

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.

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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:

L3

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:

L3 

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
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response
	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)		${}_{84}^{210}\text{Po} + {}_{-1}^0\text{e} + {}_0^0\bar{\nu}$	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)		$I = \Sigma \varepsilon / \Sigma R = \{12 - 9.0\} / \{17.7\}$ ✓ $= 0.17 \text{ (A)} \text{ OR } 0.169 \text{ (A)}$ ✓	L M	allow first mark for recognition that 3 V drives the current OR for total resistance = 17.7 Ω
34	(b)		$t = Q / I = 0.50 \times 3600 / 0.12$ ✓ $= 1.5 \times 10^4 \text{ s} = 4.2 \text{ (hours)}$ ✓	L L	beware $500 \times 10^{-3} / 0.12 = 4.17$ is nonsense (ratio of two currents) so 0/2 marks accept 4.17 (hours) from correct method
			Total	4	

Question			Answer	Marks	Guidance
35	(a)		electron forms a <u>standing wave</u> of <u>integer</u> numbers of $\lambda/2$ <u>loops</u> ✓	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 $E = hc / \lambda$
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 Total section B	6 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 / $v = H_0 d$ 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 accept ... AND (λ stretched by cosmological) redshift of photons
			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	
36	(b)		$\lambda_{\text{peak}} = 1 \text{ mm}$ read from graph ✓	M	accept in range (0.9 to 1.1) mm accept in range $(2.7 \text{ to } 3.3) \times 10^{11} \text{ (Hz)}$ accept $E = hf = 1.98 \times 10^{-22} \text{ J}$ 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)
			$f = 3 \times 10^8 / 1 \times 10^{-3} = 3 \times 10^{11} \text{ (Hz)}$ ✓	M	
			$T \approx hf / 5k \approx 6.6(3) \times 10^{-34} \times 3 \times 10^{11} / \{5 \times 1.4 \times 10^{-23}\}$ ✓	H	
			$\approx 2.8 \text{ (K)}$ ✓	H	
			Total	8	

Question			Answer	Marks	Guidance
37	(a)	(i)	p has kg m s^{-1} = E/c has $\text{kg m}^2 \text{s}^{-2} / \{\text{m s}^{-1}\}$ ✓	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 $\times 2$ at appropriate stage not $P = Fv$
			factor $\times 2$ because $mv - \{-mv\} = 2mv$ ✓	M	accept momentum is reversed no credit for just $\times 2$ with no explanation
			$T = 2n \Delta\{E/c\} / \Delta t = 2n \Delta E / c \Delta t = 2P / c$ ✓	M	must include n number of photons ($\text{m}^{-2} \text{s}^{-1}$) in calculation for third mark
37		(iii)	$a = T \times A / m = 2P \times A / mc$ OR		accept in algebra or numbers
			$= 2 \times 1400 \times 10^6 / \{10^3 \times 3 \times 10^8\}$ ✓	M	
			$= 9.3 \times 10^{-3} \text{ m s}^{-2}$ ✓	M	accept 9.3 mm s^{-2}
37	(b)	(i)	k.e. gained = e.p.e. lost OR $\frac{1}{2} m v^2 = QV$ ✓	L	energy conservation in words / algebra
			$\{mv\}^2 = 2mQV \rightarrow mv / m = \sqrt{\{2VQ/m\}}$		allow momentum per unit mass = velocity and subsequent derivation of v
			OR $mv / m = \sqrt{\{2mVQ/m^2\}} \rightarrow v = \sqrt{\{2VQ/m\}}$ ✓	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)	$T = \Delta p / \Delta t = \Delta p / \Delta m \times \Delta m / \Delta t$ OR		
			$\Delta m / \Delta t = T / \{\Delta p / \Delta m\} = 0.24 / \sqrt{\{2 \times 2000 \times 9.6 \times 10^7\}}$ ✓	S & C	No credit for only working out velocity of ions
			$= 3.87 \times 10^{-7} \text{ kg s}^{-1}$ ($< 4 \times 10^{-7} \text{ kg s}^{-1}$) ✓	S & C	
			Total	12	

Question			Answer	Marks	Guidance
38	(a)		% uncertainties in $L \ll$ % uncertainties in y ✓ ORA	L	accept % uncertainties in L are negligible on this scale accept estimates e.g. 1 in 1000 mm $\ll$ $\frac{1}{2}$ 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 = $(2.25 \times 10^{-3} / 2.2) = 1.0 \times 10^{-3}$ ✓ accept in range $\{0.9 \text{ to } 1.2\} \times 10^{-3}$ (round their values to 1dp) penalise POT error on gradient accept y/x for proportional graphs expect evidence of $\Delta y/\Delta x$ for graphs not through (0,0) uncertainty by graph of max OR min gradient or by $\pm\%$ ✓ (max gradient = 1.2×10^{-3} , min gradient = 0.7×10^{-3}) accept in range $\pm \{0.10 \text{ to } 0.5\} \times 10^{-3} / \pm \{10 \text{ to } 50\}\%$	L M H	 accept ecf on POT error on gradient i.e. missing $\times 10^{-3}$ 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)		$\lambda = d \times \text{grad} = 0.50 \times 10^{-3} \times 1.03 \times 10^{-3} = 5.(2) \times 10^{-7} \text{ (m)}$ ✓ accept values in the range 450 to 600 nm and consistent with their gradient from (b) relative uncertainty in d expressed as $\pm 20\%$ / ± 0.2 ✓ evaluation combining uncertainties from grad and d to get overall uncertainty. Credit values in range of $\{\pm 30\%$ to $\pm 70\%\}$ of their λ estimate overall uncertainty in range $\pm 150 \text{ nm}$ to 360 nm ✓	M H H	allow ecf on gradient value from (ii) accept 515 nm accept use of $\lambda = d \times \sin \theta$ (with $n = 1$) accept ecf grad $\pm \%$ from (ii) accept absolute uncertainty in d is 0.1 mm if used in max/min calculation of λ large pessimistic % due to uncertainty in grad up to $\pm 50\%$ ignore method of combining large % uncertainties (several methods are used ours include extreme limits) so $5.2 \pm \{1.5 \text{ to } 3.6\} \times 10^{-7} \text{ (m)}$
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 $PV = \text{constant}$ (T constant) <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Covers both strands using a range of relevant physics ideas. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Covers at least two physics ideas (possibly from only one strand), that are relevant to the argument. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 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 $\propto \sqrt{\text{no.steps}}$ • (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 • $P \propto \text{no. collisions s}^{-1} \times \Delta p$ per collision $\propto N/V$ OR if V is $\times 1/2$, then N/V is $\times 2$ and P is $\times 2$ OR if N is $\times 2$, then N/V is $\times 2$ and P is $\times 2$

Question			Answer	Marks	Guidance
39	(b)	(i)	$\{ \frac{1}{2} m \overline{c^2} \}_{\text{Xe}} = \{ \frac{1}{2} m \overline{c^2} \}_{\text{H}_2}$ ✓	M	method or justification accept equipartition of energy OR average k.e of two species of molecules is equal OR
			$\sqrt{\overline{c^2}_{\text{H}_2} / \overline{c^2}_{\text{Xe}}} = \sqrt{m_{\text{Xe}} / m_{\text{H}_2}}$ ✓	M	$c_{\text{r.m.s.}}$ is speed of molecule with average kinetic energy not just $\sqrt{m_{\text{Xe}} / m_{\text{H}_2}}$ OR $\sqrt{132 / 2}$
			$= \sqrt{66} \quad / \quad 8.1(2)$ ✓	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 $E = \frac{1}{2} m_{\text{H}_2} v_{\text{Escape}}^2 \quad / \quad 2.1 \times 10^{-19} \text{ J}$ ✓	H	E of H molecule part evaluation accept $m_{\text{H}_2} = 2 \times m_p$
			Boltzmann exponent $= E/kT =$ $\frac{1}{2} \times 2 \times 10^{-3} \times [11.2 \times 10^3]^2 / [6 \times 10^{23} \times 1.4 \times 10^{-23} \times 288] = 51.8$ ✓	S&C	or accept BF calculated at 3.2×10^{-23}
			number $= N_A \times e^{-E/kT} = 6 \times 10^{23} \times e^{-51.8} = 19 \text{ (mole}^{-1}\text{)}$ ✓	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
		$R_{\text{ARMATURE}} = 12.0 / 9.7 = 1.2(4) (\Omega)$ ✓	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 <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Covers both strands using a range of relevant physics ideas <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i>	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 $\mathcal{E}$ from coil cutting flux opposes V supply • $\mathcal{E} \propto$ frequency of rotation OR $\mathcal{E} \propto$ cutting of flux OR $\mathcal{E} \propto -N \Delta \Phi / \Delta t$ 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. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 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 • $\mathcal{E} \propto$ rate of cutting of flux OR $\mathcal{E} = - N \Delta \Phi / \Delta t$ OR $\mathcal{E} = - \Delta N \Phi / \Delta t$ 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 $d(\text{flux}) / dt$ OR $d(\text{flux linkage}) / dt$ 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 = $2 \times (9 \times 10^9 \times 1.6 \times 10^{-19}) / 0.5 \times 10^{-9}$ ✓ = 5.8 (V) ✓	L 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 = $(9 \times 10^9 \times (1.6 \times 10^{-19})^2) / (1 \times 10^{-9})^2$ ✓ = 2.3×10^{-10} N ✓ horizontal components will cancel (can show on diagram) ✓ sum of vertical components = $2 \times 2.3 \times 10^{-10} \times \sin 60^\circ = 3.98 \times 10^{-10}$ (N) ✓	M M H H	Look for final answer and if not correct work through scheme to credit each marking point achieved. accept shown by vector addition triangle or use of $\cos 30^\circ$ or $\sin 60^\circ$ accept use of $\cos 30^\circ$ accept 4.0×10^{-10} (N) in this instance
41	(b)	ii	Force = 3.98×10^{-10} N $\times (1 \times 10^{-9})^2 / (1 \times 10^{-15})^2$ ✓ = 398 (N) ✓	H S&C	accept 4.0×10^{-10} (N) or ecf from b(i) accept force scaled up $\times \{10^{-9} / 10^{-15}\}^2 = 10^{12}$ accept 400 (N)
			Total	9	
			Total section C	58	
			Total sections B & C	80	

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