Mark Scheme (Results)

October 2023

Pearson Edexcel International Advanced Level In Physics (WPH15)
Paper 01 Unit 5: Thermodynamics, Radiation, Oscillations and Cosmology

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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.

Question Number	Answer	Mark
1	**A is the only correct answer** B is not the correct answer, as temperature must be high for fusion C is not the correct answer, as density must be high for fusion D is not the correct answer, as temperature and density must be high for fusion	**(1)**
2	**A is the only correct answer** B is not the correct answer, as parallax measurements do not involve intensity C is not the correct answer, as parallax measurements do not involve luminosity D is not the correct answer, as parallax measurements do not involve the Hubble constant	**(1)**
3	**D is the only correct answer** A is not the correct answer, as B.E./nucleon has a maximum for ^{56}Fe B is not the correct answer, as B.E./nucleon has a maximum for ^{56}Fe C is not the correct answer, as B.E./nucleon has a maximum for ^{56}Fe	**(1)**
4	**B is the only correct answer** A is not the correct answer, as acceleration is always towards the equilibrium point C is not the correct answer, as acceleration is always towards the equilibrium point D is not the correct answer, as this would increase the energy of oscillation	**(1)**
5	**D is the only correct answer** A is not the correct answer, as motion does not change the wavelength of emission B is not the correct answer, as motion does not change the wavelength of emission C is not the correct answer, as the wavelength increases when the source is receding	**(1)**
6	**B is the only correct answer** A is not the correct answer, as gravitational potential increases C is not the correct answer, as gravitational force decreases and gravitational potential increases D is not the correct answer, as gravitational force decreases	**(1)**
7	**B is the only correct answer,** as $F = mg$ and $g = (9.81 \text{ m s}^{-2})/4$	**(1)**
8	**B is the only correct answer** A is not the correct answer, as penetration is high C is not the correct answer, as ionising power is low and penetration is high D is not the correct answer, as ionising power is low	**(1)**
9	**B is the only correct answer** A is not the correct answer, as main sequence stars to not go direct to white dwarfs C is not the correct answer, as stars do not move down the main sequence D is not the correct answer, as red giants do not return to the main sequence	**(1)**
10	**A is the only correct answer,** as $T = 2\pi\sqrt{\frac{\ell}{g}}$	**(1)**

Question Number	Answer		Mark
11	Use of $pV = NkT$ to calculate T or kT	**(1)**	
	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	**(1)**	
	[use of $\frac{1}{2}m\langle c^2\rangle = \frac{3pV}{2N}$ gets MP1 and MP2]		
	$\frac{1}{2}m\langle c^2\rangle = 5.9 \times 10^{-21}$ J	**(1)**	**3**
	<u>Example of calculation</u>		
	$T = \frac{1.15 \times 10^5 \text{ Pa} \times 1.77 \times 10^{-3} \text{ m}^3}{5.15 \times 10^{22} \times 1.38 \times 10^{-23} \text{ J K}^{-1}} = 286 \text{ K}$		
	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2} \times 1.38 \times 10^{-23} \text{ J K}^{-1} \times 286 \text{ K} = 5.93 \times 10^{-21} \text{ J}$		
	Total for question 11		**3**

Question Number	Answer	Mark
12	Two pairs of p, V readings from graph **(1)** Additional pair(s) of p, V readings from graph **(1)** $pV = 0.66$ ($\times 10^3$ Pa m^3) **(1)** [calculated for at least one pair of p, V readings] Comment that value of pV is constant and so the student's claim is valid **(1)** [dependent upon pV calculated for at least two pairs of p, V readings] <u>Example of calculation</u> p = 110 kPa, V = 0.006 m $pV = 110 \times 10^3 \text{ Pa} \times 0.006 \text{ m}^3 = 660 \text{ Pa m}^3$ p = 60 kPa, V = 0.011 m^3 $pV = 60 \times 10^3 \text{ Pa} \times 0.011 \text{ m}^3 = 660 \text{ Pa m}^3$ p = 51 kPa, V = 0.013 m^3 $pV = 51 \times 10^3 \text{ Pa} \times 0.013 \text{ m}^3 = 663 \text{ Pa m}^3$	4
	Total for question 12	**4**

