OCR
Oxford Cambridge and RSA

GCE

Physics A

Unit **H556/01:** Modelling physics

Advanced GCE

Mark Scheme for June 2018

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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.

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

SECTION B

Question			Answer	Marks	Guidance
16	(a)	(i)	vertical component =30.0 sin(70°) or 30.0 cos(20°) vertical component = 28.2 (m s^{-1})	 A1	 **Allow** 2 SF answer of 28
		(ii)	Evidence of $v^2 = u^2 + 2as$ and $v = 0$ or $gh = ½ u^2$ $h = \frac{28.2^2}{2\times9.81}$ (Any subject) h = 40.5 (m)	C1 M1 A0	**Allow** v and u interchanged; a and g interchanged **Allow** use of candidate's answer for (a)(i) at this point **Ignore** sign **Allow** $h = \frac{28^2}{2\times9.81}$ or (30 sin(70))^2/(2 x 9.81) **No ECF from (a)(i) for the second mark**
		(iii)	The ball has horizontal motion / velocity (AW)	B1	**Allow** idea of horizontal e.g. sideways, forwards **Not:** 'moving' unqualified
		(iv)	(horizontal velocity =) 30.0 cos 70° or 10.2…. (m s^{-1}) or 30.0 sin 20°. E_k = ½ × 0.057 × 10.26^2 E_k = 3.0 (J)	C1 A1	 **Allow** 1 SF answer **Not** 22 (J), v = 28 used **Not** 23 (J), v = 28.2 used **Not** 140 (J), v = 70 used

Question	Answer	Marks	Guidance

(b)*	**Level 3 (5–6 marks)**
	Clear description and 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.
	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 and limited analysis
	or 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 (NR) or no response worthy of credit (0).
		B1× 6	**Indicative scientific points may include:**
			Description
			• Ruler used to determine *x*
			• Average readings to determine *x*
			• *x* recorded for various *v*
			• Suitable method for consistent *v* or varying *v* e.g.
			  • Released from same point on a track
			  • Ejected from a spring device with different compressions
			• Suitable method of determining point of impact e.g.
			  • trial run to get eye in approximate correct position
			  • carbon paper so that ball makes a mark on paper
			  • scale in frame of video recording
			  • tray of sand to catch ball
			• 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*
			• Ensuring the initial velocity of ball is horizontal
			
			Analysis
			• Horizontal velocity is constant
			• Time of fall is independent of *v*/horizontal velocity
			• Suggested relationship: e.g. $x \propto v$,x d.p. to v^2, etc
			• Plot a graph of *x* against *v* or graph consistent with candidate's suggested relationship
			• If relationship is correct, then a **straight line** through the **origin**.
			• Suggested relationship supported by correct physics or algebra.
			• Correct relationship supported by physics.
			Note:
			L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded.

	Total	**12**	

Question			Answer	Marks	Guidance
17	(a)	(i)	Horizontal arrow pointing to the right.	B1	Judgement by eye
		(ii)	$2.14 \times 10^3 = \frac{2\times\pi\times9380\times10^3}{T}$ (Any subject) $T = 2.75 \times 10^4$ (s)	C1 A1	 **Allow** 2SF answer **Note**: 2.75… x 10^n scores 1 mark.
		(iii)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ or $v^2 = \frac{GM}{r}$ $(2.14 \times 10^3)^2 = 6.67 \times 10^{-11} \times M/9380 \times 10^3$ $M = 6.44 \times 10^{23}$ (kg)	C1 C1 A1	 **Allow** ecf of answer for T from (a)(ii) **Allow** 2 SF answer **Note:** Use of 2.8 x 10^4 seconds gives 6.3 x 10^{23} (kg) for 3 marks. **Alternative Method for C1C1** • $M = 4\pi^2R^3/(T^2G)$ (Databook formula re-arranged with M as subject) • $M = 4\pi^2(9380 \times 10^3)^3/((2.75 \times 10^4)^2 \times 6.67 \times 10^{-11})$ (i.e. *M* as subject) **Note:** In alternative method, PoT error forgetting km->m conversion gives 6.46 x 10^{14} (kg) for 2 marks.
	(b)	(i)	- 0.060 and 3.85 (Both to 2 sf after the decimal point)	B1	**Allow -** 0.06 or -0.0605 (the minus sign is required) **Not: 0.06** **Allow:** 3.845(1) **Note:** Use of ln gives -0.14 and 8.854 for 0 marks.

