GradeMax



Mark Scheme (Results)

October 2021

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

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications come from Pearson, the world's leading learning company. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk for our BTEC qualifications.
Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

If you have any subject specific questions about this specification that require the help of a subject specialist, you can speak directly to the subject team at Pearson.
Their contact details can be found on this link:
www.edexcel.com/teachingservices.

You can also use our online Ask the Expert service at www.edexcel.com/ask.
You will need an Edexcel username and password to access this service.

Pearson: helping people progress, everywhere
Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

October 2021
Question Paper Log Number P67158A
Publications Code WPH15_01_2110_MS
All the material in this publication is copyright
© Pearson Education Ltd 2021

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. '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 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	Answer	Mark
1	**C is the correct answer** A, B, D are incorrect as C is the definition of a standard candle.	**(1)**
2	**B is the correct answer** A is not the correct answer as it is true to say that he electric force between the nuclei is repulsive. C is not the correct answer as it is true to say that the gravitational force and the electric force both increase. D is not the correct answer as it is true to say that the gravitational force between the nuclei is attractive.	**(1)**
3	**D is the correct answer** A, B, C are incorrect as $T = 2\pi\sqrt{\frac{\ell}{g}}$ and $g_{\text{moon}} = \frac{g_{\text{Earth}}}{6}$	**(1)**
4	**D is the correct answer** A is not the correct answer as alpha radiation would not penetrate the body B is not the correct answer as alpha radiation is not very penetrating C is not the correct answer as gamma radiation is not very ionising	**(1)**
5	**C is the correct answer** A is incorrect as the frequency has been substituted for the period B is incorrect as period has been substituted for frequency and the half amplitude value used D incorrect as half amplitude has been substituted	**(1)**
6	**C is the correct answer** A, B and D re incorrect as $\lambda = \frac{\ln 2}{t_{½}}$ and this has been substituted incorrectly in the expression $\frac{\Delta N}{\Delta t} = (-)\lambda N$	**(1)**
7	**D is the correct answer** A is incorrect as this is the binding energy per nucleon of ^{3}He B is incorrect as this is the energy required to remove a single nucleon C is incorrect as this is the energy required to remove 2 nucleons	**(1)**
8	**D is the correct answer** A is incorrect as stars do not evolve along the main sequence B is incorrect as white dwarf stars do not evolve into main sequence stars C is incorrect as stars do not evolve along the main sequence	**(1)**
9	**D is the correct answer** A is incorrect as mass of stars increases along the main sequences B is incorrect as on an HR-diagram the temperature scale is an reverse scale C is incorrect as white dwarfs have smaller masses than main sequence stars	**(1)**
10	**D is the correct answer** A, B and C are incorrect because $T = \frac{2\pi}{\omega}$ and $\omega = \sqrt{\frac{a}{x}}$	**(1)**

Question Number	Answer	Mark
11	Use of $I = \frac{L}{4\pi d^2}$ (1) $d = 8.1 \times 10^{16}$ m (1) Example of calculation $d = \sqrt{\frac{L}{4\pi I}} = \sqrt{\frac{8.94 \times 10^{27}\ \text{W}}{4\pi \times 1.09 \times 10^{-7}\ \text{W m}^{-2}}} = 8.08 \times 10^{16}$ m	**2**
	Total for question 11	**2**

Question Number	Answer	Mark
12	Use of $\Delta E = mc\Delta\theta$ (1) Use of $P = \frac{\Delta E}{\Delta t}$ (1) Use of $\Delta E = mL$ (1) m = 0.189 kg (1) <u>Example of calculation</u> $P = \frac{0.855\ \text{kg} \times 4190\ \text{J kg}^{-1}\ \text{K}^{-1} \times (100 - 21.5)\ \text{K}}{115\ \text{s}} = 2.45 \times 10^3\ \text{W}$ $2.45 \times 10^3\text{W} \times 175\ \text{s} = m \times 2.26 \times 10^6\ \text{J kg}^{-1}$ $\therefore m = \frac{2.45 \times 10^3\text{W} \times 175\ \text{s}}{2.26 \times 10^6\ \text{J kg}^{-1}} = 0.189\ \text{kg}$	**4**
	Total for question 12	**4**