Question Number	Answer	Mark
13(a)	Calculation of mass difference **(1)** Use of $\Delta E = c^2 \Delta m$ **(1)** Conversion of energy from J to eV **(1)** E = 1.2 (MeV) **(1)** [If correct answer has been obtained by using 1 u = 931.5 MeV, then full marks can be awarded. If incorrect answer has been obtained by using 1 u = 931.5 MeV, MP1 can be awarded provided substitutions for mass difference are correct. This is the only mark that can be awarded] <u>Example of calculation</u> $(2.82185 \times 10^{-26} + 1.67299 \times 10^{-27}) - (2.32451 \times 10^{-26} + 6.64432 \times 10^{-27})$ $= (2.98915 - 2.98894) \times 10^{-26} = 2.07 \times 10^{-30}$ kg $\Delta E = (3.0 \times 10^{8}\ \mathrm{m\ s^{-1}})^2 \times 2.07 \times 10^{-30}\ \mathrm{kg} = 1.863 \times 10^{-1}\ \ \mathrm{J}$ $\Delta E = \dfrac{1.89 \times 10^{-13}\ \mathrm{J}}{1.6 \times 10^{-19}\ \mathrm{J\ eV^{-1}}} = 1.16 \times 10^{6}\ \mathrm{eV} = 1.16\ \mathrm{MeV}$	**4**
13(b)	Momentum (and energy) is conserved **(1)** [Accept symbols for momentum i.e. *mv* or *p*] (So) products must have E_k / momentum after the reaction (as the alpha particle has momentum before the reaction) **(1)**	**2**
	Total for question 13	**6**

Question Number	Answer		Mark
14(a)	The light/radiation (received) from the galaxies is red shifted **Or** Wavelength of light/radiation (received) from the galaxies was longer than expected	**(1)**	1
14(b)	**EITHER** A straight line through the origin would be consistent with Hubble's expression	**(1)**	
	There is scatter about the line but the points are distributed evenly	**(1)**	
	So the expression may be valid (dependent upon MP2)	**(1)**	
	OR A straight line through the origin would be consistent with Hubble's expression	**(1)**	
	(But) there are outliers and these are far from the line **Or** (But) only some of the points are close to the line	**(1)**	
	So the expression may not be valid (dependent upon MP2)	**(1)**	
	OR The gradient of the line is equal to H_0	**(1)**	
	There is scatter about the line, so the value of H_0 is uncertain	**(1)**	
	So the expression may not be valid (dependent upon MP2)	**(1)**	3
	Total for question 14		**4**

Question Number	Answer	Mark
*15	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 structure and lines of reasoning.	

	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 demonstrat throughout	2
Answer is partially structured with some linkages and line of reasoning	1
Answer has no linkages between points and is unstructure	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

Indicative content

IC1 Connect the thermistor to a suitable circuit with voltmeter and ammeter
Or Connect the thermistor to an ohmmeter

IC2 Place the thermistor in a water bath
Or place the thermistor in a beaker of water

IC3 Add ice to reduce the water temperature to 0^{o}C

IC4 Heat the water and use a thermometer to measure the temperature
Or Heat the water and use a temperature sensor and datalogger to measure the temperature

IC5 Determine the resistance R (for each temperature) using $R = V/I$
Or Measure the resistance (for each temperature) by reading from ohmmeter

IC6 Stir the water (to ensure that the thermistor is at the temperature measured by the thermometer)
Or Place the thermometer near to the thermistor (to ensure that the thermistor is at the temperature measured by the thermometer)
Or Stop heating and wait before taking readings
Or Use small current/p.d. (to prevent it heating the thermistor)
Or Switch current off between readings
Or Read thermometer at eye level