Question			Answer	Marks	Guidance
		(ii)1	Missing data point plotted to ± half small square consistent with candidate's value. Straight best fit line drawn	B1 B1	**Allow** ECF from (b)(i) **Allow** ECF for incorrectly plotted point or data point from **(i)** omitted
		(ii)2	(Triangle used to determine gradient and) gradient calculation is shown to be within range -1.90 to -2.20	B1	
		(ii)3	lg(g) = lg(GM) – 2lg(r) or lg(g) = – 2lg(r) + lg(GM) seen **Compared** with $y = mx + c$, and hence gradient = - 2	M1 A1	**Allow:** incorrect handling of negative g.
	(c)	(i)	Any <u>two</u> from: • Direction of g for Earth and Mars are in opposite directions • For small values of r / r < about 4.4 ($\times 10^{10}$ m) g for Earth is greater or resultant g is towards the Earth • At r about 4.4 ($\times 10^{10}$ m) the g values are the same/AW • Inverse square law for g for either planet causes curve near to either planet's surface/AW • Zero point for (resultant) g is further from the Earth (than the midpoint) since Earth has a larger mass than Mars • g at Earth's surface is larger than g at surface of Mars because Earth has a larger mass than Mars	B1×2	**Allow** field / (gravitational) force for g **Allow** for r values larger than 4.4 (x 10^{10} m) g for Mars is greater or resultant g is towards Mars

Question			Answer	Marks	Guidance
		(ii)	Any valid equation relating g_{Earth} and g_{Mars} e.g. $GM_{Earth}/r_E^2 = GM_{Mars}/r_M^2$	C1	
			ratio <u>consistent</u> with values above	A1	**Note:** the correct ratio is in the range 8.2 to 12 allowing for values of r of 4.4 ± 0.1 ($\times 10^{10}$ m) when $g = 0$
			Total	**16**	

Question			Answer	Marks	Guidance
18	(a)		$1.2 \times 10^6 = ½ \times$ (mass per second) $\times 8.0^2$ mass per s = 3.8×10^4 (kg s^{-1})	C1 A1	 Answer is 3.75×10^4 (kg s^{-1}) to 3sf **Note:** 3.8×10^n (kg s^{-1}) scores 1 for PoT error.
	(b)	(i)	$A \rightarrow$ m^2 and $\rho \rightarrow$ kg m^{-3} $P \rightarrow$ kg m^2 s^{-3} Clear working to show units are equivalent on either side of equation	M1 M1 A1	**Note**: No mark for $v \rightarrow$ m s^{-1} since units are in **(a)** **Allow** $P \rightarrow$ kg m s^{-2} m s^{-1} (from $P = Fv$ or P=Work done/t) **Note:** clear working includes m^3s^{-3} seen.
		(ii)	$1.2 \times 10^6 = ½ \times 1.3 \times A \times 8.0^3$ or $A = 3600$ (m^2) seen L = 34 (m)	C1 A1	**Allow** volume s^{-1} = 28846 (m^3) using 3.75×10^4 (kg s^{-1}) or 29231 (m^3) using 3.8×10^4 (kg s^{-1}) **Allow** ECF from (a) **Note:** 3.4×10^n (m) scores 1 for PoT error.
		(iii)	(output power =) 0.42×1.2 / 0.504 (MW) (N = 50/0.504 = 99.2) N = 100	C1 A1	**Allow:** 50×10^6 / 0.42 = 119 MW and then 119 / 1.2 **Not** 99 **Note**: answer of 99.2 scores 1 mark max
			Total	9	

