
PHYSICS

9702/51

Paper 5 Planning, Analysis and Evaluation

May/June 2016

MARK SCHEME

Maximum Mark: 30

Published

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Page 2	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	51

Question 1 Planning (15 marks)

Defining the problem (2 marks)

P λ is the independent variable, or vary λ . [1]

P V is the dependent variable, or measure V . [1]

Methods of data collection (4 marks)

M Circuit diagram showing d.c. power supply in series with diode (correct symbol needed) and method to measure potential difference across diode. Circuit must be correct. [1]

M Instrument to change p.d. across LED e.g. variable power supply/potential divider/variable resistor. [1]

M Record wavelength of light of LED from data sheet or use Young's slits/diffraction grating. [1]

M (Slowly) increase potential difference across LED until LED (just) emits light (or reverse procedure). [1]

Method of analysis (3 marks)

A Plot a graph of $\lg V$ against $\lg \lambda$ (allow natural logs). Allow $\lg \lambda$ against $\lg V$. [1]

A $n = \text{gradient}$ [1]

A $k = 10^{\text{y-intercept}}$ [1]

Additional detail (6 marks)

Relevant points might include: [6]

- 1 Use of a protective resistor (can be shown on the diagram).
- 2 Polarity of LED correct in circuit diagram.
- 3 Instrument to determine when LED just lights e.g. light meter/detector, LDR.
- 4 Method to use light detector/LDR to determine point at which LED emits light.
- 5 Expression that gives λ (symbols need to be defined) from experimental determination of wavelength of light, e.g. Young's slits/diffraction grating.
- 6 Perform experiment in a dark room/LED in tube.
- 7 Relationship is valid if graph is a straight line.
- 8 $\lg V = n \lg \lambda + \lg k$
- 9 Repeat V and average for the same λ or LED.

Do not allow vague computer methods.

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Question 2 Analysis, conclusions and evaluation (15 marks)

	Mark	Expected Answer	Additional Guidance						
(a)	A1	$\frac{4LF}{\pi E}$							
(b)	T1	$\frac{1}{d^2} / 10^6 \text{ m}^{-2}$							
	T2	<table border="1"><tr><td>13 or 12.8</td></tr><tr><td>9.8 or 9.77</td></tr><tr><td>6.9 or 6.93</td></tr><tr><td>4.7 or 4.73</td></tr><tr><td>3.2 or 3.19</td></tr><tr><td>1.9 or 1.93</td></tr></table>	13 or 12.8	9.8 or 9.77	6.9 or 6.93	4.7 or 4.73	3.2 or 3.19	1.9 or 1.93	All values to 2 s.f. or 3 s.f. Allow a mixture of significant figures. Must be values in table.
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3.2 or 3.19									
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	U1	From ± 2 to ± 0.1	Allow more than one significant figure.						
(c) (i)	G1	Six points plotted correctly	Must be within half a small square. Do not allow “blobs”. ECF allowed from table.						
	U2	Error bars in $\frac{1}{d^2}$ plotted correctly	All error bars to be plotted. Must be accurate to less than half a small square.						
(ii)	G2	Line of best fit	If points are plotted correctly then lower end of line should pass between (3.2, 3.0) and (3.6, 3.0) and upper end of line should pass between (11.2, 10.0) and (11.6, 10.0).						
	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through all the error bars.	Line should be clearly labelled or dashed. Examiner judgement on worst acceptable line. Lines must cross. Mark scored only if error bars are plotted.						
(iii)	C1	Gradient of line of best fit	The triangle used should be at least half the length of the drawn line. Check the read-offs. Work to half a small square. Do not penalise POT. (Should be about 9×10^{-10} .)						
	U3	Absolute uncertainty in gradient	Method of determining absolute uncertainty Difference in worst gradient and gradient.						
(d) (i)	C2	$\frac{4LF}{\pi \times \text{gradient}} = \frac{60.479}{\text{gradient}}$	Do not penalise POT. (Should be about 7×10^{10} .)						
	C3	N m^{-2} or Pa	Allow in base units: $\text{kg m}^{-1} \text{s}^{-2}$.						
(ii)	U4	Percentage uncertainty in E	Must be larger than 3%.						

