

GCE

Physics B

H557/01: Fundamentals of physics

Advanced GCE

Mark Scheme for June 2019

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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 available in Scoris

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	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
(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

Section A: MCQs

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

Section B

Question			Answer	Marks	Guidance
31	(a)		= 60 (Ω) ✓	L	
31	(b)		= 0.12 (S) ✓	L	
			Total	2	

Question			Answer	Marks	Guidance
32	(a)		t to fall = $\sqrt{(2s/g)}$ / $\sqrt{(2 \times 44 / 9.8)}$ ✓ $t = 3.(0)$ s ✓ $(R = vt) = (8.0 \times 3.0) = 24$ m ✓	L L M	method in words / numbers / algebra not $t = 2.99$ for part evaluation [result of rounding error from using $g = 9.81$] allow full credit for just correct answer even if used $t = 2.99$
32	(b)		Reasoning clear i.e. same t ✓ (so must have x3 horizontal v) = <u>24</u> (m s^{-1}) ✓	M M	not just x3 or $t=3$ allow falls at same rate so $t=3$ allow correct calculations involving new range 72m allow ecf from (a) for evaluation mark only
			Total	5	

Question			Answer	Marks	Guidance
33	(a)	(i)	turns ratio = 20 :1 ✓ $V_S = 240 / 20 = 12$ (V a.c.) ✓	L L	allow 2000/100 = 20 allow formulation $V_S = V_P \times (t_S / t_P)$ allow full credit for just correct answer
33	(a)	(ii)	$I_S = 24$ (W) / 12 (V) = 2.0 (A a.c.) ✓ $I_P = 2.0 / 20 = 0.10$ A ✓	L M	accept other correct formulations $P_P = P_S$ allow full credit for just correct answer accept ecf of incorrect value of V_S from a(i)
33	(b)		<u>heat</u> loss is caused in coils by electrical resistance / <u>heat</u> loss is caused in core by eddy currents / <u>heat</u> loss is caused in core by magnetic hysteresis / by vibration of parts of core or coils / by flux leakage so S coil does not cut all flux from P ✓	L	accept energy lost as heat due to (electrical) resistance of windings not power
			Total	5	

Question			Answer	Marks	Guidance
34	(a)	(i)	$\gamma = E_{\text{Total}} / E_{\text{Rest}}$ / = (140 + 73) / 140 ✓ $= 1.5(2)$ ✓	L L	method in words / algebra / numbers accept 213 / 140 evaluation
34	(a)	(ii)	$1 - (v/c)^2 = 1/\gamma^2$ ✓ $v = \sqrt{1 - 1/1.52^2} \times c = 0.753 c$ ✓	M M	transcription in / algebra / numbers allow ecf from a(i) to give answer within $0.745 \leq v < 0.755$

34	(b)		$L = \gamma \tau v \quad / \quad = 1.52 \times 2.6 \times 10^{-8} \times 0.753 \times 3 \times 10^8$ $= 8.9(3) \text{ m}$	H H	method in words / algebra / numbers accept 8.89 m if 0.75 c used accept ecf from a(i) and a(ii) within range given
			Total	6	

Question			Answer				Marks	Guidance
35			position	phasors	resultant phasor	relative intensity	M S&C S&C	accept an equilateral Δ of angle ≈ 60° any orientation accept correct three phasors drawn separately i.e. not in Δ accept an isosceles Δ of angle ≈ 120° any orientation accept correct three phasors drawn separately i.e. not in Δ
	B at 60°		✓	1	1			
	A at 120°		✓	√3	and 3	✓		
			Total				3 21	
			Total section B					

Section C

Question			Answer	Marks	Guidance
36	(a)	(i)	both scales cover: 4 orders of magnitude / from 10^0 to 10^4 ✓	L	allow to space out a very large range of values not exponential
36	(a)	(ii)	D has (directly) proportional response / D could be used for lower dose to patient / D has <u>larger</u> linear range ✓	M	allow F has smaller usable linear region OR other ORA allow D has an output for lower relative input radiation doses accept linear for all radiation doses
36	(a)	(iii)	range $10^4 = 10\,000$ / $2^n = 10\,000$ ✓ $n \log_{10} 2 = 4$ $n = 4/\log_{10} 2 = 13.2$ so 14 needed ✓	M M	allow AW using $2^{14} = 16\,384 > 10\,000$ for first mark, leading to comparison with $2^{13} = 8192 < 10\,000$ as not enough bits for second mark allow AW using $\log_2(10000) = 13.29$ for first mark leading to comparison with < 14 for second mark
36	(b)	(i)	recognition of 12 bits per pixel ($2^{12} = 4096$) ✓ ($2048 \times 1680 \times 12$) = 41.(3) M(bits) ✓	L M	not 14.1 G(bits) allow 39.4 M(bits) using computing $k = 1024$ allow correct answers in bits kbits etc
36	(b)	(ii)	bones are of particular interest to radiologist but have lower x-ray exposure than softer tissue / to spread out these low pixel values more gives more useful information than altering darker over exposed areas as much ✓	H	accept AW e.g. gives a wider range of pixel values within the bone structure rather than the background which helps identify features of interest.

