GCE

Physics A

H556/01: Modelling physics

A Level

Mark Scheme for June 2023

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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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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor 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 5 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**
   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.

   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 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. 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.

Annotation		Meaning
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).

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

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 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.

SECTION A

Question	Answer	Marks	Guidance
1	C	1	
2	B	1	
3	A	1	
4	B	1	
5	D	1	
6	B	1	
7	B	1	
8	C	1	
9	D	1	
10	C	1	
11	D	1	
12	D	1	
13	C	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	Mark	Guidance
16	(a)	(i)	=110 x 1000 ÷ 3600 =31 ms^{-1}	 B1 B1	 Allow 30.55,30.6 etc Allow answer with consistent unit i.e. 0.031 km/s
		(ii)	time = distance ÷ speed = 40 ÷ 31 =1.3 s	 B1	 Allow any number of significant figures
		(iii)	Correct calculation of thinking distance (21 m) or thinking time (0.69 s) thinking distance less than 40m (distance between markings) OR thinking time less than 1.3 s (time taken between markings) OR braking distance less than 80 m (distance for two gaps) OR stopping distance is less than 120 m **Correct** conclusion consistent with comparison	B1 M1 A1	. allow "stopping distance greater than 80m" without reference to 120 m but this prevents award of A1 ignore references to increased likelihood of collisions

	(b)	**(i)**	F=ma and a=v(-u) ÷ t (F= 1600 × 31 ÷ 5.6) =8900 N (8.86kN)	C1 A1	Allow F=change in momentum÷time Allow energy approach using the data in the table Allow table distance of 75m or calculation of distance using $v^2 = u^2 + 2as$ and then ½ mv^2 = Fs Allow ECF from (a)(ii) e.g. use of 110 gives 31, 400 Allow answers that round to fall in range from 8700 to 8900 Allow 9950 or 10100 for 2 marks (use of 5.6s as stopping time) Allow 10250 for 2 marks (use of 75m braking distance)
		(ii)	Using forces A component of the weight is acting backwards or there is additional backwards force or greater resultant force down the slope A smaller distance is required to do the <u>same</u> work or transfer the <u>same</u> quantity of KE	 B1 B1	Allow energy approach Some of the KE turns to GPE or less KE to be transferred to heat A smaller distance required because the brakes must do less work using the <u>same</u> force Allow equivalent approach e.g. justification using increased deceleration and hence shorter distance for second mark. NB Unqualified smaller distance is insufficient
			TOTAL	10	

Question			Answer	Mark	Guidance
17	(a)	(i)	Arrow **along** the line of the support rod labelled tension or T.	B1	Allow unlabelled single arrow along either rod Allow unlabelled arrows along both rods Allow arrow(s) up, down or both NOT any contradictory arrows
		(ii)	11.1 sin 35 or 11.1 cos 55 seen addition of 3.9 (half the diameter of the support disc) to candidate's horizontal component of rod length Total= 10.3m	M1 M1 A0	NOT use of tan 35 or tan 55 allow 7.8/2 for 3.9 10.27 to 2 dp NB use of 11.1 cos 35 or 11.1 sin 55 arriving at 12.99 scores 1 (wrong trig) NB reject use of radians (scores 0)
		(iii)	mg=T cos 35 T= mg ÷ cos 35 = 140 N	C1 C1 A1	Allow use of sin 55 NOT use of tan 35 or tan 55 Answer is 143.7 N to 4 sf

Question			Answer	Mark	Guidance
		(iv)	T sin 35 = mrω^2 $\omega=\sqrt{\frac{T\sin 35}{mr}}$ =0.8(17) radian s^{-1}	M1 A1 A0	Allow use of W tan 35 or W tan 55 Allow use of cos 55 and/or mv^2/r Allow use of Pythogoras to find centripetal force (82.4…) NOT use of T tan 35 or T tan 55 Allow ω^2 subject. Allow any combination of rearrangement and substitution ECF allowed for T and r. Use of 2 s.f. values for T and r gives 0.84 m

Question			Answer	Mark	Guidance
17	(b)	(i)	Use of $17=1/2\ g\ t^2$	C1	i.e. substitution of 17 and g or 9.81 or 9.8 e.g. $s=(ut)+ ½\ at^2$ $t=\sqrt{\frac{2s}{a}}$
			=1.9 (1.86) s	A1	$=\sqrt{\frac{2\ x\ 17}{9.81}}$ Allow any subject
		(ii)	Horizontal speed = rω or Horizontal distance = speed × time	C1	Use of data in the question stem (0.8 and 10) allowed, which gives 15.2 m.
			= 0.82 radians s^{-1} × 10.26 m × 1.86 s	C1	
			= 16 m (15.6 m)	A1	Ecf for use of candidate's value of r and ω, giving values rounding to between 14.9 and 16.0 m

