GCE

Physics A

H556/01: Modelling physics

Advanced GCE

Mark Scheme for June 2019

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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.

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 answer.

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 answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can 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.

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

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 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

SECTION A

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

Question			Answer	Marks	Guidance
16	(a)		The **maximum** (tensile) **stress** a material can withstand (before it breaks)	**B1**	
	(b)	(i)	Use a micrometer / (Vernier) caliper Measure the diameter along its length in different directions (to ensure uniform cross-section) AW	**B1** **B1**	 **Allow** either along length or in different directions
		(ii)	**1.** Any value between 0 and 2.0 (kN) **2.** Any value between 2.0 and 2.2 (kN)	**B1** **B1**	
		(iii)	k = gradient $k = 5.0 \times 10^5$ (N m^{-1})	**C1** **A1**	 **Allow** 1 mark for 5.0×10^n; $n \neq 5$ **Allow** 5 x 10^5 (N m^{-1})
	(c)		(A =) $\pi \times 0.0021^2$ or 1.39×10^{-5} (m^2) (σ) = 2200 / $\pi \times 0.0021^2$ $\sigma = 1.6 \times 10^8$ (Pa)	**C1** **A1**	 **Allow** 1 marks for $4(.0) \times 10^7$; diameter used as radius Answer is 1.59 x 10^8 Pa to 3sf
	(d)		Greater area under the graph (from 3 mm to 4 mm) / greater **average** force from (3 mm to 4 mm) Mention of work done = **average** force × distance or work done = area under graph	**B1** **B1**	ORA **Allow:** labelled/annotated diagram **Allow** energy (transferred) instead of work done **Allow** 2 marks for arguments including reference to W = ½ kx^2 **and** constant k **and** greater average x
			Total	**11**	

Question			Answer	Marks	Guidance
17	(a)		Tangent drawn correctly by eye Attempt made to determine the gradient of tangent acceleration = 1.3 (m s^{-2})	B1 C1 A1	 **Allow** answer in range 1.2 to 1.4 (m s^{-2})
	(b)		F (= ma = 1.2 x 10^{-2} x 1.3) = 0.016 (N)	B1	Possible ECF from **(a)** (1.2 x 10^{-2} x their answer) **Note** answer to 3 SF is 0.0156 (N)
	(c)		W = 1.2 × 10^{-2} × 9.81 or 0.118 (N) 0.0156 = 0.118 – drag (Any subject) drag = 0.10 (N)	C1 C1 A1	Possible ECF from **(b)** **Allow:** use of 'g' for 9.81 **Allow** 0.1 (N)
	(d)	(i)	Drag is the same (at a certain velocity) weight is greater or <u>resultant</u> force is larger	B1 B1	**Allow** air resistance for drag
		(ii)	(TV requires) weight = drag **and** weight is greater Clear link to idea that greater speed gives greater drag (for same cross-sectional area)	B1 B1	
			Total	11	

Question			Answer	Marks	Guidance
18	(a)	(i)	$a = -\omega^2 x$ seen	B1	
			Suitable linking $a = -\omega^2 x$ and either $\omega = 2\pi f$ or $\omega = 2\pi/T$ with substitution	M1	e.g. $4\pi^2 f^2 = 78.3$ or $f = \sqrt{3.6/4\pi^2 \times 4.6 \times 10^{-2}}$ or $f = 8.85/2\pi$ or $T = 0.71\ldots$
			$f = 1.41$ (Hz)	A1	**Allow** f = 1.408… (Hz)
		(ii)	$A = \frac{x}{\cos \omega t}$ or $A = \frac{4.6\times10^{-2}}{\cos(2\times\pi\times1.4\times6.5)}$ (Any subject)	M1	**Not:** sine for cosine.
			$A = 0.057$ (m)	A1	**Note** $A = 0.090(4)$(m) if 1.41 used **Note** A = 0.0796 (m) if 1.408 used **Allow** 1 mark for cosine used with calculator in degrees

