GCE

Physics B

H557/02: Scientific literacy in physics

Advanced GCE

Mark Scheme for November 2020

Oxford Cambridge and RSA Examinations

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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

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

Question			Answer	Marks	Guidance
1	a	i	Data logger allow higher frequency of p.d. readings/reading a (changing) voltmeter would introduce greater uncertainty/datalogger timing will be precise	1	Don't accept bald 'more accurate' or 'less uncertainty'
		ii	Either: $0.63V_0 = 2.8$ V (1), time taken to reach this value (τ), 2.3 s < τ < 2.4 s (1) giving C between 450 and 480 μF (1) Or: Use of $V = V_0(1 - e^{-\frac{t}{RC}})$ Correct pair of V and t (1) Correct rearrangement to make C the subject(1) Value = 470 μF (1)	3	Don't accept answers from Q = It when I is held constant. Range at SSU SSU to consider 1/e approximated to 1/3, i.e. (2/3) V_0 = 2.8 V (Haven't seen this in first 20% of scripts) Range at SSU e.g. V = 2.5 V at t = 2 s (1) C = - 2/(5000 x ln(1 – 2.5/4.4) (1) = 0.00047 F (1)
		iii	E = 0.5 x 5 x 10^{-4} x 4.2^2 (1) = 0.0044 J (1)	2	Use either own value from a ii or 0.0005 F
	b	i	Line of decreasing negative gradient starting at 4.2 V (1) Gradient -0.5 x gradient of charging line at any time, by eye (1) Explanation: *RC* value in the discharge circuit is twice that of the charging circuit. AW(1)	3	Accept any clearly lower magnitude of gradient.
		ii	$E \propto V^2 \Rightarrow$ p.d. when energy stored has halved = 4.2 V × $\sqrt{0.5}$ = 3.0 V (2.97 V) (1) $V = V_0\, e^{-\frac{t}{RC}}$ where R= 10 kΩ & C= 470 μF ⇒ RC = 4.7 s (1) -t/4.7 s = ln(3.0 V/4.2 V) -t = 4.7 s × -0.336 ⇒ t = 1.58 s = 1.6 s (1)	3	Range at SSU Ecf from a iii if used Or RC = double τ from (a)(ii) If 500 x 10^{-6} F used, RC = 5 s leading to value 1.68/1.7 s. Bald in-range answer gains all marks

Question			Answer	Marks	Guidance
2	a		$0.8/3 \times 10^8 = 2.7 \times 10^{-9}$ light seconds (1)	1	No s.f. penalty
	b	i	Light (is observed to) travel a greater distance (1) at the same velocity (1)	2	e.g. $2ct > 2c\tau$
		ii	$c^2t^2 = v^2t^2 + c^2\tau^2$ (1) $t^2(1 - \frac{v^2}{c^2}) = \tau^2$ (1) (leading to $t = \frac{\tau}{\sqrt{1-\frac{v^2}{c^2}}}$)	2	Expect intermediate stages. Any correct routes gain both marks.
	c		$t = \frac{611}{\sqrt{1-\frac{(5.4\times10^7)^2}{(3.0\times10^8)^2}}}$ (1) = 621 s (1)	2	Calculating γ to 1.017 gains first mark. Accept answer rounded to 620 s.
	d		For photon $v = c$ so denominator (or $\sqrt{1-\frac{v^2}{c^2}}$) is zero/ gamma factor is infinite (1) Therefore t/γ ($= \tau$) is zero (for any value of t) (1)	2	AW but both steps needed for first mark. AW