Question			Answer	Marks	Guidance
19	(a)		**A** = white dwarf and **B** = red giant	**B1**	**Allow:** red supergiant for B **Not:** neutron star for A
	(b)	(i)	(λT = constant) $550 \times 5800 = 370 \times T$ T = 8600 (K)	 **C1** **A1**	 **Allow** however expressed Answer is 8620 to 3 sf
		(ii)	**P** on the main sequence and to LEFT of Sun.	**B1**	**Allow:** ECF from **(b)(i)** **Note:** temperature of Sun is 5800 K.
			Total	**4**	

Question			Answer	Marks	Guidance
20	(a)		$E_k = ½ mv^2$ and $p = mv$ (Correct manipulation leading to) $E_k = ½ p^2/m$	M1 A1	**Allow:** any subject **Allow:** $E_k = p^2/(2m)$
	(b)	(i)	From $t = 0$ to $t = 2.0$ s: a non-zero horizontal line From $t = 2.0$ to $t = 3.5$ s: line showing $v = 0$ From $t = 3.5$ to $t = 4.0$ s: non-zero horizontal line showing v is opposite in direction and magnitude larger than that of line drawn at $t = 0$ to $t = 2.0$.	B1 B1 B1	 Judgement by eye
		(ii)	KE is constant. GPE increases linearly / proportional to t	B1 B1	 **Allow**: 'at constant rate' for 'linear' **Not:** unqualified 'constantly'
		(iii)1	$V^2 = 0.80^2 + 2 \times 9.81 \times 0.40$ $V = 2.9$ (m s^{-1})	C1 A1	 **Allow** 1 mark for $(2 \times 9.81 \times 0.40)^{1/2} = 2.8$ (m s^{-1})
		(iii)2	$F = 0.12 \times 2.9/0.025$ $F = 14$ (N)	C1 A1	 Possible ECF from **(iii)1** **Note:** use of 2.8 m s^{-1} gives F = 13(.44 N) **Note:** 1.4 x 10^n (N) scores 1 mark
			Total	11	

Question			Answer	Marks	Guidance
21	(a)		Both forces act on the same object (AW) The types of forces are different / one force is gravitational and the other force is electrostatic	B1 B1	 **Allow:** one force is gravitational (and the other is not)
	(b)		T = 60/1600 or $T = 3.75 \times 10^{-2}$ (s) ($v = \pi \times 0.50/3.75 \times 10^{-2}$) speed = 42 (m s^{-1}) uncertainty = 3 (m s^{-1})	C1 A1 A1	**Allow:** f = 26.7 or $\frac{1600}{60}$ (Hz) or ω = 168 (s^{-1}) **Note:** v must be to 2 or more SF **Note:** uncertainty must be to 1 SF **Allow:** ecf on candidate's value for speed i.e. uncertainty = candidate's value / 16 (to 1 SF) **Allow for 2 marks max: 84 ± 5 (m s^{-1})**
	(c)		$mv^2/r = mg$ or $v^2/r = g$ $v^2 = 9.81 \times 0.25$ v = 1.6 (m s^{-1})	C1 C1 A1	**Allow:** $v^2/r = a$ and $a = g$ or $mv^2/r = ma$ and $a=g$ **Allow:** any subject **Allow:** any subject **Note:** qualified 2.21 (ms^{-1}) scores 2 marks.
			Total	**8**	

Question			Answer	Marks	Guidance
22	(a)	(i)	KE is conserved (as well as momentum)	B1	**Allow:** No KE lost
		(ii)	Attempt at conservation of momentum in x- or y- direction	C1	**Allow** confusion of sin and cos at this stage **Allow** attempt at conservation of KE
			Correct expression of conservation of momentum in x- or y-direction / correct determination for velocity of Y of 55(3) m s^{-1}	C1	**Allow** any subject e.g. p cos(25°) + m x 258cos(65°) = m x 610 or p sin(25°) = m x 258sin(65°) or $(p)^2 + (m \times 258)^2 = (m \times 610)^2$ or ½ mv^2 + ½ m $(258)^2$ = ½ m$(610)^2$
			$p = 3.7 \times 10^{-24}$ (kg m s^{-1})	A1	Answer is 3.67 x 10^{-24} (kg m s^{-1}) to 3 sf

