion (ecf from (a))	**(1)**	
	OR		
	Use of $g = \frac{GM}{r^2}$	**(1)**	
	$28 \times g_E = 275\ \text{N kg}^{-1}$	**(1)**	
	Comparison of calculated field strength values and consistent conclusion (ecf from (a))	**(1)**	**3**
	<u>Example of calculation</u> $g_s = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 1.96 \times 10^{30}\ \text{kg}}{(1.39 \times 10^{9}\ \text{m}/2)^2} = 270.7\ \text{N kg}^{-1}$ $\frac{g_s}{g_E} = \frac{271\ \text{N kg}^{-1}}{9.81\ \text{N kg}^{-1}} = 27.6$		
	Total for question 14		**6**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>*15</td><td>
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 following table shows how the marks should be awarded for indicative content.
<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>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<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>
Indicative content
IC1 The people force / drive the bridge to oscillate
[Accept people set/cause the bridge into oscillation]
[Accept people walking have a driving/forcing frequency]
IC2 Resonance occurs when the forcing / driving frequency is equal to the natural frequency of the bridge
IC3 There is an efficient/maximum transfer of energy (to the bridge)
IC4 The amplitude of oscillation (of the bridge) increases
Or The amplitude of oscillation (of the bridge) is a maximum
IC5 Energy is transferred (from the bridge) to the dampers
IC6 Dampers dissipate this energy limiting amplitude (of oscillation)
[Accept work is done by dampers limiting amplitude (of oscillation)]
</td><td>6</td></tr>
<tr><td></td><td>Total for question 15</td><td>6</td></tr>
</table>

Question Number	Answer	Mark
16(a)	A standard candle is a (stellar) object of known luminosity **(1)**	1
16(b)(i)	Time period read from graph **(1)** At least 2 periods used **(1)** [Can be seen by calculation or graph annotation] Luminosity = 2000 (L_{Sun}) **(1)** **Or** Luminosity read from graph for any identified value of T $L = 7.7 \times 10^{29}$ (W) **(1)** <u>Example of calculation</u> $T = \frac{(17-2)\text{ day}}{3} = 5\text{ day}$ $L = 2000 \times 3.83 \times 10^{26}\text{ W} = 7.66 \times 10^{29}\text{ W}$	4
16(b)(ii)	Use of $I = \frac{L}{4\pi r^2}$ **(1)** $r = 1.1 \times 10^{16}$ m (ecf from (b)(i)) **(1)** <u>Example of calculation</u> $r = \sqrt{\frac{7.7 \times 10^{29}\text{ W}}{4\pi \times 5.1 \times 10^{-4}\text{ W m}^{-2}}} = 1.09 \times 10^{16}\text{ m}$	2
	Total for question 16	**7**

Question Number	Answer	Mark
17(a)	**MAX 2** The graph is a straight line through the origin with a negative gradient **(1)** (Hence) the acceleration is proportional to the displacement (from the equilibrium position) **(1)** (And) the acceleration is in the opposite direction to the displacement **(1)**	2
17(b)(i)	Value of a and corresponding value of x read from graph **(1)** Use of $a = (-)\omega^2 x$ to determine ω **Or** gradient used to determine ω **(1)** Use of $v = \omega A \sin \omega t$ with $\sin \omega t = 1$ **(1)** Use of $E_k = \frac{1}{2}mv^2$ **(1)** $E_k = 3.5 \times 10^{-3}$ J **(1)** **ALTERNATIVE SOLUTION:** Value of a corresponding to value of x_{max} read from graph **(1)** Use of $F = ma$ **(1)** Use of $E_{el} = \frac{1}{2}Fx$ **(1)** States $E_k = E_{e;}$ **(1)** $E_k = 3.5 \times 10^{-3}$ J **(1)** <u>Example of calculation</u> Gradient $= \frac{(0.7 - (-0.7))\text{ m s}^{-2}}{(-0.04 - 0.04)\text{ m}} = -17.5\text{ s}^{-2}$ $\omega = \sqrt{17.5\text{ s}^2} = 4.18\text{ rad s}^{-1}$ $v_{max} = 4.18\text{ rad s}^{-1} \times 0.04\text{ m} \times 1 = 0.167\text{ m s}^{-1}$ $E_k = \frac{1}{2} \times 0.25\text{ kg} \times (0.167\text{ m s}^{-1})^2 = 3.486 \times 10^{-3}$ J	5
17(b)(ii)	Parabolic curve with only positive value of K.E. **(1)** Graph has a single maximum. [This must be $x = 0$] **(1)** <u>Example of graph</u>  	2
	Total for question 17	**9**

