Oxford Cambridge and RSA

GCE

Physics A

H556/01: Modelling physics

Advanced GCE

Mark Scheme for November 2020

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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.

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.

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.
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

SECTION A

Question	Answer	Marks	Guidance
1	C	1	
2	C	1	
3	A	1	
4	C	1	
5	B	1	
6	C	1	
7	B	1	
8	B	1	
9	D	1	
10	D	1	
11	B	1	
12	B	1	
13	D	1	
14	C	1	
15	A	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)		Arrow vertical down and an arrow opposite to the frictional force. Both arrows labelled correctly.	M1 A1	 **Allow** weight / *mg* / W for the downward arrow and tension / *T* / 'force in rod' / 'force in tow bar' /'driving force' for the 'upward' arrow
	(b)		(W_s =) $1100 \times 9.81 \times \sin 10°$ **or** $1100 \times 9.81 \times \cos 80°$ (W_s = 1874 N or 1900 N)	C1 A0	**Allow** *g* instead of value
	(c)		force = 1900 + 300 force = 2200 (N)	 A1	 **Allow** 1870 + 300 = 2170 (N)
	(d)		(distance =) 120 / sin 10° **or** 691 (m) (work done =) 2200×691 work done = 1.5×10^6 (J)	C1 C1 A1	 **Allow** ECF from **(c)** **Allow** ECF from an incorrect attempt at first mark.
	(e)		(A =) $\pi \times 0.006^2$ **or** 1.1×10^{-4} (m^2) (stress =) $\frac{2200}{\pi \times 0.006^2}$ and $2.0 \times 10^{11} = \frac{\text{stress}}{\text{strain}}$ $x = 4.8 \times 10^{-5}$ (m)	C1 C1 A1	 **Allow** ECF from **(c)** **Allow** x (=FL/EA) = $\frac{2174 \times 0.5}{2.0 \times 10^{11} \times 1.1 \times 10^{-4}}$ **Allow** 2 marks for 1.2×10^{-5}; 1.2×10^{-2} m used as radius **Allow** answer between 4.7 and 5.1×10^{-5} (m)
			Total	10	

Question			Answer	Marks	Guidance
17	(a)	(i)	Any **THREE** from: Atoms of metal vibrate (about fixed points) Water molecules have translational KE The motion of the water molecules is random Metal atoms and water molecules have the same KE	B1x3	**Allow** particles for atoms / molecules throughout **Allow** idea that water particles move past each other **Not** idea that the water molecules have more KE than metal atoms
		(ii)	(E_{heater} =) $200 \times 10 \times 60$ **or** 120000 (J) (E_{water} =) $0.5 \times 4200 \times 40$ **or** 84000 (J) (energy transferred = 120000 – 84000) energy transferred = 3.6×10^4 (J)	C1 C1 A1	

	(b)*		**Level 3 (5–6 marks)** Clear description and explanation **and** correct calculations leading to value of L_f *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)** Clear description and explanation **or** Correct calculations leading to value of L_f **or** Some description or explanation **and** some correct calculations *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 explanation **or** Limited calculations *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1×6**	**Indicative scientific points may include:** **Description and explanation** • $m \propto t$ (for both) • Greater gradient for funnel with heater / greater rate of water from funnel with heater • Energy supplied to the ice is at a constant rate (for both beakers) • Idea that arrangement in Fig 17.2 is a control • Beaker in 17.2 heated just by surroundings / air / room • Arrangement in Fig. 17.1 gains energy from heater and surroundings / air / room **Calculation** • Gradient(s) calculated • $\Delta m = 45 \times 10^{-3}$ kg • $\Delta E = mL_{(f)}$ • $\Delta E = 5 \times 12 \times 240 = 14400$ J • $L_{(f)} = 14400 / 45 \times 10^{-3} = 3.2 \times 10^5$ • Units: J kg^{-1} **Note**: $L_{(f)}$ can be calculated using $L_{(f)} = VI \div \lvert\Delta\text{gradient}\rvert$
			Total	**12**	

Question			Answer	Marks	Guidance
18	(a)		(Kinetic energy) reduces (with height) At maximum height, KE is minimum / non-zero	B1 B1	**Allow** idea that KE is transferred to GPE/KE store reduces and GPE store increases **Not** references to KE being a vector/having components for second mark
	(b)		(u =) 68 sin 11° **or** 13.0 (m s^{-1}) t = 13.0 / 9.81 and t correctly evaluated t = 1.3(2) (s)	C1 C1 A0	**Not** t=90/(68cos(11)) =1.35 for zero marks. **Allow** any subject
	(c)		(t =) 2 × 1.3 **or** 2.6 (s) (x =) 68 cos11° × 2.6 or 174 (m) horizontal distance = 174 – 90 horizontal distance = 84 (m)	C1 C1 A1	 **Note** answer is 86 (m) if 1.32 s is used **Note** answer is 87 (m) if 1.3226... s is used **Allow** 1.3 x 68 cos11° for 1 mark **Allow** 3 or –3 m for 2 marks
	(d)	(i)	A collision in which kinetic energy is lost	B1	**Allow** KE is not conserved
		(ii)	Conservation of momentum Idea that velocity is to the right **and** velocity is very small / much smaller than 68 (m s^{-1})	B1 B1	 **Not** 'goes backwards'
			Total	10	

Question			Answer	Marks	Guidance
19*			**Level 3 (5–6 marks)** Clear description of experiment **and** measurements **and** clear 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 of experiment **and** some measurements **and** some 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 of experiment **or** Limited measurements **or** Limited analysis *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1× 6**	**Indicative scientific points may include:** **Description** • Release method • Ensure bob is not pushed • Repeat experiment for same *H* • Repeat for different H • Centre of mass of single bob and joined bob considered • Keep bob string taught **Measurements** • Measure heights *h* and *H* with ruler • Use centre of mass of bob or another suitable method • Use video camera to record motion • Use of datalogger and appropriate sensor to measure *H* and *h* • Measure mass with (top pan) **balance** **Analysis** • Construct a table of *h* and *H* • Plot graph of *h* against *H* • LoBF should pass through origin. • Determine gradient or calculate *h*/*H* ***repeatedly*** • gradient = $\left(\frac{M}{M+m}\right)^2$ (gradient must be consistent with the plot) • Masses substituted into above expression and checked against experimental gradient
			Total	**6**	

Question			Answer	Marks	Guidance
20	(a)		$F = m\omega^2 r$ **and** $\omega = 2\pi f$	**M1**	**Allow** $F = mv^2/r$ **and** $v = 2\pi fr$
			$kmg = m\omega^2 r$	**M1**	**Allow** this mark for $kmg = mv^2/r$
			Clear algebra leading to $f^2 = \left(\frac{gk}{4\pi^2}\right) \times \frac{1}{r}$	**A1**	
	(b)		y-intercept = - 0.45	**C1**	**Allow** $\pm$ 0.05 **Allow** attempt at calculating y-intercept using gradient and a point **on the line.**
			$\frac{1}{2}\lg\left(\frac{gk}{4\pi^2}\right) = -0.45$	**C1**	
			$\left(\frac{gk}{4\pi^2}\right) = 10^{-0.9}$	**C1**	**Not** $e^{-0.9}$ wrong physics
			$k = \frac{0.126 \times 4 \times \pi^2}{9.81}$ k = 0.51	**A1**	Allow k in range 0.48 to 0.63 **Note** Answer must be to 2 SF
			Total	**7**	

Question			Answer	Marks	Guidance
21	(a)	(i)	($pV = nRT$)		
			$100 \times 10^3 \times (0.46)^3 = n \times 8.31 \times (273 + 20)$	C1	**Note** $T = 20$ is XP
			$n = 4.0$	A1	**Not** 1 SF answer of 4 **Note** answer is 4.00 to 3SF
		(ii)	$\frac{100}{293} = \frac{p}{1573}$ **or** $p \times (0.46)^3 = n \times 8.31 \times 1573$	C1	**Note** $T = 1300$ is XP
			pressure = 540 (kPa)	A1	**Allow** use of correct, unrounded n
	(b)	(i)	(p =) $6.6 \times 10^{-26} \times 990$ **or** $6.5(3) \times 10^{-23}$ (kg m s^{-1})	C1	
			(Δp =) $2 \times 6.6 \times 10^{-26} \times 990$		
			$\Delta p = 1.3 \times 10^{-22}$ (kg m s^{-1})	A1	**Ignore** sign of answer
		(ii)1	$990/[2 \times 0.46]$ (= 1080)	B1	
		(ii)2	($F = \Delta p/\Delta t$)		
			(F =) $1.3 \times 10^{-22} \times 1000$	C1	Possible ECF from **(b)(i)**
			$F = 1.3 \times 10^{-19}$ N	A1	**Note** 1080 would give 1.4×10^{-19} (N)
		(iii)	Use of $p = F/A$ **or** pressure = (total) force/area	B1	
			Idea of multiplying by total number of atoms	B1	**Allow** particles or molecules for atoms
			Total	11	

