Oxford Cambridge and RSA

GCE

Physics B

H557/02: Scientific literacy in physics

Advanced GCE

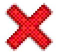
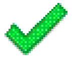
Mark Scheme for June 2019

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 RM Assessor

Annotation	**Meaning**
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
TE	Transcription error
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
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

Note about significant figures:

If the data given in a question is to 2 sf, then allow to 2 or <u>more</u> significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the <u>entire</u> paper.
Any exception to this rule will be mentioned in the Guidance.

Section A

Question			Answer	Marks	Guidance
1	(a)	i	v = (0.20 kg × 1.8 m s^{-1})/ 0.50 kg ✓ = 0.72 m s^{-1} ✓	2	Correct bald answer gains both marks Accept 0.7ms^{-1}
	(a)	ii	initial k.e. = 0.324 J ✓ = 0.32 (J) final k.e. = 0.1296 J ✓= 0.13 (J)	2	ecf from (a)(i) on final k.e.(0.36 J from v = 1.2 m/s from (i)) accept 0.216 J for final k.e. if this follows from mass and velocity error from (a) (i)
	(a)	iii	Change of momentum of 0.2 kg mass = 0.20 kg × (0.72 - 1.8) m s^{-1} = - 0.216 kg m s^{-1} ✓ Change of momentum of 0.3 kg mass = 0.30 kg × (0.72 - 0) m s^{-1} = (+) 0.216 kg m s^{-1} ✓ Force on 0.2 kg mass = -0.216 kg m s^{-1}/Δt Force on 0.3 kg mass = (+)0.216 kg m s^{-1}/Δt ✓	3	Ecf from (a) (i) (Commonly giving 0.12 kg m s^{-1} for one momentum and 0.36 kg m s^{-1} for the other) Must show working and one value of Δp is positive and the other is negative Accept use of 0.7ms^{-1} Last marking point is independent and is for recognition that the two changes occur over (the same) time Δt.
	(b)		Clear attempt at finding whole area under the line ✓ Impulse evaluated using FΔt leading to impulse of 2.0 x 10^{4} N s to 2.3 x 10^{4} N s ✓ Answer in the range (-) 14.3 m s^{-1} to 16.4 m s^{-1} ✓	3	Ecf from impulse for third mark
			Total	**10**	

Question			Answer	Marks	Guidance
2	(a)		p.d = 6.1 V × (4.7 kΩ/6.9 kΩ) = 4.155V (~ 4.2 V)	1	Must have own value, e.g. 4.16V Penalise rounding error
	(b)		total resistance of 4.7 kΩ resistor and voltmeter R_T: 3.2 V = 6.1 V x (R_T/(R_T +2.2 kΩ) ✓ ⇒ R_T = 2.4 kΩ✓ $2.4^{-1} = 4.7^{-1} + R_{voltmeter}^{-1}$ $R_{voltmeter}$ = 4.9 kΩ✓	3	Or via: 2.9 V = 6.1 V (2.2 kΩ/(R_T +2.2 kΩ) Or via: I = 2.9 V /2.2 kΩ = 1.32 mA & R_T = 3.2 V/1.32 mA = 2.4 kΩ Reverse method ok If R_v=5kΩ total parallel resistance = 2.42kΩ✓ V_v=6.1 x $\frac{(2.42\ x10^3)}{2.42\ x10^3+2.2\ x10^3}$✓ =3.197V ✓ (3.2) Using different number of sig figs for R_T gives answers in the range 4.9-5.03 kΩ
	(c)	i	I = 0.5/4.9 x 10^{-3} = 1.0 x 10^{-4} A✓	1	Same answer using 5 kΩ Ecf from (b)
	(c)	ii	From $\varepsilon = V + Ir$ =0.93 V + (0.93 V/1×10^6 Ω)r =0.5 V + (0.5 V/4.9×10^3 Ω) r ✓ 0.93 V + (9.3 × 10^{-7} A) × r = 0.5 V + (1.0 x 10^{-4} A) × r ✓ r = (0.93 V – 0.5 V)/(1.0 x 10^{-4} A – 9.3 × 10^{-7} A) = 4.3 k Ω✓	3	Accept: Assuming ε = 0.93 V ✓ (explicit) 0.50 V = 0.93 V – 1 x 10^{-4} A × r✓ r = 4.3 k Ω ✓ Correct bald answer gains two marks Expect values around 4300Ω – sensitive to sfs in values
			Total	**8**	