Question Number	Answer	Mark
18(a)	Electron/atomic energy levels are discrete **Or** Electrons can only have certain energy states **(1)** A <u>photon</u> is absorbed with an energy equal to the difference in the energy between two energy levels **(1)** Only certain (energy level) transitions are possible (so only some wavelengths/frequencies are absorbed) **(1)**	3
18(b)	Use of $\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$ **(1)** Use of $v = \omega r$ **(1)** Use of $\omega = \frac{2\pi}{T}$ **(1)** Conversion between seconds and days **(1)** $T = 25$ days < 27 days, so statement not accurate **Or** $T = 25$ days ≈ 27 days, so statement accurate **(1)** **ALTERNATIVE SOLUTION:** Use of $\omega = \frac{2\pi}{T}$ to calculate angular velocity of Sun **(1)** Use of $v = \omega r$ to calculate rotational velocity of (edge of) Sun **(1)** Use of $\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$ to calculate wavelength for approaching and receding side **(1)** Calculate difference in λ for each side of Sun **(1)** $\Delta\lambda = 7.36 \times 10^{-3}$ nm < 7.94×10^{-3} nm, so statement is inaccurate **(1)** <u>Example of calculation</u> $\Delta\lambda = \frac{7.94 \times 10^{-3}\text{ nm}}{2} = 3.97 \times 10^{-3}\text{ nm}$ $v = \left(\frac{3.97 \times 10^{-3}\text{ nm}}{589\text{ nm}}\right) \times 3.00 \times 10^{8}\text{ m s}^{-1} = 2.02 \times 10^{3}\text{ m s}^{-1}$ $\omega = \frac{2.02 \times 10^{3}\text{ m s}^{-1}}{6.96 \times 10^{8}\text{ m}} = 2.91 \times 10^{-6}\text{ rad s}^{-1}$ $T = \frac{2\pi\text{ rad}}{2.91 \times 10^{-6}\text{ rad s}^{-1}} = 2.16 \times 10^{6}\text{ s}$ $T = \frac{2.16 \times 10^{6}\text{ s}}{8.64 \times 10^{4}\text{ s day}^{-1}} = 25\text{ days}$	5
	Total for question 18	**8**

Question Number	Answer		Mark
19(a)	Use of $pV = NkT$	**(1)**	
	Use of 75%	**(1)**	
	$N = 2.4 \times 10^{21}$	**(1)**	**3**
	<u>Example of calculation</u> $N = \frac{pV}{kT} = \frac{0.75 \times 1.03 \times 10^5 \text{ Pa} \times 1.25 \times 10^{-4} \text{ m}^3}{1.38 \times 10^{-23} \text{ J K}^{-1} \times (290) \text{ K}} = 2.41 \times 10^{21}$		
19(b)	Use of $pV = NkT$ [Allow ratio of pressures equated to ratio of temperatures]	**(1)**	
	Conversion of temperature from Celsius to kelvin	**(1)**	
	Temperature of gas is 48ºC < 60ºC so statement is inaccurate **Or** Temperature of gas is 321 K < 333K so statement is inaccurate (ecf from (a) if candidates use *N*)	**(1)**	**3**
	<u>Example of calculation</u> $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ $T_2 = \frac{p_2}{p_1} \times T_1 = \frac{0.83}{0.75} \times 290 \text{ K} = 321 \text{ K}$ $\theta = 321 - 273 = 48$ºC		
19(c)(i)	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K	**(1)**	
	Use of $L = \sigma A T^4$	**(1)**	
	$L = 42$ W	**(1)**	**3**
	<u>Example of calculation</u> $T = \frac{2.898 \times 10^{-3} \text{ m K}}{1100 \times 10^{-9} \text{ m}} = 2635 \text{ K}$ $L = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times 1.55 \times 10^{-5} \text{ m}^2 \times (2635 \text{ K})^4$ $\therefore L = 42.4$ W		
19(c)(ii)	The filament may not be a perfect black body emitter (of radiation) **Or** Some energy may be absorbed by the glass (of the bulb)	**(1)**	**1**
	Total for question 19		**10**

