OCR
Oxford Cambridge and RSA

GCE

Physics B

Unit **H557A/01:** Fundamentals of 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.

LoR annotations required

A level annotation should be used where all marks for a level have been achieved e.g. a candidate has 6 marks, so they would have this annotation on their script:

If a candidate has achieved 5 marks then they have reached Level 3 but with one mark omitted. They should have the following annotations on their scripts:

The same principle should be applied to Level 2 and Level 1.
No marks (0) should have a cross.

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.

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.

The scoris **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 scoris messaging system, or e-mail.

Assistant Examiners will send a brief report on the performance of candidates to your Team Leader (Supervisor) by the end of the marking period. The Assistant Examiner's Report Form (AERF) can be found on the RM Cambridge Assessment Support Portal (and for traditional marking it is in the *Instructions for Examiners*). Your report should contain notes on particular strength displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

Annotations available in Scoris

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response
AE	Arithmetic error
	Wrong physics or equation

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
(1)	Separates marking points
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
(1)m	a method mark, awarded if a correct method is used
(1)e	an evaluation mark, awarded for correct substitution and evaluation

Section A: MCQs

Question			Answer	Marks	Guidance
1			D	1	
2			A	1	
3			D	1	
4			C	1	
5			B	1	
6			B	1	
7			A	1	
8			A	1	
9			A	1	
10			A	1	
11			C	1	
12			B	1	
13			D	1	
14			A	1	
15			C	1	
16			B	1	
17			B	1	
18			A	1	
19			B	1	
20			C	1	
21			C	1	
22			D	1	
23			D	1	
24			B	1	
25			C	1	
26			B	1	
27			D	1	
28			A	1	
29			C	1	
30			C	1	
			Total	30	

Section B

Question			Answer	Marks	Guidance
31	(a)		(power = 1/*f*) = 1/*v* – 1/*u* ✓	L	rearrangement **accept** real is + sign convention i.e. **all** signs positive
			= 1/1.5 – 1/-0.03 ✓	M	substitution with correct sign / all + ve signs
			= 34 (D) ✓	M	evaluation **not** -32.7 (D) / 32.7 (D) / -34 (D)
31	(b)		(*M* = *v*/*u* = 1.5 / 0.03) = 50 ✓	L	**accept** - 50
			Total	4	

Question			Answer	Marks	Guidance
32	(a)		time = file size / rate OR = $1.2 \times 10^9 \times 8 / 24 \times 10^6$ ✓	L	method in words / numbers **accept** 8 bits per byte missed **accept** calculation in bytes and bytes/s
			= 400 s > 360 s OR 400 s > 6 min OR 6.7 min OR 6 min 40 s ✓	L	evaluation **must** compare answers in secs to 6 minutes **accept** 6.6 s with / without recurring sign **accept** 6.8 s from using computer k = 1024
32	(b)		8 (kHz) ✓	M	**accept** labelled diagrams showing waveform being sampled twice per wave / to avoid aliasing
			because there must be at least 2 samples per cycle (to pick up any variation) ✓	M	**not** because of Nyquist theorem / sampling f must be twice highest signal f / due to information loss
			Total	4	

Question			Answer		Marks	Guidance
33	(a)		$^{210}_{84}Po + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ ✓ ✓		L L	
33	(b)		to conserve lepton number	✓	L	**accept** Po lepton number 0 electron is +1 antineutrino is -1 **accept** to conserve mass energy **accept** balance as alternative wording for conserve **not** antineutrino takes away energy
			Total		3	

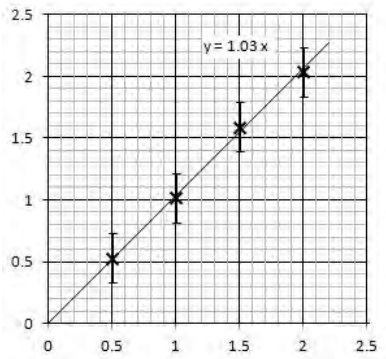
Question			Answer		Marks	Guidance
34	(a)		$I = \Sigma\varepsilon / \Sigma R$ = {12 – 9.0} / {17.7}	✓	L	**allow** first mark for recognition that 3 V drives the current OR for total resistance = 17.7 Ω
			= 0.17 (A) OR 0.169 (A)	✓	M	
34	(b)		$t = Q / I$ = 0.50 x 3600 / 0.12	✓	L	**beware** 500 x10^{-3} / 0.12 = 4.17 is nonsense (ratio of two currents) so 0/2 marks
			= 1.5 x 10^4 s = 4.2 (hours)	✓	L	**accept** 4.17 (hours) from correct method
			Total		4	