Question			Answer	Marks	Guidance
3	a		wavelength of emitted light = (6.63 x 10^{-34} x 3.00 x 10^{8})/ (1.88 x 1.60 x 10^{-19}) (1) = 6.61 x 10^{-7} m (1)	2	Accept 2 or 3 s.f. No ecf from wrong value used in calculation.
	b	i	Linear graph with x-axis intercept of 1.25 ± 0.03 x 10^{6} m^{-1}	1	Examiner to extrapolate line if it doesn't extend to axis.
		ii	$h = \frac{E\lambda}{c}$ gradient = $\Delta V / \Delta\lambda^{-1} = \Delta V \times \Delta\lambda$ (1) $E = eV$ (1) (therefore, required equation)	2	Can get the second mark as a lone mark. Accept lack of delta notation if algebra correct, but working from $\Delta V / \Delta\lambda^{-1}$ needed0.
		iii	gradient working using x-interval of at least 0.4 x 10^{6} m^{-1} (1) gradient in range 1.0 x 10^{-6} to 1.2 x 10^{-6} (V m) (1) *h* in range 5.3 x 10^{-34} to 6.4 x 10^{-34} (J s)(1)	3	Ecf from b i clear values from graph required for first point expected value = 1.1 x 10^{-6} V m expected value = 5.9 x 10^{-34} J s
		iv	Steepest-possible value = 9.3 x 10^{-34} J s. (1) Uncertainty = ± (9.3 – 5.9) x 10^{-34} = 3.4 x 10^{-34}J s (1) Answer given as 5.9 x 10^{-34} J s ± 3.4 x 10^{-34} J s (1)	3	ecf from (iii) ecf from (iii) Allow 3 sf in final answer and uncertainty. Sf of value and uncertainty must match.Accept 1 s.f. uncertainty and value

Question			Answer	Marks	Guidance
Section B					
4	**a**		$1/3.85 \times 10^{-3}$ = (+) 260 D (1)	**1**	
	b		Waves will strike lens with curvature more negative than –260D (1) Curvature still negative (or zero) on leaving the lens (1)	**2**	accept attempt to calculate v using lens equation plus comment on (non) result.
	c		for $u = 1.2$ m, $v = 0.00386$ m (1) for $u = 0.050$ m, $v = 0.0042$ m(1) In the first case the image is formed very close to the sensitive surface, this is not so when $u = 0.050$ m (1)	**3**	Can't use argument that power of the lens is insufficient Accept correct answers derived from u and v confusion
	d		length on surface = (0.00385/0.35) x 0.090 (1) = 9.9×10^{-4} m (1)	**2**	Or calculates magnification as 0.011 for first mark Accept rounding to $1(.0) \times 10^{-3}$ m as long as method clear If u = 1.2 is used, one mark for correct answer, 2.9×10^{-4} m.
	e		length of pixel = $(4.89 \times 10^{-3} \times 3.65 \times 10^{-3}/12 \times 10^{6})^{0.5}$ (1) = 1.2×10^{-6} m (1) Number of pixels along 9.9×10^{-4} m = 825 (1) Resolution = 0.090/825 = 1.1×10^{-4} m	**4**	First mark can be awarded for area of a pixel calculated as $1.49 \times 10^{-12}/1.5 \times 10^{-12}$ m. If area of pixel is used to calculate resolution, no marks.
	f		Increase brightness (1) changing each pixel by a fixed value (until brightest pixel is coded at 255) (1) OR Increase contrast (1) stretching pixel values to cover full range (1) Benefit: improving images, removing noise, aesthetic changes etc Problems: pictures can be manipulated AW	**4**	
			Total	**16**	

Question			Answer	Marks	Guidance
5	a	i	k = (0.059 x 9.81)/(1.31 – 1.15)= 3.62 (~4) (1)	1	
		ii	E = 0.5 x 3.62 x $(1.31 – 1.15)^2$ (1) = 0.046 J (1)	2	
		Iii	**Level 3 (5–6 marks)** Marshals argument in a clear manner. Clearly links acceleration of the ball with the forces acting upon it throughout the fall. Makes a clear statement of the position of greatest velocity and calculates the maximum upwards acceleration. *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)** Gives a clear explanation of the motion of the ball but does not consider forces or gives incomplete description including forces. Makes some accurate quantitative statements. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Gives incomplete description which includes some correct physics, for instance initial acceleration, position of maximum velocity and position of maximum acceleration. *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	6	**Indicative scientific points may include:** • Acceleration = 9.81 m s^{-2} from release until length of cord = 1.15 m • as only force acting on ball is mg. • Describes velocity increasing at a decreasing rate until 1.31 m • From 1.15 to 1.31 m acceleration is decreasing • as net force on ball = $mg – kx$ • Greatest velocity at 1.31 m • From 1.31 m to 1.78 m the ball is decelerating at an increasing rate • as $kx > mg$ and the upward force increases as x increases • maximum upwards acceleration occurs at lowest point • upwards acceleration = $(kx – mg)/m$; • upwards acceleration = ((3.62 x 0.63) - (0.059 x 9.81))/0.059 = 28.8 m s^{-2}