Question Number	Answer	Mark
20(a)	Use of $\rho = \frac{m}{V}$ **(1)** Use of $\Delta E = mc\Delta\theta$ **(1)** Use of $P = VI$ **(1)** Use of $\Delta E = Pt$ **(1)** $t = 420$ s **(1)** <u>Example of calculation</u> $t = \frac{997 \text{ kg m}^{-3} \times 3.0 \times 10^{-3} \times 4180 \text{ J kg}^{-1} \text{ K}^{-1} \times (110 - 12) \text{ K}}{230 \text{ V} \times 12.6 \text{ A}}$ $\therefore t = 423$ s	5
20(b)	Use of $P = \frac{E}{t}$ **(1)** Calculation of total volume of water **(1)** Calculation of total time kettle is on **(1)** $E_{\text{kettle}} = 3.28 \times 10^6$ J **and** $E_{\text{tank}} = 8.2 \times 10^5$ J **(1)** Comparison of calculated values and consistent conclusion made. **(1)** <u>Example of calculation</u> Energy transferred from tank = $9.5 \text{ W} \times (24 \times 60 \times 60)$ s Energy transferred from tank = 8.21×10^5 J Volume of 28 cups = $28 \times 3.5 \times 10^{-4} \text{ m}^3 = 9.8 \times 10^{-3} \text{ m}^3$ Number of kettles = $\frac{9.8 \times 10^{-3} \text{ m}^3}{1.4 \times 10^{-3} \text{ m}^3} = 7$ Time kettle is switched on = $7 \times 180 \text{ s} = 1260$ s Energy transferred to kettle = $2600 \text{ W} \times 1260 \text{ s} = 3.28 \times 10^6$ J $8.2 \times 10^5 \text{ J} < 3.3 \times 10^6$ J so claim is not valid	5
	Total for question 20	**10**

Question Number	Answer		Mark
21(a)(i)	The paper will absorb some of the beta radiation **Or** beta radiation will pass through the paper (So) the count rate will vary as the thickness of the paper varies	**(1)** **(1)**	**2**
21(a)(ii)	Top line correct Bottom line correct Example of equation $^{147}_{61}\text{Pm} \rightarrow {}^{147}_{62}\text{Sm} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\overline{\nu}_{e}$	**(1)** **(1)**	**2**
21(a)(iii)	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ Use of 0.75% Use of $A = A_0 e^{-\lambda t}$ t = 18.5 year [5.83 × 108 s] Example of calculation $\lambda = \frac{\ln 2}{2.62 \text{ year}} = 0.265 \text{ year}^{-1}$ $\frac{0.75}{100} = \text{e}^{-0.262 \text{ year}^{-1}\, t}$ $t = \frac{\ln(7.5 \times 10^{-3})}{-0.265 \text{ year}^{-1}} = 18.46 \text{ year}$	**(1)** **(1)** **(1)** **(1)**	**4**
21(b)	Use of 1 u = 1.66 × 10^{-27} kg [to convert mass of nucleus or mass of neutrons] Use of $\Delta E = c^2 \Delta m$ [must substitute a mass difference] Conversion from J to (M)eV B. E./nucleon = 7.6 MeV Example of calculation mass defect = $(61 \times 1.67 \times 10^{-27} \text{ kg}) + (84 \times 1.00867 \times 1.66 \times 10^{-27} \text{ kg})) - (144.913 \times 1.66 \times 10^{-27} \text{ kg})$ ∴ mass defect = 1.963×10^{-27} kg B. E. = $1.963 \times 10^{-27} \text{ kg} \times (3.00 \times 10^{8} \text{ m s}^{-1})^2 = 1.767 \times 10^{-10} \text{ J}$ ∴ B. E. = $\frac{1.767 \times 10^{-10} \text{ J}}{1.60 \times 10^{-19} \text{ J eV}^{-1}} = 1.10 \times 10^{9} \text{ eV}$ ∴ B. E./nucleon = $\frac{1.10 \times 10^{3} \text{ MeV}}{145} = 7.617 \text{ MeV}$	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for question 21		**12**

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