Question			Answer	Marks	Guidance
	(b)		EPE decreases (from bottom to top)	B1	**Not** EPE becomes 0 (or negative)
			GPE increases (from bottom to top)	B1	**Allow** for the first two marking points: description that refers to total potential energy starts at maximum, is minimum at equilibrium point and max again at top, provided total potential energy is stated to be the sum of EPE and GPE
			KE starts at zero, finishes at zero and max at equilibrium point.	B1	
			Air gains thermal energy / Total energy (of mass and spring) decreases over time	B1	**Allow** as alternative for first three marks: EPE to KE and GPE in bottom half EPE and KE to GPE in top half EPE at start to GPE at top
	(c)	(i)	(Smooth) curve showing amplitude increases and then decreases	B1	**Not:** more than 1 peak **Allow:** asymptote instead of peak
			maximum at 1.4 Hz by eye	B1	
		(ii)	Curve similar shape yet lower at all non-zero f points with peak shifted slightly to <u>left</u> (of 1.4 Hz)	B1	**Allow:** curve without shifted peak i.e. peak at 1.4 Hz ECF their K curve
		(iii)	Bridge close to <u>resonance</u> if frequency of driver is close to natural frequency of bridge	B1	**Allow:** footfall/people walking/wind for driver **Allow:** <u>resonance</u> (occurs) when frequency of driving force is at natural frequency of bridge
			(Close to resonance) giving larger amplitude which causes damage or other named consequence	B1	**Allow**: Maximum for larger
			Total	**14**	

Question			Answer	Marks	Guidance
19	a		18×0.5 or 9(.0) m	C1	
			$(a = \frac{v^2-u^2}{2s})$; (a =) $\frac{18^2}{2\times29}$ (Any subject)	C1	
			Deceleration = 5.6 (m s^{-2})	A1	**Allow** 1 mark max for 4.26 or 4.3; (38 m used instead of 29 m) **Allow** 1 mark max for 3.4 or 3.45; (47 m used instead of 29 m) **Ignore** minus sign

Question			Answer	Marks	Guidance
	b*		**Level 3 (5–6 marks)** Clear description of experiment **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 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 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, e.g. L2 for 4 marks, L2^ for 3 marks etc. **Indicative scientific points may include:** **Description** • Ruler used to determine *x* • Balance used to determine mass of marble • *x* recorded for various *v* • Average readings to determine *x* • Suitable instrument used to determine *v* (light-gate / motion sensor / video techniques) or suitable description of inference of v from other measurements such as energy released from spring of known *k* and *x*, double average speed • Suitable method for consistent *v* or varying *v* e.g. o Released from same point on a track or ramp o Ejected from a spring with different compressions **Analysis** • Plot a graph of *x* against v^2 or graph consistent with suggested relationship e.g. v^2 against *x*; *v* against $\sqrt{x}$; $\frac{1}{2} mv^2$ against *x* • If relationship is correct, then a **straight line** through the origin. • Determination of gradient • F determined by F = m/2 divided by (gradient of *x* against v^2 graph) or other relationship with F as the subject consistent with candidate's proposed graph.
			Total	**9**	

Question			Answer	Marks	Guidance
20	(a)		$F = \frac{\Delta mv}{\Delta t}$ or $F\Delta t = \Delta mv$ or (resultant force) = rate of change of momentum area under graph = Δ*mv* or Δ*p* or change in momentum or impulse	B1 B1	**Allow** *p* instead of *mv* **Allow***:* proportional for equals (rate of change of momentum)
	(b)		area under graph = 0.5 × 2.0 × 900 = 900 (N s) (*mU* = 900) *U* = 13 (m s^{-1})	C1 A1	**Not**: (initial force/mass)
	(c)		The graph showing a (smooth) **curve** of continuously/always decreasing magnitude of gradient (with respect to time). **Curve** starts at (0,*U*) and stops at (2.0,0)	M1 A1	**Note:** curve must not be asymptotic at either end of the curve.
			Total	6	

Question			Answer	Marks	Guidance
21	(a)		Section **AB** Any two from • Particles close together • Particle spacing increase with increasing time or increasing temperature • Particles in a fixed structure/(regular) lattice • Particles vibrate/perform SHM • Particles vibrate with increasing amplitude (from A to B) Section **CD** Any two from • Particles close together /(slightly) further apart (than in AB) • No regular structure /AW • Particles (are free to) move around / move past each other / flow • Particles move with increasing speed from C to D / greater KE	**B1 × 2** **B1 × 2**	**Not:** "vibrates more"
	(b)		$E = mc\Delta\theta$ (any subject) and gradient is larger for CD The specific heat capacity of the liquid is less than that of the solid.	**M1** **A1**	ORA **Allow:** $\Delta\theta$ is larger for liquid in the same time interval or same energy supplied for "gradient" **Allow** $c \propto$ gradient^{-1} **Not:** c = 1 / gradient
	(c)		The sum of the (random) kinetic and potential energy of atoms or molecules in a substance	**B1**	**Allow** 'particles'

