Mark Scheme (Results)

Summer 2023

Pearson Edexcel GCE Level 3
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. '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. Graphs

5.1 A mark given for axes requires both axes to be labelled with quantities and units, and drawn the correct way round.

5.2 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.

5.3 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.

5.4 Points should be plotted to within 1 mm.

- Check the two points furthest from the best line. If both OK award mark.
- If either is 2 mm out do not award mark.
- If both are 1 mm out do not award mark.
- If either is 1 mm out then check another two and award mark if both of these OK, otherwise no mark.
  For a line mark there must be a thin continuous line which is the best-fit line for the candidate's results.

Question Number	Acceptable answers	Additional guidance	Mark
1	**The only correct answer is C** A is not correct as upthrust is equal to weight of fluid displaced B is not correct as upthrust is equal to weight of fluid displaced D is not correct as upthrust is equal to weight of fluid displaced		**1**
2	**The only correct answer is A** B is not correct as the filter would be the same intensity as the first position if rotated through π C is not correct as the light is polarised D is not correct as the light is polarised		**1**
3	**The only correct answer is B** A is not correct as the luminosity of P must be less than Q C is not correct as P is closer than Q D is not correct as P is closer than Q		**1**
4	**The only correct answer is C** A is not correct as when Z is twice as long then the extension is doubled. When Z has twice the area then it will have half the extension. So overall the extension will be the same. B is not correct as when Z is twice as long then the extension is doubled. When Z has twice the area then it will have half the extension. So overall the extension will be the same. D is not correct as when Z is twice as long then the extension is doubled. When Z has twice the area then it will have half the extension. So overall the extension will be the same. displaced		**1**
5	**The only correct answer is D** A is not correct as there must be a resultant force downwards B is not correct as there must be a resultant force downwards C is not correct as there must be a resultant force downwards		**1**
6	**The only correct answer is B** A is not correct as the corresponding maxima must be V or Z and only V is represented by the answer option B		**1**

	C is not correct as the corresponding maxima must be V or Z and only V is represented by the answer option B D is not correct as the corresponding maxima must be V or Z and only V is represented by the answer option B		
7	**The only correct answer is C** A is not correct as $t = \frac{1}{\lambda} \times \ln \frac{N_0}{N}$ and $N_0 = 1$ B is not correct as $t = \frac{1}{\lambda} \times \ln \frac{N_0}{N}$ and $N_0 = 1$ D is not correct as $t = \frac{1}{\lambda} \times \ln \frac{N_0}{N}$ and $N_0 = 1$		**1**
8	**The only correct answer is C** A is not correct as there is total internal reflection at the first surface as c = 42° B is not correct as there is total internal reflection at the first surface as c = 42° D is not correct as the angle of incidence is equal to the angle of reflection for internal reflection		**1**
9	**The only correct answer is B** A is not correct as $E_k = 0$ when x = amplitude C is not correct as E_k is a scalar quantity D is not correct as E_k is a scalar quantity		**1**
10	**The only correct answer is A** B is not correct as the open window section of film will be dark and the lead window section of film will be white C is not correct as the open window section of film will be dark and the lead window section of film will be white D is not correct as the open window section of film will be dark and the lead window section of film will be white		**1**

(Total for Multiple Choice Questions = 10 marks)

Question Number	Acceptable answers		Additional guidance	Mark
11	• Thicker string has greater μ	**(1)**	Accept words or symbols, including ↑ and ↓ Could be answered using an equation of the form: $f = \frac{1}{\lambda}\sqrt{\frac{T}{\mu}}$ gives MP2	**4**
	• Refers to $v = \sqrt{\frac{T}{\mu}}$, so v is smaller **Or** states v is proportional to $\sqrt{\frac{1}{\mu}}$, so v is smaller	**(1)**		
	• Refers to $v = f\lambda$ with λ constant	**(1)**		
	• So thicker string has lower frequency Dependent on MP1and 2 or MP1 and 3	**(1)**		

(Total for Question 11 = 4 marks)