Question			Answer	Marks	Guidance
35	(a)		electron forms a standing wave of integer numbers of $\lambda/2$ loops ✓	M	**accept** λ is quantised in $\lambda/2$ loops of standing wave **ignore** mention of harmonics
			λ determines (mv and hence kinetic) energy ✓	M	**accept** k.e. = $h^2 / 2m\lambda^2$ **not** E = hc / λ
35	(b)		three ✓	L	
35	(c)		max photon energy $\Delta E = E_3 - E_1$ ✓	S&C	**accept** if substituted into numbers select correct levels 3 and 1 OR $\Delta E = (5.4 - 0.60) \times 10^{-17}$ (J)
			$h^2 / \{2m[2d / 3]^2]\} - h^2 / \{2m[2d]^2\} = hf$ OR 4.8×10^{-17} (J) ✓	S&C	method **accept** alternative levels of highest level and 0 energy if λ correctly substituted gives 5.4×10^{-17} J **OR** $(8.1 \text{ OR } 8.2) \times 10^{16}$ Hz for **1 mark max**
			$f = 7.3 \times 10^{16}$ (Hz) ✓	S&C	evaluation $f = h\{^9/_8 - ^1/_8\} / [md^2] = 6.6 \times 10^{-34} / \{9.1 \times 10^{-31} \times [10^{-10}]^2\}$ $= 7.3 \times 10^{16}$ (Hz)
			Total	6	
			Total section B	22	

Section C

Question			Answer	Marks	Guidance
36	(a)	(i)	Graph shows proportional relationship (between recession velocity and distance) ✓	L	**allow** shows straight line through the origin / $v = H_o d$ **not** just graph is a straight / statement "this is Hubble's Law" / just shows correlation / + correlation
			If galactic recession is played back in time then earlier on galaxies were closer, at the big bang / origin all matter was at same location and rushing out wards ✓	L	
36	(a)	(ii)	Graph shows background radiation is in the microwave region / (peak) wavelength around 1mm ✓	M	**accept** is thermal / black body radiation
			Radiation earlier (at big bang) was hotter / shorter λ / higher f / X-ray or γ-ray AND λ has been stretched by the expansion of space (since big bang so that today CMBR is colder) / longer λ ✓	M	**accept** … AND (λ stretched by cosmological) redshift of photons
36	(b)		λ_{peak} = 1 mm read from graph ✓	M	**accept** in range (0.9 to 1.1) mm
			$f = 3 \times 10^8 / 1 \times 10^{-3} = 3 \times 10^{11}$ (Hz) ✓	M	**accept** in range (2.7 to 3.3) x 10^{11} (Hz) **accept** $E = h f = 1.98 \times 10^{-22}$ J
			$T \approx hf / 5k \approx 6.6(3) \times 10^{-34} \times 3 \times 10^{11} / \{5 \times 1.4 \times 10^{-23}\}$ ✓	H	
			$\approx$ 2.8 (K) ✓	H	**allow** $k = 1.38 \times 10^{-23}$ gives 2.8(9) or 2.9 K for last 2 marks **accept** in range (2.5 to 3.2) (K)
			Total	8	