Question			Answer	Marks	Guidance
3	(a)		Any four from: • Induced emf proportional to (-) rate of change of flux (linkage)/ quote Faraday's law • Area under graph the same both sides of the x-axis **because** this is change of flux linkage (accept flux) (which is the same entering the coil and leaving) • Peak e.m.f. larger on second 'loop' **because** magnet is moving faster (and so flux change is more rapid) • Duration of second loop is shorter than first loop **because** magnet is travelling faster • No e.m.f. recorded before first loop or after second loop **because** negligible flux (linkage) with the coil at those times (and so no $\Delta\Phi$) • e.m.f. is 0 when graph crosses t axis **because** magnet is centred on coil (and so no change in net flux linkage at that instant) • positive emf when flux is increasing / negative emf when flux is decreasing	4	Answer must explain an observation from the graph in terms of electromagnetic induction
	(b)		Any two from: • conductor subject to changing magnetic field • a (changing) e.m.f. is induced • e.m.f. drives a current in the disk Any two from: • induced current produces a magnetic field • magnetic field produced by current interacts with that of the magnets • By Lenz's Law (interaction is such that) the induced field acts to minimise the change producing it.	4	AW throughout Accept the **direction** of the eddy current is such as to oppose the change causing it. Accept forces linked to eddy currents opposing motion.

Question			Answer	Marks	Guidance
3	(c)	i	Exponential decrease where rate of decrease of quantity is proportional to the value of the quantity. AW ✓ Any three from: • Induced e.m.f. proportional to rate of change of flux • Magnitude of rate of change of flux linked to rate of rotation • (therefore) magnitude of (induced) currents/ field linked to rate of rotation • (therefore) magnitude of (braking) force linked to rate of rotation • As the effect of friction has not been removed, exponential behaviour might not be observed	4	Accept constant ratios idea Accept any link between magnitude of current and speed
	(c)	ii	Test for constant ratio property on two data pairs ✓ Test for constant ratio property on third data pair ✓ Conclusion linked to test on three pairs ✓ **OR** Taking two values of ln (speed) and finding time interval ✓ Taking another two values of ln(speed) and finding time interval ✓ Δ ln(speed)/Δt compared ✓	3	Accept other valid method If the method is not valid then zero marks e.g. finding and comparing gradients. If $v = v_0 e^{-kt}$, Δ ln(speed)/$\Delta t = k$
			Total .	**15**	

Section B

Question			Answer	Marks	Guidance
4	(a)	i	$E_k = eV = 1.60\times10^{-19}$ C × 4.3×10^{3} V (= 6.88×10^{-16} J) ✓ $v = \sqrt{(2 E_k/m)}$ = $\sqrt{(2\times6.88\times10^{-16}\ \text{J} / 9.11 \times 10^{-31}\ \text{kg})} = 3.9 \times 10^{7}$ m s^{-1} ✓	2	Correct bald answer gains both marks
		ii	rest mass of electron = 512 keV/8.20×10^{-14}J ✓ Gamma factor = (4.3keV + 512keV)/512 keV =1.008(4) ✓ Not much bigger than 1, therefore reasonable to ignore. ✓	3	Accept calculation of gamma from $\frac{1}{\sqrt{1-\frac{(3.9\times10^{7})^2}{(3\times10^{8})^2}}}$ ✓ (= 1.0086) = 1.009 ✓ Allow ecf of speed from (a)i If simply stated that relativistic effects can be ignored because velocity is about 0.1 *c*, one mark.
		iii	$\lambda = 6.63\times10^{-34}$ J s/(9.11×10^{-31} kg × 3.9×10^{7} m s^{-1}) = 1.87×10^{-11} m ✓	1	Allow ecf from a)i
	(b)		(higher energy electrons have) shorter wavelength✓ Angle to first order maximum decreases as wavelength decreases✓ More energetic electrons produce more photons when they strike the screen. ✓	3	Stating or implying that the electron energy is given by $E={hc}/{\lambda}$ negates first mark Accept 'shorter wavelengths diffract less' or reference to equation Accept 'smaller rings giving more concentrated release of photons/ more intense light'/ electrons strike smaller area of screen

