

GCE

Physics B

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

Advanced GCE

Mark Scheme for June 2017

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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
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Level 1
	Level 2
	Level 3
	Transcription error (in copying data from root of question – ALLOW method mark(s) if no further error but zero credit for evaluation)
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Error in number of significant figures
	Correct response
	Wrong physics or equation

Section A: MCQs

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

Section B

Question			Answer	Marks	Guidance
31	(a)		(usually air is not a conductor) having no charge carriers (to support a current) / the ions and / or electrons provide charge carriers (for the air to conduct)	1	expect concept of charged particles free to move not just air is an insulator or non-conductor / just ions are charged / just charges can conduct allow charge carriers / delocalised or free electrons or charges / charges available to carry current / charges can flow
31	(b)		$(\Delta Q = I \Delta t) = 30 \times 10^3 \times 250 \times 10^{-6}$ $= 7.5 \text{ (C)}$	1 1	 bare correct value scores both marks ignore units
			Total	3	

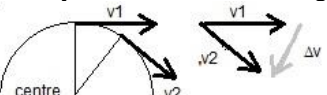
Question			Answer	Marks	Guidance
32	(a)		$\frac{c / c_{\text{glass}}}{c / c_{\text{water}}}$	1	
32	(b)		${}_g n_w = 1.3 / 1.6 = 0.81(3)$	1	first mark for evaluating / using correct index
			$r = \sin^{-1}(\sin 30^\circ / 0.813) = 38^\circ$	1	not 24° have inverted the index
			OR $n_1 \sin \theta_1 = n_2 \sin \theta_2$ method		only if this method is clear
			$r = \sin^{-1}(\sin 30^\circ \times 1.6 / 1.3) = 38^\circ$		allow $n_1 / n_2 = 1.6 / 1.3 = 1.2(3)$ for first mark
			Total	3	

Question			Answer	Marks	Guidance
33	(a)	(i)	$\Delta E = m c \Delta \theta$ ✓	1	method evaluation accept 71 (kJ)
			= 4200 x 17 = 71.4 (kJ) ✓	1	
33	(a)	(ii)	$\Delta t = m c \Delta \theta / I V$ or = 71.4 x 10 ³ / (230 x 46) ✓	1	method in rearranged algebra or numbers accept $t = E / P$ evaluation not 6.74 (s) RE allow ecf on value from (a)
			= 6.7(5) (s) ✓	1	
33	(b)		$\Delta \theta$ doubled ✓	1	accept mass flow rate drops from 0.15 to 0.075 kg s ⁻¹ not ΔE doubles so time doubles / other time reasoning max 1 for just flow (rate) less or slower
			so flow (rate) or $\Delta m / \Delta t$ will have to halve ✓	1	
			Total	6	

Question			Answer	Marks	Guidance
34	(a)		$(4.5 \times 1 / 10) = 0.45$ ✓	1	ignore 4.1
			$(4.5 - 0.45) = 4.05$ ✓	1	
34	(b)	(i)	$\Delta Q \approx I \Delta t = V \Delta t / R$ ✓	1	accept algebra expressed in words / = or $\approx$ symbols not credit for any exponential type reasoning
			and $V = Q / C$ ($\Rightarrow \Delta Q \approx Q \Delta t / R C$) ✓	1	
34	(b)	(ii)	assumes current / voltage / charge (on capacitor) is constant during Δt (instead of continuously decaying) ✓	1	assumption not just rate is constant accept rate of charge flow is constant or rate of discharge is constant how overcome for 1 standalone mark if no answer to assumption
			overcome by making Δt smaller / as small as possible (as needed for better approximation) not just make Δt small ✓	1	
			Total	6	