Question Number	Answer	Mark
13(a)	Mass difference calculated (1) Conversion from u to kg (1) Use of $\Delta E = c^2 \Delta m$ (1) ΔE = 5.53 (MeV) (1) For full marks to be awarded some working should be shown – a bald answer scores zero. "Some working" must include at least two of the steps to the answer. <u>Example of calculation</u> Mass difference = (228.02873 - 224.02021 - 4.00260) u = 5.92×10^{-3} u Mass difference = 5.92×10^{-3} u × 1.66×10^{-27} kg u^{-1} = 9.83×10^{-30} kg $\Delta E = \left(3.00 \times 10^{8} \text{ m s}^{-1}\right)^2 \times 9.83 \times 10^{-30} \text{ kg} = 8.85 \times 10^{-13} \text{ J}$ $\Delta E = \frac{8.85 \times 10^{-13}\text{J}}{1.60 \times 10^{-13}\text{J MeV}^{-1}} = 5.53 \text{ MeV}$	**4**
13(b)	(Mathematical) statement of momentum conservation (1) Use of $E_\text{k} = \frac{p^2}{2m}$ **Or** use of $E_\text{k} = \frac{1}{2}mv^2$ and $p = mv$ (1) (Mathematical) statement of energy conservation (1) E_k=5.4 MeV and statement is correct (1) <u>Example of calculation</u> $p_\alpha = -p_\text{Ra}$ $2m_\alpha \ E_\alpha = \ 2m_{Ra} \ E_{Ra}$ $E_{Ra} = \frac{m_\alpha}{m_{Ra}} \times E_\alpha$ $E_\alpha + E_{Ra} = 5.5 \text{ MeV}$ $E_\alpha + \frac{m_\alpha}{m_{Ra}} \times E_\alpha = 5.5 \text{ MeV}$ $E_\alpha = \frac{m_{Ra}}{m_{Ra} + m_\alpha} \times 5.5 \text{ MeV}$ So $E_\text{k} = \frac{224}{228} \times 5.53 \text{ MeV} = 5.43 \text{ MeV}$	**4**
	Total for question 13	**8**

Question Number	Answer	Mark
14(a)	Use of $pV = NkT$ **(1)** Temperature conversion **(1)** $N = 6.02 \times 10^{23}$ **(1)** Example of calculation $N = \frac{pV}{kT} = \frac{1.01 \times 10^5 \text{ Pa} \times 0.0241 \text{ m}^3}{1.38 \times 10^{-23} \text{J K}^{-1} \times (20.0 + 273) \text{ K}} = 6.02 \times 10^{23}$	**3**
14(b)	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ **(1)** Use of 60.5 % **(1)** Ratio = 2.7 (Do not award MP3 if a value for either mass has been assumed) **(1)** Example of calculation $\frac{1}{2}m_1\langle {c_1}^2\rangle = \frac{1}{2}m_2\langle {c_2}^2\rangle$ $\therefore \frac{m_1}{m_2} = \frac{\langle {c_2}^2\rangle}{\langle {c_1}^2\rangle}$ $\frac{\langle {c_C}^2\rangle}{\langle {c_m}^2\rangle} = 0.605^2 = 0.366$ $\frac{m_c}{m_m} = \frac{\langle {c_m}^2\rangle}{\langle {c_C}^2\rangle} = \frac{1}{0.366} = 2.73$	**3**
	Total for question 14	**6**

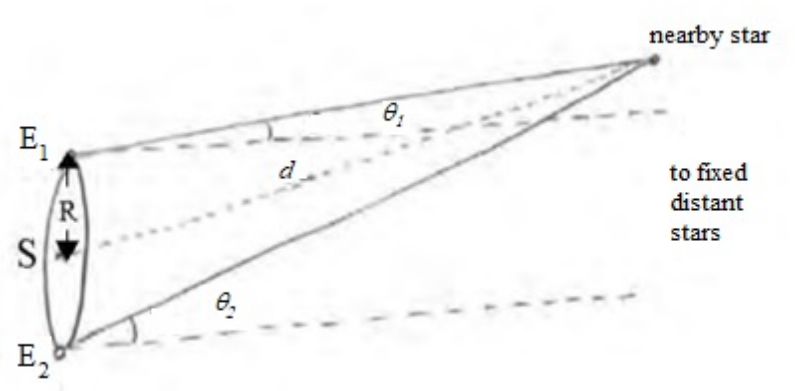
<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>*15</td><td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