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	Mark	Expected Answer	Additional Guidance
(e)	C4	e in the range 15.5×10^{-3} to 18.0×10^{-3} and given to 2 or 3 s.f.	Allow mm.
	U5	Absolute uncertainty in e	Note $e = \frac{\text{gradient}}{d^2}$ is possible.

Uncertainties in Question 2

(c) (iii) Gradient [U3]

uncertainty = gradient of line of best fit – gradient of worst acceptable line

uncertainty = $\frac{1}{2}$ (steepest worst line gradient – shallowest worst line gradient)

(d) (ii) [U4]

$$\text{percentage uncertainty} = \left(\frac{\Delta \text{gradient}}{\text{gradient}} + \frac{0.01}{2.50} + \frac{0.5}{19.0} \right) \times 100 = \left(\frac{\Delta \text{gradient}}{\text{gradient}} \right) \times 100 + 3.03\%$$

$$\max E = \frac{4 \times \max L \times \max F}{\pi \times \min \text{gradient}} = \frac{4 \times 2.51 \times 19.5}{\pi \times \min \text{gradient}} = \frac{62.319}{\min \text{gradient}}$$

$$\min E = \frac{4 \times \min L \times \min F}{\pi \times \max \text{gradient}} = \frac{4 \times 2.49 \times 18.5}{\pi \times \max \text{gradient}} = \frac{58.652}{\max \text{gradient}}$$

(e) [U5]

$$\text{percentage uncertainty} = \left(\frac{0.5}{19.0} + \frac{0.01}{2.50} + 2 \times \left(\frac{0.02}{0.23} \right) \right) \times 100 + \%E = 20.4\% + \%E$$

$$\text{percentage uncertainty} = \left(\frac{\Delta \text{gradient}}{\text{gradient}} + 2 \times \left(\frac{0.02}{0.23} \right) \right) \times 100$$

$$\max e = \frac{\max \text{gradient}}{d_{\min}^2}$$

$$\max e = \frac{4 \times L_{\max} \times F_{\max}}{\pi \times E_{\min} \times d_{\min}^2}$$

$$\min e = \frac{\min \text{gradient}}{d_{\max}^2}$$

$$\min e = \frac{4 \times L_{\min} \times F_{\min}}{\pi \times E_{\max} \times d_{\max}^2}$$

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Question 1 Planning (15 marks)

Defining the problem (2 marks)

P θ is the independent variable and a is the dependent variable, or vary θ and measure a . [1]

P Keep F constant. [1]

Methods of data collection (4 marks)

M Diagram showing inclined plane with labelled support (not if a ruler used as the inclined plane or as vertical support). [1]

M Method to measure angle e.g. use a protractor to measure θ or use a ruler to measure marked distances from which $\sin \theta$ or θ may be determined. (Allow a labelled protractor in the correct position.) [1]

M Method to measure a time or velocity to determine a , e.g. measure the time using a stopwatch, light gate(s) connected to a timer, motion sensor connected to a time display. [1]

M Use a balance to measure the mass of the trolley. [1]

Method of analysis (3 marks)

A Plot a graph of a against $\sin \theta$. or Plot a graph of ma against $\sin \theta$. or Plot a graph of ma against $mg \sin \theta$. [1]

A Relationship is valid if the graph is a straight line and does not pass through the origin [1]

A $k = F - m \times (\text{y-intercept})$ or $k = F - (\text{y-intercept})$ or $k = F - (\text{y-intercept})$ [1]

Do not allow lg-lg graphs.

