
PHYSICS

9702/51

Paper 5 Planning, Analysis and Evaluation

May/June 2019

MARK SCHEME

Maximum Mark: 30

Published

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GENERIC MARKING PRINCIPLE 1:

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- the specific skills defined in the mark scheme or in the generic level descriptors for the question
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GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

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- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
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- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

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PUBLISHED**GENERIC MARKING PRINCIPLE 5:**

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

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Question	Answer	Marks
1	Defining the problem	
	L is the independent variable and s is the dependent variable or vary L and measure s	1
	keep mass of load or M <u>constant</u>	1
	Methods of data collection	
	labelled diagram of workable experiment including: - method of fixing strip at one end, e.g. with a G-clamp or (heavy) mass placed on top of strip over bench - load shown touching at point P - load and G-clamp or (heavy) mass labelled	1
	method of attaching load to strip, e.g. use glue/tape/attach with a hook and string	1
	use a rule to measure L <u>and</u> s	1
	use a balance to measure M	1
	Method of analysis	
	plot a graph of s against L^3 (allow $\lg s$ against $\lg L$, or $\log$)	1
	relationship valid if a straight line through (0,0) (for $\lg s$ against $\lg L$ gradient of straight line = 3)	1
	$E = \frac{4Mg}{bt^3 \times \text{gradient}}$ (for $\lg s$ against $\lg L$, $E = \frac{4Mg}{bt^3} \div 10^{y-\text{intercept}}$)	1

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Question	Answer	Marks
1	Additional detail including safety considerations	Max. 6
D1	use cushion/foam/sandbox <u>in case mass/load falls</u> or wear goggles <u>in case strip snaps or recoils</u>	
D2	use same wooden strip or keep b <u>and</u> t <u>constant</u>	
D3	clamp rule <u>vertically</u> to measure s	
D4	method to ensure <u>clamped rule to measure s</u> is vertical, e.g. correctly positioned set square indicated at right angles to the horizontal surface or plumb line shown in appropriate position	
D5	s = reading of vertical rule with loaded strip – reading of vertical rule with no load	
D6	repeat s measurement for each L (unloading and loading strip) <u>and</u> average s	
D7	use a micrometer/calipers to determine t	
D8	repeat readings for b and/or t at different points along/across the strip <u>and</u> average	
D9	method to ensure strip is perpendicular to the bench, e.g. repeat measurements of L <u>on each side of strip</u> to check that L is constant or set square correctly indicated on diagram	
D10	wait until block is stationary/in equilibrium or measure s after a fixed time	

Question	Answer	Marks							
2(a)	gradient = $\frac{K}{E}$	1							
2(b)	<table><tr><td>$\frac{1}{I} / \text{A}^{-1}$</td></tr><tr><td>180 or 175</td></tr><tr><td>210 or 213</td></tr><tr><td>250</td></tr><tr><td>290 or 286</td></tr><tr><td>320 or 323</td></tr><tr><td>370</td></tr></table>	$\frac{1}{I} / \text{A}^{-1}$	180 or 175	210 or 213	250	290 or 286	320 or 323	370	1
$\frac{1}{I} / \text{A}^{-1}$									
180 or 175									
210 or 213									
250									
290 or 286									
320 or 323									
370									
	uncertainties in $\frac{1}{I}$ from ± 3 or ± 4 to ± 10 – 15	1							
2(c)(i)	Six points plotted correctly. Must be accurate to the nearest half small square. Diameter of points must be less than half a small square.	1							
	Error bars in $\frac{1}{I}$ plotted correctly. All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.	1							

Question	Answer	Marks
2(c)(ii)	Line of best fit drawn. Do not allow line from top point to bottom point. If points are plotted correctly then lower end of line should pass between (122, 230) and (126, 230) and upper end of line should pass between (186, 350) and (190, 350).	1
	Worst acceptable line drawn (steepest or shallowest possible line that passes through all the error bars). All error bars must be plotted.	1
2(c)(iii)	Gradient determined with clear substitution of points from the line into $\Delta y/\Delta x$. Distance between points must be at least half the length of the drawn line.	1
	uncertainty = gradient of line of best fit – gradient of worst acceptable line or uncertainty = $\frac{1}{2}$ (steepest worst line gradient – shallowest worst line gradient)	1
2(d)	9.4 ± 0.2 (V)	1
2(e)(i)	K determined from gradient and given to 2 or 3 significant figures. $K = E \times \text{gradient} = 9.4 \times \text{(c)(iii)}$.	1
	K determined from gradient with correct unit ($\Omega / ^\circ$).	1
2(e)(ii)	% uncertainty in $K = \left(\left(\frac{\Delta \text{gradient}}{\text{gradient}} \right) + \left(\frac{\Delta E}{E} \right) \right) \times 100$	1