6

	Total for question 15	**6**

Question Number	Answer		Mark
16(a)	Use of $\rho = \frac{m}{V}$	(1)	
	Use of $\Delta E = mc\Delta\theta$	(1)	
	Use of $P = \frac{\Delta E}{\Delta t}$	(1)	
	$P = 1630$ (W) [at least 3 sig fig required] [rounded data may give 1640 W] [If reverse calculation shown then MAX 3 marks] [Do not allow intermediate rounding to less than 3 sig figs for *m* or Δ*E*]	(1)	4
	<u>Example of calculation</u> $m = 4.25 \times 10^{-4}\ \mathrm{m^3} \times 998\ \mathrm{kg\ m^{-3}} = 0.424\ \mathrm{kg}$ $\Delta E = 0.424\ \mathrm{kg} \times 4190\ \mathrm{J\ kg^{-1}K^{-1}} \times (100 - 22)\ \mathrm{K} = 1.386 \times 10^5\ \mathrm{J}$ $P = \dfrac{1.386 \times 10^5\ \mathrm{J}}{85\ \mathrm{s}} = 1631\ \mathrm{W}$		
16(b)	Use of $\Delta E = L\Delta m$	(1)	
	Use of $P = \frac{\Delta E}{\Delta t}$	(1)	
	$t = 440$ s (ecf from (a)) [show that value for *P* gives 449 s]	(1)	3
	<u>Example of calculation</u> $\Delta E = 0.75 \times 0.424\ \mathrm{kg} \times 2.26 \times 10^6\ \mathrm{J\ kg^{-1}} = 7.19 \times 10^5\ \mathrm{J}$ $t = \dfrac{7.19 \times 10^5\ \mathrm{J}}{1630\ \mathrm{W}} = 441\ \mathrm{s}$		
	Total for question 16		**7**

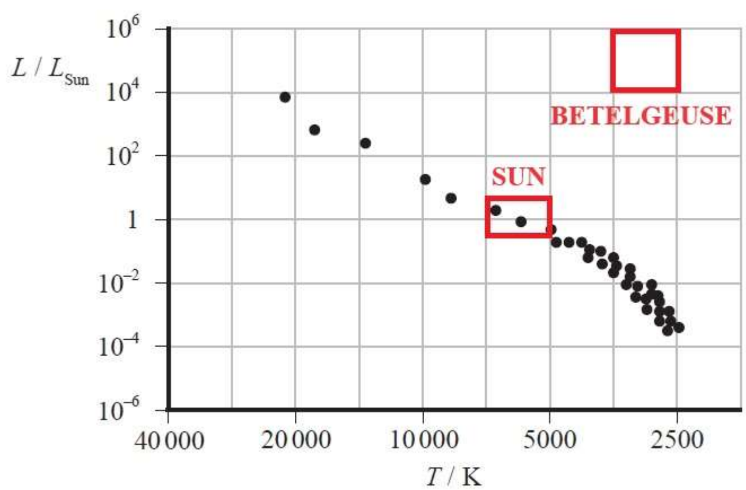
Question Number	Answer		Mark
17(a)	Use of $g = \frac{GM}{r^2}$ $g = 0.40$ N kg^{-1} [allow m s^{-2} for unit] [The correct value is 0.4045 to 4 sig figs, as the value is 0.404459…] <u>Example of calculation</u> $g = \dfrac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 3.1 \times 10^{21}\ \text{kg}}{(7.15 \times 10^5\ \text{m})^2} = 0.404\ \text{N kg}^{-1}$	**(1)** **(1)**	**2**
17(b)	Equates $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$ Use of $\omega = \frac{2\pi}{T}$ $T_M = 9.7 \times 10^9$ s Conversion between seconds and years [Must see a unit for *T*, either in MP3 or MP4] Calculates ratio of orbital time of Makemake with orbital time of Pluto [Ratio includes a percentage calculation] Comparison of values **and** consistent conclusion **OR** Equates $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$ Use of $v = \frac{2\pi r}{T}$ $T_M = 9.7 \times 10^9$ s Conversion between seconds and years Calculates ratio of orbital time of Makemake with orbital time of Pluto [Ratio includes a percentage calculation] Comparison of values **and** consistent conclusion <u>Example of calculation</u> $\frac{GMm}{r^2} = m\omega^2 r$ $\omega = \sqrt{\frac{GM}{r^3}} = \sqrt{\frac{6.67 \times 10^{-1}\ \ \text{N m}^2\ \text{kg}^{-1} \times 1.99\ \times 10^{30}\ \text{kg}}{(6.80\ \times\ 10^{12}\ \text{m})^3}}$ $\therefore \omega = 6.50 \times 10^{-10}\ \text{rad}\ s^{-1}$ $T = \frac{2\pi}{\omega} = \frac{2\pi\ \text{rad}}{6.50 \times 10^{-1}\ \ \text{rad s}^{-1}} = 9.67 \times 10^9\ \text{s} = \frac{9.67 \times 10^9\ \text{s}}{3.15\ \times\ 10^7\ \text{s year}^{-1}}$ $= 307$ year orbital time ratio $= \frac{307\ \text{year}}{248\ \text{year}} = 1.24$ The orbital time of Makemake is 24% greater than that of Pluto, so website statement is not quite accurate	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
	Total for question 17		**8**

