

GCE

Physics B

H157/02: Physics in depth

Advanced Subsidiary 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.

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Annotations available in Scoris

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response
	Arithmetic error
	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
(1)m	a method mark, awarded if a correct method is used
(1)e	an evaluation mark, awarded for correct substitution and evaluation

All questions with mark totals > 1 should be annotated with ticks to show where marks have been awarded in the body of the text. Ticks must NOT be used in 6(b) or 8(e), just L3, L3[^], L2, L2[^], L1, L1[^] and X for 6 to 0 marks respectively.

Question	Answer	Marks	Guidance
Section A			
1 (a)	Strain = 0.45 % = 0.0045 ✓ Extension = 0.0045 × 31 cm = 0.1395 cm So length = 31 cm + 0.1395 cm = 31.1 cm [3 s.f.] ✓	2	Ecf own strain, but must be to 3 s.f.: strain = 0.45% misinterpreted as 0.45 leads to extension = 13.95 cm giving length = 44.95 cm = 44.9/45.0 cm to 3 s.f.
(b)	$A = \pi[13 \times 10^{-3} \text{ m}/2]^2 = 1.3(3) \times 10^{-4} \text{ m}^2$ ✓ At 0.1% strain, stress $\sigma = 161 \text{ MPa}$ ✓ $F = \sigma A = 1.61 \times 10^8 \text{ Pa} \times 1.33 \times 10^{-4} \text{ m}^2 = 21000/21400 \text{ N}$ ✓	3	ACCEPT stress in range 160 – 165 MPa Ecf own value A
(c)	Choice of suitable σ & ε values, e.g. 100 MPa, 0.05% ✓ $E = \sigma/\varepsilon = 100 \times 10^6 \text{ Pa}/0.05\% = 1.0 \times 10^8 \text{ Pa}/0.00005$ ✓ $= 2.0 \times 10^{11} \text{ Pa}$ ✓	3	Needs $\sigma \leq 100 \text{ MPa}$ unless correctly extrapolated e.g. to (0.115%, 225 MPa) Correct conversions and substitution. ALLOW $E = FL/Ae$ Typical values: F 13 000N, e $1.55 \times 10^{-4} \text{ m}$
	Total	8	
2 (a)	490 nm < λ < 500 nm converted to m, e.g. $4.97 \times 10^{-7} \text{ m}$ ✓ THEN $f = c/\lambda = [3.00 \times 10^8 \text{ m s}^{-1}]/[4.97 \times 10^{-7} \text{ m}] = 6.04 \times 10^{14} \text{ Hz}$ ✓ $E = hf = 6.63 \times 10^{-34} \text{ J s} \times 6.04 \times 10^{14} \text{ Hz} = 4.00 \times 10^{-19} \text{ J}$ ✓ OR recall of $E = hc/\lambda$ ✓ evaluation of E ✓	3	
(b)	$P = 12 \times 4.00 \times 10^{-19} \text{ J}/0.1 \text{ s}$ ✓ $= 4.8 \times 10^{-17} \text{ W}$ ✓	2	e.c.f. own E from (a) or use of $5 \times 10^{-19} \text{ J} \Rightarrow 6 \times 10^{-17} \text{ W}$
	Total	5	
3	$d = 5.0 \times 10^{-2} \text{ m}/52 = 9.62 \times 10^{-4} \text{ m} = 9.6 \times 10^{-4} \text{ m}$ ✓ $\lambda = d \sin \theta \Rightarrow \theta = \arcsin[\lambda/d] = \arcsin[630 \times 10^{-9} \text{ m}/9.6 \times 10^{-4} \text{ m}]$ $= 0.0376^\circ$ ✓ $x/L = \tan \theta \Rightarrow x = 3.6 \text{ m} \times \tan(0.0376^\circ) = 2.36 \times 10^{-3} \text{ m}$ ✓	3	ALLOW 53 gaps $\Rightarrow d = 9.43 \times 10^{-4} \text{ m}$ 53 gaps $\Rightarrow \arcsin(6.68 \times 10^{-4} \text{ m}) = 0.382^\circ$ or recall of $x/L = \lambda/d$ ✓ evaluation of λ ✓ no ecf from m.p.2 53 gaps $\Rightarrow x = 2.41 \times 10^{-3} \text{ m}$
	Total	3	