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 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>
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
(1)
(1)
(1)
(1)
(1)
(1)
Indicative content

IC1 There is a very high temperature (in the core)
IC2 (So) nuclei/protons have a high <u>kinetic</u> energy
IC3 (Sufficient) to overcome electrostatic repulsion
IC4 And allow nuclei/protons to get close enough to fuse
IC5 Gravitational forces produce a very high density (in the core)
IC6 (So) the collision rate is high enough to sustain fusion
</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)	<table><tr><th>H_α / nm</th><th>Point</th></tr><tr><td>656.2837</td><td>B</td></tr><tr><td>656.2797</td><td>C</td></tr><tr><td>656.2757</td><td>A</td></tr></table> **(1)**	**1**
16(b)	**MAX 2 from:** Light from the edge of the Sun moving toward the Earth is received with a shorter wavelength [Accept "point A" for "edge moving toward the Earth" and "blue shift" for "shorter wavelength"] **(1)** Light from the edge of the Sun moving away from the Earth is received with a longer wavelength [Accept "point B" for "edge moving away from the Earth" and "red shift" for "longer wavelength"] **(1)** There is a variation in the relative velocity between the Earth and different points on the Sun's surface [Can be awarded if A and B incorrectly linked to change in wavelength] **(1)** [Reference to Doppler effect can score max 1]	**2**
16(c)	Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ with λ = 656.2797 nm **(1)** Use of $v = \frac{2\pi r}{T}$ to calculate T **(1)** Conversion of T into days. **(1)** T = 27.8 days which is approximately 28 days **(1)** **OR** Conversion of T = 28 days into seconds Use of $v = \frac{2\pi r}{T}$ to calculate v [1820 m s^{-1}] **(1)** Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ with λ = 656.2797 nm **(1)** v = 1830 m s^{-1} which is approximately 1820 m s^{-1} **(1)** **OR** Conversion of T = 28 days into seconds Use of $v = \frac{2\pi r}{T}$ to calculate v [1820 m s^{-1}] **(1)** Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ with λ = 656.2797 nm to calculate $\Delta\lambda$ **(1)** $\Delta\lambda = 3.98 \times 10^{-3}$ m which is approximately 4.0×10^{-3} m **(1)** Full credit for other approaches e.g. comparison of calculated value of v/c from T = 28 days and calculated value of v/c from $\frac{\Delta\lambda}{\lambda}$ **(1)** <u>Example of calculation</u> $v = c \times \frac{\Delta\lambda}{\lambda} = 3.00 \times 10^8 \text{ m s}^{-1} \times \frac{(656.2837 - 656.2797) \text{ nm}}{656.2797 \text{ nm}} = 1828 \text{ m s}^{-1}$ $T = \frac{2\pi r}{v} = \frac{2\pi \times 7.0 \times 10^8 \text{ m}}{1828 \text{ m s}^{-1}} = 2.41 \times 10^6 \text{ s}$ $T = \frac{2.41 \times 10^6 \text{ s}}{86400 \text{ s day}^{-1}} = 27.8 \text{ days}$	**4**
	Total for question 16	**7**

Question Number	Answer	Mark
17(a)	Find (angular) displacement of the star (as Earth moves around the Sun) over a 6 month period **Or** find (angular) displacement of the star (as Earth moves around the Sun) over a diameter of the Earth's orbit **(1)** Measurements are made against the background of (more) distant stars **(1)** Radius/diameter of the Earth's orbit about the Sun must be known/measured (to calculate the distance to the star) **(1)** [For full credit, it must be clear that angles are being measured] [Marks can be obtained from an annotated diagram]  [Accept the symmetrical diagram seen in many textbooks]	**3**
17(b)	**EITHER** Distant galaxies are receding **(1)** The velocity of recession can be calculated from the redshift **(1)** A graph of recessional velocity against distance has a gradient equal to the Hubble constant H_0 **(1)** The age of the universe is $1/H_0$ **(1)** **OR** Distant galaxies are receding **(1)** The redshift can be calculated **(1)** A graph of redshift against distance has a gradient equal to H_0/c **(1)** The age of the universe is $1/H_0$ **(1)**	**4**
	Total for question 17	**7**