Additional detail (6 marks)

Relevant points might include: [6]

- 1 Keep mass of trolley constant/use same trolley.
- 2 Correct trigonometry relationship to determine $\sin \theta$ or θ using marked lengths.
- 3 Use ruler to measure appropriate distance to determine a , e.g. length of slope, length of card for light gate method, position of motion sensor.
- 4 Equation to determine a from measurements taken appropriately with a as the subject.
- 5 Measurement of F for a valid method e.g. take reading from newton-meter or from stretched elastic/spring from extension (allow falling weight e.g. $F = mg$).
- 6 Use a constant extension to produce a constant force when using stretched spring/elastic.

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- 7 Method to ensure the inclined plane is the same height each side of the plane or spirit level across plane or ensure force F (or string) is parallel to the plane.
- 8 Safety precaution linked to falling mass/trolley or spring/elastic breaking (not string).
- 9 Rearrangement of relationship into $y = mx + c$ e.g. $ma = -mg \sin \theta + (F - k)$ or
 $a = -g \sin \theta + \frac{F - k}{m}$ or correct y-intercept (subject must be y-axis).
- 10 Repeat experiment for each angle θ to find average for a .

Do not allow vague computer methods.

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Question 2 Analysis, conclusions and evaluation (15 marks)

	Mark	Expected Answer	Additional Guidance						
(a)	A1	$\frac{4\rho L}{\pi}$							
(b)	T1	$\frac{1}{d^2} / 10^6 \text{ m}^{-2}$							
	T2	<table border="1"><tr><td>1.2 or 1.21</td></tr><tr><td>3.2 or 3.19</td></tr><tr><td>4.7 or 4.73</td></tr><tr><td>6.9 or 6.93</td></tr><tr><td>9.8 or 9.77</td></tr><tr><td>14 or 13.7</td></tr></table>	1.2 or 1.21	3.2 or 3.19	4.7 or 4.73	6.9 or 6.93	9.8 or 9.77	14 or 13.7	All values to 2 s.f. or 3 s.f. Allow a mixture of significant figures. Must be values in table.
1.2 or 1.21									
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6.9 or 6.93									
9.8 or 9.77									
14 or 13.7									
	U1	From ± 0.03 to ± 1	Allow more than one significant figure. Allow zero for first uncertainty and up to 1.2 for largest uncertainty.						
(c) (i)	G1	Six points plotted correctly	Must be within half a small square. Do not allow “blobs”. ECF allowed from table.						
	U2	Error bars in $\frac{1}{d^2}$ plotted correctly	All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.						
(ii)	G2	Line of best fit	Lower end of line must pass between (2.6, 4.0) and (3.0, 4.0) and upper end of line must pass between (12.4, 18.0) and (13.0, 18.0).						
	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through all the error bars.	Line should be clearly labelled or dashed. Examiner judgement on worst acceptable line. Must be steepest/shallowest line. Mark scored only if error bars are plotted.						
(iii)	C1	Gradient of line of best fit	The triangle used should be at least half the length of the drawn line. Check the read-offs. Work to half a small square. Do not penalise POT. (Should be about $1.4 - 1.5 \times 10^{-6}$.)						
	U3	Absolute uncertainty in gradient	Method of determining absolute uncertainty: difference in worst gradient and gradient.						

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	Mark	Expected Answer	Additional Guidance
(d) (i)	C2	$\frac{\pi \times \text{gradient}}{4L} = 0.7854 \times \text{gradient}$	Must use gradient value. Do not penalise POT (Should be about 1×10^{-6} .)
	C3	$\Omega \text{ m}$	Correct unit and correct power of ten.
(ii)	U4	Percentage uncertainty in ρ	Percentage uncertainty in gradient + 1%.
(e)	C4	R in the range 25.5 to 28.4 and given to 2 or 3 s.f.	Allow 26 or 27 or 28. Allow ECF for POT error in (d)(i) e.g. 2.7×10^7 .
	U5	Absolute uncertainty in R	Percentage uncertainty must be greater than 8.6%.