Question	Answer	Marks	Guidance
4 (a)	Currents at 3.0 V are 25 mA & 46.5 mA ✓ Total current drawn = 25 mA + 46.5 mA = 71.5 mA = 0.0715 A ✓ THEN $G = I/V = 0.0715 \text{ A}/3.0 \text{ V} = 0.0238 \text{ S} = 0.024 \text{ S} \text{ (2 s.f.)} \checkmark$ OR $R = V/I = 3.0 \text{ V}/0.0715 \text{ A} = 42.0 \Omega$ and $G = 1/R \checkmark$	3	Needs 46 mA < I_B < 47 mA. Ecf own I_B Can calculate both $G_1 = 0.0083 \text{ S}$, $G_2 = 0.0155 \text{ S}$ separately for marking point 2 and add for marking point 3 or $R_1 = 120 \Omega$ & $R_2 = 64.5 \Omega$ for m.p.2 $\Rightarrow R_{\text{tot}} = 42.0 \Omega$, $G = 0.024 \text{ S}$ for m.p.3 If wrong V chosen, can get mp2 & mp3 ecf. No ecf for mp3 if two errors preceded it.
(b)	p.ds. across the two components must add to give 6.0 V ✓ at 36 mA, $V_A = 4.4 \text{ V}$ and $V_B = 1.6 \text{ V}$ (which add to give 6.0 V) ✓	2	e.g. $V = 6.0 \text{ V}$ is shared (in a series circuit) allow tolerance of 0.1 V on each V but must add to 6 V. m.p. 2 may subsume m.p.1 or $R_1 + R_2 = 119 \Omega + 47 \Omega \Rightarrow I = 6 \text{ V}/166 \Omega = 0.0361 \text{ A}$
Total		5	
5 (a)	$F = 8.2 \text{ N} \times \sin(35^\circ) = 4.70 \text{ N} \checkmark$ $m = 8.2 \text{ N}/9.81 \text{ N kg}^{-1} = 0.836 \text{ kg} \checkmark$ $a = F/m = 4.70 \text{ N}/0.836 \text{ kg} = 5.6(2) \text{ m s}^{-2} \checkmark$ OR Vertical acceleration in absence of the ramp would be $g \checkmark$ Component of g along slope = $g \sin 35^\circ / g \cos 55^\circ \checkmark$ $= 9.81 \text{ m s}^{-2} \times 0.574 = 5.62 \text{ m s}^{-2} = 5.6 \text{ m s}^{-2} \text{ (2 s.f.)} \checkmark$	3	Alternative methods possible Mp1 is resolution, mp2 is finding m , mp3 = evaluation of a Can be implied by resolution, or even just a correct use of g anywhere
(b)	$\Delta E_k = \text{work done} = 4.70 \text{ N} \times 0.68 \text{ m} = 3.2 \text{ J} \checkmark$	1	a bald answer of 3.2 J (ecf own F or a) is enough. Other approaches possible, e.g. $\Delta E_{\text{gpe}} = mgh$ where $h = 0.68 \text{ m} \sin(35^\circ) = 0.390 \text{ m}$
Total		4	
Section A total		25	

Question	Answer	Marks	Guidance
Section B			
6 (a) (i)	$d = 2.04 \text{ nm}/8 = 0.255 \text{ nm}$ so $r = 0.1275 \text{ nm}$ ✓ $V = (4/3)\pi r^3 = (4/3)\pi[1.275 \times 10^{-10} \text{ m}]^3$ ✓ $= 8.682 \times 10^{-30} \text{ m}^3 (\approx 9 \times 10^{-30} \text{ m}^3)$ ✓	3	Unit conversion and substitution Evaluation
(a) (ii)	$m = 63.5 \text{ g}/N_A$ ✓ $= 0.0635 \text{ kg}/6.02 \times 10^{23} = 1.055 \times 10^{-25} \text{ kg} = 1.05/6 \times 10^{-25} \text{ kg}$ ✓	2	
(a) (iii)	$\rho = m/V = 1.05 \times 10^{-25} \text{ kg} / 8.682 \times 10^{-30} \text{ m}^3 = 12100 \text{ kg m}^{-3}$ ✓	1	$V = 9 \times 10^{-30} \text{ m}^3$ gives 11700 kg m^{-3} e.c.f. own m Ignore s.f.e.
(a) (iv)	In the real solid here are spaces between the atoms ✓ So a real solid has a smaller mass per unit volume/ so a given mass takes up more space ✓	2	

Question	Answer	Marks	Guidance
6 (b)*	(Level 3) (5 – 6 marks) Identifies lack of dislocation movement in the alloy. Recognises that the looser structure implies reduced density for similar atoms. Links crystal changes/lack of dislocation movement correctly to differences in at least one physical property (density, hardness, stiffness) with justification OR correctly links lack of dislocation movement to two physical properties. Links changed alloy properties to desirable properties of coins, e.g. hardness, stiffness. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> (Level 2) (3 – 4 marks) Identifies lack of dislocation movement in the alloy. Attempts to link to differences in at least one physical property but does not link to a desirable property for coins. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> (Level 1) (1 – 2 marks) Makes simple comparisons between the crystal structures in terms of regularity but unlikely to mention dislocations or to use to predict differences in physical properties relevant for coins <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> (0 marks) No response or no response worthy of credit.	[6]	Indicative scientific points may include: Difference between individual atoms: • Zinc atoms are larger than copper atoms • so lattice will be disrupted/include gaps Discussion of crystal structure and bonding • Alloy has larger inter-atomic gaps • Resulting in lower overall density (even ignoring atom density differences) • Crystal structure is not a regular lattice • Larger Zn atoms will ‘pin’ dislocations • So dislocations cannot readily move Discussion of different physical properties and suitability for coins • Lack of dislocation movement will make the metal harder • So coins will not easily scratch • Lack of dislocation movement will make the metal stiffer • So coins will not easily bend • Coins need to be malleable to be formed Use the L1, L2, L3 annotations in Assessor; do not use ticks.
	Total	14	

Question	Answer	Marks	Guidance
7 (a)	Mass m of air displaced = $\rho V = 1.2 \text{ kg m}^{-3} \times 3.4 \times 10^{-5} \text{ m}^3$ $= 4.08 \times 10^{-5} \text{ kg}$ ✓m ✓e So weight of air = $mg = 4.08 \times 10^{-5} \text{ kg} \times 9.81 \text{ N kg}^{-1}$ $= 4.00 \times 10^{-4} \text{ N}$ ✓ Compared with W: $4.00 \times 10^{-4} \text{ N} / 0.026 \text{ N} = 0.0154$ $= 1.54 \%$ (which $\approx 1\%$) ✓	4	One-stage calculation of $W = 4.00 \times 10^{-4} \text{ N}$ can get marking points 1 to 3 in one stage, even without working. Requires a clear comparison with 0.026 N
(b)	$A = \pi r^2 = \pi(0.020 \text{ m})^2 = 1.2566 \times 10^{-3} \text{ m}^2 = 1.26 \times 10^{-3} \text{ m}^2$ ✓ $D = \frac{1}{2} \rho A C_d v^2$ $= 0.5 \times 1.2 \text{ kg m}^{-3} \times 1.26 \times 10^{-3} \text{ m}^2 \times 0.4 \times (9.3 \text{ m s}^{-1})^2$ $= 0.026 \text{ N}$ ✓ $D = W$ (- U) as it is not accelerating ✓	3	$1.25 \times 10^{-3} \text{ m}^2$ is a rounding error (RE) Must have evidence of evaluation of this, e.g. by substitution of correct values into the equation e.g. $D = W$, possibly in words
(c) (i)	Tangent drawn at $t = 1 \text{ s}$ ✓ $v = \Delta s / \Delta t = (22.4 \text{ m} - 0 \text{ m}) / (4.0 \text{ s} - 0.42 \text{ s})$ ✓ $= 6.3 \text{ m s}^{-1}$ ✓	3	line should be tangent at $t = 1 \text{ s}$ and cut $t = 4 \text{ s}$ between 22.0 m and 28 m. Award this mark only if $\Delta t \geq 1.0 \text{ s}$. e.c.f. own triangle: range of readings acceptable. Must have 2 or 3 s.f. for marking point 3.(evaluation)
(c) (ii)	Curve becomes a straight line (by $t = 3 \text{ s}$) (1)	1	NOT directly proportional
(d)	Denser gas so increased upthrust ✓ larger ρ AND C_d ✓ so greater drag D at any v OR smaller v to give same drag ✓ produces lower terminal velocity / reaches terminal velocity sooner due to greater D ✓	4	
Total		15	
Section B total		29	