Question		Answer	Marks	Guidance
35	(a)	$v = 0.24 \times 60 \times 3 \times 10^8 / \{60 \times 60 \times 24\}$ ✓ $= 5.0 \times 10^4 \text{ (m s}^{-1}\text{)}$ ✓	1 1	accept { $4.32 \times 10^9 \text{ m} \div 8.64 \times 10^4 \text{ s}$ }
35	(b)	range $R = 44.444 \times 60 \times 3 \times 10^8 = (8.0 \times 10^{11} \text{ m})$ ✓ $v_{\text{perp.}} = R \omega = 8.0 \times 10^{11} \times 1.8 \times 10^{-3} / (24 \times 3600)$ ✓ $= 1.66 \times 10^4 \text{ (m s}^{-1}\text{)}$ ✓ OR alternative method for last 2 marks $s_{\text{perp.}} \approx R \theta = 8 \times 10^{11} \times 1.8 \times 10^{-3} = (1.44 \times 10^9 \text{ m})$ $v_{\text{perp}} = s_{\text{perp}} / t = 1.44 \times 10^9 / (24 \times 3600) = 1.66 \times 10^4 \text{ (m s}^{-1}\text{)}$	1 1 1	accept ranges based on either time or mean time of signal travel all give range = $8.0 \times 10^{11} \text{ m}$ (2 S.F.) method evaluation method accept $\sin \theta \approx \tan \theta \approx \theta$ for small angle θ n.b. $s_{\text{perp.}} = 0.08$ light minutes can be credited more method & evaluation allow answers close to 280 m s^{-1} to score 2/3 marks because light mins treated as light secs so 1/60 of correct answer so one small error
		Total Total section B	5 23	

Section C

Question			Answer	Marks	Guidance
36	(a)		velocity vector is changing direction constantly towards the centre of the orbit (magnitude / speed remains constant) ✓ and acceleration = rate of change of velocity so there is an acceleration ✓ OR (circular motion) requires a force towards the centre of the circle (otherwise the mass will move in a straight line at a tangent to the circle) ✓ and acceleration $\propto$ force so there is an acceleration (towards the centre) ✓	1 1	accept in annotated diagram form  dependent on the first mark accept (circular motion) requires centripetal force ignore references to gravitational force of Earth on Moon cause Moon to accelerate towards earth dependent on the first mark accept $a = F / m$ so there is an acceleration (towards the centre)
36	(b)	(i)	$a = v^2 / R = \{2\pi R\}^2 / \{T^2 R\} = \dots\dots$ ✓ OR $a = R \omega^2 = R \{2\pi / T\}^2 = \dots\dots\dots$	1	algebraic reasoning accept using forces and $F = ma = m v^2 / R$ and cancelling m and completing
36	(b)	(ii)	$4\pi^2 \times 3.84 \times 10^8 / (2.35 \times 10^6)^2 = 0.0027 \text{ m s}^{-2}$ ✓	1	evaluation accept $2.74 \text{ mm s}^{-2} / 2.75 \text{ mm s}^{-2} (\pi \approx)$
36	(b)	(iii)	$g_{\text{at moon orbit}} = g_{\text{Earth surface}} / 60^2$ ✓ $= 9.8 / 3600 = 2.7(2) \times 10^{-3} \text{ m s}^{-2}$ ✓ same value as (ii) ✓	1 1 1	method using inverse square law reasoning in numbers / words / algebra evaluation accept $g = 9.81 \text{ m s}^{-2}$ / correct use of $a = G M / D^2$ comparison allow ecf from (ii) if compared sensibly to 3 mm s^{-2}
			Total	7	