Question Number	Answer		Mark
18(a)	Use of $V = \frac{4}{3}\pi r^3$	(1)	
	Use of $\rho = \frac{m}{V}$	(1)	
	Use of $F = \frac{Gm_1m_2}{r^2}$	(1)	
	$F = 7.4 \times 10^5$ N	(1)	4
	<u>Example of calculation</u> $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{5.65\text{ m}}{2}\right)^3 = 94.437\text{ m}^3$ $m = \rho V = 1950\text{ kg m}^{-3} \times 94.437\text{ m}^3 = 1.842 \times 10^5\text{ kg}$ $F = \frac{Gm_1m_2}{r^2}$ $= \frac{6.67 \times 10^{-1}\ \text{N m}^2\text{ kg}^{-3} \times 5.98 \times 10^{24}\text{ kg} \times 1.842 \times 10^5\text{ kg}}{(6.38 \times 10^6\text{ m} + 3.59 \times 10^6\text{ m})^2}$ $\therefore F = 7.39 \times 10^5$ N		
18(b)	Use of $V_{grav} = (-)\frac{GM}{r}$	(1)	
	Use of $E_{grav} = m \times V_{grav}$	(1)	
	$\therefore \Delta E_{grav} = (-)\ 4.1 \times 10^{12}$ J (Allow ecf for mass from (a))	(1)	3
	[Either mass can be used for M in the potential equation, but to award MP2 the multiplier m. must not be the mass used in the potential equation.] <u>Example of calculation</u> $\Delta E_{grav} = -6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 1.842 \times 10^5\text{ kg} \times 5.98 \times 10^{24}\text{ kg}$ $\times \left(\frac{1}{6.38 \times 10^6\text{ m}} - \frac{1}{(6.38 \times 10^6 + 3.59 \times 10^6)\text{ m}}\right)$ $\therefore \Delta E_{grav} = -4.14 \times 10^{12}$ J [Note the following values, but different degrees of rounding may change these slightly: $V_{final} = (-)\ 6.252 \times 10^7\text{ J kg}^{-1}$ $V_{initiall} = (-)\ 4.001 \times 10^7\text{ J kg}^{-1}$ $E_{final} = (-)1.152 \times 10^{13}$ J $E_{initial} = (-)\ 7.296 \times 10^{12}$ J]		
18(c)	Work would be done on the asteroid by frictional forces **Or** Drag/friction causes heating (of the asteroid)	(1)	
	Asteroid burns up	(1)	2
	Total for question 18		**9**

