GCE

Physics B

H157/02: Physics in depth

Advanced Subsidiary 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
X	Incorrect 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
Section A				
1	**(a)**	$a = F/m$ = 260 000 N/(369000 kg) = 0.705 m s^{-2} ✓ v = 200 000 m/(3600 s) = 55.6 m s^{-1} ✓ $a = \Delta v/t \Rightarrow t = \Delta v/a$ = 55.6 m s^{-1}/0.705 m s^{-2} = 78.8 s = 80 s ✓	**3**	ALLOW use of $F = \Delta mv/t$ with conversion of v to m s^{-1} ✓ correct substitution ✓ evaluation ✓ Neglecting to convert v to m s^{-1} loses 1 mark in either approach
	(b)	Any two points from: Resultant force is reduced by frictional forces ✓ As train speeds up, resistive forces increase (so that resultant forward force decreases further) ✓ $F\downarrow \Rightarrow a\downarrow \Rightarrow t\uparrow$ ✓	**2**	
		Total	**5**	
2	**(a)**	Similarity: both have very strong inter-particle bonds ✓ Difference: metals have dislocations which can move (preventing brittle fracture) ✓	**2**	Allow atoms or molecules Allow opposite reasoning for ceramics
	(b)	Identifying unit indicates energy per something ✓ Identifying m^2 as area created in deforming ✓	**2**	'It's the energy per area produced to create new surface' gets both marks
		Total	**4**	
3	**(a)**	V_{total}/V_{noise} = 0.5 V/[2×10^{-3} V] = 250 ✓ Maximum number of useful levels, $b = \log_2(250)$ = 7.97 ✓ 8 is the next integer value greater than this, and any value > 8 would confer no advantage. ✓	**3**	Allow calculation of 2^8 = 256 ✓ 250 < 256, so 256 will be enough levels. ✓
	(b)	Amount of data in 1 s = 2 × 8 × 44.1 × 10^3 bits ✓ = 705600 bit s^{-1} = 0. 70(56) Mbit s^{-1} ✓	**2**	
		Total	**5**	

Question			Answer	Marks	Guidance
4	(a)		Thermistor resistance will decrease (as T increases) ✓ Smaller resistance takes a smaller share of the p.d. of the battery ✓	2	Or approach via current increasing resulting in greater p.d. across fixed resistor
	(b)	(i)	$V_{2.2k}$ = 4.5 V – 2.1 V = 2.4 V ✓ 2200 Ω / 2.4 V= R_T /2.1 V ✓ R_T = 2.1 V × 2200 Ω / 2.4 V = 1925 / 1920 / 1930 V✓	3	m.p. 2 may subsume m.p.1
	(b)	(ii)	R_T is between the values at 30 ° C and 40 ° C, but closer to the latter, so temperature is in the range 35°C < T < 40° C ✓	1	Allow linear interpolation, even though behaviour is exponential
			Total	**6**	
5			sin $\theta = \lambda/d$ and sin $\theta = x/L$ ✓ $\lambda/d = x/L$ ✓ $\lambda = dx/L$ = 13×10^{-3} m × 0.2×10^{-3} m / 4.20 m ✓ = 6.2 ×10^{-7} m = 620 nm ✓		d = slit separation, x = fringe separation recall of the Young's slits equation gets m.p.1 & m.p.2 must include correct powers of 10 for this mark ACCEPT 1 or 2 s.f.
			Total	**4**	
			Section A total	**24**	