Question			Answer	Marks	Guidance
5	a	iv	Sensible, practicable suggestion (1) Description of method (1)	2	E.g. video against a ruled background (1) Analyse frame by frame (1) NOT just 'use a video camera' OR Place board on floor and move up until the ball just touches the board at lowest point (1) Judge by sight or sound Measure distance (1)
	b		4 points from: • (Such a polymer is an example of) a long chain molecule • which can rotate about its bonds/untangle • Bonds are strong so polymer has high breaking stress • Elastic region has relatively low *k*, reducing force on bungee jumper • Metal structure is an array of positive ions in a sea of delocalised electrons • Mobile dislocations lead to plastic behaviour • Metals are only elastic for small strains as the deforming force pulls bonds apart • Plastic deformation occurs in metal for small strains • Decelerating force on jumper would be very great as metals have higher *k*	4	AW throughout. First and fourth bullet points can be given diagrammatically.
			total	**15**	

Question			Answer	Marks	Guidance
6	a	i	Starting height = 6.40×10^6 m & ending height = 7.225×10^6 m (1) Change in V_{grav}. is the area between the line and the axis (bounded by the starting and ending height) (1) Change in energy = change in V_{grav} x 2300 kg. Value between 1.55×10^{10} J and 1.75×10^{10} J (1)	3	Must show own value; from graph should be ~ 7.2×10^6 J kg^{-1}. Accept calculating to values of *GM/r* by multiplying *g* values by *r:* First mark for identifying heights correctly, Second mark for method Third mark for evaluation. Candidate must show how the result is achieved, even if a full explanation is not present. Accept ½ base x height calculations(plus rectangle) giving answers of around 1.7×10^{10} J Use of E = mgh is neutral in this case. Calculated value = 1.64×10^{10} J
	a	ii	$1.6 \times 10^{10} = GMm\left(\frac{1}{6.4 \times 10^6} - \frac{1}{7.225 \times 10^6}\right)$ (1) = 1.78×10^{-8} *GMm* $M = 1.6 \times 10^{10}/(6.67 \times 10^{-11} \times 2300 \times 1.78 \times 10^{-8})$ (1) = 5.8×10^{24} kg ($\approx 6 \times 10^{24}$ kg) (1)	3	e.c.f. own answer to ai. Must show working but steps in the working may be conflated.
	b	i	$F = (-)\frac{6.67 \times 10^{-11} \times 2300 \times 6 \times 10^{24}}{(7.225 \times 10^6)^2}$ (1) = (-) 1.763×10^4 N = 1.8×10^4 N (1)0	2	Bald correct answer gains two marks. Allow ecf from POT error in method – if clearly shown.
		ii	$v = \sqrt{\frac{1.8 \times 10^4 \times 7.225 \times 10^6}{2300}}$ = 7520 m s^{-1} (1) $T = \frac{2\pi \times 7.225 \times 10^6}{7520}$ (1) = 6037 s = 6040 s (1) OR $a = -\omega^2 r$ $1.8 \times 10^{44}/2300 = 4\pi f^2 \times 7.225 \times 10^6$ (1)	3	Allow for rounding differences. Bald correct answer gains three marks. Ecf from b(i). If 1.763×10^4 used, T = 6100 s

			$f^2 = 2.74 \times 10^{-8}$ (1) $f = 1.66 \times 10^{-4}\ s^{-1}$ T = 6037 s (1) OR $v = (GM/r)^{0.5} = 7520\ m\ s^{-1}$ (1) for first mark		
	c		Any three from: Advantages to low polar orbit: • High(er) resolution imaging AW • Image more of the planet as the Earth spins underneath the satellite Geostationary: • Remain at the same position in the sky so dishes can keep locked on to signal AW • Higher orbit means greater coverage	**3**	Not just ‘image more of planet’ or ‘see more clearly’ Note stem of question informs candidates that geostationary satellites are always above the same point on the Earth’s surface.
			total	**14**	