Question	Answer	Marks	Guidance
(b)*	**Level 3 (5–6 marks)** Clear explanation and correct calculation. *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 explanation and limited calculation, or limited explanation and correct calculation. *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 explanation and missing or incomplete 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 (NR) or no response worthy of credit (0).	B1x6	**Indicative scientific points may include:** **Explanation** • At a certain temperature all atoms have the same <u>average</u> kinetic energy • Helium behaves as an ideal gas • $E_K = \frac{3}{2}kT$ • Mean / r.m.s speed of atoms is less than the escape velocity • Atoms have range of speeds / velocity or mention of Maxwell-Boltzmann distribution • Faster atoms have escaped the Earth (over long period of time) • Earth was significantly hotter in the (ancient) past **Calculation** • T = 283 K • $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ • $c_{r.m.s.} = \sqrt{\frac{3kT}{m}}$ • $c_{r.m.s.}$ = 1.3 km s^{-1}
	Total	**10**	

Question			Answer	Marks	Guidance
23	(a)		Uniform distribution of matter (everywhere in the Universe)	B1	**Allow:** density of Universe (approximately) constant throughout **Not:** references/idea of isotropic/"looks the same in all directions"
	(b)	(i)	$v = 68 \times 200 = 13600$ (km s^{-1}) or 13.6×10^6 m s^{-1} $(\Delta\lambda = \frac{v}{c} \times \lambda)$ (change in λ =) $13600 \times 10^3 \times 280/3.00 \times 10^8$ or 13 (nm) or 13×10^{-9} (m) ($\lambda = 280 + 13$) $\lambda = 290$ (nm)	C1 C1 A1	**Allow:** Any correct velocity if unit matches. **Allow:** ECF for incorrect v **Answer to 3 sf is 293 (nm)** **Allow:** ECF for incorrect $\Delta\lambda$
		(ii)	Any suitable <u>one</u> from: • Very/infinitely dense • Idea that escape velocity $\geq$ c or 'light cannot escape it'	B1	**Allow:** singularity **Allow:** physical radius ≤ event horizon radius **Allow:** Distorts space(time) **significantly** / bends light **significantly** **Allow:** Emits Hawking radiation
	(c)		Any three from: 1. At the Big Bang the Universe is a singularity / very dense / very hot 2. Expansion / inflation / high energy (gamma) photons but no matter 3. Quarks and leptons form / Quark-Gluon Plasma phase 4. Quarks combine to form neutrons / protons / hadrons 5. **Hadrons / neutrons <u>and</u> protons / nucleons combine** to make nuclei All candidate's points in the correct sequence	M1x3 A1	**Allow for point 1:** fundamental forces unified **Ignore:** Any phase after nuclei phase e.g. recombination era /formation of atoms/formation of CMBR
			Total	9	

Question			Answer	Marks	Guidance
24	(a)		y = sin (θ) $\sqrt{x^2+y^2}$ compared with "y=mx+c"	B1	**Allow:** gradient = $\frac{\Delta y}{\Delta(\sqrt{x^2+y^2})}$ with sin (θ) = O/H **Not:** gradient = $\frac{y}{(\sqrt{x^2+y^2})}$ **unless** "c=0" seen.
	(b)	(i)	(Straight line of best fit showing) gradient = 0.73 ($d\sin\theta = n\lambda$) $\frac{1.0\times10^{-3}}{600}\times 0.73 = 2\times\lambda$ $\lambda = 6.1\times10^{-7}$ (m)	C1 C1 A1	**Allow:** gradient in range 0.70-0.76. **Allow:** evaluation of θ = 44-50 (degrees) in place of gradient **Allow:** any subject **Note**: Gradient in range 0.70-0.76 gives λ in range (5.8 - 6.4) × 10^{-7} m
		(ii)	(Scales/distances are large compared with the absolute uncertainty so) **absolute uncertainty is too small** to be shown (reasonably on this graph's scale) (AW)	B1	**Ignore**: **error** too small
		(iii)	(The values for λ or θ will be) less precise (as independent measurements less likely to agree) (AW)	B1	
			Total	6	

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

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Head office
Telephone: 01223 552552
Facsimile: 01223 552553