

GCE

Physics B

H557/01: Fundamentals of physics

Advanced GCE

Mark Scheme for November 2020

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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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Annotations

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Level 1
	Level 2
	Level 3
	Transcription error
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Error in number of significant figures
	Correct response
	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
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: MCQs

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

Section B

Question			Answer	Marks	Guidance
31	(a)		${}^{134}_{54}\text{Xe}$ ✓	L	
31	(b)		$\Delta m = 0.20401 \text{ u}$ ✓ convert u to kg OR convert via $1 \text{ u} \equiv 931 \text{ MeV}$ ✓ $(\Delta E = \Delta m c^2) = 190(\text{MeV})$ ✓	L M M	allow mark for evidence of correct approach, even if final (third) mark for evaluation is not awarded accept correct calculation of energy on each side of equation for the first mark leading to a correct evaluation for the second mark accept 189.9, 189.93, 189.933 or 189.9333 for full credit (as allows 2SF) allow 186.2 for MAX 2 as a result of using fewer SF for Δm – annotate as SF error
			Total	4	

Question			Answer	Marks	Guidance
32	(a)		method: $n = PV / RT$ / $= 450 \times 10^3 \times 4 / [8.3 \times 288]$ ✓ evaluation: $= 75(3) \text{ moles}$ ✓	L L	method in words / numbers / algebra accept 75(2) if using $R = 8.31$ allow calculations leading to values around 188 moles (as a result of dividing by 4 tyres) for MAX 1
32	(b)		Any two from : molecules move faster / have more <u>kinetic</u> energy / collide more frequently / harder / momentum changes at collision are greater ✓✓ P increases $\times 320 / 288 = 1.1$ OR P increases to 500	MM	not reference to force increasing

Question			Answer	Marks	Guidance
			kPa OR P increases by 50kPa ✓	L	MAX 2 for responses that are qualitative only allow one mark for just “pressure increases” within MAX 2 for qualitative only argument
			Total	5	

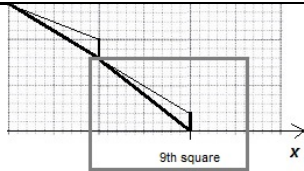
Question			Answer	Marks	Guidance
33	(a)		curves path / slows velocity ✓	L	allow accelerates the α / changes direction / changes velocity / slows down
33	(b)		(most) has been stored as / converted to <u>electrical</u> potential energy OR $k Q_1 Q_2 / R$ ✓	L	allow (small) fraction converted to k.e. of recoiling nucleus (which carries original momentum of alpha at closest approach)
33	(c)	(i)	low Z and high k.e. i.e. bottom left of table ✓	M	
33	(c)	(ii)	method: $R = k \times 2 \times 13 \times e^2 / [7.7 \text{ MeV}]$ ✓ OR $= 9 \times 10^9 \times 2 \times 13 \times 1.6 \times 10^{-19} / [7.7 \times 10^6]$ ✓ evaluation: $= 4.9 \times 10^{-15} \text{ m}$ ✓	M H	allow $5.7 \times 10^{-15} \text{ m}$ as 15% alpha k.e. in Al nucleus at closest approach (due to momentum transfer) for 2 marks allow 4.85×10^{-15} as a result of using $k=8.98$ for 2 marks
			Total	5	

Question			Answer	Marks	Guidance
34	(a)		method : calculation of initial gradient using values taken from 1.5 GPa and 10% strain ✓	L	ignore POT errors on this graph for this marking point allow method for MAX 1 based on values taken around (4,0.4) not just a line or markings drawn on graph, must have values used to calculate a gradient from their values
			evaluation: $= 1.5 \times 10^{10} \text{ Pa}$ ✓	M	
34	(b)		$W = \rho ALg \propto \rho$ for equal dimensions and gravity OR strength / weight $\propto \sigma_B / \rho$ ✓	H	must have explanation of approach in words or symbols for first mark not just two calculations of σ_B / ρ
			silk / steel = $[1.4 / 1.2 \times 10^3] / [2.8 / 7.8 \times 10^3] = 3.3 (\approx 3)$ ✓	H	
			Total	4	

Question			Answer	Marks	Guidance
35	(a)		as h increases the path difference ($TM + MR - TR$) increases ✓ (two sets of waves superpose meaning) waves in phase at max and out of phase at min / whole number of wavelengths path difference gives constructive interference and $(n+1/2)\lambda$ gives destructive interference ✓	M M	allow equivalent phasor description or in terms of wave amplitudes adding allow idea that waves are changing phase with respect to each other for MAX 1
35	(b)		method: between two consecutive max $\Delta \text{p.d.} = \lambda$ ✓ substitution: $2\{\sqrt{[1^2+0.213^2]} - \sqrt{[1^2+0.123^2]}\}$ ✓ evaluation: $=2.98 \times 10^{-2} \text{ m}$ ✓	H H H	allow any valid method e.g. between adjacent max and min $\Delta \text{p.d.} = \lambda / 2$ answer of 1.49×10^{-2} scores 1 MAX as a result of omitting x2
			Total	5 23	

Section C

Question			Answer	Marks	Guidance
36	(a)	(i)	$44 \times 10^3 \times 16 \times 2 = 1.4(1) \times 10^6 \text{ bit s}^{-1}$ ✓	L	allow 1.3(4) Mbit s ⁻¹ using 1 k = 1024
36	(a)	(ii)	$t = \text{info} / \text{rate} = 840 \times 10^6 \times 8 / [1.41 \times 10^6 \times 60]$ ✓ = 79.(4) mins ✓	M M	method allow 4760 s for first mark evaluation
36	(b)	(i)	there is a high f wave whose amplitude varies regularly at a lower f ✓	M	allow AW that convincingly explains there are two distinct frequencies with associated amplitude variation present
36	(b)	(ii)	noise is present with the signal (and should be ignored) ✓	L	
36	(b)	(iii)	11 bits ($2^{11} \approx 2048 (> 1600 \text{ Hz})$) ✓	M	
36	(b)	(iv)	evaluation: $4 \times 24 \times 100 = 9.6 \text{ k bit s}^{-1}$ ✓ show that fraction: $9.6 \text{ k} / 1.4 \text{ M} = 0.0069 \approx 1/146$ ✓	H H	allow $9.6 \text{ k} / 1.0 \text{ M} = 0.0096 \approx 1/104$ allow ecf from a(i) allow 0.0068 if using 1.41M
			Total	8	

Question			Answer	Marks	Guidance
37	(a)	(i)	should cut 9 th large square exactly ✓	L	
37	(a)	(ii)	$(100\sqrt{2}) = 14(1)$ OR $(\sqrt{100^2 + 100^2}) = 14(1) \text{ m s}^{-1}$ ✓	M	allow by discussion of equal x and y velocity components of 100 m s^{-1} accept 141.4
37	(a)	(iii)	1 each large square represents a displacement of $100 \text{ m s}^{-1} \times 2.0 \text{ s} = 200 \text{ m}$ ✓ 2 so range is $200 \times 9 = 1800 \text{ m}$ ✓	L M	allow correct evaluation of any incorrect answer from 1 multiplied by 9
37	(a)	(iv)	$R = 141^2 \sin 90^\circ / 10 = 19(90) \text{ (m)}$ ✓	M	allow 2000 (m) allow use of $100^2 + 100^2$ instead of 141^2 (from part a(ii)) leading to either 2000 (from $g=10$) or 2038 (from $g=9.81$) allow use of $g=9.81$ leading to 2026 (m) allow use of 140 (from “show that” in a(ii)) for acceptable values of g
37	(b)		horizontally: $(R = 140^2 \sin 30^\circ / 10 = 980 \text{ m})$ times of flight $t_{75^\circ} = 980 / 140 \cos 75^\circ = 27.0 \text{ s}$ ✓ and $t_{15^\circ} = 980 / 140 \cos 15^\circ = 7.2 \text{ s}$ ✓ all 3 marks for $\Delta t = 27 - 7.2 = 19.8 \text{ s}$ ✓ OR vertically: $t_{75^\circ} = 2 \times 140 \sin 75^\circ / 10 = 27.0 \text{ s}$ ✓ and $t_{15^\circ} = 2 \times 140 \sin 15^\circ / 10 = 7.2 \text{ s}$ ✓ all 3 marks for $\Delta t = 27 - 7.2 = 19.8 \text{ s}$ ✓	S & C S & C S & C ✓ ✓ ✓	for both horizontal and vertical approaches allow use of $g = 9.8 \text{ m s}^{-2}$ leading to $27.6 - 7.4 = 20.2$