Section C					
Question			**Answer**	**Marks**	**Guidance**
7	**a**		400 Hz (1)	**1**	
	b		Highest frequency component = 800 Hz (1) Need twice this to avoid aliasing (AW) (1) Minimum sampling frequency = 1600 Hz (1)	**3**	The time period of the 'wobble' is ~ 0.0006 s. This may lead students to a high frequency component of 1670 Hz and therefore a minimum frequency of around 3300 Hz. Two marks max for this. (SSU) Can get the second two marks from the wrong highest frequency component. Two marks max for doubling the frequency in (a)
	c	**i**	Velocity increases whilst wavelength constant (1)	**1**	Need wavelength constant
		ii	$\frac{445}{440} = \frac{\sqrt{T_2}}{\sqrt{285}}$ (1) T_2 = 291.5 Hz so temperature rise = 6.5 K (1)	**2**	Bald answer gains both marks Accept 7 K
			total	**7**	

Question			Answer	Marks	Guidance
8	a		particle identified as anti-neutrino (1) (No leptons on LHS of equation), anti-lepton (anti-neutrino) balances lepton (electron) on RHS (1) Electrons released in beta decay have range of energies, (1) (the energy of the neutrino makes up the difference between energy released and the energy of the electron)	**3**	AW Mark for recognising the spectrum of energies of electrons emitted.
	b		Using $t = -\tau \ln\left(\frac{R_t}{R_0}\right)$: $9000 = \frac{-5700}{\ln 2} \ln\left(\frac{R_t}{1.4 \times 10^{-12}}\right)$ (1) Ratio = 4.7×10^{-13} (1) OR $\lambda = \ln 2/5700$ years $= 1.216 \times 10^{-4}$ year^{-1} (1) $R_t = R_0 e^{-\lambda t}$ $= 1.4 \times 10^{-12} \exp(-1.216 \times 10^{-4}$ year$^{-1} \times 9000$ year) $= 4.7 \times 10^{-13}$ (1)	**2**	Other methods possible. Correct bald answer gains both marks. Accept 3.8×10^{-12} (s^{-1}) for λ

Question			Answer	Marks	Guidance
8	c		**Level 3 (5–6 marks)** Marshals argument in a clear manner. Explains the idea of 'old carbon' released from volcanoes having lower $^{14}C/^{12}C$ ratio than living material. Clearly explains the use of tree ring data (which can also have its $^{14}C/^{12}C$ ratio measured) and links use of tree ring data back to measurement of plant age. Includes a clear and correct calculation of the effect of 'old-carbon' contamination. *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)** Gives a clear and complete qualitative explanation of the effect of old carbon and the use of tree ring data but the calculation is incomplete or incorrect in some aspects. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Gives a description of the effect of old carbon and the use of tree rings but the explanation is superficial or incomplete. Calculation, if attempted, is limited or incorrect. *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	6	**Indicative scientific points may include:** • Carbon-14 originally present in volcanic material has decayed • Carbon from volcanoes combines with oxygen to give carbon-dioxide which plants take up (through photosynthesis) • Take up of ancient carbon reduces $^{14}C/^{12}C$ ratio • Reduced $^{14}C/^{12}C$ ratio suggests a greater age • Trees absorb CO_2 during growth cycle • Age of trees can be directly measured by counting tree rings • $^{14}C/^{12}C$ ratio in each ring can be measured and compared with organic material in the vicinity. • Calculation: • 10% ancient carbon will reduce $^{14}C/^{12}C$ ratio to 1.26×10^{-12} • Apparent age = $\frac{-5700}{\ln 2}\ln(\frac{1.26}{1.4})$ • Apparent age = 866 years (2 s.f.)
			total	**11**	

Question			Answer	Marks	Guidance
9	a		$p = \sqrt{2mE_k} = \sqrt{2mqV}$ (= 2.50 × 10 $^{-19}$ N s) (1) $r = \frac{\sqrt{2 \times 2.33 \times 10^{-26} \times 4.2 \times 10^{6} / 3.2 \times 10^{-19}}}{0.72}$ (1) = 1.1 m (2 s.f.) (1)	3	Other routes possible. Correct bald answer gains three marks. Correct calculation following incorrect velocity value gains two marks ecf. Double error in charge (giving v = 7.59 x 10^{6} and r = 1.54 gains two marks) 0 1.55 or 1.6 m gains two marks (use of 1.6 x 10^{-19} rather than 3.2 x 10^{-19})
	b		These have the same mass as ^{14}C (1) and those with the same charge will be deflected the same amount in the magnetic field, (1) producing spurious ^{14}C results.	2	

OCR (Oxford Cambridge and RSA Examinations)
The Triangle Building
Shaftesbury Road
Cambridge
CB2 8EA

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk