GCE

Physics B

H557/03: Practical skills in physics

Advanced 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.

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 more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td>a</td><td>i</td><td>(n = sin i ÷sin r =) sin 40÷sin 22

(n =) 1.7(2)</td><td>1

1</td><td>If radians are used answer = -84 (award 1 mark for correct method even is working is missing).
Answer correct to 2sf. Don’t penalise 1.71.
Raw answer of 1.7 gains both marks.</td></tr>
<tr><td></td><td></td><td>ii</td><td><table><tr><td>angle</td><td>maximum value / °</td><td>minimum value / °</td></tr><tr><td>angle of incidence, i</td><td>44</td><td>36</td></tr><tr><td>angle of refraction, r</td><td>26</td><td>18</td></tr></table>
Find max value of n = sin 44÷sin 18 (= 2.248)
AND/OR
Find min value of n = sin 36÷sin 26 (= 1.3408)

Uncertainty = 2.25 – 1.72 = 0.53 [max value – 1.7]
OR
Uncertainty = 1.72 – 1.34 = 0.38 [1.7 – min value]
OR
Uncertainty = ½(2.25 – 1.34) = 0.46 or 0.45 (depending on rounding) [½(max – min)]</td><td>1

1

1</td><td>All 4 values needed for the mark.

Allow ecf of incorrect max and/or min values of angles from table.

ALLOW correct use of the their max and/or min values and value of n calculated in part (i).
eg. sin 44÷sin 26 = 1.6 and sin 36÷sin 18 = 1.9, so uncertainty = 0.2 or 0.1.
ALLOW answers to 1sf.

Do not credit a raw answer of 0.5, which can be achieved by adding percentage uncertainties of angle i and angle r – an incorrect method.</td></tr>
</table>

	b		**Level 3 (5-6 marks)** ✓✓ Detailed description of experimental procedure and/or analysis with meaningful description of the other strand. For example, a response having a detailed description of the analysis but only limited experimental procedure can get a level 3. *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)** ✓✓ Workable description of experimental procedure and/or analysis. *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)** ✓✓ Limited description of experimental procedure and/or analysis. *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.	**1 × 6**	**Indicative scientific points may include:** **Experimental procedure:** • vary angle of incidence and measure angle of refraction • angle of incidence goes up increments (eg 5° or 10°) • draw round block on paper and mark path of light with points, then draw lines through points with ruler (especially inside block) • place block on top of large protractor • measure angles when light enters and when light leaves rectangular block (as a repeat) • use set square/protractor to mark normal • use a large/higher resolution protractor to measure angles or trigonometry (measure length of opposite side) • use a very narrow ray of light with parallel sides or laser • dark room and/or bright light source • use monochromatic light source **Analysis:** • calculate $n = \sin i \div \sin r$ • <u>compare</u> values of n from different values of i. • plot graph of sin i against sin r • draw straight line of best fit • find gradient of line and hence refractive index • use 'large triangle' to find gradient • add error bars to plotted points • draw 'worst-fit' lines • use gradient of 'worst-fit' lines to find min and max values of n.
			Question total	**11**	

Question			Answer	Marks	Guidance
2	a	i	Resolving forces horizontally gives $F = T\,sin\theta = T\,(\frac{x}{L})$ Displacement from equilibrium position / *x*, is in opposite direction to *F*, hence negative sign.	**1** **1**	ALLOW $F = T\,tan\theta = T\,(\frac{x}{L})$ IGNORE reference to W (as this is resolving horizontally)
		ii	Equating the two expressions for acceleration, $-4\pi^2 f^2 x = -g\frac{x}{L}$ and cancelling *x* and negative sign to give $4\pi^2 f^2 = \frac{g}{L}$ (Substituting $T = \frac{1}{f}$)to give $\frac{4\pi^2}{T^2} = \frac{g}{L}$, and rearrangement (to give $T^2 = \frac{4\pi^2 L}{g}$)	**1** **1**	Any subject for the simplified equation, omitting one or more negative signs will lose the first marking point. Allow alternative methods, eg substitute $x = -\frac{aL}{g}$ into $a = -4\pi^2 f^2 x$.
	b	i	Reaction time or error in starting and/or stopping watch. Longer time (to measure) gives smaller percentage/relative/fractional uncertainty (due to reaction time) (or vice versa)	**1** **1**	Not just human error or random error. ALLOW uncertainty reduced to $\frac{1}{10}$ or 10% (of previous value)
		ii	1.613 2.085 2.375	**1**	All values calculated correctly to 4 SF:

		iii	*x*-axis suitably scaled and labelled as L (ignore units), using at least half of the printed graph grid, minimum distance between scale marking is 3 large squares.	**1**	Do not allow awkward scales including those going up in multiples of 3. Smallest acceptable x-axis scale is 1 large square:0.05m. Put tick/cross by *x*-axis.
			y-axis suitably scaled and labelled as T^2 (ignore units), using at least half of the printed graph grid, minimum distance between scale marking is 3 large squares.	**1**	Smallest acceptable y-axis scale is 1 large square:0.2s^2. Put tick/cross by *y*-axis.
			Points plotted correctly (to within half a small square)	**1**	Do not award for blobs (points with diameter > ½ small square. Put tick/cross by the third plot.
			Acceptable straight line of best fit drawn. Line must not have kinks or be too thick or hairy and must be long enough to cover all the plotted points.	**1**	Best line should be just to the left of the top plot and almost through the bottom plot. If all 4 plots are correct the line should not pass through the origin. Put tick/cross near top of line.
		iv	Calculation of gradient of line using co-ordinates of 2 points on the drawn line at least half the length of the drawn line apart.	**1**	Gradient = $\frac{dy}{dx}$, and denominator should be at least 0.15m. Using data points from the table is only acceptable if the points are on the drawn line (by half a small square)
			Evaluation of g from calculated gradient value, $g = \frac{4\pi^2}{gradient}$.	**1**	A good line in part (iii) will give range 9 < g < 11 m s^{-2} A raw value for g (eg 9.81) scores zero. Working must be shown.
	c		ANY 2 from: Same (absolute) uncertainty/resolution/precision. Time period for shorter pendulums is less (hence percentage uncertainty in time is greater) Uncertainty in time is more significant than uncertainty in length. Uncertainty in time is increased because T^2.	**2**	ALLOW same instrument used to measure
			Question total	**15**	

Question			Answer	Marks	Guidance
3	a		**Level 3 (5-6 marks)** ✓✓ Detailed description of procedure including workable circuit diagram and relevant graphical methods and discussion of sources of uncertainty. *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)** ✓✓ Workable circuit with description of procedure to determine conductivity and at least one source of uncertainty mentioned. *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)** ✓✓ Limited description of procedure and/or at least one uncertainty mentioned. *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:** **Procedure:** • Workable circuit (diagram) to enable resistance of wire to be calculated. • Measure length of wire (with metre rule). • Find cross-section area of wire: o measure diameter of wire (with micrometer); o in several planes and/or several places; o $A = \frac{\pi d^2}{4}$. • Change length of wire (and repeat). • Find $R = \frac{V}{I}$; o use ρ = RA÷L and σ = 1÷ ρ o find R for different lengths of wire; o plot graphs of *R* against *L;* o ρ = gradient × A; o σ = 1 ÷ (gradient x A); o (positive) intercept of graph due to contact resistance. • Find $G = \frac{i}{V}$; o use σ = GL÷A o for different lengths of wire; o plot graphs of *G* against 1/*L;* o σ = (gradient x A). **Uncertainties:** • ± 0.01mm for micrometer readings • Relative/percentage uncertainty in diameter doubled for area. • Wire may not have circular cross section. • Wire may have kinks. • Absolute uncertainty in length is ±1 mm to ± 5 mm • Uncertainty in voltmeter and ammeter depend on resolution of digital meters or size of division on analogue meters. • Contact resistance • Wire may neat up whilst current flows through it or circuit ensures same current through all lengths of wire. • Higher temperature wire will have a lower conductivity (or vice versa).

	b	**i**	Use of $\frac{I}{V} = \frac{\sigma A}{L}$ $I = (2.1 \times 10^{6})(0.166 \times 10^{-6})(2.0) \div 0.330$ $I = 2.1$ A Alternative method: Either $G = \sigma A \div L = 1.06\Omega^{-1}$ or $R = L \div \sigma A = 0.95\ \Omega$ ✓ $I = GV = 1.05 \times 2$ OR $I = V \div R = 2 \div 0.95$ ✓ $I = 2.1$ A ✓	**1** **1** **1**	POT error in area – either incorrect or missing will not gain this last mark.
	b	**ii**	$v = I/nAq = 2.1/(10^{28})(0.166 \times 10^{-6})(1.6 \times 10^{-19})$ $v = 8 \times 10^{-3}$ m s^{-1} [this is only an estimate so 1sf is acceptable]	 **1**	ALLOW ecf of incorrect value for current calculated in part (i), [*v = current ÷ 265.6]* Incorrect POT for area should cancel out with incorrect POT in current from part (i).
	b	**iii**	Positive ions/atoms have more <u>kinetic</u> energy More energetic vibrations obstruct path of electrons more/electrons make more (frequent) collisions (So) mean drift velocity decreases	**1** **1** **1**	IGNORE electrons have more KE. IGNORE reference to thermal expansion of wire and resistance of wire.
			Question total	**13**	