Question	Answer	Marks
2(f)	θ calculated. Correct substitution of numbers required. $\theta = \frac{E}{IK} = \frac{9.4}{0.01 \times (\mathbf{e})(\mathbf{i})}$ or $\theta = \frac{1}{I \times \text{gradient}} = \frac{1}{0.01 \times (\mathbf{c})(\mathbf{iii})}$	1
	Absolute uncertainty in θ. Correct substitution of numbers required. Use of ΔI not required but allow if included by the candidate. Using E and K: $\text{uncertainty in } \theta = \left(\frac{\Delta E}{E} + \frac{\Delta K}{K} \left(+ \frac{\Delta I}{I} \right) \right) \times \theta$ $\text{uncertainty in } \theta = \left(\frac{0.2}{9.4} + \frac{(\mathbf{e})(\mathbf{ii})}{100} \right) \times \theta$ $\max \theta = \frac{\max E}{0.01 \times \min K} \quad \text{or} \quad \min \theta = \frac{\min E}{0.01 \times \max K}$ Using gradient: $\text{uncertainty in } \theta = \left(\frac{\Delta \text{gradient}}{\text{gradient}} \left(+ \frac{\Delta I}{I} \right) \right) \times \theta$ $\max \theta = \frac{1}{0.01 \times \min \text{gradient}} \quad \text{or} \quad \min \theta = \frac{1}{0.01 \times \max \text{gradient}}$	1

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GENERIC MARKING PRINCIPLE 6:

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Question	Answer	Marks
1	Defining the problem	
	m is the independent variable and θ is the dependent variable or vary m and measure θ or θ is the independent variable and m is the dependent variable or vary θ and measure m	1
	keep position of load <u>constant</u> or L <u>constant</u>	1
	Methods of data collection	
	labelled diagram of workable experiment including: - load shown touching at P - load labelled and at least one other label	1
	use a protractor to measure θ	1
	if m is the independent variable: (slowly) change the angle until the block (just) topples or if θ is the independent variable: (slowly) change mass until block (just) topples	1
	use a balance to measure m	1

Question	Answer	Marks
1	Method of analysis	
	plot a graph of $\cos \theta$ against $1/m$ (or reverse axes $1/m$ against $\cos \theta$) (not $1/\cos \theta$ against m or m against $1/\cos \theta$)	1
	relationship valid if a straight line (not ‘through the origin’ unless the choice of axes indicates the intercept is zero)	1
	$\alpha = \frac{2L \times \text{gradient}}{V \times w}$ or $\alpha = \frac{\text{gradient}}{V \times y\text{-intercept}}$ for reverse axes: $\alpha = \frac{2L}{V \times w \times \text{gradient}}$ or $\alpha = -\frac{1}{V \times y\text{-intercept}}$	1

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Question	Answer	Marks
1	Additional detail including safety considerations	Max. 6
D1	use cushion/foam/sandbox <u>in case block/load falls</u>	
D2	measure L with a rule	
D3	correctly positioned protractor to measure θ , e.g. protractor with its centre over the nail and its straight edge parallel to an edge of the block	
D4	method to fix m to strip	
D5	method to determine volume of block, e.g. $V = w \times h \times l$	
D6	measure w , h and l with calipers/micrometer/rule	
D7	(if m is the independent variable:) repeat experiment for θ <u>and</u> determine the average θ or (if θ is the independent variable:) repeat experiment for m <u>and</u> determine the average m	
D8	equation must be in the form of $y = mx + c$ with $\cos \theta$ on one side and m on the other side e.g. for a graph of $\cos \theta$ against $1/m$ $\cos \theta = \frac{\alpha V w}{2 L m} + \frac{w}{2 L}$ or for a graph of $1/m$ against $\cos \theta$ $\frac{1}{m} = \frac{2 L \cos \theta}{\alpha V w} - \frac{1}{\alpha V}$	
D9	method to determine centre of load or centre of block e.g. measure diameter/width and halve or diagonals across the block	
D10	method to ensure that block or strip is horizontal, e.g. check with a spirit level that table/block is horizontal or use a rigid strip	