Question Number	Answer	Mark
18(a)(i)	Use of $\Delta F = k\Delta x$ **(1)** k = 346 (N m^{-1}) **(1)** Example of calculation $k = \frac{15.0 \text{ kg} \times 9.81 \text{ m s}^{-2}}{0.425 \text{ m}} = 346.2 \text{ N m}^{-1}$	**2**
18(a)(ii)	(When the cradle is displaced): there is a (resultant) acceleration/force that is proportional to the displacement from the equilibrium position **(1)** and (always) acting towards the equilibrium position **(1)** (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**
18(a)(iii)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** T = 1.1 s **(1)** Example of calculation $T = 2\pi\sqrt{\frac{(7.25+2.55) \text{ kg}}{350 \text{ N m}^{-1}}} = 1.05 \text{ s}$	**2**
18(b)	The maximum load the spring can support when oscillating is less than the maximum load the spring supports when in equilibrium. **(1)** As when the mass is below the equilibrium position the force exerted on the spring is greater than the force at equilibrium. **(1)**	**2**
	Total for question 18	**8**

Question Number	Answer		Mark
19(a)(i)	Top line correct Bottom line correct Example of calculation $^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_e$	**(1)** **(1)**	**2**
19(a)(ii)	The mass of the Ni nucleus is much larger than total mass of the other two particles	**(1)**	**1**
19(b)	Use of $\lambda = \frac{\ln 2}{t_{½}}$ Use of $A = A_0 e^{-\lambda t}$ t = 6.0 (years) Example of calculation $\lambda = \frac{\ln 2}{5.27 \times 3.16 \times 10^7\ \text{s}} = 4.16 \times 10^{-9}\ \text{s}^{-1}$ $1.85 \times 10^{14}\text{Bq} = 4.07 \times 10^{14}\ \text{Bq}\ \text{e}^{-4.16 \times 10^{-9} \times t}$ $\therefore t = \frac{\ln\left(\frac{4.07 \times 10^{14}\ \text{Bq}}{1.85 \times 10^{14}\ \text{Bq}}\right)}{4.16 \times 10^{-9}\ \text{s}^{-1}} = 1.886 \times 10^8\ \text{s}$ $\therefore t = \frac{1.894 \times 10^8\ \text{s}}{3.16 \times 10^7\ \text{s year}^{-1}} = 5.996\ \text{years}$	**(1)** **(1)** **(1)**	**3**
19(c)	Required % transmission calculated Distance *x* read from graph for required transmission *x* =1.1 cm, so shielding would be insufficient **OR** Required % transmission calculated % transmission read from graph for 1.0 cm shielding % transmission ≈ 33%, so shielding would be insufficient Example of calculation Required % transmission $\leq \frac{1.2 \times 10^{14}\ \text{Bq}}{4.0 \times 10^{14}\ \text{Bq}} \times 100\% = 30\ \%$ From graph, for required % transmission thickness of shielding = 1.1 cm,	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
	Total for question 19		**9**