Question	Answer	Marks	Guidance
Section B			
6 (a) (i)	(Energy gained by electron falling through a p.d. V,) $E = eV$ ✓ (Electron gains kinetic energy ½ mv^2 so) eV = ½ mv^2 ✓ Rearranges to $v = \sqrt{\frac{2eV}{m}}$ ✓	**3**	If m.ps 1 & 2 combined, needs to be explain that energy gained = eV Evidence of rearrangement needed for marking point 3
(a) (ii)	$v_{max} = \sqrt{\frac{2eV_{max}}{m}} = \sqrt{\frac{2 \times 1.60 \times 10^{-19}\ \text{C} \times 5000\ \text{V}}{9.11 \times 10^{-31}\ \text{kg}}}$ ✓ $= 4.19 \times 10^7$ m s^{-1} ($\approx 4 \times 10^7$ m s^{-1}) ✓	**2**	m.p.1 needs substitution of values, including V_{max} m.p.2 needs evidence of evaluation
(a) (iii)	$\lambda = h/p$ = [6.63×10^{-34} J s]/[9.11×10^{-31} kg×4 × 10^7 m s^{-1}] ✓ = 1.74× 10^{-11} m ✓ $\lambda \propto 1/p$ (& $v_{max} \Rightarrow p_{max}$) so $\lambda_{min} \Rightarrow p_{max}$ ✓	**3**	e.c.f. own v or 'show that' value from (ii).
(b) (i)	$\lambda = d \sin \theta$ = 0.14 × 10^{-9} m × sin[7.5°] = 1.83 × 10^{-11} m ✓ $p = h/\lambda$ = [6.63×10^{-34} J s]/[1.83×10^{-11} m] = 3.628×10^{-23} N s ✓ $v = p/m$ = [3.628×10^{-23} N s]/[9.11×10^{-31} kg] = 3.983×10^7 m s^{-1} ✓ V = ½ mv^2/e = [0.5× 9.11×10^{-31} kg×{3.983×10^7 m s^{-1}}^{2}]/[1.60×10^{-19} C] = 4515 V = 4.5 kV ✓	**4**	m.ps 1 – 3 can be subsumed into subsequent calculations. 4.5 kV gets 4 marks automatically
(b) (ii)	Suitable adjacent, equally-spaced layers indicated ✓ Spacing > d ✓ sin θ < sin[7.5°] so θ < 7.5° ✓	**3**	Needs at least 3 adjacent equidistant layers with spacing $\neq d$ for this mark.
	Total	**15**	

Question			Answer	Marks	Guidance
7	(a)	(i)	$t = d/v$ = 18.2 m/28 m s^{-1} = 0.65 s ✓	1	
	(a)	(ii)	Δp = 58.0×10^{-3} kg × 28 m s^{-1} = 1.624 N s✓ $F = \Delta p/\Delta t$ = 1.624 N s/ [2.0×10^{-3} s] = 812 N ✓	2	Or via $a = \Delta v/\Delta t$ = 14 000 m s^{-2} ✓and $F = ma$ = 812 N ✓
	(b)		$\Delta s = r + x$ = 6.70 cm/2 + [6.70 cm/2]/3 = 4.467 cm = 0.0467 m ✓ Energy stored = Work done on deformation = $F_{mean} \times \Delta s$ ✓ = 800 N × 0.0467 m = 35.7 J ✓ $E_k = ½ m v^2$ = 0.5× 58.0×10^{-3} kg × [28 m s^{-1}]^2 = 22 J ✓ Energy is dissipated/'lost'/converted to internal energy ('heat') in strings and ball ✓	5	Using ½ [$F_{mean} \times \Delta s$] loses this mark. e.c.f. (a)(ii). 812 N gives 37.9 J Must identify what has gained the [E_p - E_k]. e.c.f. own energy, e.g. if $E_p < E_k$ needs suggestion for source of extra energy e.g. continuing accelerating force applied by moving racquet while strings still deformed.

Question			Answer	Marks	Guidance
7	(c)*		**(Level 3) (5 – 6 marks)** Time of contact and mean force correctly related to the graph. Calculates force here > force in (a)(ii). Second curve drawn by candidate clearly has smaller F_{max}, longer t and smaller area under the curve (by eye). Difference in curves related to behaviour of strings and ball during contact and to subsequent motion of ball. *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)** Makes an estimate, possibly inaccurate, of area under graph. Incomplete or partially inaccurate justification of graph of data presented. New curve drawn has at least two correct features. May attempt to relate new curve to behaviour of ball, but does so in a superficial way unrelated to mechanics or material properties, e.g. “Ball will be slower.” *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)** Superficial or no attempt to find area under graph. New curve added should be the right shape but may be inaccurate in many ways, e.g. duration wrong or not starting at t = 0. Explanation of differences absent or vague. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant* **(0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	**[6]**	**Indicative scientific points may include:** **Using the graph to find the mean force** • Total time of contact = 2 ms • Mean force ≈ 1400 N (± 200 N) because … • … a horizontal line at 1400 N roughly bisects the curve area • …or drawing a regular shape e.g. triangle of same area (by eye) and calculate Δp = 2.8 N s (± 0.4 N s) as above and dividing by 2 ms gives this value • …or counting squares to get Δp= 2.8 N s (± 0.4 N s) and dividing by 2 ms gives this value **New curve for slacker racket** • Similar bell-like shape • Longer time of contact • Lower maximum force • Area under graph smaller/similar **Explanation of differences between the curves** • Strings take longer to reach maximum tension, so time longer • Energy stored not greater, so smaller mean force • Smaller area ⇒ less momentum gained by ball • $\Delta t \uparrow$& $\Delta p\downarrow$ so $F_{mean} \downarrow$ • Ball leaves racket slower than previous value **Use the L1, L2, L3 annotations in RM Assessor 3; do not use ticks.**
			Total	**14**	
			Section B total	**29**	