Question			Answer	Marks	Guidance
4	(c)		**Level 3 (5–6 marks)** *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* Marshals argument in a clear manner. Clearly explains evidence for wave-like properties, evidence for particle-like properties and explains phasor model in context. **Level 2 (3–4 marks)** *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* Gives a clear explanation of two of the three strands to the question but may ignore one strand. Or, gives a less detailed explanation of all strands but misses out vital links in the explanations. **Level 1 (1–2 marks)** *There is an attempt at a logical structure with a line of reasoning. The information is for the most part relevant.* Explains one strand clearly and completely, or two strands in a less complete manner. **0 marks** No response or no response worthy of credit	6	**Indicative scientific points may include:** **Wave-like behaviour** • Diffraction usually (classically) considered a wave property • Explained by waves superposing • Producing areas/places of maximum and minimum amplitude • Dependent on the phase relationship of the superposing waves **Particle-like behaviour:** • Electrons producing (discrete) flashes of light is evidence of particle like behaviour • Flash suggests discrete/point-like interactions with the screen • rather than the energy of each electron spread across the screen in the manner expected of waves • electrons have been accelerated (without changing medium) **Phasor model** • phasors described as rotating arrows (representing phase and amplitude) accept rotating vectors • electron (or electron phasor) explores all possible paths • between (e.g.) graphite layer and screen • resultant phasor is the sum of all the phasor amplitudes (added tip to tail) • Probability of electron detected at a given position can be calculated from the square of the resultant phasor
			total	**15**	

Question			Answer	Marks	Guidance
5	(a)		$N_0 - N = N_0 - N_0e^{-\lambda t}$ $= N_0(1 - e^{-\lambda t})$ ✓	1	Must work through to final equation.
	(b)	i	Change in proton number from 8 alpha decays = 8 ×-2 = -16 Change in proton number from 6 beta decays = 6 × +1 = +6, Therefore, Total change in proton number = -10 ✓ Change in nucleon number = 8 × -4 = -32✓	2	Alternative routes possible but working must be shown, e.g. putative decay series completely sketched out
	(b)	ii	Decay constant = ln 2/$T_{½}$ = 0.693/4.47 × 10^9 years = 1.55 × 10^{-10} year^{-1} (~ 1.6 x 10^{-10} yr^{-1}) ✓	1	Must show working and correct value
	(b)	iii	(No. U-238 decayed)/(initial No. U-238) = 1 – 0.39 = 0.61✓ $0.61 = e^{-1.6\times10^{-10}t}$ ✓ ln 0.61 = - 1.6 × 10^{-10} $t \Rightarrow t$ = 3.1 or 3.2 × 10^9 yr ✓	3	Working must be shown. Use of 0.39 giving answer of t = 5.9 or 6.1 × 10^9 yr scores maximum of 2 marks.
	(c)	i	$N_0 = \frac{N}{e^{-\lambda t}}$ $\therefore D = \frac{N}{e^{-\lambda t}} - N$ ✓ $(=N(\frac{1}{e^{-\lambda t}} - 1))$	1	Alternative routes possible but derivation must be clear.
	(c)	ii	22.8 = $(N_0-N)/N = N_0/N$ - 1so N_0/N = 23.8 $23.8 = \frac{1}{e^{-\lambda t}} \therefore 23.8 = e^{\lambda t}$ ln 23.8 = λt ✓ λ = ln(2) /$T_{½}$ = ln(2)/7.0×10^8 years = 9.90×10^{-10} year^{-1} ✓ t = ln 23.8/9.90×10^{-10} year^{-1} = 3.2 × 10^9 years ✓	3	Other routes possible. Correct bald answer gains all the marks but don't allow copying of answer from b iii.
	(c)	iii	Any two from: • Allows the mean to be calculated • Some daughter product may have left the sample • Contamination less likely to affect three decay series • (Use of three series) allows identification of anomalous results/series • Spread of results indicates uncertainty.	2	,
			total	**13**	