Question Number	Answer	Mark
19(a)(i)	Use of $\lambda = \frac{\ln 2}{t_{½}}$ **(1)** $\lambda = 7.31 \times 10^{-10}$ (s^{-1}) [Minimum 3 sig fig] **(1)** <u>Example of calculation</u> $\lambda = \dfrac{\ln 2}{30.1 \times 3.15 \times 10^{7}\ \mathrm{s}} = 7.31 \times 10^{-10}\ \mathrm{s}^{-1}$	**2**
19(a)(ii)	Use of $\frac{dN}{dt} = -\lambda N$ **(1)** Use of $u = 1.66 \times 10^{-27}$ kg with 137 [Allow use of 1.67×10^{-27} kg with 137] **(1)** $m = 5.9 \times 10^{-6}$ (kg) (Allow ecf from (a)(i)) **(1)** <u>Example of calculation</u> $N = \dfrac{19 \times 10^{9}\ \mathrm{s}^{-1}}{7.31 \times 10^{-1}\ \ \mathrm{s}^{-1}} = 2.60 \times 10^{19}$ $m = 2.60 \times 10^{19} \times 137 \times 1.66 \times 10^{-27}\mathrm{kg} = 5.91 \times 10^{-6}\ \mathrm{kg}$	**3**
19(a)(iii)	Use of $A = A_0 e^{-\lambda t}$ **(1)** A = 18.1 GBq (Allow ecf from (a)(i)) **(1)** <u>Example of calculation</u> $A = 19 \times 10^{9}\mathrm{Bq} \times \mathrm{e}^{-7.31 \times 10^{-10}\ \mathrm{s}^{-1} \times 2 \times 3.15 \times 10^{7}\ \mathrm{s}}$ $A = 1.81 \times 10^{10}\ \mathrm{Bq}$ [2 years = 6.3×10^{7} s]	**2**
19(b)	Use of total energy released $= \left(\frac{\Delta N}{\Delta t}\right) \times \Delta t \times E$ **Or** Use of total energy released $= \Delta N \times E$ **(1)** Use of 1 eV $= 1.6 \times 10^{-19}$ J **(1)** Total energy released = 4.3×10^{3} (J) **(1)** [If $\left(\frac{\Delta N}{\Delta t}\right) \times \Delta t$ determined by using exponential decay equation to calculate number of undecayed nuclei after 14 days; final answer should round to 4300 (J)] <u>Example of calculation</u> $E = 19 \times 10^{9}\ \mathrm{s}^{-1} \times 14 \times 86\,400\ \mathrm{s} \times 1.17\ \mathrm{MeV} = 2.69 \times 10^{16}\ \mathrm{MeV}$ $E = 2.69 \times 10^{16}\ \mathrm{MeV} \times 10^{6} \times 1.6 \times 10^{-19}\ \mathrm{J\ eV^{-1}} = 4.30 \times 10^{3}\ \mathrm{J}$	**3**
	Total for question 19	**10**

Question Number	Answer	Mark
20(a)	There is a (resultant) force that is proportional to the displacement from the equilibrium position **(1)** and (always) acting towards the equilibrium position **(1)** (Allow references to acceleration. An equation with symbols defined correctly is a valid response for both marks. For equilibrium position accept: undisplaced point/position or fixed point/position or central point/position.)	2
20(b)	**EITHER** Use of $F = mg$ **(1)** Use of $\Delta F = (-)k\Delta x$ **(1)** Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** Use of $\omega = \frac{2\pi}{T}$ [Allow use of $\omega = \sqrt{\frac{k}{m}}$ for MP3 and MP4] **(1)** Use of $v = \omega x_0 \sin \omega t$ **(1)** $v_{\max} = 0.34\ \mathrm{m\ s^{-1}}$ **(1)** **OR** Use of $F = mg$ **(1)** Use of $\Delta F = (-)k\Delta x$ **(1)** Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ **(1)** Use of $E_k = \frac{1}{2}mv^2$ **(1)** Use of energy conservation **(1)** $v_{\max} = 0.34\ \mathrm{m\ s^{-1}}$ **(1)** [If $T = 2\pi\sqrt{\frac{\ell}{g}}$ is used, then correct answer scores 6 marks. If answer is incorrect, then credit **may** be obtained for MP1, MP2, MP4, MP5] Example of calculation $F = 0.150\ \mathrm{kg} \times 9.81\ \mathrm{N\ kg^{-1}} = 1.47\ \mathrm{N}$ $k = \frac{1.47\ \mathrm{N}}{7.5 \times 10^{-2}\ \mathrm{m}} = 19.6\ \mathrm{N\ m^{-1}}$ $T = 2\pi\sqrt{\frac{0.150\ \mathrm{kg}}{19.6\ \mathrm{N\ m^{-1}}}} = 0.549\ \mathrm{s}$ $\omega = \frac{2\pi\ \mathrm{rad}}{0.549\ \mathrm{s}} = 11.4\ \mathrm{rad\ s^{-1}}$ $v_{\max} = 11.4\ \mathrm{rad\ s^{-1}} \times 3.0 \times 10^{-2}\ \mathrm{m} = 0.343\ \mathrm{m\ s^{-1}}$	6