Question	Answer	Marks	Guidance
Section C			
8 (a)	Mean = [0.313 + 3×0.314 + 3×0.315 + 2×0.316 + 0.317]/10 = 0.3149 (mm) ✓ Range = [0.317 (mm) – 0.313 (mm)] = 0.004 (mm) So uncertainty ≈ ± ½ range = ± 0.002 (mm) ✓ Uncertainty should rounded to 1 s.f. (it is) and the mean rounded to the same precision, i.e. 0.315 (mm) ✓	**3**	

Question	Answer	Marks	Guidance
8 (b)*	**(Level 3) (5 – 6 marks)** A detailed procedure described in such a way that an experimenter could use it to perform the experiment. Safety issues are covered as well as care to avoid damaging the wire. General procedural details related to reproducibility and accuracy are well described. Awareness of the need to stay within the elastic range of the given wire is shown. *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)** Main points of the procedure covered but may lack detail. Method for ensuring low strains may be missing or not clear. *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)** Incomplete or superficial description of the procedure which could probably not be done adequately by someone with no prior experience of the experiment. Safety issues and considerations of damage to the copper wire are unlikely to be mentioned. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant* **(0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	[6]	**Indicative scientific points may include:** **General procedural details** • Make repeated readings • e.g. by loading, unloading, re-loading • Pay attention to safety • e.g. wearing eye protection, possibly gloves • e.g. preventing wire whip-back on breaking by surrounding with 'bridges' • Avoid parallax errors in reading position of marker attached to wire • By having ruler close to marker and at same height above bench • And by reading e from directly above • Values of m and e tabulated **Details related to the behaviour of copper** • Ensure that • Copper wire is firmly held between wood strip and block by clamping firmly • while ensuring wire is not deformed by crushing • Check maximum extension expected for elastic strain • 0.1% of 2.8 m = 2.8 mm • And ensure the values of x are less than this • Wait before adding further masses to ensure wire is not creeping • Do not drop slotted masses onto the holder/ add the masses gently (to avoid sudden excessive strain) **Use the L1, L2, L3 annotations in RM Assessor; do not use ticks.**

Question	Answer	Marks	Guidance
(c) (i)	$E = \sigma/\varepsilon$ **and** $\sigma = F/A$ **and** $\varepsilon = x/L$ ✓ $F = mg \Rightarrow E = \{[mg/A]/[x/L]\} = [mgL]/[Ax]$ ✓	2	All three relationships need to be clearly stated or subsumed in further steps to get m.p.1 Rearrangement and incorporation of $F = mg$ must be clear.
(c) (ii)	Draws best-fit straight line m/x and finds Δm and Δx ✓ Gradient: m/x= 0.9 kg/[0.00254 m – 0.00013 m]= 370 kg m^{-1} ✓ Draws a suitable extreme plausible line and finds its gradient $\Delta[m/x]$ correctly deduced from extreme line and best-fit line ✓	3	Ignore s.f.e. in this question part (tested in (a)(i)) Needs a reasonable best-fit straight line. Do not award this mark if base of gradient triangle < 0.0005. Gradients for steepest and shallowest plausible lines are 405 kg m^{-1} and 340 kg m^{-1} $\Rightarrow \Delta[m/x] \approx 30$ kg m^{-1}.
(c) (iii)	$A = \pi d^2/4 = \pi\times(0.315\times10^{-3}\text{ m})^2/4 = 7.79\times10^{-8}\text{ m}^2$ ✓ $m/x = EA/gL$ = [120×10^9 Pa × 7.79×10^{-8} m^2)]/[9.81 N kg^{-1} × 2.800 m] = 340 (kg m^{-1}) ✓ 340 is within the range of 370 ± 30 ✓	3	e.c.f. own d from (a)(i) e.c.f. own A. Correct substitution of π and d can get m.p.1 here e.c.f. own answer: must use answers from (c)(ii).
	Section C Total	**17**	

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