Question			Answer		Marks	Guidance
37	(a)	(i)	p has kg m s^{-1} = E/c has kg m^2 s^{-2} / {m s^{-1}}	✓	L	**allow** cancellation as implicit **allow** use of J for unit of energy leading to Ns for momentum **accept** algebra that mixes units and symbols
37		(ii)	T = rate of change of momentum OR = $\Delta p / \Delta t$	✓	L	**allow** introduction of x 2 at appropriate stage **not** P = Fv
			factor x 2 because mv - { - mv} = 2 mv	✓	M	**accept** momentum is reversed **no credit** for just x 2 with no explanation
			T = 2 n Δ{E/c} /Δt = 2 n ΔE/cΔt = 2 P / c	✓	M	**must** include n number of photons (m^{-2} s^{-1}) in calculation for third mark
37		(iii)	a = T x A /m = 2 P x A / mc OR			**accept** in algebra or numbers
			= 2 x 1400 x 10^6 / {10^3 x 3 x 10^8}	✓	M	
			= 9.3 x 10^{-3} m s^{-2}	✓	M	**accept** 9.3 mm s^{-2}
37	(b)	(i)	k.e. gained = e.p.e. lost OR ½ m v^2 = Q V	✓	L	energy conservation in words / algebra
			{mv}^{2} = 2 m Q V → mv / m = √{ 2 VQ /m}			**allow** momentum per unit mass = velocity and subsequent derivation of v
			OR mv / m = √{ 2 m V Q /m^2 } → v = √{ 2 VQ /m}	✓	H	
		(ii)	H^+ has highest Q / m	✓	S&C	**ignore** Xe^+ is safer / energy to lift mass of H from Earth
			so best momentum transfer / larger p/m	✓	S&C	**expect** momentum comment
		(iii)	T = $\Delta p / \Delta t$ = $\Delta p / \Delta m$ x $\Delta m / \Delta t$ OR			
			$\Delta m / \Delta t$ = T / {$\Delta p / \Delta m$} = 0.24 / √{2 x 2000 x 9.6 x 10^7}	✓	S & C	No credit for only working out velocity of ions
			= 3.87 x 10^{-7} kg s^{-1} (< 4 x 10^{-7} kg s^{-1})	✓	S & C	
			Total		12	

Question			Answer	Marks	Guidance
38	(a)		% uncertainties in *L* << % uncertainties in *y* ✓ ORA	L	**accept** % uncertainties in *L* are negligible on this scale **accept** estimates e.g. 1 in 1000 mm << ½ in 2 mm **expect** percentage / relative / estimated uncertainties **not** just uncertainty is less **ignore** comments on *d*
38	(b)		best fit line **expect** through the origin but **accept** lines starting at (0.5,0.5) ✓ **accept** intercepts up to +2 squares on y-axis or +1 square on x-axis gradient of best fit line = (2.25 x 10^{-3} / 2.2) = 1.0 x 10^{-3} ✓ **accept** in range {0.9 to 1.2} x 10^{-3} (round their values to 1dp) penalise POT error on gradient **accept** y/x for proportional graphs **expect** evidence of Δy/Δx for graphs not through (0,0) uncertainty by graph of max **OR** min gradient or by ±% ✓ (max gradient = 1.2 x 10^{-3} , min gradient = 0.7 x 10^{-3}) **accept** in range ± {0.10 to 0.5} x 10^{-3} / ± {10 to 50}%	L M H	 **accept** ecf on POT error on gradient i.e. missing x 10^{-3} can still score uncertainty mark e.g. 1 ± 0.2 **allow** a little pessimism comparing to max or min gradients through data

Question			Answer	Marks	Guidance
38	(c)		$\lambda = d$ x grad = 0.50 x 10^{-3} x 1.03 x 10^{-3} = 5.(2) x 10^{-7} (m) ✓ **accept** values in the range 450 to 600 nm and consistent with their gradient from (b)	M	**allow** ecf on gradient value from **(ii)** **accept** 515 nm **accept** use of $\lambda = d$ x sin θ (with n = 1) **accept** ecf grad ± % from **(ii)**
			relative uncertainty in d expressed as ± 20% / ± 0.2 ✓	H	**accept** absolute uncertainty in d is 0.1 mm if used in max/min calculation of λ
			evaluation combining uncertainties from grad and d to get overall uncertainty. Credit values in range of {± 30% to ± 70% } of their λ estimate		large pessimistic % due to uncertainty in grad up to ± 50% **ignore** method of combining large % uncertainties (several methods are used ours include extreme limits)
			overall uncertainty in range ± 150 nm to 360 nm ✓	H	so 5.2 ± {1.5 to 3.6} x 10^{-7} (m)
38	(d)		**refine design**: use travelling microscope to measure d or y or both more precisely ✓ **OR refine procedure**: repeat measurements (to improve cluster and improve precision)	L	**accept** other sensible improvements in apparatus e.g. increase L so y is larger **OR** measure a larger number of fringes / increase d to see more fringes / decrease d to increase fringe separation (changing d needs justification for credit) **not** just measure d or y more precisely OR make y larger **accept** use of tube to exclude background light / use of brighter lamp / use of collimator round lamp to improve fringe contrast
			Total	8	

Question			Answer	Marks	Guidance
39	(a)		**This is LoR not tick-based marking – see page 4 of this mark scheme.** **Level 3 (5–6 marks)** Includes clear explanation of both strands: • random motion • explaining *PV* = constant (*T* constant) *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)** Covers both strands using a range of relevant physics ideas. *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)** Covers at least two physics ideas (possibly from only one strand), that are relevant to the argument. *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	6	**accept labelled diagrams or graphs throughout.** **Indicative physics may include:** **Strand 1: random path motion: not** any credit for mentioning random walk but for illustrations of the idea • particles have a spread of speeds / Maxwell-Boltzmann distribution of speeds • particles bounce off each other at all possible angles in 3-dimensions • particles transfer momentum during collisions exerting forces on each other / surrounding surfaces • many tiny chaotic collisions per unit time set up a steady pressure within the gas / on surrounding surfaces • particles move in straight paths between collisions • paths vary in length between collision / spread of free path lengths / there is a mean free path • paths vary in angle at collision in 3-d / all angles are possible but occur by the chance approach of colliding particle / displacement $\propto \sqrt{}$ no.steps • (random) change of velocity in magnitude or direction at each collision • labelled diagram of random walk **Strand 2: explaining $P \propto 1/V$ (T constant)** • constant *T* means constant average energy and average momentum change per particle • *P* due to collisions with walls of container • $P \propto$ no. collisions s^{-1} x Δp per collision $\propto N/V$ **OR** if *V* is x ½ , then N/V is x 2 and *P* is x 2 **OR** if *N* is x 2, then N/V is x 2 and *P* is x 2

Question			Answer	Marks	Guidance
39	(b)	(i)	$\{ ½ m \overline{c^2}\}_{Xe} = \{ ½ m \overline{c^2}\}_{H2}$ ✓	M	method or justification **accept** equipartition of energy OR average k.e of two species of molecules is equal OR
			$\sqrt{\{ \overline{c^2}_{H2} / \overline{c^2}_{Xe} = \sqrt{\{m_{Xe} / m_{H2}\}}}$ ✓	M	$c_{r.m.s.}$ is speed of molecule with average kinetic energy **not** just $\sqrt{\{m_{Xe} / m_{H2}\}}$ OR $\sqrt{\{132 / 2\}}$
			$= \sqrt{66} / 8.1(2)$ ✓	M	evaluation
39	(b)	(ii)	number $= N_A \times e^{-E/kT}$ ✓	H	method **accept** {Boltzmann factor expressed in recognisable algebra / numbers} x Avogadro's number
			where $E = ½ m_{H2} v_{Escape}^2$ / 2.1×10^{-19} J ✓	H	E of H molecule part evaluation **accept** $m_{H2} = 2 \times m_p$
			Boltzmann exponent = E/kT = $½ \times 2 \times 10^{-3} \times [11.2 \times 10^3]^2 / [6 \times 10^{23} \times 1.4 \times 10^{-23} \times 288] = 51.8$ ✓	S&C	or accept BF calculated at 3.2×10^{-23}
			number $= N_A \times e^{-E/kT} = 6 \times 10^{23} \times e^{-51.8} = 19$ (mole^{-1}) ✓	S & C	correct evaluation scores full marks ignore fractions of molecules **accept** range between 8 and 52 (mole^{-1}) - extra sf in data book can give a large range of number of molecules since the answer is very sensitive to the value in the exponent
			Total	13	

Question			Answer	Marks	Guidance
40	(a)		best fit straight line drawn to intercept the current axis ✓	L	**must** be sensible l.o.b.f. expect line to miss some uncertainty bars (intercept may be off top of the y-axis)
			giving intercept from graph current = 9.7 A ✓	M	**expect** in range 9.5 to 9.9 A but **allow** ecf from their graph
			$R_{ARMATURE}$ = 12.0 / 9.7 = 1.2(4) (Ω) ✓	M	**FT allow** ecf 12 / current value correctly evaluated **accept** in range 1.2 to 1.3 (Ω)
40	(b)		**This is LoR not tick-based marking – see page 4 of this mark scheme.** **Level 3 (5–6 marks)** Includes clear explanation of both strands: • explaining action of self-regulating d.c. motor • induced e.m.f. and laws of Faraday and Lenz Explanations can be simple and non-algebraic and gain the highest level *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)** Covers both strands using a range of relevant physics ideas *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.*	6	**accept labelled diagrams or graphs throughout.** **Indicative physics may include:** **Strand 1: self-regulating d.c. motor** a simple answer based on information in the stem and graph should allow access to Level 3 • when motor connected to supply coil rotates at high f drawing a small current • as motor is mechanically loaded it slows drawing more current into coil • motor can now work harder • induced ε from coil cutting flux opposes V supply • $\varepsilon \propto$ frequency of rotation OR $\varepsilon \propto$ cutting of flux OR $\varepsilon \propto -N\Delta\Phi/\Delta t$ explained • the opposing e.m.f . limits current drawn into coil • until the current supplies the torque required by the mechanical load then motor reaches constant rate of rotation

Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) Covers at least two physics ideas (possibly from only one strand), that are relevant to the argument. *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		self-regulation aspects are essential for highest level award but some credit can be given for explanation of d.c. motor (but not essential): • $F = B I L$ force acts on each current at 90° to flux • F mutually perpendicular to B and I • exerts a couple / torque on armature coil / cause spin • electrical energy does work / produces kinetic energy **Strand 2: induced e.m.f. and laws of Faraday and Lenz** • $\varepsilon \propto$ rate of cutting of flux OR $\varepsilon = - N \Delta\Phi / \Delta t$ OR $\varepsilon = - \Delta N \Phi / \Delta t$ rate of change of flux linkage where $\Phi = B A$ explained • - ve sign indicates that induced e.m.f. opposes the change which is causing it Lenz's Law • being clear and consistent about d(flux) /dt OR d(flux linkage) /dt discussion of Faraday and Lenz appears in both strands. If the candidate uses these ideas to explain self-regulation (e.g. opposes, explains –ve sign, current adjusts until…, load applied determines current drawn, back emf) then they have covered both strands, allowing access to up to L3.
			Total	**9**	

Question			Answer	Marks	Guidance
41	(a)	i	Field at point X from one proton is equal and opposite to that from the other proton AW ✓	L	**accept** Force per unit / test charge at point X ..... **not** just fields cancel
41	(a)	ii	Potential = 2 x ($9 \times 10^9 \times 1.6 \times 10^{-19}$)/$0.5 \times 10^{-9}$ ✓	L	
			= 5.8 (V) ✓	M	**accept** 5.7 if 8.98×10^9 used for *k* **allow** 2.9 (V) for for MAX 1 (missing x2)
41	(b)	i	Force on third proton due to one other in triangle = ($9 \times 10^9 \times (1.6 \times 10^{-19})^2$)/$(1 \times 10^{-9})^2$ ✓	M	Look for final answer and if not correct work through scheme to credit each marking point achieved.
			= 2.3×10^{-10}N ✓	M	
			horizontal components will cancel (can show on diagram) ✓	H	**accept** shown by vector addition triangle or use of cos 30° or sin 60°
			sum of vertical components = $2 \times 2.3 \times 10^{-10}$ x sin 60° = 3.98×10^{-10} (N) ✓	H	**accept** use of cos 30° **accept** 4.0×10^{-10} (N) in this instance
41	(b)	ii	Force = 3.98×10^{-10} N x $(1 \times 10^{-9})^2/(1 \times 10^{-15})^2$ ✓	H	**accept** 4.0×10^{-10} (N) or ecf from b(i) **accept** force scaled up x $\{10^{-9} / 10^{-15}\}^2$ $=10^{12}$
			= 398 (N) ✓	S&C	**accept** 400 (N)
			Total	9	
			Total section C	58	
			Total sections B & C	80	

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