OCR
Oxford Cambridge and RSA

GCE

Physics A

H556/01: Modelling physics

Advanced GCE

Mark Scheme for Autumn 2021

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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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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, formulæ 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	A	1	
3	C	1	
4	B	1	
5	A	1	
6	B	1	
7	B	1	
8	D	1	
9	D	1	
10	C	1	
11	C	1	
12	B	1	
13	C	1	
14	B	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)	(i)	$(g \rightarrow)$ [m s^{-2}] **and** $(t \rightarrow)$ [s] **or** $(gt^2 \rightarrow)$ [m s^{-2} × s^2]	M1	
			Clear evidence of working leading to m on both sides	A1	
		(ii)	*s* / distance measured with a ruler / tape measure	B1	
			Timer mentioned for measuring *t* / time	B1	
			Measure distance from bottom of ball to (top of) trapdoor	B1	
			Any <u>one</u> from: • Take repeated readings (for *t* for same *s*) to determine average *t* • Avoid parallax error when using the ruler	B1	
	(b)	(i)	(p_1 = 4.4 × 0.050) = 0.22 (kg m s^{-1})	B1	
		(ii)	(impulse =) ½ × 30 × 0.02 **or** 0.30 (kg m s^{-1})	C1	
			-0.30 = p_2 – 0.22	C1	Allow any correct re-arrangement Possible ECF from **(b)(i)**
			p_2 = (–) 0.08 (kg m s^{-1})	A1	**Ignore** sign **Allow** 0.52 for 2 marks
		(iii)	(momentum of trapdoor =) 0.30 (kg m s^{-1})	C1	Allow ($KE_{trapdoor}$ =) ½ × 0.05 × (4.4^2 – 1.6^2) **or** 0.42 (J) Possible ECF from **(b)(ii)**
			v = 3.0 (m s^{-1})	A1	**Allow** 1 SF answer here **Allow** alternate methods involving CoE (giving 2.9) and e(giving 2.8)
			Total	12	

Question			Answer	Marks	Guidance
17	(a)		(mean) = 1.87(2) (mm)	C1	
			(range) = 0.04 mm	C1	**Allow** use of resolution of micrometer (gives percentage uncertainty of 0.5%)
			(percentage uncertainty =) $\frac{0.02}{1.872} \times 100$		**Allow** use of maximum or minimum deviation from the mean
			percentage uncertainty = 1 (%)	A1	**Allow** 2 or 3 SF answer

	(b)*		**Level 3 (5–6 marks)** Clear description **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 **and** some analysis **or** Clear description **or** Clear 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 analysis *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**	Use level of response annotation in RM Assessor. **Indicative scientific points may include:** **Description** • Determine T by measuring several oscillations • Independent and dependent variables identified (e.g. L and T) • Variables kept constant (e.g. for L and T experiment, m is kept constant) • Repeating to determine average T • Measure length L and width w with ruler • Measure thickness t with a vernier (calliper) / micrometer • Use video/phone camera / stopwatch / data-logger and motion sensor / light gates and timer • Use top-pan balance / scales to measure m **Analysis** • Plot an <u>appropriate</u> graph, e.g. T^2 against L^3 **or** tabulate $T^2 \div L^3$ • Gradient of **best line** determined **or** average of $T^2 \div L^3$ • Use a large triangle to determine gradient • Gradient (or equivalent) related to E, e.g. gradient = $16\pi^2 m/wEt^3$ for T^2 against L^3 graph
			Total	**9**	

Question			Answer	Marks	Guidance
18	(a)	(i)	(energy =) 150 × 7 **or** 1050 (J)	C1	
			1050 = 0.025 × c × 20	C1	**Allow** any correct re-arrangement
			(c =) 2100 (J kg^{-1} K^{-1})	A1	
		(ii)	(energy=) 150 × (63 – 7) **or** 8400 (J)	C1	
			8400 = $L_{(f)}$ × 0.025		
			(L_f =) 3.4 × 10^5 (J kg^{-1})	A1	
		(iii)	Longer time to heat water (through the same temperature) / shorter time to heat (ice) through same temperature / gradient of graph is greater for ice / gradient of graph is smaller for water/AW	M1	**Allow** calculation of gradients
			Water has greater specific heat capacity	A1	
	(b)	(i)	Molecules in **X** vibrate about fixed positions /AW	B1	**Allow** references to ice for **X** and water / liquid for **Z**
			Molecules in **Z** are free to move/random/AW	B1	**Allow** <u>one</u> correct for **B1** from: • Molecules in **X** have lower <u>K</u>E/speed/velocity • Speed/velocity of molecules increases with temp/time • Amplitude or frequency increases with temp/time in **X**