37	(c)*	Level 3 (5–6 marks) Marshals argument in a clear manner and includes clear explanation of all strands including : • origin of air resistance • x and y components of v • trajectory <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 all strands at a superficial level and does not include enough depth 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 only 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 No response or no response worthy of credit	LL MM HH	accept labelled diagrams or graphs with “exaggeration for clarity” Indicative scientific points may include: origin of air resistance • projectile collides with air molecules / knocks them out of the path, transfers momentum / which exert a backwards force opposing the velocity • $F_{\text{res}} = \Delta(mv)/\Delta t \propto \rho A v_x v \propto \rho A v^2$ • surface friction / viscous drag concepts x and y components of v horizontally • component of v is no longer constant / but decreases more quickly at start when v is larger / rate of acceleration less noticeable as v slower vertically • acceleration no longer constant / g but starts larger due to extra downwards force of drag / equals g when $v = 0$ because no vertical drag at max height of trajectory / becomes less than g on way down because drag force is now upwards opposing gravity $v \sin 75^\circ / v \cos 75^\circ = 3.7$ / vertical component is affected more because $>$ horizontal component trajectory shape not parabolic / not symmetric about maximum height / descent covers shorter horizontal distance than ascent height travels less far / less than $v^2 \sin 150^\circ / g = 980\text{m}$ less area under $v(t)$ graph to max height / less than $\frac{1}{2} g t^2 = \frac{1}{2} \times 10 \times 13.5^2 = 910\text{ m}$ / reaches max sooner / $t_{\text{descent}} > t_{\text{ascent}}$ for equal area under $v(t)$ graph range is smaller
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					credit diagrams / sketch graphs indicative allow exaggeration for clarity
			Total	14	

Question			Answer	Marks	Guidance
38	(a)		pattern of lines is moved towards the red end of spectrum / blue line becomes blue-green, nearer the red end of spectrum ✓	L	remember red wavelengths and longer (i.r., μ , radio) are shifted away from red end of spectrum during red-shift!
38	(b)		method: $\Delta\lambda / \lambda = \text{constant}$ ✓ eval: $22/434 = 0.051$ $24/486 = 0.049$ $33/656 = 0.050$ so sensibly constant ✓	M M	allow any two correct checks
38	(c)		$v = 0.050 \times 3 \times 10^8 = 15 \times 10^6 \text{ (m s}^{-1}\text{)}$ ✓	L	
			Total	4	

Question	Answer	Marks	Guidance
39	Level 3 (5–6 marks) Marshals argument in a clear manner and includes clear explanation of all strands including : • why ratio $^{235}\text{U} / ^{238}\text{U}$ changes in time • estimation of age of atoms • assumptions <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 all strands at a superficial level 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 only 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 No response or no response worthy of credit	LL MM S&C S&C	Indicative scientific points may include: ratio $^{235}\text{U} / ^{238}\text{U}$ changes in time • ^{235}U has shorter half-life, decays more quickly • $^{235}\text{U} / ^{238}\text{U}$ drops < 1 after atoms have formed • accept sketch decay graphs differing $t_{1/2}$ • $^{235}\text{U} / ^{238}\text{U} = N_0 e^{-\lambda_1 t} / N_0 e^{-\lambda_2 t}$ estimation of age of atoms • $^{235}\text{U} / ^{238}\text{U} = N_0 e^{-\lambda_1 t} / N_0 e^{-\lambda_2 t}$ • $= e^{\ln 2(\lambda_2 - \lambda_1) t} = 0.00725$ • $t = \ln\{0.00725\} / \ln 2 \{1/\lambda_2 - 1/\lambda_1\}$ $t = -4.926 / \{0.693 \times [1/4.5 - 1/0.71]\}$ Gyears = 5.99×10^9 years assumptions • early universe had only H and He atoms • U only formed later after star formation and supernova explosions • probability of forming U nuclei is small but equal for both isotopes of similar complexity so $^{235}\text{U} / ^{238}\text{U} \approx 1$ at start • aging is from formation of U atoms rather than the formation of the rocks • the Earth's U is from one short epoch / no new material added from later supernovae which would re-enrich the ratio • all the U nuclei remaining today are only produced by this process and have not been added to since by other processes