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Uncertainties in Question 2

(c) (iii) Gradient [U3]

uncertainty = gradient of line of best fit – gradient of worst acceptable line

uncertainty = $\frac{1}{2}$ (steepest worst line gradient – shallowest worst line gradient)

(d) (ii) [U4]

$$\text{percentage uncertainty} = \left(\frac{\Delta \text{gradient}}{\text{gradient}} + \frac{0.01}{1.00} \right) \times 100 = \left(\frac{\Delta \text{gradient}}{\text{gradient}} \right) \times 100 + 1\%$$

$$\max \rho = \frac{\pi \times \max \text{gradient}}{4 \times \min L} = \frac{\pi \times \max \text{gradient}}{4 \times 0.99}$$

$$\min \rho = \frac{\pi \times \min \text{gradient}}{4 \times \max L} = \frac{\pi \times \min \text{gradient}}{4 \times 1.01}$$

(e) [U5]

$$\text{percentage uncertainty} = \left(\frac{\Delta \text{gradient}}{\text{gradient}} + 2 \times \left(\frac{0.01}{0.23} \right) \right) \times 100 = \left(\frac{\Delta \text{gradient}}{\text{gradient}} + 0.086 \right) \times 100$$

$$\text{percentage uncertainty} = \left(\frac{\Delta \rho}{\rho} + \frac{0.01}{1.00} + 2 \times \left(\frac{0.01}{0.23} \right) \right) \times 100 = \left(\frac{\Delta \rho}{\rho} + 0.096 \right) \times 100$$

$$\max R = \frac{\max \text{gradient}}{d_{\min}^2}$$

$$\max R = \frac{4 \times L_{\max} \times \rho_{\max}}{\pi \times d_{\min}^2}$$

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M Instrument to change p.d. across LED e.g. variable power supply/potential divider/variable resistor. [1]

M Record wavelength of light of LED from data sheet or use Young's slits/diffraction grating. [1]

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A Plot a graph of $\lg V$ against $\lg \lambda$ (allow natural logs). Allow $\lg \lambda$ against $\lg V$. [1]

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Additional detail (6 marks)

Relevant points might include: [6]

- 1 Use of a protective resistor (can be shown on the diagram).
- 2 Polarity of LED correct in circuit diagram.
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	U3	Absolute uncertainty in gradient	Method of determining absolute uncertainty Difference in worst gradient and gradient.						
(d) (i)	C2	$\frac{4LF}{\pi \times \text{gradient}} = \frac{60.479}{\text{gradient}}$	Do not penalise POT. (Should be about 7×10^{10} .)						
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$$\text{percentage uncertainty} = \left(\frac{\Delta \text{gradient}}{\text{gradient}} + \frac{0.01}{2.50} + \frac{0.5}{19.0} \right) \times 100 = \left(\frac{\Delta \text{gradient}}{\text{gradient}} \right) \times 100 + 3.03\%$$

$$\max E = \frac{4 \times \max L \times \max F}{\pi \times \min \text{gradient}} = \frac{4 \times 2.51 \times 19.5}{\pi \times \min \text{gradient}} = \frac{62.319}{\min \text{gradient}}$$

$$\min E = \frac{4 \times \min L \times \min F}{\pi \times \max \text{gradient}} = \frac{4 \times 2.49 \times 18.5}{\pi \times \max \text{gradient}} = \frac{58.652}{\max \text{gradient}}$$

(e) [U5]

$$\text{percentage uncertainty} = \left(\frac{0.5}{19.0} + \frac{0.01}{2.50} + 2 \times \left(\frac{0.02}{0.23} \right) \right) \times 100 + \%E = 20.4\% + \%E$$

$$\text{percentage uncertainty} = \left(\frac{\Delta \text{gradient}}{\text{gradient}} + 2 \times \left(\frac{0.02}{0.23} \right) \right) \times 100$$

$$\max e = \frac{\max \text{gradient}}{d_{\min}^2}$$

$$\max e = \frac{4 \times L_{\max} \times F_{\max}}{\pi \times E_{\min} \times d_{\min}^2}$$

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