Question			Answer	Marks	Guidance
36	(b)	(iii)	edge enhancement and helps to look for bone fractures and splinters OR noise removal and of scattered x-rays improves visibility of real bone details ✓	M	not just to see bones more clearly not any reasoning based on contrast change / adjustment requires named process and with reasoning for the mark
			Total	8	

Question			Answer	Marks	Guidance
37	(a)	(i)	$\rightarrow \frac{4}{2}\text{He} + \frac{1}{0}\text{n}$ ✓	L	expect all symbols 2 , 1 and 0 for the mark
37	(a)	(ii)	1. reactants binding energy / MeV = $2[-1] + 3[-2.5]$ = -9.5 OR 2. products binding energy / MeV = $4[-7]$ = -28.0 ✓ binding energy released $-28.0 - [-9.5]$ = -18.5 (MeV) ✓	M H	accept values in range -9.5 to -10 MeV accept values in range -28.0 to -28.4 first mark for either reactants or products energy correct accept values in range -18.0 to -18.9 accept final answer with + sign for energy released second mark for correct evaluation of released energy expect correct evaluations for first and second marks that are based on reading of ^2H of -1.0 to -1.1 and ^3H of -2.5 to -2.6
37	(a)	(iii)	momenta are equal and opposite $4m \times v = m \times 4v$ so neutron has x4 speed of the ^4He nucleus ✓ energies in ratio ($n : ^4\text{He}$) = $\frac{1}{2} m (4v)^2 : \frac{1}{2} 4m v^2$ = 4 : 1 (so neutron has $\frac{4}{5}$ of energy released) ✓	S & C S & C	accept in numbers / words / algebra / use of $v/4$ and v not just momentum is shared/conserved

Question			Answer	Marks	Guidance
37	(b)	(i)	LHS: (electrical) potential energy of two proton charges approaching to a separation of R when strong nuclear attractive forces overcome electrical repulsion ✓ RHS: (an estimate of) the mean thermal energy per particle at absolute temperature T ✓	S & C H	accept two electronic charges approaching to separation R when strong nuclear attractive forces overcome electrical repulsion allow mean kinetic energy per particle at absolute temperature T allow at temperature T it is the energy at which many ^2H and ^3H nuclei could overcome their electrical repulsion and possibly cause fusion
		(ii)	$T = (9.0 \times 10^9)(1.6 \times 10^{-19})^2 / (1.4 \times 10^{-23} \times 2 \times 10^{-14})$ $= 820 \text{ M(K)}$ ✓	H	evaluation allow 800 M(K) or 1 G(K) estimate allow 830 / 833 / 834 M(K)
	(c)	(i)	$n \text{ atoms} = \rho V N_A / m_{\text{average}}$ ✓ $= 230 \times 4.2 \times 10^{-9} \times 6 \times 10^{23} / 2.5 \times 10^{-3} = 2.3(2) \times 10^{20}$ ✓ $E = nkT = 2.3 \times 10^{20} \times 1.4 \times 10^{-23} \times 4 \times 10^8 = 1.3 \text{ M(J)}$ ✓	S & C S & C S & C	 correct evaluation of $2.3(2) \times 10^{20}$ scores first two marks allow 2.6 M(J) if candidates count in electrons i.e. doubling particles in plasma
37	(c)	(ii)	$E_{\text{Fusion}} = (^2\text{H } ^3\text{H pairs}) \times E_{\text{Binding}}$ $= \frac{1}{2} \times 2.3 \times 10^{20} \times 18.5 \times 10^6 = 2.1 \times 10^{27} \text{ eV}$ ✓ (convert to J) $E_{\text{Fusion}} \times 1.6 \times 10^{-19} = 340 \text{ MJ}$ so $E_{\text{Fusion}} \gg E_{\text{Heating}}$ ✓	S & C S & C	allow ecf on E_{Binding} from a(ii) and number of atoms from c(i) allow $1.3 \text{ MJ} \equiv 8.1 \times 10^{24} \text{ eV}$ and comparison in eV allow x 260 energy to heat plasma allow x 130 energy to heat plasma if electrons considered must have comparison for full credit
37	(c)	(iii)	production of high energy laser pulse / producing solid pellets of ^2H and ^3H in 1:1 ratio / short duration needed for pulse / balancing radiation pressure from opposing lasers for inertial confinement / timing of laser pulses to hit bead simultaneously / /	M	allow any sensible practical difficulty / H & S aspect not just large temperatures needed not just high energy usage / economic benefit

			containing super hot plasma away from vessel sides / absorbing hot neutrons from fusion		
			Total	14	