Question	Answer		Marks														
2(a)	gradient = $4\pi^2 M$		1														
2(b)	<table><tr><td>T / s</td><td>T^2 / s^2</td></tr><tr><td>1.12 or 1.120</td><td>1.25 or 1.254</td></tr><tr><td>0.950 or 0.9500</td><td>0.903 or 0.9025</td></tr><tr><td>0.815 or 0.8150</td><td>0.664 or 0.6642</td></tr><tr><td>0.655 or 0.6550</td><td>0.429 or 0.4290</td></tr><tr><td>0.570 or 0.5700</td><td>0.325 or 0.3249</td></tr><tr><td>0.47 or 0.470</td><td>0.22 or 0.221</td></tr></table>		T / s	T^2 / s^2	1.12 or 1.120	1.25 or 1.254	0.950 or 0.9500	0.903 or 0.9025	0.815 or 0.8150	0.664 or 0.6642	0.655 or 0.6550	0.429 or 0.4290	0.570 or 0.5700	0.325 or 0.3249	0.47 or 0.470	0.22 or 0.221	
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Values of T as above.		1															
Values of T^2 as above.		1															
Uncertainties in T increase from ± 0.01 to ± 0.02 .		1															
Uncertainties in T^2 about ± 0.02 .		1															
2(c)(i)	Six points plotted correctly. Must be accurate to the nearest half a small square. Diameter of points must be less than half a small square.	1															
	Error bars in T^2 plotted correctly. All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.	1															
2(c)(ii)	Line of best fit drawn. If points are plotted correctly then lower end of line should pass between (0.048, 0.5) and (0.052, 0.5) and upper end of line should pass between (0.098, 1.0) and (0.104, 1.0).	1															
	Worst acceptable line drawn (steepest or shallowest possible line that passes through all the error bars). All error bars must be plotted.	1															

Question	Answer	Marks
2(c)(iii)	Gradient determined with clear substitution of points from the line of best fit into $\Delta y / \Delta x$. Distance between points must be at least half the length of the drawn line.	1
	uncertainty = gradient of line of best fit – gradient of worst acceptable line or uncertainty = $\frac{1}{2}$ (steepest worst line gradient – shallowest worst line gradient)	1
2(d)(i)	M determined from gradient and given to 2 or 3 significant figures and with correct unit. $M = \frac{\text{gradient}}{4\pi^2} = \frac{\text{(c)(iii)}}{39.478}$	1
2(d)(ii)	% uncertainty in M = % uncertainty in gradient	1

Question	Answer	Marks
2(e)	k calculated. Correct substitution of numbers required. $k = \left(\frac{4\pi^2 M}{T^2} \right) = \frac{4\pi^2 (\text{d})(\text{i})}{2.5^2} \text{ or } 6.3165 \times (\text{d})(\text{i})$ or $k = \left(\frac{\text{gradient}}{T^2} \right) = \frac{(\text{c})(\text{iii})}{2.5^2} \text{ or } \frac{(\text{c})(\text{iii})}{6.25}$	1
	Absolute uncertainty in k. Correct substitution of numbers required. Using M: $\text{uncertainty in } k = \left(\frac{\Delta M}{M} + 2 \times \frac{\Delta T}{T} \right) \times k$ $\text{uncertainty in } k = \left(\frac{(\text{d})(\text{ii})}{100} + 0.008 \right) \times k$ $\max k = \frac{4\pi^2 \times \max M}{\min T^2} \text{ or } \min k = \frac{4\pi^2 \times \min M}{\max T^2}$ Using gradient: $\text{uncertainty in } k = \left(\frac{\Delta \text{gradient}}{\text{gradient}} + 0.008 \right) \times k$ $\max k = \frac{\max \text{gradient}}{\min T^2} \text{ or } \min k = \frac{\min \text{gradient}}{\max T^2}$	1

