GCE

Physics A

H556/01: Modelling physics

A Level

Mark Scheme for June 2022

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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.

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 available in RM Assessor.

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

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% 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 via the RM Assessor messaging system in the first instance.

5. **Crossed Out Responses**
   Where a candidate has crossed 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.

   Multiple Choice Question Responses
   When a multiple-choice 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
When a candidate provides 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. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

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. On each blank page the icon BP must be inserted to confirm that the page has been checked. For additional objects (if present), a tick must be inserted on each page to confirm that it has been checked.
Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there.

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.

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8. The RM Assessor **comments box** is used by the Principal Examiner or 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 RM Assessor messaging system.

9. A*ssistant 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. **Level of response (LoR)**

    Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance.

    Using a 'best-fit' approach based on the science content of the answer, first decide which set of level descriptors, Level 1 (L1), Level 2 (L2) or Level 3 (L3), **best** describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme.

    Once the level is located, award the higher or lower mark.

    The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met. **The lower mark** should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

    In summary:
    - the **science** content determines the **level**
    - the **communication statement** determines the **mark within a level**.

    Levels of response questions on this paper are **18b** and **22b**.

11. Here are the subject specific instructions for this question paper.

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 it refers 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

If the data given in a question is to 2 sf, then allow an answer to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

12. Annotations available in RM Assessor

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.
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).

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
Reject	Answers which are not worthy of credit
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

13. 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

SECTION A

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

SECTION B

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

Question			Answer	Marks	Guidance
16	a		Hang (known) masses/weights on the cord **or** pull with a newtonmeter to different tensions	B1	**Allow** mention of spring
			Determine the extension	B1	**Allow** measure the length
			Graph of force against extension	B1	**Allow** length for extension
			Force constant is the gradient (of force-extension graph)	B1	**Note** if axes swapped, must be 1/gradient
	b	i	Extension (from graph) is 6.0 (cm)	M1	
			Use of $E = ½\ kx^2$	M1	**Allow** Use of E = ½ Fx and F = kx
			elastic potential energy = 0.90 (J)	A1	**Allow** 1 SF of 0.9 (J)
		ii	(KE = $½\ mv^2$)		
			$0.90 = ½ \times 0.030 \times v^2$	M1	**Allow** 1 J instead of 0.90 J
			v =7.7 (m s^{-1})	A1	**Note** using 1 J gives an answer of 8.2 m s^{-1} **Note** allow possible ECF with energy approx 1 J
		iii	$1.5 = ½\ gt^2$	C1	
			t = 0.55 (s)	C1	
			(R = 7.7 × 0.55)		
			R = 4.2 (m)	A1	**Allow** 8 m s^{-1} or 8.2 m s^{-1} instead of 7.7 m s^{-1} **i.e.** 4.4, 4.5 (m) **Possible** ECF from **(b)(ii)**

Question			Answer	Marks	Guidance
		iv	(Actual distance is smaller than calculated R) Valid explanation The velocity /speed (in flight) smaller than expected **or** The initial velocity / speed will be smaller than expected	**M1** **A1**	Examples of valid explanation include: For velocity / speed decreases • drag/air resistance For initial velocity /speed is smaller • not all the energy transfers to the ball • the cord also has KE • hysteresis (so cord heats up) **Ignore** references to efficiency and unqualified energy dissipation.
			Total	**14**	

Question			Answer	Marks	Guidance
17	a		Working that leads to $t = \frac{15 \times 10^6}{280 \times 10^3}$ = 54 (s)	B1	**Allow** KE = t × P approach
	b		Horizontal arrow to the left same size as F At least one horizontal magnitude given as 6700 (N) At least one vertical magnitude given as 170 000 (N)	B1 B1 B1	by eye **Allow** $280 \times 10^3 \div 42$ or 6670 (N) **Allow** 17000×9.81 or 167000 (N)
	c		(thinking distance =) 0.40 × 42 or 17 m Acceleration = 7 (m s^{-2}) or ½ m v^2 = F d (braking distance =) 125 m Total stopping distance is 142 m (which is less than 167m)	B1 C1 A1 B1	**Allow** ECF in subsequent marks if thinking distance incorrect or omitted **Alternative approach using braking distance** (work done =) $120 \times 10^3 \times$ (167 – thinking distance) (work done =) 18×10^6 (J) Work done calculated **and** this is less than the initial KE **Allow** braking distance calculated and 125 m is less than the available braking distance of (167 – thinking distance)
			Total	8	

Question			Answer	Marks	Guidance
18	(a)	i	(area of shaded region =) 1.9 × 6.0 or 11.4 (m^2)	C1	
			(volume of air in 3.0 s =) 11.4 × 3.0 × 12	C1	**Allow** volume found in one second leading to mass per second multiplied by 3 for 2nd and 3rd mark
			(mass of air = 11.4 × 3.0 × 12 × 1.2)		**Note:** volume of air is 410 (m^3)
			mass of air = 492(.48) (kg)	A1	
		ii	Δp = 12 × 490 or 5900 (kg m s^{-1}) (force = Δp / Δt = 5900/3.0)	C1	Expect to see mass of 490, 492, 492.5, 492.48
			F = 2000 (N)	A1	**Note** answer is 1970 to 3 SF using 492.48 **Note** answer is 1960 to 3 SF using 490