Question Number	Acceptable answers	Additional guidance	Mark
12	• Energy lost by block = energy gained by water and/ or glass **(1)** • Use of $\Delta E = mc\Delta\theta\ldots$ **(1)** • …using temperature change of block **(1)** • c = 310 (J kg^{-1} K^{-1}) **Or** Required temperature change for tin = 103 K **Or** required starting temperature for tin = 126 °C **(1)** • Block is copper with justification e.g. some energy transferred to surroundings (so causes an underestimate in c) **or** block not fully at 100°C (so causes an underestimate in c) **or** tin cannot produce the required temperature change **(1)**	<u>Example of calculation:</u> $0.22\ \text{kg} \times c \times (100 - 23)\text{K}$ $= 0.05\ \text{kg} \times 840\ \text{J kg}^{-1}\ \text{K}^{-1} \times 4\ \text{K} + 0.3\ \text{kg} \times 4200\ \text{J kg}^{-1}\ \text{K}^{-1} \times 4\ \text{K}$ 16.94 c = 168 + 5040 = 5208 J c = 307 J kg^{-1} K^{-1} MP1 may be awarded for approach comparing energy gained by water and/or glass with maximum energy lost by block without equating them	**5**

(Total for Question 12 = 5 marks)

Question Number	Acceptable answers	Additional guidance	Mark
13(a)	**Max** three from: • Very high temperatures **(1)** • High magnetic flux density **(1)** • Bombardment by neutrons **(1)** • Material is a plasma or material is fully ionised **(1)**	Accept T~10^7 K -10^8 K for MP1 Accept conditions for stars: High density High pressure	**3**
13(b)	An explanation that makes reference to the following points: • Small(er) nuclei fuse to form larger nuclei **(1)** • The binding energy (per nucleon) increases releasing energy **or** mass deficit increases and $\Delta E = c^2 \Delta m$ **(1)** • Comparison of values from the graph **(1)**	Example comparison: Calculation of $\Delta E_{binding}$, e.g.From 5.2 MeV at 12 nucleons to 8.7 MeV at 50 nucleons; H to He is 7 MeV;	**3**

(Total for Question 13 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
14(a)	An explanation that makes reference to the following points: • There is an increase in the potential energy of molecules leaving the liquid **Or** latent heat must be supplied to convert liquid to gas **Or** only faster molecules have enough energy to escape **Or** work is done by the expanding gas **(1)** • The internal energy of the liquid decreases **Or** the average kinetic energy of the molecules remaining in the liquid decreases **(1)** • so the temperature of the liquid decreases **Or** some of the energy for latent heat is provided by the internal energy of the canister **(1)**		**3**

Question Number	Acceptable answers		Additional guidance	Mark
14(b)(i)	• Use of $V = \pi r^2 l$ • Use of $pV = NkT$ • Conversion of °C to K • $N = 4.7 \times 10^{23}$	**(1)** **(1)** **(1)** **(1)**	Example of calculation: $V = \pi \times 0.11^2$ (m)$^2 \times 0.23$(m) $= 8.74 \times 10^{-3}$ m^3 T = 21 °C + 273 = 294 K 2.2×10^5 Pa $\times$ 8.7 $\times 10^{-3}$ m^3 $= N \times 1.38 \times 10^{-23}$ J K^{-1} $\times$ 294 K $N = 4.74 \times 10^{23}$	**4**
14(b)(ii)	• Use of $\frac{1}{2}m < c^2 >= \frac{3}{2}kT$ • r.m.s. speed = 360 m s^{-1} **Or** • Use of $pV = \frac{1}{3}Nm < c^2 >$ • r.m.s. speed = 360 m s^{-1} (ecf from (i))	**(1)** **(1)** **(1)** **(1)**	Give full credit if a mistake has been made calculating temperature in part (i) e.g if T = 21 °C then r.m.s. speed = 95 m s^{-1} Similarly for V Example of calculation: $\frac{1}{2} \times 9.6 \times 10^{-26}$ kg $< c^2 > = \frac{3}{2}$ 1.38 $\times 10^{-23}$ J K^{-1} $\times$ 294 K $< c^2 >$ = 127000 m^2 s^{-2} r.m.s. speed = 356 m s^{-1} Alternative: 2.2×10^5 Pa $\times$ 8.7 $\times 10^{-3}$ m^3 $= \frac{1}{3} 4.7 \times 10^{23} \times 9.6 \times 10^{-26}$ kg $< c^2 >$ r.m.s. speed = 360 m s^{-1}	**2**

(Total for Question 14 = 9 marks)

Question Number	Acceptable answers	Additional guidance	Mark
15(a)(i)	• Use of $v = H_0 d$ and $v = d/t$ to derive equation **(1)**	Example of derivation: $v = H_0 d$ $v = d/t$ $d/t = H_0 d$ $1/t = H_0$ Need to see v = d/t	**1**
15(a)(ii)	• Expansion (of Universe) has been uniform **Or** Expansion (of Universe) at a constant rate **Or** Galaxy moves at constant velocity **(1)**	Accept H_0 is constant	**1**
15(a)(iii)	• Converts to s **(1)** • Use of $H = 1/T$ **(1)** • 75 ($km\,s^{-1}\,MPc^{-1}$) and conclusion that it lies within range **(1)** **Or** Upper and lower limits of values of the Hubble constant are 2.58×10^{-18} s^{-1} to 1.94×10^{-18} s^{-1}, so it is in range	Example of calculation: Age of universe = $13 \times 10^9 \times 3.16 \times 10^7 = 4.11 \times 10^{17}$ s $H = 1 / 4.11 \times 10^{17}$ s $= 2.43 \times 10^{-18}$ s^{-1} $(2.43 \times 10^{-18}\ s^{-1} \div 10^3$ (k) $\times 10^6$ (M) $\times 3.1 \times 10^{16}$ (Pc)) $= 75.5$ km s^{-1} MPc^{-1}	**3**
15(b)(i)	• Use of $z = \frac{\Delta\lambda}{\lambda}$ **(1)** • Uses $\Delta\lambda = 4.0 \times 10^{-6}$ m $- \lambda$ and λ as the denominator **(1)** • Wavelength emitted = 2.7×10^{-7} m **(1)**	Example of calculation: $z = 14 = \frac{4.0 \times 10^{-6}\ \text{m} - \lambda}{\lambda}$ Wavelength emitted = 2.67×10^{-7} m	**3**
15(b)(ii)	An explanation that makes reference to the following points: • Wavelength of light has increased **(1)** One from: • Visible / UV light which was initially emitted might arrive as IR / radio **(1)** • Due to expanding universe/space **(1)**		**2**

15(c)	• Use of $c = f\lambda$ • Maisie is moving away from us	**(1)**	Example of calculation:	
	• Use of $E = hf$ • Use eV to joule conversion factor • Compares correct values with conclusion such as the photon energy is larger than the work function so should be detected **Or** Compares correct values with conclusion such as the photon frequency is larger than the threshold frequency so should be detected **Or** Compares correct values with conclusion such as the photon wavelength is smaller than the wavelength for the threshold frequency so should be detected	**(1)** **(1)** **(1)**	Frequency of light = 3.0×10^{8} m s $^{-1}$ / 4.0×10^{-6}m = 7.5×10^{13} Hz $E = 6.63 \times 10^{-34}$ J s $\times 7.5 \times 10^{13}$s^{-1} = 4.97×10^{-20} J **Or** 0.31 eV $W = 0.30$ V $\times 1.6 \times 10^{-19}$ J V^{-1} $= 4.8 \times 10^{-20}$ J **Or** $W = 0.30$ V $\times 1.6 \times 10^{-19}$ J V^{-1} $= 4.8 \times 10^{-20}$ J Threshold frequency = 4.8×10^{-20} J ÷ 6.63×10^{-34} J s = 7.2×10^{13} Hz Frequency of light = 3.0×10^{8} m s^{-1} / 4.0×10^{-6}m = 7.5×10^{13} Hz **Or** $W = 0.30$ V $\times 1.6 \times 10^{-19}$ J V^{-1} $= 4.8 \times 10^{-20}$ J Threshold frequency = 4.8×10^{-20} J ÷ 6.63×10^{-34} J s = 7.2×10^{13} Hz Wavelength for threshold frequency = 3.0×10^{8} m s^{-1} / 7.2×10^{13} Hz = 4.2×10^{-6} m	**4**

(Total for Question 15 = 14 marks)

Question Number	Acceptable answers	Additional guidance	Mark
16(a)	• (Within the elastic limit,) if the load is removed the specimen/spring will return to its original shape / length **Or** above the elastic limit the specimen remains permanently deformed if the load is removed **(1)**	Or the converse for each	**1**
16(b)(i)	• Use of $W = mg$ **(1)** • Use of $F = kx$ **(1)** • $k = 17700$ (N m^{-1}) **(1)**	Example of calculation: $275\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 2700\ \text{N}$ $2700\ \text{N} = k \times 0.152\ \text{m}$ $k = 17\,748$ N m^{-1}	**3**
16(b)(ii)	• Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** • Use of $f = 1/T$ **(1)** • $f = 1.3$ Hz (ecf from (b)(i)) **(1)**	Example of calculation: $T = 2\pi\sqrt{\frac{1100\ \text{kg}}{4 \times 17\,700\ \text{N m}^{-1}}}$ $f = 1 / 0.783$ s $f = 1.28$ Hz	**3**
16(c)	• (Resultant) force/acceleration is proportional to the displacement from the equilibrium position **(1)** • (Resultant) force/acceleration is in the opposite direction to the displacement **Or** (resultant) force/acceleration is always directed towards the equilibrium position **(1)**		**2**
16(d)	An explanation that makes reference to the following points: • High viscosity oil will mean a large resistive force applied to the oscillations **(1)** • (When piston moves) a large amount of work will be done **(1)** • (Heavy damping so) energy of oscillation is quickly dissipated to the oil **(1)**	May refer to to $F = 6\pi\eta rv$ Mar refer to $\Delta W = F\Delta s$	**3**

(Total for Question 16 = 12 marks)

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>*17(a)</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.

Indicative content:

IC1 (Waves from different slits) undergo superposition/interference

IC2 Constructive (interference) where path difference = $n\lambda$
Or Constructive (interference) where in phase

IC3 (Bright) lines seen where constructive interference

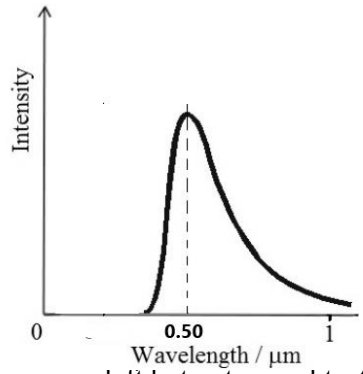
IC4 Central maximum/line due to mixture of red and blue light

IC5 $n\lambda = d\sin\theta$, so the angle/spacing of lines is larger for greater wavelength

IC6 Blue wavelength shorter than red, so next blue spot closer than red spot to centre spot</td>
<td>
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</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>

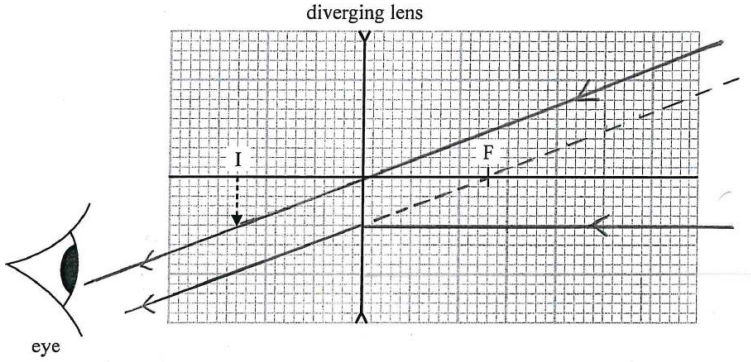
IC3 accept spots/lines/fringes maxima – colour reference to red/blue mix

IC4 accept purple/violet/magenta/mauve
</td>
<td>6</td>
</tr>
</table>

17(b)(i)	An explanation that makes reference to the following points: • Electrons / atoms exist in discrete/fixed/certain energy levels **Or** there are only a certain number of specific differences in energy levels of electrons / atoms **(1)** • (Absorbing) a <u>photon</u> causes an electron / atom to move to a higher energy level **Or** (Absorbing) a <u>photon</u> causes an electron / atom to become excited **(1)** • Photons are (only) absorbed when the <u>photon</u> energy is equal to the difference between energy levels **(1)** • <u>Photon</u> energy depends on frequency/wavelength, so photons of specific frequencies/wavelengths are absorbed, (producing dark lines) **(1)**	May refer to photon energy $E = hf$	**4**
17(b)(ii)	• Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K **(1)** • $\lambda_{max} = 5.0 \times 10^{-7}$ (m) **(1)** • Curve with a peak at candidate's value of λ_{max} **(1)** • Black body asymmetric curve with intensity = 0 when wavelength = 0 **(1)**	<u>Example of calculation:</u> $\lambda_{max} = \frac{2.898 \times 10^{-3} \text{ m K}}{5800 \text{ K}}$ $= 5.0 \times 10^{-7}$ m  Meets x axis on left but not on right, steeper on the left than on the right and narrower on the left at every point than on the right	**4**