Question			Answer	Marks	Guidance
	(d)	(i)	½ m c_{RMS}^2= 3/2 kT $c_{RMS}^2 = 3 \times 1.38 \times 10^{-23} \times 523 / 4.8 \times 10^{-26}$ (Any subject) root mean square speed = 670 (m s^{-1})	C1 C1 A1	**Allow** this mark even when T = 250 is used subsequently **Not** 250°C Allow $c^2 = 4.5 \times 10^5$ **Allow** 2 marks for 4.5×10^5; mean square speed calculated **Allow** 1 mark for 464; no conversion to kelvin.
		(ii)	(number of molecules =) $1.3 \times 6.02 \times 10^{23}$ or 7.83×10^{23} mean KE = $\frac{3}{2} \times 1.38 \times 10^{-23} \times 523$ or 1.08×10^{-20} total kinetic energy = 8.5×10^3 (J)	C1 C1 A1	**Not** 250°C **Allow** 8.4 x 10^3 for use of 670 m s^{-1} **Allow** full credit for use of total KE = 1.5nRT **Allow** full credit for use of E_k for one molecule = ½ m c_{RMS}^2 (which may include ECF for their c_{RMS} in (d)(i)) **Allow** 2 marks for 4.0(5…) x 10^3 (J) ; no conversion to kelvin.
			Total	**13**	

Question			Answer	Marks	Guidance
22	(a)		(torque =) 350×0.0050 torque = 1.8 (N m)	C0 A1	 Answer is 1.75 to 3 sf. **Allow:** 1.7 (N m)
	(b)		(Clockwise moments = anticlockwise moments) $7 \times 10^n \times F = 30 \times 10^n \times 31$ F = 130 (N) $(\text{mass} = \frac{F}{g})$ mass = 14 (kg)	C1 C1 A1	**Allow** any power of 10 for distance as long as unit consistent. **Allow** R = 164 (N) found by taking moments about flat head of screw/point A **Note** F to 3SF is 133 (N)
			Total	4	

Question			Answer	Marks	Guidance
23	(a)*		**Level 3 (5–6 marks)** Correct calculations for radius and temperature range or distance or intensity for Earth-like temperature within given distance range, with clear 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)** Radius calculated or at least one temperature of planet calculated and some 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)** Some explanation and an attempt at least one calculation. *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, e.g. L2 for 4 marks, L2^ for 3 marks etc. **Indicative scientific points may include:** **Explanation** • TRAPPIST-1 is cooler than the Sun • The planets are closer to TRAPPIST-1 • Possible for temperature on planets to be like Earth • For life to exist, temperature is not the only factor • $L = 4\pi r^2\sigma T^4$ (Any subject) **Calculations** • Calculation of 'constant' for Earth: $4(.19) \times 10^5$ • For inner-most planet, T = 430 K • For outer-most planet, T = 180 K • Calculation of distance for T = 290 K, i.e. 3.4×10^9 (m) • There must therefore be a planet with temperature similar to that of the Earth • $L = 4\pi r^2\sigma T^4$ used to calculate radius of TRAPPIST-1 • Radius of TRAPPIST-1 is 8.5×10^7 (m) **or** L/T^4 is smaller for TRAPPIST-1 • Comparison of calculated intensities at extreme distances around TRAPPIST-1 to intensity at Earth

Question			Answer	Marks	Guidance
	(b)	(i)	$T^2 = \frac{4\pi^2}{GM} r^3$	B1	
		(ii)	$86400^2 = (4\pi^2/6.0 \times 10^{24} \times 6.67 \times 10^{-11}) r^3$ (Any subject) radius = 4.23×10^7 (m)	C1 A1	
			Total	**9**	

Question			Answer	Marks	Guidance
24	(a)	(i)	distance between positions = 3.1 cm $2p$ = 3.1/2 (any subject) p = 0.78 arc seconds	M1 M1 A0	**Allow** distance in the range 2.9 to 3.2 cm
		(ii)	(d = 1 / p); d = 1 / 0.8) or 1.25 (pc) d =1.25 × 3.26 d = 4.1 (ly)	C1 A1	**Allow**: their value for p Possible ECF from **(a)(i)** Answer is 4.2 using 0.78 arc seconds
	(b)	(i)	$F = GMm/r^2$ $F = G \times (2.0 \times 10^{41})^2 / (1.4 \times 10^{23})^2$ force = 1.4×10^{26} (N)	 C1 A1	 **Note** the mark is for substitution, value of G is not required **Ignore:** minus sign **Allow** 1 mark for 1.4 x 10^4 N ;use of mass of star instead of mass of galaxy.
		(ii)	density = $10^{11} \times 2.0 \times 10^{30}/2.7 \times 10^{69}$ density = 7.4×10^{-29} (kg m^{-3})	M1 A0	
		(iii)	Any reasonable answers questioning model such as observed average distance may be different, average mass may be wrong etc.	B1	**e.g.** black holes, dark energy/matter, expanding universe
			Total	8	

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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Head office
Telephone: 01223 552552
Facsimile: 01223 552553