Question		Answer	Marks	Guidance
38	(a)	This is LoR not tick-based marking – see page 4 of this mark scheme. Level 3 (5–6 marks) Marshals argument in a clear manner and includes clear explanation of both strands, including gravitational force and energy aspects: • circular motion at constant speed • elliptical motion cannot be constant speed <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 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 HH	accept labelling on Fig. 38.1 and diagrams or graphs throughout. Credit correct labelling of F and v. Indicative physics may include: Strand 1 : circular motion at constant speed • force of gravity remains perpendicular to the velocity doing no work on comet, so constant speed and k.e. • the acceleration produced is centripetal and is a change of the velocity direction only, not magnitude accept $a=v^2/r$ as part of reasoning • $GMm / R^2 = mv^2 / R \rightarrow v = \sqrt{GM / R}$ • any m can orbit at constant R with the same speed in a circular orbit centred on M • orbit follows a gravitational equipotential $V = - GM / R$ showing no change in p.e. or k.e. • comet is trapped in a potential well not just circular orbit has constant speed Strand 2 : elliptical motion cannot be constant speed • comet in elliptical orbit changes distance from the Sun and changes gravitational potential $V = - GM / R$ • comet rises and falls in Sun's potential well, increasing g.p.e. when further from Sun slowing down and losing k.e. • max p.e. and min k.e. furthest from Sun / min p.e. and max k.e. when nearest • at B1 gravity component parallel to v speeds comet up and component perpendicular to v changes direction accept AW e.g. at B1 a gravity component acts in the same direction as the speed, so the speed increases

Question			Answer	Marks	Guidance
					- at B2 gravity component anti-parallel to v slows comet down and component perpendicular to v changes direction accept AW e.g. at B2 a gravity component acts in the opposite direction to the speed, so the speed decreases - gravitational force increases as distance from Sun decreases so acceleration / velocity increases not just elliptical orbit has changing speed
38	(b)	(i)	$\theta = 10^{-6}$ rads from diagram ✓ $r = d \tan \theta = 26 \times 10^3 \times 9.5 \times 10^{15} \times \tan(10^{-6}) = 2.5 \times 10^{14}(\text{m})$ OR $r = d \theta = 26 \times 10^3 \times 9.5 \times 10^{15} \times 10^{-6} = 2.5 \times 10^{14} (\text{m})$ ✓	M H	not using 1×10^{-6} as radius of circle / in $2\pi r$ not incorrect use of $\sin \theta$ accept $2.47 \times 10^{14} / 2.46 \times 10^{14} / 2.6 \times 10^{14}$
38	(b)	(ii)	$GM/R^2 = (2\pi R/T)^2/R$ / $M = 4\pi^2 R^3/(GT^2)$ ✓ solar masses $= 4\pi^2 \{2.5 \times 10^{14}\}^3 / \{6.7 \times 10^{-11} \times 2 \times 10^{30} \times [33 \times 3.2 \times 10^7]^2\}$ ✓ $= 4.1 \times 10^6$ ✓	H S & C S & C	1st mark stating K3 OR rearrangement for unknown M 2nd mark substitution including division by solar mass OR evaluation of black hole mass $M = 8.3 \times 10^{36} \text{ kg}$ 3rd mark final evaluation
38	(b)	(iii)	$R_S = 2 \times 6.7 \times 10^{-11} \times 8.3 \times 10^{36} / 9 \times 10^{16} = 1.2 \times 10^{10} \text{ m}$ ✓	M	accept $R_S \approx 1/_{53}$ closest approach of S2 ecf from bii allow question b(ii) values for M $4 \times 10^6 \times 2 \times 10^{30} \text{ kg}$
			Total	12	

Question			Answer	Marks	Guidance

Question			Answer	Marks	Guidance																
3 9	(a)	(i)	initial current is initial gradient of graph / $\Delta Q / \Delta t$ ✓	L	method accept sensible tangent drawn at graph origin																
			= 0.60 / 14 = 0.043 (A) ✓	M	evaluation accept in range 0.040 to 0.05 (A)																
3 9	(a)	(ii)	$R = V / I$ / 10 / 0.043 ✓	L	allow ecf on (a)(i) not $V=IR$ or $I=V/R$																
			= 233 (Ω) ✓	M	evaluation expect in range 200 to 250 (Ω) allow ecf on (a)(i)																
3 9	(b)		as capacitor charges p.d. across it increases and opposes the applied 10 V so less than 10 V is across the resistor and current decreases ✓	H	explanation must be complete for the mark																
3 9	(c)	(i)	<table><tr><td>s</td><td>C</td><td></td><td>V</td><td></td><td>A</td><td></td><td>C</td></tr><tr><td>6</td><td>0.244</td><td>and</td><td>4.88 ✓</td><td></td><td>0.0256</td><td>and</td><td>0.0512 ✓</td></tr></table>	s	C		V		A		C	6	0.244	and	4.88 ✓		0.0256	and	0.0512 ✓	L M	one mark each for two pairs of values correct
			s	C		V		A		C											
6	0.244	and	4.88 ✓		0.0256	and	0.0512 ✓														
3 9	(c)	(ii)	at $t = 4$ s Q on capacitor is 0.16 C / iterative model value is larger than experimental value ✓	L	comparison from graph accept in range 0.155 to 0.165 C																
			the charge flow ΔQ in time Δt is too large because current is assumed constant during Δt (in reality it is decaying as capacitor charges). / to improve make Δt smaller (until difference is negligible) ✓	M		explain / improve															
			Total	9																	