Question	Answer	Marks	Guidance
Section C			
8 (a)	Correct explanation of systematic error ✓ (For any pair of readings), Δu will be the same size as Δv ✓ Δu & Δv will be in opposite directions ✓	3	Must have the idea that it is built into the system of measurement used i.e. not measuring from the (optical) centre but from some point to one side of it. May refer to calibration or zero error. e.g. if $ u $ is too small, v will be too big by the same amount
(b)	Taking all 8 values, range of v is (34 cm, 42 cm) $\Delta v = (42 \text{ cm} - 34 \text{ cm})/2 = 4 \text{ cm}$ ✓ mean $v = (34 \text{ cm} + 42 \text{ cm})/2 = 38 \text{ cm}$ ✓ OR mean $v = (34+35+34+36+41+41+40+42)/8$ $= 38 \text{ cm}$ rounded to nearest cm ✓	2	Correct answer is $38 \text{ cm} \pm 4 \text{ cm}$ and can be obtained in different ways. If mean quoted as 37.9 cm, accept either $42 \text{ cm} - 37.9 \text{ cm} = 4.1 \text{ cm}$ or $37.9 \text{ cm} - 34 \text{ cm} = 3.9 \text{ cm}$ for Δv ALLOW mean = (mean v_{max} – mean v_{min}) = 37.8 cm
(c)	$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{u} + P$ ✓ $y = mx + c$ so $m = 1$ and $c = P$ if $y = 1/v$ and $x = 1/u$ ✓	2	Rewriting the lens equation in terms of u , v and P Identifying m and c from the lens equation
(d)	$1/v$ values of 13.9 m^{-1} AND 15.9 m^{-1} respectively ✓ At least one uncertainty in $1/v$ correctly found ✓ Points and uncertainty bars correctly plotted with e.c.f. ✓	3	ALLOW 13.89 m^{-1} AND 15.87 m^{-1} . See table below. Allow 1 m^{-1} or 2 m^{-1} Tolerance $\pm$ half a small square.

v	Δv	v_{min}	v_{max}	$1/v$	$1/v_{\text{min}}$	$1/v_{\text{max}}$	diff/2	$1/v - 1/v_{\text{max}}$	$1/v_{\text{min}} - 1/v$	$\Delta(1/v)$
0.072	0.008	0.064	0.08	13.889	15.625	12.5	1.5625	1.389	1.736	1, 2, 2
0.063	0.007	0.056	0.07	15.873	17.857	14.286	1.786	1.587	1.984	2, 2, 2

Question	Answer	Marks	Guidance
8 (e)*	(Level 3) (5 – 6 marks) Maximum and minimum gradients and at least one intercept value found with sensible comparison of gradient with 1 and intercept with 20 m^{-1}. Realises that data contradicts expected results, even though graph looks good. Recognises that systematic errors may be responsible for incorrect gradient and intercept. <i>There is well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> (Level 2) (3 – 4 marks) Two reasonable lines drawn and at least one value each of values of gradient and intercept found correctly. Other evaluation superficial, as level 1. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> (Level 1) (1 – 2 marks) At least one acceptable line drawn through data. Gradient found, possibly with too small a triangle. Intercept read correctly. Unlikely to refer to expected values, and evaluation may be simplistic, e.g. repeat experiment. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> (0 marks) No response or no response worthy of credit.	[6]	Indicative scientific points may include: Analysis of graph • Max gradient found (I get 2.4) • Min gradient found (I get 1.7) • Max y-axis intercept found (I get 32.0 m^{-1}) • Min y-axis intercept found (I get 25.7 m^{-1}) Comparison with expected results • Expected gradient = 1 is lower than the minimum found • Expected y-axis intercept = power of lens with 50 mm focal length • $1/(50 \times 10^{-3} \text{ m}) = 20 \text{ D}$ • Expected y-axis intercept is lower than the minimum found Evaluation of the graph • Data all fall within a reasonable straight line with no obvious outliers • Uncertainty decreases with larger $1/u$ • i.e. when object is closer to lens, results are more uncertain Evaluation of the procedure followed • systematic error (as in part (a)) could explain the ‘wrong’ gradient and intercept • random uncertainties would create greater spread of data but should not make gradient and intercept so wrong. • Need to have more data to clarify, e.g. more data points, or trying a different zero of measurements on the lens body. Use the L1, L2, L3 annotations in Assessor; do not use ticks.
Section C Total		16	

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