Question			Answer	Marks	Guidance
4	a	i	particles/molecules have negligible volume (compared to that of the container) elastic collisions with container/walls/surfaces OR (all) collisions are elastic. no interactions between particles/molecules (except during collisions)	**1** **1** **1**	ALLOW atoms ALLOW no loss of KE instead of elastic ALLOW atoms
		ii	$\frac{3}{2}\ kT = \frac{1}{2}m\overline{c^2}(=\text{mean kinetic energy})$ Use of $pV = \frac{1}{3}Nm\overline{c^2}$ clearly leading to $p = \frac{NkT}{V}$ (any subject) As *N* and *V* (and *k)* are constants, (so $p \propto T$)	**1** **1** **1**	IGNORE v² (if the first step is $\frac{3}{2}\ kT = \frac{1}{2}mv^2 = \frac{1}{2}m\overline{c^2}$ award the first mark) NOT c is a constant
	b		Rearranging $\frac{3}{2}\ kT = \frac{1}{2}mc^{\bar{2}}$ to give $\overline{c^2} = \frac{3kT}{m}$ or $\sqrt{\overline{c^2}} = \sqrt{\frac{3kT}{m}}$ Substituting correct values into equation (ignoring POT errors): EITHER $\sqrt{\overline{c^2}} = \sqrt{\frac{3kT}{m}}$ where m = 0.0399 ÷ 6.02×10^{23} = 6.63×10^{-26} kg OR $\sqrt{\overline{c^2}} = \sqrt{\frac{3RT}{m}}$, using R = 8.31 and m = 0.0399 root mean square speed = 430 m s^{-1}	**1** **1** **1**	If k is used with molar mass the $\sqrt{\overline{c^2}}$ = 5.5×10^{-10} or $\overline{c^2}$ = 3.0×10^{-19}. If R is used with molecular mass the answer $\sqrt{\overline{c^2}}$ = 3.3×10^{-12} or $\overline{c^2}$ = 1.1×10^{-23}. Any of these values (with or without a POT error) or 7.7×10^{-22} or 5.05×10^{-43} on answer line will gain the first marking point. Final answer of ($\overline{c^2}$=)1.8×10^5 for first two marking points. **Note**: Correct bald answer gains three marks. First marking point can be implicit. A POT error will lose a mark.
	c	i	Two from: • Record the temperature will all the thermometers (in the water bath) • Uncertainty = ± range ÷ 2 or ± spread. • Ignore/identify anomalous values or outliers as values greater than x2 spread from mean	**1 × 2**	IGNORE find mean, percentage uncertainty. ALLOW uncertainty = max value – mean, OR uncertainty = mean – min value. ALLOW outliers identified as being clearly different from the other readings. NOT just ignore outliers.

	c	**ii1**	Worst fit line has steeper gradient and passes through all the uncertainty bars.	**1**	In particular, watch for the top of the fourth error bar and the bottom of the first within half a small square in vertical direction. Put a tick/cross near the 4th error bar. Line from (250, 68) to (370, 112) to nearest half a small square
		li2	Gradient calculated ($\frac{dy}{dx}$ or) $\frac{dP}{dT}$ ✓ dT ≥ 60 K ✓ Coordinates of two points on the line read off to the nearest half square ✓ EITHER: Find intercept by substituting coordinates of point on line into $P = mT + c$, using their value of gradient as *m*.✓ Substitute P=0 to find T. ✓ OR: Calculation of the temperature drop required to reach zero pressure from a stated temperature by dividing a value of pressure on the line by the gradient. Temperature at 0 Pa calculated;	**1** **1** **1** **1** **1** **(1)** **(1)**	All coordinates to be read off to the nearest half a small square. e.g. (250,68) and gradient value = 0.37 68 = 0.37 × 250 + c; to give c = -24.5 ✓ Substitute P = 0; 0 = 0.37T – 24.5; T = 66K No ecf for wrong value of c (unless transcription or arithmetic error). Watch for false origin read-off. e.g taking (250,68) as a point on their worst fit line. 68 ÷ gradient = 185 ✓ 250 – 185 = 65K ✓ IGNORE any calculation of gradient and/intercept of the printed line of best fit. ALLOW ecf of incorrect gradient calculated for intercept calculation. ALLOW ecf for incorrect read-offs used in subsequent calculations. [ie only penalise incorrect read-off once] If both read-offs are wrong for the gradient calculation and either of them are used again in subsequent calculations then the fourth mark will be lost.

Question			Answer	Marks	Guidance
4	d		Any four points from: • Systematic error means that measurements differ from true value by a consistent amount each time a measurement is taken.) • Systematic error is not reduced by taking multiple readings of each measurement. • Actual temperature of the gas will be lower than measured temperature (for most data points) • For the first data point (at 283K) the actual temperature will be higher than measured. • The effect will be more significant when the temperature difference between the water bath and the air is higher. • A small change in the line will have a significant effect on the temperature when P=0 (x-intercept). • Convection currents within the gas inside the flask will help to maintain uniform temperature. • The significance of the effect depends on the proportion of the flask/volume/air which is above the water level. • Glass/bung provide insulation which will reduce significance.	**1 × 4**	IGNORE descriptions of other types of systematic error, eg zero error. IGNORE any reference to pressure readings. ALLOW the error will result in an overestimate of T when P=0 (x-intercept). ALLOW small proportion means less significance or vice versa. ALLOW other creditable arguments relating to significance (use professional judgement).
			Question total	**21**	

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

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Head office
Telephone: 01223 552552
Facsimile: 01223 552553