Question			Answer	Mark	Guidance
		(iii)	Relevant variable identified Effect on speed of shoe or time of flight of shoe correctly identified Conclusion consistent with relevant physics e.g. ● Shoe is lower mass yet no change in angular velocity or radius since independent of mass so no change in horizontal displacement. ● Shoe is below seat so would be travelling with larger radius/speed so larger distance travelled horizontally ● Shoe might have be kicked off backwards so have lower speed so lower distance ● Shoe would come from below the seat/lower than the sandbag i.e. vertical distance to fall less, thus time of flight and horizontal distance less. ● Effect of air resistance hadn't been included so shoe suffers drag, decelerating horizontally so distance would be smaller	M1 M1 A1	e.g mass/weight, drag/air resistance, radius, height, starting condition (e.g. kicking shoe off) Assume "it" in response refers to the shoe. ignore velocity for first M1 allow correct explanation of "no effect" on speed or time by change of mass
			TOTAL	16	

Question			Answer	Mark	Guidance
18			**Level 3 (5–6 marks)** Detailed quantitative discussion and comparison of uncertainties, and clear description of graphical 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 quantitative discussion of uncertainty for one method and clear description of graphical analysis Or Discussion, with some quantitative ideas and comparison of uncertainty for both methods with some graphical 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)** Incomplete discussion of uncertainty with no comparison Or Description of analysis *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*	B1 x 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Discussion of uncertainty** ● No repeat makes experiment inherently uncertain ● Height +/- 1cm ● Ramp length +/- 1mm ● Resolution/"precision" of stopclock is 0.01s, but reaction time is much greater ● Times +/- 0.1 s (or more) ● Calculation of g will use time squared so double the percentage uncertainty in t ● Angle likely to be +/- 1 or 2 degrees ● Ramp calculation uses sine of angle, so difficult to quantify the uncertainty as a percentage to combine with other variables **Comparison** ● Ramp method has greater time and length both greater so smaller percentage uncertainties ● Frictional effects ramp method more ● More difficult to measure times for drop ● Uncertainty for height and ramp different **Analysis** ● Ignore references to comparisons of the value of g found from both methods ● Find g from $s = \frac{1}{2} a t^2$ for multiple values of s **and average**

Question			Answer	Mark	Guidance
			0 marks *No response or no response worthy of credit.*		● Appropriate graphs plotted i.e. plotting t^2 on y-axis and s on x-axis, following some analysis/comparison with "y=mx+c" ● Significance of gradient (e.g. t^2 against 2s gives gradient 1/g for drop method ● Determine uncertainty graphically using best/worst line method
			TOTAL	6	

Question			Answer	Mark	Guidance
19	(a)		Suspend object (freely) and mark vertical (down) Repeat(s) (from different point) and reference to intersection of verticals Plumb line/ plumb bob /AW	B1 B1 B1	Allow methods with unstable equilibrium e.g. balance shape on a pin/finger for 1 mark max Accept spirit level
	(b)	(i)	P = work ÷ time = 120 kN x (6.3+1.3) ÷ 90 = 10100 W	 C1 A1	 Omission of 1.3 m giving 8400 W scores 1 mark
		(ii)	Any reasonable suggestion e.g. ● Motor not 100% efficient / AW ● The value found is an average/the power required varies during the lift / AW ● decreased time such as needing to raise the bridge in a shorter time / AW ● External forces such as drag or extra weight change required work done / AW	B1	
			TOTAL	6	

Question			Answer	Mark	Guidance
20	(a)		pV=nRT mass (or m) = nM Substitution into $\rho = \frac{m}{V}$ for m and V and cancelling n to give $\rho = \frac{pM}{RT}$	M1 M1 M1 A0	 Not n=1 Not n=1
	(b)	(i)	$\rho = \frac{100.000 \times 0.029}{8.31 \times 293}$ =1.19 kg m^{-3}	M1 A0	 Accept R for 8.31, T = 293.1(5) Reject 20 for T.
		(ii)	Mass of air = 1.19 × 12,000 = 14 300 kg Weight of air = mg = 140 000 N	C1 A1	 Accept all answers that round to 140 000 N, eg 140210, 141264
		(iii)	<u>Upthrust</u> = weight of fluid or air displaced Airship in equilibrium/resultant force is 0 (so upthrust = weight of the airship)	B1 B1	Do not accept unqualified “Archimedes’ principle” Not water for fluid

Question			Answer	Mark	Guidance
		(iv)	**Two** from ● (Greater pressure) would increase the density/mass/weight of the helium ● (increased pressure but) no change in volume therefore no more upthrust. ● If the volume goes up then the upthrust will increase / ORA ● Pressure only needs to be large enough to inflate the gasbag ● (increased pressure difference or volume) may cause structural failure ● (higher pressure means) more collisions of helium atoms with walls so more leakage of helium	B1 x 2	