Question			Answer	Marks	Guidance
40	(a)	(i)	$r = 0.30 / 0.080 = 3.8 \text{ } (\Omega)$ ✓	L	evaluation accept in range 3.7 to 4.0 (Ω)
40	(a)	(ii)	max electrons per sec = max current / e OR $= 0.068 / 1.6 \times 10^{-19}$ ✓ $= 4.3 \times 10^{17} \text{ } (\text{s}^{-1})$ ✓	L M	method accept in algebra / numbers / words evaluation accept $4.25 \times 10^{17} \text{ } (\text{s}^{-1})$
40	(a)	(iii)	in solar cell each electron is given energy by one photon being absorbed from the max total in the photon flux ✓	H	accept photon flux incident on cell limits the charge flow accept surface area of cell limits charge flow at given illumination intensity
40	(b)		This is LoR not tick-based marking – see page 4 of this mark scheme. Level 3 (5–6 marks) Marshals argument in a clear manner and includes clear explanation of three strands: • circuit diagram • experimental method • precautions to ensure reliability <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	LLL MMH	Indicative physics may include: Strand 1: circuit diagram with standard symbols • the solar cell with <u>variable</u> load resistor ($\approx 500 \text{ } \Omega$) • voltmeter (5 V) in parallel (with solar cell) and ammeter (100 mA) in series with (load resistor) • switch to bring load into circuit Strand 2: experimental method • illuminate cell by fixed distance mains lamp • measure ϵ of cell with only meters connected • switch in load resistance set to max position • measure a pair of p.d. and current readings • alter load value and repeat V and A readings • continue until short circuit current is measured for very low load Strand 3: precautions to ensure reliability

Question			Answer	Marks	Guidance
			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 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		• repeat readings at same p.d. and / or current settings so that mean values and uncertainties can be estimated • monitor cell temperature so that it is known to be constant during the data collection • if mains lamp causes significant heating, it could be switched off between readings and only turned on during data collection • monitor the light intensity of the lamp with a digital light-meter to check for mains variation and avoid readings if mains voltage drops / appropriate method for keeping light intensity constant accept well labelled diagrams throughout for credit if integrated into the explanation allow MAX Level 1 for credit of correct points that relate to an experiment in which light intensity is varied whilst load resistor value is fixed.
			Total	10	

Question			Answer	Marks	Guidance
41	(a)	(i)	$v = 13 \text{ (ms}^{-1}\text{)}$ from Fig 41.3 ✓ peak $f = 34 \text{ (Hz)}$ from Fig 41.2 ✓ OR $s = 1 / \text{gradient} = 24 / 60 = 0.40 \text{ (m)}$ ✓ peak vibration at $v = 13.5 \text{ m s}^{-1}$ so peak $f = 13.5 / 0.40$ $= 34 \text{ (Hz)}$ ✓	L M	accept in range 13 to 14 (ms^{-1}) expect methods but give full credit for correct evaluations in range 32 to 35 (Hz) expect methods but give full credit for correct evaluations in range 0.39 to 0.41 (m) accept 13 or 14 m s^{-1} accept in range 32 to 35 (Hz)
41	(a)	(ii)	$f \propto v$ so intensity graph is resonant response graph with frequency response the resonant response shows high Q / quality / low damping large amplitude oscillations build up around one input frequency (speed) / when it matches natural frequency of cavity the oscillation in car is only excited over a narrow band of velocities / frequencies when amplitude increases a lot there is a periodic / harmonic / simple harmonic input (the eddies being formed) driving another oscillator (the air volume in car) ✓	 M H	credit any two correct separate marking points
41	(b)		$f = (340/2\pi)\sqrt{(0.18/(3.2 \times 0.14))}$ ✓	L	substitution

Question			Answer	Marks	Guidance
			= 34.(3) (Hz) ✓	L	evaluation
			Total	6	
			Total section C	59	
			Total sections B & C	80	

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