Question			Answer	Marks	Guidance
	(b)*		**Level 3 (5–6 marks)** Clear descriptions **and** explanations, supported by quantitative analysis *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)** Some description and some explanation or quantitative analysis **or** Clear explanation **or** Clear description **or** Clear quantitative analysis *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)** Limited description **or** Limited explanation *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1× 6**	**Indicative scientific points may include:** **Description** • Increasing the area/diameter of the guy ropes • A different material with a larger breaking or yield stress • A more streamlined shape that allows the wind to pass over or around the tent **Explanation** • Correct reference/use of $F = \Delta p / \Delta t$ • Greater cross-sectional area of rope would reduce the stress • The rope would not exceed a higher breaking/yield stress • Changing shape produces a smaller momentum change and a smaller force • If the air passes over/around the tent, it still has some forward momentum and hence the change and force is less • Reduction of angle of ropes from ground reduces component of tension perpendicular to ground so tension decreases. **Quantitative analysis** • Mass (per unit time) and velocity **both** double (at 40 m/s) • Momentum change is x4 • Force would increase by a factor of 4 • Rope cross section must be × 4 (or diameter × 2) • Breaking or yield stress of material would need to be × 4 • Use of trigonometry to determine the angle of deflection that would reduce the momentum change by a factor of 4 (about 15° compared to the original 90°)
			Total	**11**	

Question			Answer	Marks	Guidance
19	a		Kinetic energy of particles is constant **and** the potential energy increases. internal energy has increased (as the internal energy = KE + PE)	**B1** **B1**	 **Allow** internal energy of a gas is the kinetic energy of the particles **Allow** potential energy of particles in a liquid is negative/the potential energy has increased to zero
	b	i	$pV = nRT$ **and** T = 296 (K) $100 \times 10^3 \times 15 = n \times 8.31 \times 296$ n = 610 (mol)	**C1** **C1** **A1**	 **Note** answer is 609.81559… **Allow** 1 mark for 7850; 23 used instead of 300 K
		ii	(mass = 610 × 0.028) = 17 (kg)	**B1**	**Allow** ecf from (b)(i) Expect n=600,610,609(.8…)
		iii	Reduce the pressure or increase the temperature (at which it is added)	**B1**	
		iv	The energy is transferred from the water vapour is equal to the energy gained by the liquid nitrogen $L_v = \frac{m_{H_2O} \times (L_{fusion\ H_2O} + L_{evaporation\ H_2O})}{m_{N_2}}$ $L_v = \frac{1.3 \times (334000 + 2260000)}{17}$ L_v = 2.0 × 10^5 (J kg^{-1})	**C1** **C1** **C1** **A1**	**Allow** use of only one of the specific latent heats of water at this stage e.g. $m_{N_2} \times L_{N_2} = m_{H_2O} \times L\ vaporisation_{H_2O}$ **NOTE:** this can be awarded across whole response Evidence of addition of **both** latent heats (of water) is required **Note** answer is 1.97 × 10^5 to 3 SF **Note: 1 mark only for :** answer using only fusion = 2.5 or 2.6 × 10^4 (J kg^{-1}) answer using only vaporisation = 1.7 × 10^5 (J kg^{-1})
			Total	**11**	

Question				Answer	Marks	Guidance
20	a			$\omega \rightarrow$ s^{-1} **or** $\omega^2 \rightarrow$ s^{-2}	**M1**	**Allow** $\omega \rightarrow$ (radians) s^{-1} **Allow** $\omega^2 = (2\pi f)^2$ **or** $(2\pi/T)^2$ with some evidence of units afterwards
				LHS = m s^{-2} **and** RHS = m s^{-2} clearly shown by unit algebra	**A1**	e.g. RHS = m . (s^{-1})^2
	b	**i**		Δp = 0.10 × 1000 × 9.81	**C1**	
				Δp = 980 (Pa)	**A1**	**Allow** 1 mark for 490 Pa; 5.0 cm used
		ii	**1**	$\omega^2 = \frac{2\rho g A}{m}$ **or** $\boldsymbol{\omega^2}$ = 37.7 (rad^2 s^{-1})	**C1**	**NOT** ω = 37.7
				ω = 6.1	**C1**	
				$T = \frac{2\pi}{6.1}$	**C1**	**Alternative route:** • Substitution of expression for omega • Re-arrangement to make T subject • Evidence of evaluation to T = 1.02 (s)
				T = 1.02 (s)	**A0**	
			2	Oscillation is isochronous starting from (0,5)	**B1**	Period same by eye.
				Correct value(s) on the horizontal axis	**B1**	**Note** scale must be linear and increasing
				At least 2 oscillations shown **and** amplitude is decreasing	**B1**	Amplitude of 2nd oscillation smaller by eye.
			3	The (driving) frequency is close to the natural frequency (of the system) / resonance will occur	**B1**	
				(Level of) water will oscillate with large amplitude	**B1**	**Allow** a description of consequence such as water leaving the tube or being unable to measure the height of liquid
				Total	**12**	

Question			Answer	Marks	Guidance
21	a		Gravitational force	B1	**Allow** 'gravity'
	b	i	(diameter =) $6.4 \times 3.1 \times 10^{16}$ **or** 2.0×10^{17} (m) (volume =) $4/3\ \pi \times (9.9 \times 10^{16})^3$ (volume =) 4.1×10^{51} (m^3)	C1 C1 A0	**Allow** (radius =) $3.2 \times 3.1 \times 10^{16}$ **or** 9.9×10^{16} (m)
		ii	$(E = \frac{3}{2}kT)\ \frac{3}{2} \times 1.38 \times 10^{-23} \times 250$ **or** 5.2×10^{-21} (J) (N =) $1.0 \times 10^{12} \times 4.1 \times 10^{51}$ **or** 4.1×10^{63} ($E_k = 4.1 \times 10^{63} \times 5.2 \times 10^{-21}$) $E_k = 2.1 \times 10^{43}$ (J)	C1 C1 A1	
	c	i	Mass is proportional to volume **or** diameter^3 **or** radius^3 **or** $(\frac{6.4}{3})^3$ **or** $(\frac{3.2}{1.5})^3$ ratio = 9.7	C1 A1	**Allow** attempt at calculating volume of second nebula and comparing volumes directly **Allow** 9.76 (if volume divided by volume of Sun's nebula)
		ii	Fuel (hydrogen) runs out Super red giant star (Mass of core > Chandrasekhar limit /1.4 therefore) supernova neutron star or black hole (formed)	B1 B1 × 3	**Note: incorrect order is CON** **Allow** alternative route: Red giant formed (mass of star< 10 solar masses, therefore) planetary nebula (and) white dwarf formed
			Total	12	

Question			Answer	Marks	Guidance
22	(a)		(%) uncertainty of *T* will be 4 times as significant as the uncertainty of *L* Should improve measurements leading to *T*	M1 A1	**Allow** reference to 4^{th} power of T **Allow** comparison of $L^{(-)1/2}$ and T^2
	(b)*		**Level 3 (5–6 marks)** Clear description of method and analysis of data **and** correct explanation. *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)** Some description of method **and** analysis of data **or** explanation. *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)** Limited description **or** Limited analysis **or** Limited explanation *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	B1× 6	**Indicative scientific points may include:** **Description of method** • Equation using lg of both sides • Use of the lg X^b = *b* lg *X* • Comparison with *y* = *mx* (+ *c*) • (*y*-intercept = 0) **Analysis of data** • Straight line through the origin • Gradient of the graph is *b* • Gradient calculated to be between 3 and 4 **Explanation** • Labelled sketch of HR diagram • Reference to Stefan's Law • Hotter stars (than the Sun) have greater luminosity (ratio) / luminosity ratio >1 • Hotter stars have much smaller mass ratio than luminosity ratio • Use of data (e.g luminosity of ×10,000 means mass of about ×14) • **therefore** hotter stars lose mass at a much higher rate (compared to their mass) • **therefore** hotter star lifespans are very much shorter than cooler stars
			Total	**8**	

Question			Answer	Marks	Guidance
23	a		$G\frac{Mm}{r^2} = \frac{mv^2}{r}$ **or** $G\frac{Mm}{r^2} = mr\omega^2$ $v = \frac{2\pi r}{T}$ **or** $\omega = \frac{2\pi}{T}$ Substitution **and** manipulation to give $T^2 = \frac{4\pi^2}{GM}r^3$ (with $\frac{4\pi^2}{GM}$ is constant)	**M1** **M1** **A1**	**Allow** any subject
	b	**i**	$\left(\frac{168}{365}\right)^2 = \left(\frac{r}{1.50 \times 10^{11}}\right)^3$ distance = 8.9×10^{10} (m)	**C1** **A1**	**Ignore** calculation of arithmetic mean of data in question **Allow** substitution into $T^2 = \frac{4\pi^2}{GM}r^3$ **Ignore** units for subs into Kepler's law **NOT** 8.95 or 9(.0) $\times 10^{10}$ (m) (mean calculated)
		ii	(ΔGPE = ΔKE) $GMm\left(\frac{1}{4.20 \times 10^{10}}\right)$ **or** $GMm\left(\frac{1}{1.37 \times 10^{11}}\right)$ (change in KE =) $6.67 \times 10^{-11} \times 2.0 \times 10^{30} \times m\left(\frac{1}{4.20 \times 10^{10}} - \frac{1}{1.37 \times 10^{11}}\right)$ change in kinetic energy = 4.6×10^{11} (J)	**C1** **C1** **A1**	**Allow** this mark without the *m* **Allow** this mark without the *m* **Allow** 2 marks for 2.2×10^9; ΔV calculated **Ignore** sign
		iii	Description of reasonable effect of Earth has been ignored / work done by fuel (during lift off) / idea that atmosphere has been ignored previously	**B1**	
			Total	**9**	

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