Question			Answer	Marks	Guidance
37	(a)		$v_{\text{terminal}} = 0.65 \text{ (m s}^{-1}\text{)}$ ✓	1	v_{terminal} read from graph accept in range 0.64 to 0.66 (m s ⁻¹)
			$\pm 0.02 \text{ (m s}^{-1}\text{)}$ ✓	1	uncertainty estimate apply SF penalty for 2 or 3 SF e.g. 0.019 or 0.0195 (m s ⁻¹) scores 0
37	(b)		(at $t = 0.5 \text{ s}$) ball is accelerating (and a is decreasing) ✓	1	credit numerical estimates of acceleration $\approx 0.55 \text{ m s}^{-2}$
			because downwards weight is larger than upwards drag force ✓	1	accept in algebra $W > D$ or $> (D + U)$ accept if upthrust U is overlooked / air resistance or friction for drag not U confused with D not just because net force is downwards
37	(c)	(i)	temperature should be monitored or held constant ✓	1	accept density of the glycerol ; as it will affect upthrust
			since the viscosity / drag force will depend on T ✓	1	accept viscosity of the glycerol ; as it will affect drag accept purity of the glycerol ; as moisture affects viscosity accept density of ball bearing ; as it will affect the weight accept mass of ball bearing ; as it will affect the weight not height drop or air bubbles in glycerol or keep same liquid ignore edge effect
37	(c)	(ii)	$D^2 / v_T = \text{constant}$ OR $v_T / D^2 = \text{constant}$ ✓	1	proposal if $v_T / D^2 = \text{constant}$ accept log / log graph allow $v_T = k D^2$
			D^2 / v_T values: 144, 145, 144, 204, 221 (mm ² m ⁻¹ s) ✓✓ OR v_T / D^2 values (6.9, 6.9, 6.9, 4.9, 4.5) $\times 10^{-3} \text{ (m s}^{-1} \text{ mm}^{-2}\text{)}$ ✓✓	2	working expect at least 2 data tests for credit 1 mark and all 5 data tested for 2 marks accept table of D^2 values (for v_T vs D^2 sketch graph) accept calculated log v_T and log D values same rule on data

Question			Answer	Marks	Guidance
			noticing smallest three b.bs have almost constant k / largest two b.bs have a different sensible constant / smallest and largest b.bs k not constant consideration of quantitative uncertainty in k $D^2 / v_T = 144, 145, 144$ constant to $\pm 0.3\%$ / $= 204, 221$ constant to $\pm 4\%$ correct statement about their test showing proportionality or not showing proportionality If graphs sketched 2 marks from: sketches of log / log graph or sketches of v_T vs D^2 correct comment on gradient or linearity of their graph	2	conclusions 2 marks available for any sensible test involving 2 or more data points accept any two or all three of smallest b.bs have almost constant k accept largest two b.bs have sensible constant k (if only 2 tested) accept use of 3% uncertainty based on the uncertainty in v_T from (a) OR comment on differences in their k values 144, 221 show increase in k of about 50% / decrease of about 35% for graph method candidates
			Total	11	

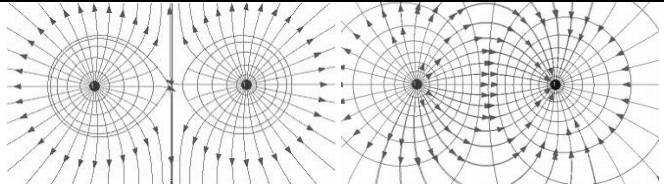
Question			Answer	Marks	Guidance
38	(a)		draw tangent and suitable large Δ at $t = 1$ or 3 s ✓	1	method accept tangent and $\Delta s / \Delta t = 1.6 / 1.5$
			1.1 (m s^{-1}) ✓	1	ignore signs here award magnitude evaluation accept in range 1.0 to 1.2 (m s^{-1})
			OR identifying $A = 0.70$ m $f = 1/4$ Hz $v_{\text{max}} = A \omega$; $= 0.7 \times 2 \pi \times 1/4 = 1.1$ (m s^{-1})		alternative method for two marks
38	(b)		- sin graph of period 4 s and shape by eye ✓	1	accept - sin graph scaled to agree with (a) ecf
			scaled to amplitude of 1.1 m s^{-1} ✓	1	ignore shape of graph here just peak values
38	(c)	(i)	$L = T^2 g / 4\pi^2$ or equivalent using numbers ✓	1	method not just $T = 2 \pi \sqrt{L / g}$
			$= 4^2 \times 9.8 / 4\pi^2 = 3.97$ m ✓	1	evaluation accept $g = 9.81$ gives $L = 3.98$ m
			Total	6	

Question			Answer	Marks	Guidance
39	(a)		X pure β no γ at background with 5 mm lead ✓	1	all identifications correct for first mark even if no explanations total zero if three sources incorrect two correct explanations for second mark three correct explanations for third mark ignore comments on β as present in all three sources not credit for descriptions of data expect logical analysis
			Y α, β, γ large drop with paper $\therefore$ must have α ✓	1	
			Z β, γ (no drop with paper $\therefore$ no α) counts with lead so some γ ✓	1	
39	(b)	(i)	$\Delta \log C / \Delta \log R$ or e.g. $(4.0 - 0.5) / (0.4 - 1.9) =$ ✓	1	method evidence of sensible gradient taken or tangent drawn or Δ constructed in downward section of graph even if sign is wrong
			$= -2.3$ ✓	1	evaluation accept in range - 2.0 to - 2.5 must have correct sign here allow both marks if bare answer in this range
39	(b)	(ii)	✓ ✓ ✓ ✓ Graph comments: $C = k / R^2$ gives $\log C = \log k - 2 \log R$ OR gradient close to 2 suggests R^2 variation and – sign indicates inverse relation $1 / R^2$ accuracy: - 2.3 is close but not perfect fit for low range is not a good fit (log graph flat) OR higher range only is a reasonable fit	4	any 4 points from the list but must include a comment on graph AND a suggestion about radiation for full marks i.e. a max 3 from each section complete log analysis worth 2 marks accept if k taken as 1 conclusion ecf on their gradient value if outside range then not a good fit accept need to know $\pm$ uncertainties to estimate the significance of the small difference i.e. recognising the significance of knee in graph

Question			Answer	Marks	Guidance
			Suggestions about radiation: α attenuated by a few cms in air inverse square law applies to point sources, close to source will not be a good approximation / it will be more constant γ should follow $1 / R^2$ dilution γ travel in straight lines from (point) source with little interaction / absorption by the air		accept β with explanation that these follow $1 / R^2$ reasonably well up to this range
			Total	9	

Question			Answer	Marks	Guidance
40	(a)		$(50 \text{ MPa} / 7 \times 10^{-4}) = 7.1(4) \times 10^{10} \text{ (Pa)}$ ✓	1	evaluation accept in range 7.0 to $7.3 \times 10^{10} \text{ (Pa)}$
40	(b)		alloy absorbs more energy (per volume) ✓ alloy is stronger / has higher breaking stress ✓	1 1	choice explained accept alloy because it is tougher not stiffer not any credit for pure metal takes greater strain and prolongs time of collision
40	(c)	(i)	method: any {scaled distance ÷ appropriate number of atoms} ✓ evaluation: e.g. 4 atoms per nm gives $0.25 \text{ nm} / 2.5 \times 10^{-10} \text{ (m)}$ ✓ OR 5 atoms per nm gives $0.20 \text{ nm} = 2.0 \times 10^{-10} \text{ (m)}$	1 1	allow atom counting angled to atomic rows not unreal estimates like 10 atoms per 1 nm estimation accept in range $\{ 1.8 \text{ to } 2.7 \} \times 10^{-10} \text{ (m)}$ credit 2 marks for answer in range with no working
40	(c)	(ii)	a dislocation / edge dislocation ✓	1	accept extra half-plane of atoms
40	(d)		Level 3 (5–6 marks) Marshals argument in a clear manner and includes clear explanation of three strands : • metallic bonding • structure of metal and alloy • elastic and plastic deformation <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i>	6	Look for number of strands attempted to help decide the Level, then look at quality. Indicative scientific points may include: Metallic bonding • +ve ion lattice in sea / gas of free mobile electrons • non-directional strong electrostatic bond electron glue • similar for pure metal and alloy Structure of metal and alloy • ordered regular stacking of atoms in planes in metal • alloy has a few impurity metal atoms of different size • most metals are polycrystalline with grains and grain boundaries between crystals of different orientation • ions can slip and atomic planes move

