Oxford Cambridge and RSA

GCE

Physics B

H557/01: Fundamentals of physics

Advanced GCE

Mark Scheme for November 2020

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

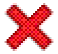
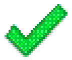
It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

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

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)		Δm = 0.20401 u ✓ convert u to kg OR convert via 1 u ≡ 931 MeV ✓ ($\Delta E = \Delta m\, c^2$) = 190(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 x 10^3 x 4 / [8.3 x 288] ✓ evaluation: = 75(3) 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 x 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**	

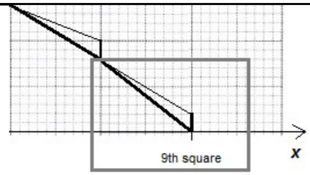
Question			Answer	Marks	Guidance
33	(a)		curves path / slows velocity ✓	L	**allow** accelerates the α / changes direction / changes velocity / slows down
33	(b)		(most) has been stored as / converted to <u>electrical</u> potential energy OR $k\,Q_1\,Q_2\,/\,R$ ✓	L	**allow** (small) fraction converted 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: $= 4.9 \times 10^{-15}$ m ✓	M H	**allow** 5.7×10^{-15} 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 ✓ evaluation: $= 1.5 \times 10^{10}$ Pa ✓	L M	**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
34	(b)		$W = \rho AL g \propto \rho$ for equal dimensions and gravity OR strength / weight $\propto \sigma_B / \rho$ ✓ silk / steel = $[1.4 / 1.2 \times 10^3] / [2.8 / 7.8 \times 10^3] = 3.3$ (≈3) ✓	H H	must have explanation of approach in words or symbols for first mark not just two calculations of σ_B / ρ
			Total	**4**	

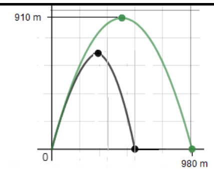
Question			Answer	Marks	Guidance
35	(a)		as h increases the path difference (**TM** + **MR** – **TR**) increases ✓ (two sets of waves superpose meaning) waves in phase at max and out of phase at min **/** whole number of wavelengths path difference gives constructive interference and (n+1/2)λ gives destructive 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 Δ p.d. = λ ✓ substitution: 2{$\sqrt{[1^2+0.213^2]}$ - $\sqrt{[1^2+0.123^2]}$} ✓ evaluation: =2.98 x 10^{-2} m ✓	H H H	**allow** any valid method e.g. between adjacent max and min Δ p.d. = λ / 2 answer of 1.49 x 10^{-2} scores 1 MAX as a result of omitting x2
			Total **Total section B**	**5** **23**	

Section C

Question			Answer	Marks	Guidance
36	(a)	(i)	$44 \times 10^3 \times 16 \times 2 = 1.4(1) \times 10^6$ bit s^{-1} ✓	L	**allow** 1.3(4) Mbit s^{-1} using 1 k = 1024
36	(a)	(ii)	t = info / 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 Hz)) ✓	M	
36	(b)	(iv)	evaluation: 4 x 24 x 100 = 9.6 k bit s^{-1} ✓ show that fraction: 9.6 k / 1.4 M = 0.0069 $\approx {}^{1}/_{146}$ ✓	H H	 **allow** 9.6 k / 1.0 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 9th large square exactly ✓	L	
37	(a)	(ii)	$(100\sqrt{2}) = 14(1)$ OR $(\sqrt{\{100^2 + 100^2]}) = 14(1)$ 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 m s^{-1} x 2.0 s = 200 m ✓ **2** so range is 200 x 9 = 1800 m ✓	L M	**allow** correct evaluation of any incorrect answer from **1** multiplied by 9
37	(a)	(iv)	$R = 141^2 \sin 90° / 10 = 19(90)$ (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**: ($R = 140^2 \sin 30° / 10 = 980$ m) times of flight $t_{75°} = 980 / 140\cos75° = 27.0$ s ✓ and $t_{15°} = 980 / 140\cos15° = 7.2$ s ✓ all 3 marks for $\Delta t = 27 – 7.2 = 19.8$ s ✓ OR **vertically**: $t_{75°} = 2 \times 140 \sin75° /10 = 27.0$ s ✓ and $t_{15°} = 2 \times 140 \sin15° /10 = 7.2$ s ✓ all 3 marks for $\Delta t = 27 – 7.2 = 19.8$ s ✓	S & C S & C S & C	for both horizontal and vertical approaches **allow** use of g = 9.8 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 *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 all strands at a superficial level and does not include enough depth 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** 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_{res} = $\Delta(mv)/\Delta t \propto \rho A v \times v \propto \rho A v^2$ • 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 $v \sin 75° / v \cos 75° = 3.7$ / 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 $v^2 \sin 150° / g = 980$m less area under $v(t)$ graph to max height / less than $\frac{1}{2} g t^2 = \frac{1}{2} \times 10 \times 13.5^2 = 910$ m / reaches max sooner / $t_{descent} > t_{ascent}$ for equal area under $v(t)$ graph **range** is smaller

					 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: $\Delta\lambda / \lambda$ = 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)**		$v = 0.050 \times 3 \times 10^{8} = 15 \times 10^{6}$ (m s^{-1}) ✓	**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}U / ^{238}U changes in time • estimation of age of atoms • assumptions *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 all 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** **S&C** **S&C**	**Indicative scientific points may include:** **ratio ^{235}U / ^{238}U changes in time** • ^{235}U has shorter half-life, decays more quickly • ^{235}U / ^{238}U drops < 1 after atoms have formed • accept sketch decay graphs differing $t_{½}$ • ^{235}U / ^{238}U = $N_0 e^{-\lambda_1 t}$ / $N_0 e^{-\lambda_2 t}$ **estimation of age of atoms** • ^{235}U / ^{238}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} / ln2 {1/λ_2 – 1/λ_1} t = - 4.926 / {0.693 x [1/4.5 – 1/0.71]} Gyears = 5.99 x 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}U / ^{238}U ≈ 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**	

Question			Answer	Marks	Guidance
40	**(a)**	**(i)**	method: $E = 40000 / 6 \times 10^{23}$ ✓ evaluation: 10^{23} = 6.66×10^{-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 x10 T so **bond energy** is x 10 = 6.7×10^{-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 x 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 = ln2/μ = 0.11 m / 11 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: $^3/_4$ x flux I x A x time x E photon^{-1} / mass worker ✓ ✓ evaluation: 1.3×10^{-3} [Sv] ✓	S & C S & C S & C	OR $\left[\dfrac{^3/_4 \times 1.2 \times 10^{16} \times e^{-6.3 \times 2} \times 0.5 \times 1200 \times 1.3 \times 10^{6} \times 1.6 \times 10^{-19}}{4\pi 2^2 \times 60}\right]$ Sv 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 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 V ✓ $v = \sqrt{[2\,e\,V_c / m]}$ evaluation = $1.3 \times 10^6\ m\ s^{-1}$ ✓	M M	accept values for anode potential of 48< V < 50
	(b)	(ii)	Method : $4 \times 3.7 \times 10^5\ m^2 / [3.70001 \times 10^5\ m]^2 = 1.08 \times 10^{-5}$ ✓	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 $V_{back\ off}$ 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 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 **Total sections B & C**	**57** **80**	

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

Cambridge Assessment