<table>
<tr>
<td></td><td></td><td>(ii)</td>
<td>
<table>
<tr><th>Region</th><th>Physical quantity, or quantities, that increase as time increases</th><th>Physical quantity, or quantities, that remain constant as time increases</th></tr>
<tr><td>X</td><td>K</td><td>P</td></tr>
<tr><td>Y</td><td>P</td><td>K</td></tr>
<tr><td>Z</td><td>K</td><td>P</td></tr>
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</td>
<td>B1×3</td>
<td>Note that each B1 mark is for a correct row
Allow KP/- for both X and Z</td>
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<tr>
<td></td><td></td><td>(iii)</td>
<td>Absolute zero / 0 K / - 273 °C</td>
<td>B1</td>
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<td></td><td></td><td></td>
<td>Total</td>
<td>13</td>
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Question			Answer	Marks	Guidance
19	(a)		For a body in (rotational) equilibrium the sum of the clockwise moments (about any point) is equal to the sum of the anticlockwise moments (about the same point)	B1	**Note** Accept Σ / total (AW) for sum
	(b)	(i)	(horizontal component of F =) $F \times \cos 20°$ $F \cos 20° \times 1.30 = 0.30 \times 40 \times 9.81$ F = 96.4 (N)	M1 M1 A1	 **Allow** ECF for incorrect trig i.e. use of sine (gives F =265) or cos(20 radians) which gives F = 222 for 2 marks. **Allow ECF** for incorrect units for angle and incorrect trig sin(20 radians) which gives F = 99(.2) for 1 mark
		(ii)	$R = F \cos 20°$ **or** $96(.4) \times \cos 20°$ (R =) 91 (N)	C1 A1	**Allow** ECF from (b)(i) **Answer is 90.6 (N) to 3sf if 96.4 used.** **Answer is 90(.2) (N) to 3sf if 96 used**
	(c)		When (line of force of the) weight falls to the right of the (bottom of the) wheel/AW	B1	
			Total	7	

Question			Answer	Marks	Guidance
20	(a)	(i)	Straight symmetrical radial field lines and correct direction of field	B1	**Ignore** field lines inside the Earth
		(ii)	X and Y labelled which should be an equal distance away from the centre of the Earth	B1	**Note** Judge by eye **Allow** X and Y both on the surface of the Earth

	(b)*		**Level 3 (5–6 marks)** Clear description **and** correct calculations leading to value of total energy (must include the negative sign) *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 correct calculations **or** Correct calculations (including the negative sign) *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 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** • Orbit above the equator / equatorial orbit • Orbit from west to east/same direction of orbit as Earth's rotation • Orbital period is 24 hours / 1 (sidereal) day /23hrs 56mins (4 s) • Orbit is circular / above the same point on the Earth **Calculation** • $E = (-)\frac{GMm}{r}$ • $E = \frac{6.67\times10^{-11}\times5.97\times10^{24}\times2500}{4.22\times10^{7}}$ = (-) 2.4×10^{10} J • $v = \frac{2\pi r}{T} = \omega r$ • $v = \frac{2\pi\times4.22\times10^{7}}{24\times3600} = 3.07\times10^{3}$ m s^{-1} • $E = \frac{1}{2}mv^2$ • $E = \frac{1}{2}\times2500\times[3.07\times10^{3}]^2$ = 1.2×10^{10} J • Total energy = - 2.4×10^{10} + 1.2×10^{10} = - 1.2×10^{10} J • Allow full credit for algebraic proof using $\frac{GMm}{r^2} = \frac{mv^2}{r}$, $E = (-)\frac{GMm}{r}$, $E = \frac{1}{2}mv^2$ and total energy = KE + PE Allow higher order answers in terms of Lagrange's Identity
			Total	**8**	