Question			Answer	Marks	Guidance
			Level 2 (3–4 marks) Shows clear understanding of at least two of the three strands above to the argument or covers all three at a superficial manner and does not include enough indicative points for level 3. <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) Makes at least two independent points (possibly from one strand) that are relevant to the argument but does not link them together and shows only superficial engagement with 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 <i>no response worthy of credit remember</i> <i>No response at all record NR</i>		- dislocations are stacking imperfections e.g. extra half plane reduce stress at which planes slip by localising stress Elastic and plastic deformation - elastic behaviour atoms return to original position when stress removed stretched stiff bonds spring back - metals and alloys are stiff and elastic for small strains - dislocation movement in pure metals allows slip and plastic deformation at relatively low stress this is permanent and ions do not return when stress removed - dislocations are pinned by impurity atoms in alloy which restricts slip giving a smaller plastic region at higher yield stress - reference to Fig. 40.2 accept well labelled diagrams throughout for credit if integrated into the explanation
			Total	12	

Question			Answer	Marks	Guidance
41	(a)		. N on Fig. 41.1 ✓ ; . V on Fig. 41.2 ✓	2	both at mid-points of charges judged by eye and field lines (may need magnification to see amongst field lines)
41	(b)	(i)		1 1	both sketches any 3 equipotentials of roughly correct shape judged by eye accept ΔV not equal (as diagram) expect attempt at orthogonality accept on Fig. 41.1 three equipotential loops surrounding both charges
41	(c)		$E = 2kQ/R^2$ or $= 2 \times 9 \times 10^9 \times 1 / 500^2$ ✓ $= 7.2 \times 10^4 \text{ (V m}^{-1}\text{)}$ ✓	1 1	method must have 2 factor for method mark evaluation allow 1 mark for 3.6×10^4 (½ correct value)
41	(d)		Level 3 (5–6 marks) Marshals argument in a clear manner and includes clear explanation of three strands : • work done • area under $E(R)$ field graph • gradient of $V(R)$ potential graph <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) Shows clear understanding of at least two of the three strands above to the argument or covers all three at a superficial manner and does not include enough indicative points for level 3. <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	Look for number of strands attempted to help decide the Level, then look at quality. Do not penalise incorrect signs in this answer. Indicative scientific points may include: work done • work W is done against electrical attraction of + and – charges which increases the electrical potential energy of the system • + charge is worked on in raising it up the potential well of the – charge • $W_{\text{total}} = \Sigma \Delta W = \Sigma F \Delta s = \Sigma F \Delta R$ area under $E(R)$ graph: accept algebraic or numerical reasoning • $W_{\text{total}} = \Sigma \Delta W = \Sigma F \Delta s = \Sigma F \Delta R$ only credit once • $E_{\text{field}} = F/q$ but test charge is unit charge $q = 1 \text{ C}$ • in this example $E_{\text{field}} = F$

Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) Makes at least two independent points that are relevant to the argument but does not link them together and shows only superficial engagement with 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 worthy of credit scores zero No response record NR		• $\therefore W = \text{Area under the field graph}$ • 15 squares $\times 4 \times 10^6 \text{ J per square} = 60 \text{ MJ C}^{-1}$ or MV • agrees with increase in potential from (-90 to -30) MV • recognising that $E = k Q / R^2$ gradient of $V(R)$ graph • $E_{\text{field}} = - \text{gradient of } V(R) = - dV / dR = - \Delta V / \Delta R$ • tangent to graph drawn and shown = field • e.g. at $R = 200 \text{ m}$ grad = $(120 \text{ MV}) / 600 \text{ m}$ $= 2 \times 10^5 \text{ V m}^{-1}$ • agrees with the field at $R = 200 \text{ m}$ of $20 \times 10^4 \text{ V m}^{-1}$ • recognising that $V = k Q / R$ check graphs for annotation credit
			Total	12	
			Total section C	56	
			Total sections B & C	80	

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