Question			Answer	Marks	Guidance
6	(a)		Uniformly/equally spaced (field) lines✓	1	
	(b)	i	Forces are equal (& opposite)✓ AW $qvB_s = qE_s$ ✓	2	Can be stated algebraically Accept *e* for *q* .
	(b)	ii	Units of E_s/B_s : N C^{-1}/N A^{-1} m^{-1} ✓ =C^{-1}/ C^{-1} s m^{-1} ✓ (= m s^{-1})	2	Accept alternative units for E_s/B_s Alternative routes possible but derivation of units must be clear.
	(b)	iii	Particle is deflected in the vertical plane ✓ Particle will follow a curved path ✓ Particle <u>accelerates/experiences resultant force</u> (in a vertical plane). ✓	3	Accept moves up or down Allow parabolic or circular motion for second marking point.
	(c)	i	$F = 1.6 \times 10^{-19}$ C × 5.2 x 10^6 m s^{-1} × 0.64 T = 5.32×10^{-13} N (~ 5.3×10^{-13} N) ✓	1	Working must be shown. Accept worked answer to 2 s.f.
		ii	$F = mv^2/r$ $r = 1.673\times10^{-27}$ kg × $(5.2 \times10^6 \text{ m s}^{-1})^2/(5.3 \times 10^{-13}$ N)✓ = 0.085 m ✓	2	Do not accept 0.08 m (rounding error)
		iii	(*F* is same, so) $\frac{m_{C(14)}v^2}{r_{C(14)}} = \frac{m_{C(12)}v^2}{r_{C(12)}}$✓ $\frac{r_{C(14)}}{r_{C(12)}} = \frac{m_{C(14)}}{m_{C(12)}}$ ✓ $m_{(C14)} = 14$ & $m_{(C12)} = 12$, so = $\frac{m_{C(14)}}{m_{C(12)}}$= 1.1666… = 1.2✓	3	Accept 1.17, not 1.16 Answers of 7/6 award two marks maximum.
			total	**14**	