Question Number	Answer		Mark
20(a)	A main sequence star is fusing hydrogen (into helium) in the core of the star	**(1)**	**1**
20(b)(i)	Use of $L = A\sigma T^4$ **and** $A = 4\pi r^2$	**(1)**	
	$r = 6.94 \times 10^8$ (m)	**(1)**	**2**
	Example of calculation $r = \sqrt{\frac{L}{4\pi\sigma T^4}} = \sqrt{\frac{3.83 \times 10^{26}\ \text{W}}{4\pi \times 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}\ (5780\ \text{K})^4}} = 6.94 \times 10^8\ \text{m}$		
20(b)(ii)	Use of $L = A\sigma T^4$ **and** $A = 4\pi r^2$	**(1)**	
	Use of $\lambda_{max} T = 2.898 \times 10^{-3}$ m K	**(1)**	
	$\lambda_{max} = 9.8 \times 10^{-7}$ (m) (ecf value of r from (i))	**(1)**	**3**
	Example of calculation $T = \sqrt[4]{\frac{L}{4\pi r^2 \sigma}} = \sqrt[4]{\frac{1600 \times 3.83 \times 10^{26}\ \text{W}}{4\pi\ (150 \times 7.0 \times 10^8\ \text{m})^2 \times 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}}}$ $= 2972$ K $\lambda_{max} = \frac{2.898 \times 10^{-3}\ \text{m K}}{2972\ \text{K}} = 9.75 \times 10^{-7}$ m		
20(b)(iii)	λ_{max} is not in the wavelength range for red light **Or** λ_{max} is in the infrared wavelength range	**(1)**	
	There is a range of wavelengths emitted around the value of λ_{max}	**(1)**	
	The most intense region of the visible spectrum will be red light (dependent upon MP2)	**(1)**	**3**
	[Accept annotated sketches of the black body curve]		
20(c)	(The mass of the Sun decreases and so) the gravitational force exerted on the planet decreases	**(1)**	
	The gravitational force provides a centripetal force	**(1)**	
	$F = m\omega^2 r$, ω decreases and so T must increase	**(1)**	
	OR		
	(The mass of the Sun decreases and so) the gravitational force exerted on the planet decreases	**(1)**	
	The gravitational force provides a centripetal force	**(1)**	
	$F = \frac{mv^2}{r}$, v will decrease and so T must increase	**(1)**	
	OR		
	Equate $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	**(1)**	
	Derive expression for T	**(1)**	
	Deduce that T will increase	**(1)**	**3**
	Total for question 20		**12**

Question Number	Answer		Mark
21(a)(i)	Use of $V_{\text{grav}} = -\frac{GM}{r}$	**(1)**	
	$V_{\text{grav}} = (-)\ 5.53 \times 10^7\ (\text{J kg}^{-1})$	**(1)**	**2**
	Example of calculation		
	$V_{\text{grav}} = -\frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 5.98 \times 10^{24}\ \text{kg}}{(6.36 \times 10^6 + 8.5 \times 10^5)\ \text{m}} = -5.532 \times 10^7\ \text{J kg}^{-1}$		
21(a)(ii)	Use of $\Delta V \times m$	**(1)**	
	$\Delta E_{grav} = 3.7 \times 10^{10}$ J	**(1)**	**2**
	Example of calculation		
	$\Delta E_{\text{grav}} = (-5.53 - (-6.27)) \times 10^7\ \text{J kg}^{-1} \times 4990\ \text{kg} = 3.69 \times 10^{10}\ \text{J}$		
21(b)	Equate $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	**(1)**	
	Substitute for ω using $\omega = \frac{2\pi}{T}$	**(1)**	
	Use of $T^2 = \frac{4\pi^2 r^3}{GM}$	**(1)**	
	T = 6090 s **Or** T = 1.69 hours	**(1)**	
	Number of orbits in 1 day = 14.2, so claim is not valid	**(1)**	
	OR		
	Equate $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	**(1)**	
	Substitute for v using $v = \frac{2\pi r}{T}$	**(1)**	
	Use of $T^2 = \frac{4\pi^2 r^3}{GM}$	**(1)**	
	T = 6090 s **Or** T = 1.69 hours	**(1)**	
	Number of orbits in 1 day = 14.2, so claim is not valid	**(1)**	**5**
	Example of calculation		
	$\frac{GMm}{r^2} = m\omega^2 r$		
	$\therefore T = 2\pi \times \sqrt{\frac{r^3}{GM}} = 2\pi \times \sqrt{\frac{(6.36 \times 10^6\ \text{m} + 8.5 \times 10^5\ \text{m})^3}{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 5.98 \times 10^{24}\ \text{kg}}} = 6091\ \text{s}$		
	$\therefore T = \frac{6090\ \text{s}}{(60 \times 60)\ \text{s hour}^{-1}} = 1.69\ \text{hours}$		
	Number of orbits in 1 day $= \frac{24\ \text{hours}}{1.69\ \text{hours}} = 14.2$		

21(c)	Advantage:	satellite can cover more of the Earth's surface **Or** satellite passes close to the polar regions **Or** better resolution, as satellite closer to the Earth	**(1)**	
	Disadvantage:	satellite has to be tracked in the sky **Or** satellite data cannot be received continuously **Or** cannot provide continuous viewing of a single location	**(1)**	**2**
	Total for question 21			**11**

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom