GCE

Physics A

H556/01: Modelling physics

A Level

Mark Scheme for June 2026

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone or the RM Assessor messaging system, or by email.

5. **Crossed Out Responses**
   Wherea candidate hascrossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

   Rubric Error Responses – Optional Questions
   Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple Choice Question Responses
When a multiplechoice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
Whenacandidateprovides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(Theunderlyingassumption isthatthecandidateisattemptingtohedgetheirbets andthereforegettingunduebenefitratherthanengagingwiththe questionandgivingthemost relevant/correctresponses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add a tick to confirm that the work has been seen.

7. Award No Response (NR) if:
    - there is nothing written in the answer space

Award Zero '0' if:

- anything is written in the answer space and is not worthy of credit (this includes text and symbols).

Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by your team leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:
    a. **To determine the level** – start at the highest level and work down until you reach the level that matches the answer
    b. **To determine the mark within the level**, consider the following

Descriptor	Award mark
On the borderline of this level and the one below	At bottom of level
~~Just enough achievement on balance for this level~~	Above bottom and either below middle or at middle of level (depending on number of marks available)
~~Meets the criteria but with some slight inconsistency~~	Above middle and either below top of level or at middle of level (depending on number of marks available)
~~Consistently meets the criteria for this level~~	At top of level

11.

Annotations

Annotation		Meaning
	Correct response	Used to indicate the point at which a mark has been awarded (**one tick per mark awarded**).
	Incorrect response	Used to indicate an incorrect answer or a point where a mark is lost.
AE	Arithmetic error	Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
BOD	Benefit of doubt given	Used to indicate a mark awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done.
BP	Blank page	Use BP on additional page(s) to show that there is no additional work provided by the candidates.
CON	Contradiction	No mark can be awarded if the candidate contradicts himself or herself in the same response.
ECF	Error carried forward	Used in numerical answers only, unless specified otherwise in the mark scheme. Answers to later sections of numerical questions may be awarded up to full credit provided they are consistent with earlier incorrect answers. Within a question, ECF can be given for AE, TE and POT errors but not for XP.
L1	Level 1	L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded.
L2	Level 2	L2 is used to show 4 marks awarded and L2^ is used to show 3 marks awarded.
L3	Level 3	L3 is used to show 6 marks awarded and L3^ is used to show 5 marks awarded.
POT	Power of 10 error	This is usually linked to conversion of SI prefixes. Do not allow the mark where the error occurs. Then follow through the working/calculation giving ECF for subsequent marks if there are no further errors.

Annotation		Meaning
SEEN	Seen	To indicate working/text has been seen by the examiner.
SF	Error in number of significant figures	Where more SFs are given than is justified by the question, do not penalise. Fewer significant figures than necessary will be considered within the mark scheme. **Penalised only once in the paper.**
TE	Transcription error	This error is when there is incorrect transcription of the correct data from the question, graphical read-off, formulae booklet or a previous answer. Do not allow the relevant mark and then follow through the working giving ECF for subsequent marks.
XP	Wrong physics or equation	Used in numerical answers only, unless otherwise specified in the mark scheme. Use of an incorrect equation is wrong physics even if it happens to lead to the correct answer.
^	Omission	Used to indicate where more is needed for a mark to be awarded (what is written is not wrong but not enough).

Annotation	Meaning
/	Alternative and acceptable answers for the same marking point
□	Separates marking points
Not	Answers which are not worthy of credit
Ignore	Statements which are irrelevant
Allow	Answers that can be accepted
( )	Words which are not essential to gain credit
___	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

12. **Subject Specific Marking Instructions**

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

M marks These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which itrefers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

A marks These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

C marks These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

B marks These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

SIGNIFICANT FIGURES

There is no paper-wide significant-figures penalty. Apply only the guidance given in the mark scheme for each question part.

SECTION A

Question	Answer	Marks	Guidance
1	A	1	
2	D	1	
3	B	1	
4	D	1	
5	B	1	
6	B	1	
7	A	1	
8	D	1	
9	C	1	
10	A	1	
11	B	1	
12	C	1	
13	C	1	
14	A	1	
15	A	1	
	Total	15	

SECTION B

General rule: For substitution into an equation, allow any subject - unlessstated otherwise in the guidance

Question			Answer	Mark	Guidance
16	**(a)**	**(i)**	0.5 (s)	B1	**Allow** values read from the graph in the range 0.45 to 0.55s
		(ii)	Valid tangent drawn at t=0.5 Gradient calculated using at least half their tangent to obtain a deceleration of about 6 ms^{-2}	M1 A1	**Note**: if line extrapolated, x-axis intercept would be between 2.4 and 3.0 (Braille/modified version 2.4-2.8) **Allow** answers in the range 5.2 to 6.8 **from a valid tangent.** **Ignore** negative sign if the magnitude is correct
		(iii)	No braking force during thinking time (first 0.5s) Braking force (largest at first and then) decreases (for remainder of time)	B1 B1	**Allow** wording such as before the brakes are applied Must indicate change over time, not just that braking occurs. **Allow** answers linked to decreasing deceleration
	(b)	**(i)**	Reads suitable values from the graph for stopping region i.e. (0.3,13) and (2.7,0) within half a small square Attempt to find area under velocity-time graph Calculates combined area correctly using candidate's 2 data points (to obtain stopping distance = 19.5 (m))	C1 C1 A1	**Note**:Check graph for markable response **Allow**: alternative SUVAT based methods that arrive at 19.5 (m) Braille/modified version- rectangle is 0->0.25s at velocity 12.5 m/s and deceleration is from 0.25 to 2.5. (0.25x12.5) + (½ x 2.25 x 12.5) = 3.125+14.0625 = 17.1875 m unrounded

Question			Answer	Mark	Guidance
		(ii)	Thinking distance is less because computer reaction time is less than human / AW. Braking distance is less because the braking force is constant/does not decrease / AW comparing braking force in (b) with the braking force in (a)	B1 B1	**Allow** reaction time is smaller provided qualified with valid reason. **Allow** 'deceleration' for 'force'
	(c)		Continue moving at constant velocity (forward in a straight line) / AW Because no (resultant) force has acted on it /AW	B1 B1	**Allow** keeps moving forward only if idea of not slowing with the car is clear e.g. Until another (resultant) force acts or until hitting an object fixed to the car

Question			Answer	Mark	Guidance
17	(a)		substitution into P = h g e.g. h g= 105 x 1000 x 9.81 arriving at an answer that rounds to 1.0 MPa	M1 A1	**Note**: evidence of anything not P = h g is XP **Allow** symbols for rho and g **Allow** numbers from question for rho and g **Allow** g = 9.8, 9.81, 10 **Note**: use of h = 95 (m) gives 0.9(30) MPa and scores 1 mark MAX **Note:** Pressure = h g= 105 x 1000 x 9.81 = 1.03... × 10^6 (MPa)
	(b)	(i)	Area of plate = r^2 or $d^2/4$ (0.79m^2) Force on one bolt =1.03. × 10^6 × 0.79 /4 = 2.03 × 10^5 N Stress = load / area (= 203 kN / 0.001 $m^{2)}$ = 203 MPa Reference that the candidate's value of stress is less than the elastic limit or in the straight line section of the graph.	C1 C1 A1 B1	 **Allow ECF** from **(a)** **Allow** ECF from incorrect plate area **Allow:** alternative approach e.g. total force over area of all for bolts **Allow:** any stress that rounds to 200 MPa to 1sf **Allow**: alternative approach that reads elastic limit off graph at 320 MPa within ½ a small square (C1), calculates force that corresponds to elastic limit using force = stress × area (C1), calculates force on bolt (A1) and compares the two forces for one bolt showing that force on bolt is less than that for the elastic limit (B1)
		(ii)	Strain = 0.0010 (reading from graph) Extension =0.001 × 0.10 = 0.0001 m	C1 A1	**Allow ECF** from candidate's calculated stress in 17 **(b)(i)**

Question			Answer	Mark	Guidance
					Allow alternative route: Young Modulus calculated (C1) and then formula E = FL/Ax giving the right answer (A1) Modified papers: Strain at 200 MPa is 0.0012 so extension will be 0.00012 (m)
		(iii)	(Extension causing) a gap/possible leak / AW	B1	
	(c)		Mass of water stored = volume x density (10 000 x 1000 = 10 000 000 kg) Time = stored mass ÷ 10000 = 1000 s Energy = power x time = 8000 MJ	C1 C1 A1	**Allow:** alternate valid route e.g. calculation of volume flow per second (C1) then dividing total volume by volume flow rate to give time (C1) **Allow** ECF from candidate's value for time.
	(d)		Greater density means greater pressure (for same depth) Therefore more energy can be transferred from the water / greater power output can be produced	M1 A1	**Allow** equivalent idea such as greater pressure difference across turbine / greater force from the water /greater mass (of water-stone mix)/greater GPE Explanation must follow from increased density not just vague statement such as it works better

Question	Answer	Mark	Guidance
	Stone particles can cause clogging / erosion / abrasion / wear / heating / overextension of the pipes, turbine or components/ AW or increasing pressure can be a disadvantage /AW	M1	**Allow** need for stronger / more resistant machinery or pipes only if linked to higher pressure or abrasive particles
	This could reduce efficiency / increase maintenance / increase risk of damage or failure /AW	A1	Explanation must develop the stated disadvantage

Question			Answer	Mark	Guidance
18	**(a)**		Change in momentum each second = 1.2Av x v Substitutes A = 35 to get $D = 42v^2$	M1 A1	**Allow** words or symbols or substitution of A as 35. **Note:** evidence of use of F = mass x acceleration is XP
	(b)		$42v^2$ x 3.8 = 20000 x 2.0 or equivalent rearrangement	C1	**Note**: use of 4(.0) m i.e. width of lorry for 3.8 is XP. **Note**: evidence of 20000 N providing an anticlockwise moment is XP except for alternative method below **Allow:** D × 3.8 = 20000 × 2.0, followed by $D = 42v^2$.

Question			Answer	Mark	Guidance
			$v = \sqrt{\frac{20000\ x\ 2.0}{42\ x\ 3.8}}$	C1	**Do not allow:** $42v^2 \times 4.0 = 20000 \times 2.0$, because this uses 4.0 m as the height of the wind force; the wind force acts 3.8 m above the ground. **Do not allow:** $42v^2 \times 3.8 = 20000 \times 4.0$, because this uses 4.0 m as the moment arm for the weight; the centre of mass is 2.0 m from the pivot side. **Do not allow:** $42v^2 = 20000$, or any force-balance route with no moments. Alternative method: using moments to calculate normal reaction at the left wheel. subtracting that from weight to give normal reaction at right wheel gives same equation to solve for v.
			v= 16 ms^{-1}	A1	**Allow**: answer that rounds to 15.8 (ms^{-1}) or has been rounded to 20 (ms^{-1})
	(c)		Air is deflected through a smaller angle, so the change in momentum perpendicular to the side of the lorry is smaller, giving smaller force Turning effect is smaller because the force is smaller / AW	B1 B1	**Allow** equivalent wording such as smaller perpendicular change in velocity / smaller area of presentation **Allow**: perpendicular distance is smaller so turning effect is smaller **Note**: Do not treat the direction of the deflected air particles as the direction of force D. Force D acts perpendicular to the side of the lorry, as stated in the question. **Ignore**: reference to moment of weight of truck

Question			Answer	Mark	Guidance
					Not: force is same, distance is same therefore moment or turning effect is the same

Question			Answer	Mark	Guidance
19	(a)		Acceleration proportional to displacement (from the equilibrium position) Acceleration is in the opposite (direction) to the displacement / towards the equilibrium position	B1 B1	**Allow** use of equation with symbols explained Negative sign alone is insufficient **Allow** resultant force or restoring force for 'acceleration'
	(b)	(i)	Arrow labelled T or tension or spring force Magnitude of upward force = $k(e_0 + x)$	B1 B1	 **Do not allow** mg+kx
		(ii)	Resultant force = T – W Acceleration = $\frac{k(e_0 + x) - ke_0}{m}$ (= kx/m)	C1 A1	**Allow** equivalent route using $ke_0 = mg$ **Allow** correct substitutions for T and W i.e. $T = k(e_0 + x)$, and $W = mg$ or $W = ke_0$ using the equilibrium condition. **Allow** alternative route using $k = 4\pi^2m/T^2$ and $a = \omega^2x$, with $\omega^2 = 4\pi^2/T^2$, to arrive at $a = kx/m$. **Do not allow** simple substitution of F = kx into F = ma.

Question			Answer	Mark	Guidance
19	(c)		**Level 3 (5–6 marks)** A detailed discussion of the percentage uncertainties in both methods, explains how those uncertainties can be reduced without extra equipment, and explains the spring characteristics that limit those improvements. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Asounddiscussion that determines some relevant percentage uncertainties and explains some improvements and some limiting spring characteristics, though detail may be uneven. *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Alimiteddiscussion with partial determination of uncertainty or limited explanation of improvements or limiting spring characteristics. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *Noresponse or no response worthy of credit.*	B1 x 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** <u>Uncertainties</u> • Mass 1% for both methods • Extension twice the absolute uncertainty (either 0.5 or 1 mm) on a single measurement =50 +/- 1 mm or 2mm = 2% or 4% • Total 1% + 4% = 5% (Hooke's law) • reasonable uncertainty on time between 0.1 and 0.5 seconds (because of reaction time) • Time uncertainty 7.80 +/- (0.1 to 0.5) = between 1.3% and 6.4% • Total 1% + (2 x uncertainty on time) = 3.8% to 13.8% (oscillations) <u>Improvements</u> • Graphical analysis for both methods • Use longer extensions (Hooke's law) • Time more oscillations/longer time (oscillations) • Percentage uncertainty will reduce <u>Limitations</u> • Cannot stretch spring beyond elastic limit, so there is a maximum extension possible. • Spring will not oscillate indefinitely because of damping. • oscillations may not remain vertical

Question			Answer	Mark	Guidance
20	(a)	(i)	The total kinetic energy of the particles	B1	**Do not allow** reference to non-zero potential energy for an ideal gas **Allow:** alternative wording for 'total' **Allow** alternative wording for 'particles' e.g. atoms, molecules **Not** 'of the gas' for 'of the particles'
		(ii)	$\frac{1}{2}mc^2 = \frac{3}{2}kT$ seen or $pV = \frac{1}{3}Nmc^2$	M1	
			Total internal energy = Total KE = $N \times \frac{1}{2}mc^2$	M1	**Not** use of N=1 or ignoring N.
			$\frac{1}{2}Nmc^2 = \frac{3}{2}NkT = (\frac{3}{2}pV)$ i.e. combination of previousresultwithpV=NkT	A1	**Allow** equivalent starting point in symbols or words i.e. KE of 1 particle is 3/2 kT, (M1) KE of N particles is 3/2 NkT (M1) and use of pV = NkT arriving at the required expression. Allow use of N = n × N_A and use of pV = nRT **Not** use of N=1 or ignoring N.
	(b)	(i)	Formation of $1.0 \times 10^5 \times 350 \times 10^{-6} = p_2 \times 50 \times 10^{-6}$	C1	**Allow** equivalent handling or cancellation of the powers of ten volume factors
			$(p = 1.0 \times 10^5 \times 350 \times 10^{-6} / 50 \times 10^{-6} =) 7(.0) \times 10^5$ (Pa)	A1	**Allow** 700 kPa or alternative correct representations **Do not** credit unsupported use of E = 3/2 pV
		(ii)	Their y-value correctly plotted at x = 50	B1	Within ½ a small square.

Question			Answer	Mark	Guidance
		(iii)	Energy at 3 = 3/2 x 50×10^{-6} x 15.6×10^{5}= 117 OR Energy at 4 = 3/2 x 350×10^{-6} x 2×10^{5} = 105 giving difference consistent with the two energies i.e. 12	B1 B1	**Allow ECF** from candidate's graph readings Allow read off within ½ a small square Braille/modified papers: energy at three is 112(.5) J
		(iv)	(Efficiency = (117-105) ÷ 43 =) 0.28	B1	**Allow** ECF/candidate's value for energy difference in part (iii) **Allow** use of 10 for energy change giving (10 ÷ 43 =) 0.23 **Allow** expression as a percentage

Question			Answer	Mark	Guidance
21	(a)	(i)	The Sun is a typical main sequence star/lies near the middle of the main sequence on an HR diagram/AW	B1	**Do not allow** "is an average star" as it is in the question stem.
		(ii)	$=2.0\times10^{30}$ x 1×10^{11} $=2(.0)\times10^{41}$ (kg	B1	**Allow** 1sf
	(b)	(i)	$r=66\ 000 \times 3.1 \times10^{16} = 2.0 \times10^{21}$ m $=v/r= 300\ 000 \div 2.0 \times10^{21} = 1.47 \times10^{-16}$ (rad s^{-1})	C1 A1	 **Allow** ECF from candidate's converted distance **Allow** use of 1.5×10^{-16} giving 4.2×10^{16}
		(ii)	$T= 2 \quad \div 1.47 \times10^{-16} = 4.3 \times10^{16}$ (s)	A1	**Not** 50 000 ly or equivalent
		(iii)	Correct formula for Kepler's 3rd Law selected and distance of hypervelocity star selected for r (e.g. 66 kpc or $2(.046) \times10^{21}$ m) Rearrangement to M= $\frac{4^2\pi r^3}{GT^2}$ $=2.760719640\ldots\times10^{42}$ (kg) $=2.8 \times 10^{42}$ (kg) (2sf)	C1 C1 A1 B1	**Note** formula in data book is $T^2 = (4\ \pi/GM)r^3$ **Note**: data book value for metres in a pc = 3.1×10^{16} gives r = $2(.046) \times10^{21}$ m. **Allow** ECF from incorrect r. **Allow** use of 4.2×10^{16} gives 2.9×10^{42} **Allow** use of 4.0×10^{16} gives 3.2×10^{42} **Allow** use of 4.3×10^{16} gives 2.7×10^{42} **Allow** ECF from unrounded answer
		(iv)	**Any one from:** • Numberof stars may be incorrect	B1	

Question			Answer	Mark	Guidance
			• The existence of dark matter or black holes • The average stellar mass may be incorrect • Interstellar medium has mass • mass of star as percentage of solar system mass may be incorrect		**Not** dark energy by itself **Allow** dark matter even if dark energy is also mentioned **Not** vague reference to 'stellar masses aren't all the same' unless linked to average mass not being the same as the Sun's mass. **Not:** mass of planets hasn't been accounted for
		(v)	Reference to modelling the galaxy as a point mass	B1	**Allow** stars inside the galaxy are affected by nearby stars' gravitation/AW

Question			Answer	Mark	Guidance
22	(a)		(Magnitude of change in)gravitational potential =GM/r i.e. neglects outer edge term or (Magnitude of change in) gravitational potential = $GM/r_{protostar} - GM/r_{cloud}$ $=(G \times 3.5\times10^{31})/ 620\times10^{9} = 3.8\times10^{9}$ (J/kg)	C1 A1	**Allow** equivalent statement that the potential at the edge of the nebula is approximately zero because the radius is very large **Allow** calculation of potential at distance of 90 ly and finding of difference leading to unrounded value of 3.765... x 10^{9} (J/kg) hence leading to about 4 x 10^{9} (J/kg) **Ignore** sign if magnitude is correct
	(b)	(i)	$KE=GPE=mV_g=3.8\times10^{9}\times1.6\times10^{-27} = 6(.08)\times10^{-18}$ $T=2/3 \times 6(.0)\times10^{-18}/k = 2.96 \times10^{5}$(K)	M1 A1	Allow use of 4 $\times10^{9}$ giving 309 000 K (to 3sf) Allow candidate's value for (a)
		(ii)	Greater mass gives a greater (change in) GPE/V_g, so (some) particles gain more kinetic energy	B1	**Ignore** references to mass alone with no link to gravitational potential / energy and temperature **Not** reference to fusion
		(iii)	Nuclear energy released by fusion once in main sequence	B1	**Allow** alternative: further contraction or particles falling further causing a greater change in GP(E) causing a larger rise in KE.

Question			Answer	Mark	Guidance
22	c)		**Level 3 (5–6 marks)** Adetailed comparison of red giants and super giants that explains the transition from main sequence, compares conditions in and around the core, and compares the likely next stage in the life cycle. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Asound comparison of red giants and super giants that includes some relevant points about the transition from the main sequence, core conditions, and/or the likely next stage. *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Alimited comparisonwith partial reference to one or more of the transitions, core conditions, or likely next stage. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *Noresponse or no response worthy of credit.*	B1 x 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** <u>Transition</u> • Hydrogen running out • Initial contraction and increase in temperature • Expansion and cooling • Mass of star determines the outcome between giant and supergiant <u>Conditions</u> • Giant star fusing hydrogen **outside** the core • Super giant fusing helium and heavier elements **inside** the core • Super giant (core) hotter • Super giant lifespan shorter • no more fusion in a giant star core • fusing continues in supergiant core <u>Evolution</u> • Red giant likely to form white dwarf and planetary nebula • Super giant likely to supernova • Neutron star or black hole dependence on mass • Reference to mass of core and Chandrasekhar limit

Question			Answer	Mark	Guidance
23	(a)		Reads laboratory wavelength and galaxy wavelength, giving between 3.8 and 4.2 (nm) v = 3x 10^8 × acceptable value for ☐ ÷ acceptable value for laboratory ☐ giving a speed e.g. v= 3x 10^8 × 4.0 / 486.4 = 2500 kms^{-1}(to 2sf) i.e. close to 3000 km s^{-1}	M1 A1	**Note**: use of anything other than the laboratory wavelength in the denominator is XP for the A mark **Note**: use of values between 3.8 and 4.2 give values of v between 2300 and 2600 (to 2sf)
	(b)		Value consistent with candidate's answer to part (a) or 3000 km s^{-1}	B1	**Allow ECF** from candidate's answer to **(a)** Alternative: calculate H_o from best fit line, then use equation of straight line correctly to find d. **Note**: expect d around 44 if v=3000 and allowing ½ a small square tolerance **Note:** expect d around 32-40 for value of v in range 2300 to 2600 to and allowing ½ a small square tolerance Braille/modified papers: expect value for d around 44 if v=3000 expect value for d between 30 and 40 if value of v in range 2300 to 2600
	(c)		reference to appropriate distance unit conversion / AW Find reciprocal (of gradient or of H_o)	B1 B1	i.e. reference to cancelling distance units or converting between Mpc and km or the unit of the gradient should be $time^{-1}$ **Not**: reciprocal of any other quantity **Allow** 'inverse' for 'reciprocal'

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