			Total	6	
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Question			Answer	Marks	Guidance
40	(a)	(i)	method: $E = 40000 / 6 \times 10^{23}$ ✓ evaluation: $10^{23} = 6.66 \times 10^{-20}$ (J) ✓	L L	Must be 'show that'
40	(a)	(ii)	$kT = 1.38 \times 10^{-23} \times [273 + 70] = 4.7(3) \times 10^{-21}$ (J) ✓	L	
40	(a)	(iii)	$E = \{6.66 \times 10^{-20} / 4.7(3) \times 10^{-21}\} kT \approx 14.(1) kT$ ✓ $f = e^{-E/kT} = e^{-14} = 8.3 \times 10^{-7}$ ✓	H H	OR $E/kT \approx 14.(1)$ allow ecf from a(i) and (ii)
40	(a)	(iv)	molecules making many collisions per second ($\approx 10^{10}$) so lots of opportunities to break hydrogen bonds OR energetic molecules are replaced by new ones by those molecules that "get lucky" in random collisions and keep gaining energy up to the bond breaking level ✓✓	M M	
40	(b)		same BF at $\times 10$ T so bond energy is $\times 10 = 6.7 \times 10^{-19}$ (J) ✓	H	OR may involve more complex calculations using BF e.g. $\ln 10^{-7} = -E/[k \times 3000] \rightarrow E = 6.7 \times 10^{-19}$ J
			Total	8	

Question			Answer	Marks	Guidance
41	(a)	(i)	γ only penetrating radiation getting deep inside the food α absorbed by few cms in air / in surface layer of solids β absorbed in surface layer mm of food / would not irradiate whole sample ✓✓	LL	not has best penetration not α stopped more easily not β stopped more easily any two points from γ , α , β (mention of two points about same radiation type is MAX 1). To score 2 marks , the response must mention γ
41	(a)	(ii)	a 1 s dose received would be $[500 \times 1]/300$ ✓ = 1.7 [Gy] ✓	M M	accept 1.67
41	(b)	(i)	exponential dilution due to absorption of γ -rays by water OR fixed small probability / fraction removed from each equal thickness layer → exponential decay with distance ✓ γ -rays spread in all spatial directions diluting over the surface of sphere of surface area $4\pi R^2$ gives inverse square law dilution due to geometry ✓	H H	allow linear absorption coefficient μ for water as probability of absorption per track length OR half-thickness = $\ln 2/\mu = 0.11 \text{ m} / 11 \text{ cm}$ allow diagram explanation OR doubling R quadruples area exposed arguments expect high level reasoning including $4\pi R^2$ not descriptions of exponential relationships for either marking point since the question requires an explanation of terms in the equation and/or the context.
41	(b)	(ii)	method: $\frac{3}{4} \times \text{flux } I \times A \times \text{time} \times E \text{ photon}^{-1} / \text{mass worker}$ ✓ ✓ evaluation: $1.3 \times 10^{-3} [\text{Sv}]$ ✓	S & C S & C S & C	OR $[\frac{3}{4} \times 1.2 \times 10^{16} \times e^{-6.3 \times 2} \times 0.5 \times 1200 \times 1.3 \times 10^6 \times 1.6 \times 10^{-19}] \text{ Sv}$ $[4\pi 2^2 \times 60]$ Credit part calculations for 1 mark e.g. $e^{-6.3 \times 2} = 3.4 \times 10^{-6}$

Question			Answer	Marks	Guidance
					OR $1/[4\pi 2^2] = 2 \times 10^{-2}$ OR calculating I from formula given in b(i)
			Total	9	

Question			Answer	Marks	Guidance
42	(a)	(i)	straight horizontal line at $\frac{1}{3}$ AB from A ✓	L	
42	(a)	(ii)	linear decrease from 12 to 0 V from A to B ✓	L	
42	(a)	(iii)	2400 (V m^{-1}) ✓	L	
42	(b)	(i)	method: $V_c = 49/10 = 4.9 \text{ V}$ ✓	M	accept values for anode potential of $48 < V < 50$
			$v = \sqrt{2 e V_c / m}$ evaluation = $1.3 \times 10^6 \text{ m s}^{-1}$ ✓	M	
	(b)	(ii)	Method : $4 \times 3.7 \times 10^5 \text{ m}^2 / [3.70001 \times 10^5 \text{ m}]^2 = 1.08 \times 10^{-5}$ ✓	H	must show full evaluation, not just 10^{-5}
	(b)	(iii)	must be <u>inelastic</u> collisions removing electrons k.e. so they can no longer climb the potential hill of $V_{\text{back off}}$ means mercury atom must have an internal energy level at 4.9 eV above ground state / evidence of a quantized electrical potential energy level inside mercury atom ✓✓	S&C S&C	any two points allow $4.9 \pm 0.1 \text{ V}$ OR electron from ground state can be promoted by sufficient energy to a higher energy state, but cannot exist in between states etc...
			Total	8	
			Total section C	57	
			Total sections B & C	80	

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