Section C

Question			Answer	Marks	Guidance
7			resolution = 70 km/(832 pixels × 5/7) ✓ = 0.12 ✓	2	range 0.10 to 0.13 km pixel $^{-1}$
			total	**2**	
8	a	i	r = $\sqrt{}$(6.7 × 10 $^{-11}$ N m ^{2} kg $^{-2}$ × 6.4 × 10 ^{23} kg/3.7 N kg $^{-1}$) ✓ = 3.404 × 10 ^{6} m (≈ 3.4 × 10 ^{6} m) ✓	2	Must show own value and working G = 6.67 × 10 $^{-11}$ N m ^{2} kg $^{-2}$ gives 3.397 × 10 ^{6}m
	b*		**Level 3 (5–6 marks)** *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* Marshals argument in a clear manner. Calculations correct, clear, giving units and correct number of s.f. Explanation of reasoning about energy needed to escape clear and using correct technical vocabulary. Description and explanation of potentials in the Solar System unambiguous. **Level 2 (3–4 marks)** *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* Calculations correct and sufficiently clearly structured to follow argument. Reasoning behind calculations attempted, but may be incomplete or superficial. Some attempt made to explain the energy needed to reach Earth or escape the Solar System. **Level 1 (1–2 marks)** *There is an attempt at a logical structure with a line of reasoning. The information is for the most part relevant.* Attempts calculation and reaches the expected answer but may not explain reasoning. Little or no comment on the energy required to reach Earth or leave the Solar System **0 marks** No response or no response worthy of credit.	6	Indicative scientific points may include: **Calculation**: • V_{grav} calculated as -12.6 x 10 ^{6} J kg $^{-1}$ • Clear link to energy required per kg to escape Mars = (+) 12.6 J kg $^{-1}$ • Energy to eject rock = 2.5 x 10 ^{6} J • Explanation that work is required to move rock through Martian gravitational field or to lift it out of the potential well. Can be expressed algebraically. AW **Explanation of gravitational potential in the Solar System.** (answers are given here in terms of gravitational potential wells, accept other terminology) • Sun has its own gravitational field • Mars in the Sun's gravitational well • Rock has to 'climb out' of Mars's potential well AND that of the Sun, requiring more energy • Earth is deeper in the Sun's potential well than Mars • Earth has its own potential well • Rock leaving Mars can 'fall into' Earth's well • And is falling into the Sun's potential well. Accept calculations or estimates or diagrams

			total	**8**	

Question			Answer	Marks	Guidance
9			$h = -(\ln 0.03/0.6) \times 1.4 \times 10^{-23} \times 210/7.3 \times 10^{-26} \times 3.7$ ✓ $= 3.26 \times 10^4$ m✓ Comment: *T* may not be constant. ✓ Lower *T* will give lower pressure (as e is raised to a bigger negative number) AW, ORA✓ OR Comment: *g* may not be constant ✓ Lower g will give higher pressure (as e is raised to a smaller negative number) AW, ORA ✓	**4**	Using $k = 1.38 \times 10^{-23}$ J K^{-1} gives 32.1 km Accept atmosphere not all CO_2 for 1 mark.
			total	**4**	
10	**a**		risk on Earth = 5% Sv^{-1} × 3 a × 0.4×10^{-3} Sv a^{-1}= 0.006% ✓ Any two from: • Risk on Earth is about 1000 times smaller✓ • magnetic field shields Earth✓ • atmosphere interacts with cosmic rays, (absorbing, scattering) ✓	**3**	Accept considerably smaller
	b		Radiation damages (body/tissue) cells (and their DNA) ✓ Suggestion for buildings (thick walls, underground etc.) linked with absorption/penetration of cosmic rays✓	**2**	Accept ionisation Accept use of lead. Require suggestion and reasoning for mark
			total	**5**	
11	**a**		centripetal force $= mv^2/r = m(2\pi r/T)^2/r$ $= m(4\pi^2)r^2/T^2)\ /r = m(4\pi^2)r/T^2$ $= (-)1000 \text{ kg} \times 4\pi^2 \times (2.27 \times 10^{11} \text{ m})/(5.94 \times 10^7 \text{ s})^2$ ✓ = (-) 2.54 N ✓ Force from Sun calculated to (-) 2.60 N ✓ Force from Mars calculated to 0.04 N ✓ Net force = (-) 2.56 N (≈ 2.54 N) ✓	**5**	Ecf within question but working must be clear. N.B. Data are to 3 s.f. so datasheet value of $G = 6.67\times10^{-11}$ N m^2 kg^{-2} is appropriate 2.589 N to 3 d.p. 0.037 N to 3 d.p. 2.552 N to 3 d.p.
	b		Other (massive) bodies in the Solar System (distort gravitational field) ✓	**1**	Allow radiation pressure on shield Accept hit by asteroid/space debris Accept non-circular orbits
			total	**6**	

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