17(b)(iii)	An explanation that makes reference to the following points: • Fusion takes place (from hydrogen to helium) **(1)** • This releases energy and leads to an (outward) pressure/force which balances gravitational forces **(1)**	Accept high temperature for energy	**2**

(Total for Question 17 = 16 marks)

Question Number	Acceptable answers	Additional guidance	Mark
18(a)	An explanation that makes reference to the following points: • The rays must be parallel (to converge to the focal length) **(1)** • So the object must be a large distance away **(1)**	accept use of $1/u + 1/v = 1/f$ with indication that $v = f$ Accept at infinity	**2**
18(b)	• Virtual means that the ray(s) of light do not pass through (the image position) **Or** Virtual means the image cannot be produced on a screen **(1)** • Upright means that the image is the same way up as the original object being observed **(1)**	Accept same orientation (as original object) Accept right way up Do not accept 'not inverted'	**2**
18(c)	• Ray from top right through centre of lens and through arrowhead of image at I **(1)** • Ray (below and parallel to principal axis) refracted as if from focal point F **(1)** • Arrow on at least one ray towards eye **(1)**		**3**

18(d)	• Focal length of converging lens is length of telescope + focal length of diverging lens **or** focal length of converging lens = 90 cm + focal length of diverging lens **(1)** • fc = 100 cm **and** f_d = 10 cm **(1)**	Example of calculation: $10 = \frac{f_c}{f_d}$ $f_c = 90 + f_d$ $10 = \frac{90 + f_d}{f_d}$ f_d = 10 cm and fc = 100 cm Alternate method: $90 = f_c - f_d$ $90 = 10f_d - f_d = 9f_d$ f_d = 10 cm and fc = 100 cm accept f_d = −10 cm as it is a diverging lens	**2**
18(e)	• Converts hours to seconds **(1)** • Equates $F = \frac{GMm}{r^2}$ and $F = \frac{mv^2}{r}$ **(1)** **Or** Equates $F = \frac{GMm}{r^2}$ and $F = mr\omega^2$ **(1)** • Substitutes $v = \frac{2\pi r}{T}$ or $\omega = \frac{2\pi}{T}$ **(1)** • $GM = \frac{4\pi^2 r^3}{T^2}$ derived and used • $M = 1.9 \times 10^{27}$ kg	Example of calculation: $171 \times 60 \times 60 = 615\,600$ s $\frac{GMm}{r^2} = \frac{mv^2}{r}$ and $v = \frac{2\pi r}{T}$ Leads to $GM = \frac{4\pi^2 r^3}{T^2}$ $M = \frac{4\pi^2 \times (1.07 \times 10^9\ \text{m})^3}{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}(171 \times 3600)^2(\text{s})^2}$ $M = 1.91 \times 10^{27}$ kg	**5**

	OR • Converts hours to seconds • Use $v = \frac{2\pi r}{T}$ or $\omega = \frac{2\pi}{T}$ • Equates $F = \frac{GMm}{r^2}$ and $F = \frac{mv^2}{r}$ **Or** Equates $F = \frac{GMm}{r^2}$ and $F = mr\omega^2$ • $GM = r^3\,\omega^2$ **Or** $GM = v^2\,r$ derived and used • $M = 1.9 \times 10^{27}$ kg	Alternative method: $171 \times 60 \times 60 = 615\,600$ s $$v = \frac{2\pi \times 1.07 \times 10^9\ m}{615600\ s}$$ $v = 10900\ \text{ms}^{-1}$ $$\frac{GMm}{r^2} = \frac{mv^2}{r}$$ $$GM = v^2 r$$ $$M = \frac{(10900\ \text{m}s^{-1})^2 \times 1.07 \times 10^9\ \text{m}}{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}}$$ $M = 1.9 \times 10^{27}$ kg Alternative via $\omega = 1.02 \times 10^{-5}$ rad s^{-1}	

(Total for Question 18 = 14 marks)
TOTAL FOR PAPER = 90 MARKS

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