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.

Annotations available in Scoris

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
SF	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 = √(2s/g) / √(2 x 44 / 9.8) ✓ t = 3.(0) s ✓ (R = v t) = (8.0 x 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 Vs from a(i)
33	(b)		heat loss is caused in coils by electrical resistance / heat loss is caused in core by eddy currents / heat 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)	$\gamma = E_{Total} / E_{Rest}$ / = (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 <= v < 0.755

34	**(b)**		L = $\gamma \tau$ v / = 1.52 x 2.6 x 10^{-8} x 0.753 x 3 x 10^{8} ✓ = 8.9(3) 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			<table><tr><th>position</th><th>phasors</th><th>resultant phasor</th><th>relative intensity</th></tr><tr><td>B at 60°</td><td>  ✓</td><td>1</td><td>1</td></tr><tr><td>A at 120°</td><td>  ✓</td><td>$\sqrt{3}$</td><td>and 3 ✓</td></tr></table>	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
			Total **Total section B**	**3** **21**	

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 x 1680 x 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 pixl 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)	$\rightarrow \ {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} +$ ✓	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 ^{2}H of -1.0 to -1.1 and ^{3}H of -2.5 to -2.6
37	(a)	(iii)	momenta are equal and opposite 4m x v = m x 4v so neutron has x4 speed of the ^{4}He nucleus ✓ energies in ratio (n : ^{4}He) = ½ m $(4v)^2$: ½ 4m v^2 = 4 : 1 (so neutron has $^{4}/_{5}$ of energy released) ✓	S & C S & C	**accept** in numbers / words / algebra / use of v/4 and v **not** just momentum is shared/conserved

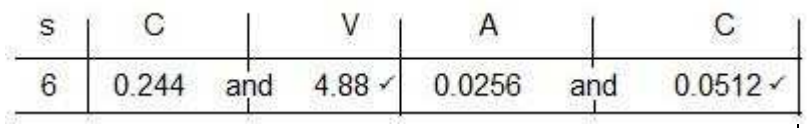
Question			Answer	Marks	Guidance
37	(b)	(i)	LHS: (electrical) potential energy of two proton charges approaching to a separation of R when strong nuclear attractive forces overcome electrical repulsion ✓ RHS: (an estimate of) the mean thermal energy per particle at absolute temperature T ✓	S & C H	**accept** 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)	$T = (9.0 \times 10^9)(1.6 \times 10^{-19})^2 / (1.4 \times 10^{-23} \times 2 \times 10^{-14})$ $= 820$ M(K) ✓	H	evaluation **allow** 800 M(K) or 1 G(K) estimate **allow** 830 / 833 / 834 M(K)
	(c)	(i)	n atoms = $\rho V N_A / m_{average}$ ✓ $= 230 \times 4.2 \times 10^{-9} \times 6 \times 10^{23} / 2.5 \times 10^{-3} = 2.3(2) \times 10^{20}$ ✓ $E = nkT = 2.3 \times 10^{20} \times 1.4 \times 10^{-23} \times 4 \times 10^8 = 1.3$ 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_{Fusion} = (^2H ^3H pairs) x $E_{Binding}$ $= ½ \times 2.3 \times 10^{20} \times 18.5 \times 10^6 = 2.1 \times 10^{27}$ eV ✓ (convert to J) $E_{Fusion} \times 1.6 \times 10^{-19} = 340$ MJ so $E_{Fusion} >> E_{Heating}$ ✓	S & C S & C	**allow** ecf on $E_{Binding}$ from a(ii) and number of atoms from c(i) **allow** 1.3 MJ ≡ 8.1×10^{24} 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 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 at a superficial level and does not include enough indicative points for level 3. 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)** 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. 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	**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)**	θ = 10^{-6} rads from diagram ✓ r=d tan θ = 26 x 10^3 x 9.5 x 10^{15} x tan(10^{-6}) = 2.5 x 10^{14}(m) OR r = d θ = 26 x 10^3 x 9.5 x 10^{15} x 10^{-6} = 2.5 x 10^{14} (m) ✓	**M** **H**	**not** using 1x10^{-6} as radius of circle / in 2 π r **not** incorrect use of sin θ **accept** 2.47 x 10^{14} / 2.46 x 10^{14} / 2.6 x 10^{14}
38	**(b)**	**(ii)**	GM / R^2 = $(2\pi R / T)^2$ / R / M = $4\pi^2R^3$ / (G T^2) ✓ solar masses = $4\pi^2${2.5 x 10^{14}}^{3}/{6.7 x 10^{-11}x 2 x 10^{30} x [33 x 3.2 x 10^7]^2} ✓ = 4.1 x 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 x 10^{36} kg **3rd mark** final evaluation
38	**(b)**	**(iii)**	R_S = 2 x 6.7 x 10^{-11} x 8.3 x 10^{36} / 9 x 10^{16} = 1.2 x 10^{10} m ✓	**M**	**accept** $R_S \approx {}^1/_{53}$ closest approach of **S2** **ecf** from bii **allow** question b(ii) values for M 4 x 10^6 x 2 x 10^{30} kg
			Total	**12**	

Question			Answer	Marks	Guidance

Question			Answer	Marks	Guidance
39	(a)	(i)	initial current is initial gradient of graph / $\Delta Q / \Delta t$ ✓ = 0.60 / 14 = 0.043 (A) ✓	L M	method **accept** sensible tangent drawn at graph origin evaluation **accept** in range 0.040 to 0.05 (A)
39	(a)	(ii)	R = V / I / 10 / 0.043 ✓ = 233 (Ω) ✓	L M	**allow** ecf on (a)(i) **not** V=IR or I=V/R evaluation **expect** in range 200 to 250 (Ω) **allow** ecf on (a)(i)
39	(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
39	(c)	(i)		L M	**one mark each** for two pairs of values correct
39	(c)	(ii)	at t = 4 s Q on capacitor is 0.16 C / iterative model value is larger than experimental value ✓ 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) ✓	L M	**comparison** from graph **accept** in range 0.155 to 0.165 C **explain / improve**
			Total	9	

Question			Answer	Marks	Guidance
40	(a)	(i)	r = 0.30 / 0.080 = 3.8 (Ω) ✓	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 x 10^{-19} ✓ = 4.3 x 10^{17} (s^{-1}) ✓	L M	method **accept** in algebra / numbers / words evaluation **accept** 4.25 x 10^{17} (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 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)** 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 variable load resistor (≈ 500 Ω) • 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. 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)** 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. 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		• 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 (ms^{-1}) from Fig 41.3 ✓ peak f = 34 (Hz) from Fig 41.2 ✓ OR s = 1 / gradient = 24 / 60 = 0.40 (m) ✓ peak vibration at v = 13.5 m s^{-1} so peak f = 13.(5) / 0.40 = 34 (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 = (340/2π)$\sqrt{}$(0.18/{3.2 x 0.14}) ✓	L	substitution

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

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