20(c)	Energy is transferred out of the oscillating system **Or** energy is dissipated (to surroundings) **(1)** Because work is done by/against resistive forces **(1)** (Allow MAX 1 for reference to damping)		**2**
	Total for question 20		**10**

Question Number	Answer		Mark
21(a)(i)	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ Use of $L = \sigma AT^4$ **and** $A = 4\pi r^2$ **Or** Use of $L = \sigma AT^4$ to calculate A **and** $A \propto r^2$ $\frac{r_B}{r_S} = 990$ [Probable values for r: $r_B = 6.831 \times 10^{11}$m and $r_S = 6.892 \times 10^8$m Watch out for variation due to rounding, particularly for T] $\frac{r_B}{r_S}$ is approximately equal to 1000, so claim is accurate **Or** $\frac{r_B}{r_S}$ is less than 1000, so claim is inaccurate **Or** $\frac{r_B}{r_S}$ is not equal to 1000, so claim is inaccurate (Allow use of calculated ratio with consistent conclusion) <u>Example of calculation</u> $T = \frac{2.898 \times 10^{-3}\text{ m K}}{850 \times 10^{-9}\text{ m}} = 3410\text{ K}$ $\frac{L_B}{L_S} = \frac{4\pi\sigma r_B^2 T_B^4}{4\pi\sigma r_S^2 T_S^4}$ $\frac{r_B}{r_S} = \sqrt{\frac{L_B}{L_S} \times \frac{T_S^4}{T_B^4}} = \sqrt{\frac{4.49 \times 10^{31}\text{ W}}{3.83 \times 10^{26}\text{ W}} \times \left(\frac{5800\text{ K}}{3410\text{ K}}\right)^4} = 991$	(1) (1) (1) (1)	4
21(a)(ii)	Sun in correct position Betelgeuse in correct position 	(1) (1)	2
21(a)(iii)	A main sequence star is a star that is fusing <u>hydrogen</u> in its <u>core</u> [Accept “burning” for “fusing”]	(1)	1

21(b)	Use of $\omega = \frac{2\pi}{T}$ Use of $v = r\omega$ Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ Determines range by taking 91.2 nm ± Δλ [Δλ is their calculated value] [This may be awarded by seeing two substitutions into the Doppler equation. Once with Δλ = (91.2 − λ) **and** once with Δλ = (λ − 91.2)] Maximum wavelength = 91.8 (nm) Minimum wavelength = 90.6 (nm) <u>Example of calculation</u> $\omega = \frac{2\pi}{T} = \frac{2\pi \text{ rad}}{33.5 \times 10^{-3} \text{s}} = 187.6 \text{ rad s}^{-1}$ $v = 10.25 \times 10^3 \text{ m} \times 187.6 \text{ rad s}^{-1} = 1.922 \times 10^6 \text{ m s}^{-1}$ $\frac{\Delta\lambda}{91.2 \times 10^{-9} \text{ m}} = \frac{1.922 \times 10^6 \text{ m s}^{-1}}{3.00 \times 10^8 \text{ m s}^{-1}}$ $\therefore \Delta\lambda = 6.408 \times 10^{-3} \times 91.2 \times 10^{-9} \text{ m} = 5.84 \times 10^{-10} \text{ m}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **6**
	Total for question 21		**13**

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