Question			Answer	Marks	Guidance
21	(a)		$\omega^2 = k/m$ **or** 60/0.080 **or** $\omega^2 = 750$	C1	**Allow** correct algebraic expression for T
			$T = 2\pi/27.39$ **or** $T = 0.2295$ (s)	C1	**Allow** incorrect value for omega
			$t = ¼ \times 0.2295$	C1	**Allow** incorrect value of T
			$t = 0.057$ (s)	A1	
	(b)	(i)	$E = \frac{1}{2}kx^2$ **or** $E = mgh$ **or** $0.080 \times 9.81 \times 0.20$ **or** $\frac{1}{2} \times 60 \times x^2$	C1	
			$0.080 \times 9.81 \times 0.20 = \frac{1}{2} \times 60 \times x^2$	C1	
			$x = 0.072$ (m)	A1	
		(ii)1	Time of flight is independent of speed/AW	B1	
			Because distance of fall is the same **and** initial velocity vertically is zero / velocity is horizontal at **X**	B1	**Allow** algebraic answers that assume initial vertical velocity is zero/velocity is horizontal at X.
		(ii)2	*D* increases as speed at **X** increases because the time of flight is constant/AW	M1	
			D is directly proportional to speed at **X**	A1	**Allow** d = vt idea "*D* is directly proportional to speed at **X** because the time of flight is constant" scores 2.
			Total	11	

Question			Answer	Marks	Guidance
22	(a)	(i)	{$v = \omega r$ **and** $\omega = 2\pi f$} **or** $v = 2\pi fr$	B1	
			Comparison with $y = mx$ leading to gradient = $2\pi r$ **or** $\Delta v/\Delta f = 2\pi r$	B1	**Allow** $v/f = 2\pi r$
		(ii)	Line of best fit drawn	B1	
			Gradient = 62.5 (m)	M1	**Allow** ± 3
			$2\pi r = 62.5$	M1	**Allow** ECF on gradient
			r = 9.9 (m)	A0	
		(iii)	$F = \frac{mv^2}{r}$ **or** $F = ma$ **and** $a = \frac{v^2}{r}$	C1	
			$F = \frac{1.7 \times 10^{-27} \times [2.0 \times 10^7]^2}{9.9}$	C1	**Allow** use of candidate's answer for (ii) or use of '10'
			$F = 6.8 \times 10^{-14}$ (N)	A1	Expect answers of 6.8 or 6.9×10^{-14} (N)
	(b)		$r \propto v^2$ / speed increases by a factor of $\sqrt{2}$	C1	**Allow** substitution into correct equation with r doubled
			maximum speed = 2.8×10^7 (m s^{-1})	A1	**Allow** recalculation from previous value of force in (a)(iii)
			Total	10	

Question			Answer	Marks	Guidance
23	(a)		$g = \frac{G \times 6.31 \times 10^{30}}{(1.90 \times 10^{9})^2}$	C1	
			g = 117 (N kg^{-1})	C1	
			$2 \times \frac{0.14}{1.90} + \frac{0.42}{6.31}$ **or** 0.21 **or** 21%	C1	**Reject** 0.42/(0.14^2) = 21.4
			(absolute uncertainty =) 25 (N kg^{-1})	A1	**Note:** final answer of g = 117 ± 25 (N kg^{-1}) with no working scores all 4 marks. **Allow** correct identification of %(r) and %(m) for 1 mark max if no other marks scored. **Allow** alternate method using max/min values of m and r that give the correct absolute uncertainty (28)
	(b)	(i)	The (total radiant) power (of a star) /AW	B1	
		(ii)	($L = 4\pi r^2 \sigma T^4$)		
			ratio = $\sqrt{(\frac{6.92 \times 7500^4}{10.0 \times 4500^4})}$	C1	
			ratio = 2.3(1)	A1	**Allow** 1 mark for 5.3; square root omitted **Allow** 1 mark for 1:2.3 or 0.43
		(iii)	$\lambda_{(max)} \propto \frac{1}{T}$	B1	**Allow** word equation
			Lower temperature star will have the longest wavelength, so it is Aa2	B1	**Note** Must mention wavelength <u>and</u> temperature
		(iv)	From their (different) colours	B1	

		(v)	Any <u>three</u> from: • Continuous spectrum • Light / radiation / photons passes through cooler gas/star's atmosphere • Photon(s) absorbed by electron(s) • Electron(s) excited / jump / make transition to higher energy level(s) • Electron only promoted if energy of photon matches energy gap between two given levels • Photons remitted in different directions • (so) idea of contrast with non-absorbed wavelengths	**B1 × 3**	
	(c)		Any <u>two</u> from: • Black hole has smaller mass / radius / size • Black hole has higher density/gravitational field strength/ stronger gravitational field • black hole absorbs light / does not emit visible light • Has an escape velocity => c • No fusion in a black hole (ORA)	**B1** **B1**	**Allow** black hole emits Hawking radiation
			Total	**15**	

OCR (Oxford Cambridge and RSA Examinations)
The Triangle Building
Shaftesbury Road
Cambridge
CB2 8EA

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

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