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1	Defining the problem	
	L is the independent variable and s is the dependent variable or vary L and measure s	1
	keep mass of load or M <u>constant</u>	1
	Methods of data collection	
	labelled diagram of workable experiment including: - method of fixing strip at one end, e.g. with a G-clamp or (heavy) mass placed on top of strip over bench - load shown touching at point P - load and G-clamp or (heavy) mass labelled	1
	method of attaching load to strip, e.g. use glue/tape/attach with a hook and string	1
	use a rule to measure L <u>and</u> s	1
	use a balance to measure M	1
	Method of analysis	
	plot a graph of s against L^3 (allow $\lg s$ against $\lg L$, or $\log$)	1
	relationship valid if a straight line through (0,0) (for $\lg s$ against $\lg L$ gradient of straight line = 3)	1
	$E = \frac{4Mg}{bt^3 \times \text{gradient}}$ (for $\lg s$ against $\lg L$, $E = \frac{4Mg}{bt^3} \div 10^{y-\text{intercept}}$)	1

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D1	use cushion/foam/sandbox <u>in case mass/load falls</u> or wear goggles <u>in case strip snaps or recoils</u>	
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D3	clamp rule <u>vertically</u> to measure s	
D4	method to ensure <u>clamped rule to measure s</u> is vertical, e.g. correctly positioned set square indicated at right angles to the horizontal surface or plumb line shown in appropriate position	
D5	s = reading of vertical rule with loaded strip – reading of vertical rule with no load	
D6	repeat s measurement for each L (unloading and loading strip) <u>and</u> average s	
D7	use a micrometer/calipers to determine t	
D8	repeat readings for b and/or t at different points along/across the strip <u>and</u> average	
D9	method to ensure strip is perpendicular to the bench, e.g. repeat measurements of L <u>on each side of strip</u> to check that L is constant or set square correctly indicated on diagram	
D10	wait until block is stationary/in equilibrium or measure s after a fixed time	

Question	Answer	Marks							
2(a)	gradient = $\frac{K}{E}$	1							
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180 or 175									
210 or 213									
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370									
	uncertainties in $\frac{1}{I}$ from ± 3 or ± 4 to ± 10 –15	1							
2(c)(i)	Six points plotted correctly. Must be accurate to the nearest half small square. Diameter of points must be less than half a small square.	1							
	Error bars in $\frac{1}{I}$ plotted correctly. All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.	1							

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	Worst acceptable line drawn (steepest or shallowest possible line that passes through all the error bars). All error bars must be plotted.	1
2(c)(iii)	Gradient determined with clear substitution of points from the line into $\Delta y/\Delta x$. Distance between points must be at least half the length of the drawn line.	1
	uncertainty = gradient of line of best fit – gradient of worst acceptable line or uncertainty = $\frac{1}{2}$ (steepest worst line gradient – shallowest worst line gradient)	1
2(d)	9.4 ± 0.2 (V)	1
2(e)(i)	K determined from gradient and given to 2 or 3 significant figures. $K = E \times \text{gradient} = 9.4 \times \text{(c)(iii)}$.	1
	K determined from gradient with correct unit ($\Omega / ^\circ$).	1
2(e)(ii)	% uncertainty in $K = \left(\left(\frac{\Delta \text{gradient}}{\text{gradient}} \right) + \left(\frac{\Delta E}{E} \right) \right) \times 100$	1

Question	Answer	Marks
2(f)	θ calculated. Correct substitution of numbers required. $\theta = \frac{E}{IK} = \frac{9.4}{0.01 \times (\mathbf{e})(\mathbf{i})}$ or $\theta = \frac{1}{I \times \text{gradient}} = \frac{1}{0.01 \times (\mathbf{c})(\mathbf{iii})}$	1
	Absolute uncertainty in θ. Correct substitution of numbers required. Use of ΔI not required but allow if included by the candidate. Using E and K: $\text{uncertainty in } \theta = \left(\frac{\Delta E}{E} + \frac{\Delta K}{K} \left(+ \frac{\Delta I}{I} \right) \right) \times \theta$ $\text{uncertainty in } \theta = \left(\frac{0.2}{9.4} + \frac{(\mathbf{e})(\mathbf{ii})}{100} \right) \times \theta$ $\max \theta = \frac{\max E}{0.01 \times \min K} \quad \text{or} \quad \min \theta = \frac{\min E}{0.01 \times \max K}$ Using gradient: $\text{uncertainty in } \theta = \left(\frac{\Delta \text{gradient}}{\text{gradient}} \left(+ \frac{\Delta I}{I} \right) \right) \times \theta$ $\max \theta = \frac{1}{0.01 \times \min \text{gradient}} \quad \text{or} \quad \min \theta = \frac{1}{0.01 \times \max \text{gradient}}$	1