Question			Answer	Marks	Guidance
22	(a)	(i)	The upthrust (on an object in a fluid) is equal to the weight of fluid (it displaces)	B1	**Note** 'fluid' or 'liquid' must be mentioned at least once. **Allow** a named fluid, e.g. water
		(ii)	($p = h\rho g$) $1.9 \times 10^3 = 0.15 \times \rho \times 9.81$ $\rho = 1.3 \times 10^3$ (kg m^{-3})	 C1 A1	
	(b)	(i)	$x = A \cos(\omega t)$ **or** $x = A \cos(2\pi ft)$ $x = 2.0 \cos(2\pi \times 1.4 \times 0.60)$ displacement = 1.1 (cm)	C1 C1 A1	**Note**: Treat use of sine as **TE** **Note** answer is 1.07 (cm) to 3SF **Note** answer if calculator left in degrees of 1.99cm scores 2 marks.
		(ii)	(v_{max} =) $2\pi \times 1.4 \times 0.02$ maximum speed = 0.18 (m s^{-1})	C1 A1	
		(iii)	**1** Larger (amplitude) **2** Same (period)	B1 B1	
			Total	10	

Question			Answer	Marks	Guidance
23	(a)	(i)	**X** at closest point on orbit to the Sun	**B1**	**Allow X** on the orbit to the left of the Sun
		(ii)	(When the asteroid orbits the sun a) line segment joining the asteroid to the Sun sweeps out equal areas in equal time (intervals) Longer distance (in orbit for the same time)	**B1** **B1**	**Allow** this mark on diagram (no labelling required) **Allow** 'equal area swept in same time'
	(b)	(i)	Work done per unit mass to move an object from infinity (to that point)	**B1**	**Not** 'work done on 1 kg'
		(ii)	Manipulation of $V_{(g)} = (-)\ GM/r$	**B1**	
		(iii)	gradient = (-)30.4 or equivalent working candidate's gradient or expression = $6.67 \times 10^{-11} \times M$ and M calculated correctly from that gradient $M = 4.6 \times 10^{11}$ (kg)	**C1** **C1** **A0**	**Allow** $\pm$ 2 Possible ECF from incorrect gradient **Allow** any subject
	(c)		**Method 1:** Evidence of 2.3×10^{-3} and 600^{-1} or $(2.3 \times 10^{-3})^{-1}$ and 600 $½\ v^2 = 6.67 \times 10^{-11} \times 4.6 \times 10^{11} \times (2.3 \times 10^{-3} - 600^{-1})$ $v = 0.20$ (m s^{-1}) **Method 2:** Evidence of 7.0×10^{-2} and 5.1×10^{-2} from graph $½\ v^2\ (= \Delta V_{(g)}) = 7.0 \times 10^{-2} - 5.1 \times 10^{-2}$ $v = 0.19$ (m s^{-1})	**C1** **C1** **A1** **(C1)** **(C1)** **(A1)**	Possible ECF from **(b)(iii)** for either value of *GM* or *M* **Allow** $½\ v^2 = 30 \times (2.3 \times 10^{-3} - 600^{-1})$ **Note** answer can be 0.19 or 0.20 or 0.2 m s^{-1} **Note** answer can be 0.19 or 0.20 or 0.2 m s^{-1} **Allow** correct use of one piece of data arriving at a value for v for 1 mark max
			Total	**10**	

Question			Answer	Marks	Guidance
24	(a)	(i)	Any **four** from • reduction in energy released by fusion • gravitational force is greater than that from radiation and gas pressure • core collapses • fusion no longer takes place in the core • fusion continues in the shell around the core • outer layers of star expand and cool • outer layers are released • reference to planetary nebula • reference to white dwarf (left as remnant hot core)	**B1 x 4**	**Ignore** current or previous stages of the Sun's evolution
	(b)	**(i)**	λT = constant however expressed $500 \times 5.8 \times 10^3 = 240 \times T$ and T correctly evaluated T = 12000 (K)	**C1** **C1** **A0**	 **Note** answer is 12080 (K) to 4 SF **Allow** any subject
		(ii)	($L = 4\pi r^2\sigma T^4$) $4.62 \times 10^{31} = 4\pi \times 5.67 \times 10^{-8} \times r^2 \times 12000^4$ radius = 5.6×10^{10} (m)	 **C1** **A1**	 **Note** 12080 K gives 5.5×10^{10} (m)
	(c)		(A white dwarf has mass equal to or) less than 1.4(4) solar masses / Chandrasekhar limit (ORA)	**B1**	**Allow** $M_\odot$ for solar mass **Allow** reference to neutron star (over Chandrasekhar limit) **Allow** correct reference to electron degeneracy pressure/Pauli Exclusion Principle
			Total	**9**	

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