Question			Answer	Mark	Guidance
20	(c)	(i)	F = ([delta mass ÷ delta time] x speed =) 7.8 x 45 = 350N	C1 A1	 reject ‘F=ma = 7.8 x 45’ score zero annotate XP
	(d)		Density or mass per unit time is less so the (rate of) momentum change from the engines is reduced. There is less drag/resistive force on the airship.	B1 B1	
			TOTAL	14	

21	**(a)**	**(i)**	newton in base units is kg m s^{-2} Substitution and cancelling of kg and m arriving at s^2 -> s^2	C1 A1	
		(ii)	One force is increased by kx and one is reduced by kx /AW Some working to include kx - (-kx)	B1 B1	reject 2 springs in series or 2 springs in parallel idea XP. accept one extension is reduced by x and one is increased by x / AW
		(iii)	period is independent of <u>amplitude</u> / AW No effect	M1 A1	Allow isochronous
	(b)	**(i)**	Units omitted from T **and** T^2 Valid statement about significant figures	B1 B1	 allow correct statement about individual data points or decimal place or "precision" e.g. sf of T does not match sf of 20T or sf of T not consistent throughout column or idea that 1 sf never enough
		(ii)	Correct plotting within half a small square Correct line of best fit	B1 B1	 ECF for incorrect plotting. NB Same number of points above and below the line AND fair distribution of distances from line

		(iii)	Gradient between 1.22 and 1.44 $k=2\pi^2 \div$ gradient k between 13.7 and 16.2	C1 C1 A1	reject use of data table ECF use of candidate's line ECF use of candidate's gradient as per rubric
	(c)		maximum four from: EPE gain (in stretched spring) > EPE lost (in relaxed spring) EPE is dependent on x^2 Total energy increases (and so KE increases since EPE -> KE) Max KE when the system has minimum EPE / at equilibrium position/when x=0 Minimum EPE is unchanged Omega is same, amplitude has increased v_{max} when x=0 so v_{max} has increased ($omega^2 = sqrt(A^2-x^2)$) v_{max} increased so KE_{max} increased	4 x B1	Allow EPE max is dependent on A^2 NOT EPE dependent on x alone Allow EPE dependent on x and F which is dependent on x (EPE = ½ Fx idea) KE = ½ kx^2 is XP
			TOTAL	17	

Question			Answer	Mark	Guidance
22			**Level 3 (5–6 marks)** Clear description, explanation and limitations with correct annotations on diagram *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 evolution **and** some explanation of analysis or Some description of evolution **and** some limitations *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 or limitations *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 x 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description of evolution** ● Main sequence labelled ● Red giants/supergiants labelled ● White dwarves labelled ● Correct order of evolution ● Dependence on mass/Chandrasekhar's limit ● Evolutionary track shown on diagram **Explanation of analysis** ● Identification of peak wavelength from graph ● Use of Wien's law ● Determination of temperature ● Gives the horizontal co-ordinate **Limitations** ● Does not give luminosity data ● Cannot distinguish between similar temperature stars (e.g. white dwarf, main sequence or a hot super giant) ● Need luminosity data to classify the star ● Difficult to isolate light from stars in other galaxies to analyse ● If looking at stars in other galaxies, have to account for red shift requiring emission data.

Question			Answer	Mark	Guidance
23	(a)	(i)	=1 ÷ 0.00097 =1000 parsecs	A1	1030 to 3sf
		(ii)	=0.00097÷7.5 x 10^{-3} (x100%)	C1	NOT half of the precision here (reference specification)
			=13%	A1	Accept 1 sig fig value 10% Unrounded answer is 12.93… %
	(b)	(i)	Use of KE_{mean}= 3/2 kT = 3/2 x *k* x 4.0 x 10^6 $= \frac{3}{2} \times 1.38 \times 10^{-23} \times 4 \times 10^{6}$ =8.3×10^{-17} J.	C1 A1	Allow k Unrounded answer is 8.28… x 10^{-17}
		(ii)	= – 2.3×10^{-16} + 8.3×10^{-17} = -1.5×10^{-16} J.	B1	Allow use of 10^{-16} J from stem to give -1.3×10^{-16} J Reject response without negative sign

Question			Answer	Mark	Guidance
		(iii)	selection of GMm/r Substitution of values for M,m and energy and rearrangement 3.2×10^{10} m e.g. (-) $\frac{GMm}{r}$ = (-)1.5×10^{-16} $r = \frac{6.67 \times 10^{-11} \times 1.1 \times 10^{31} \times 6.6 \times 10^{-27}}{1.5 \times 10^{-16}}$ = 3.2×10^{10} m	C1 C1 A1	 Allow ECF from (b)(ii) NB Use of values in stem gives 3.7×10^{10}
		(iv)	Reference to Boltzmann distribution / AW OR Some particles will have greater kinetic energies /lower masses	B1	
			TOTAL	10	

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