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VICTORIA JUNIOR COLLEGE
2021 JC2 PRELIMINARY EXAMINATION
Higher 2

Name : ____________________ CT group : ______________

PHYSICS **9749/04**

Paper 4 Practical

2 September 2021

THURSDAY

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions.

READ THESE INSTRUCTIONS FIRST

Write your name and CT group in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Shift
Laboratory

Answer **all** questions.
Write your answers in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory, where appropriate, in the boxes provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
Total	

This document consists of **15** printed pages and **1** blank page.

1 In this experiment, you will investigate the motion of an oscillating system.

(a) Tape a 20g mass to the 30 cm mark of the ruler as shown in **Fig. 1.1**.

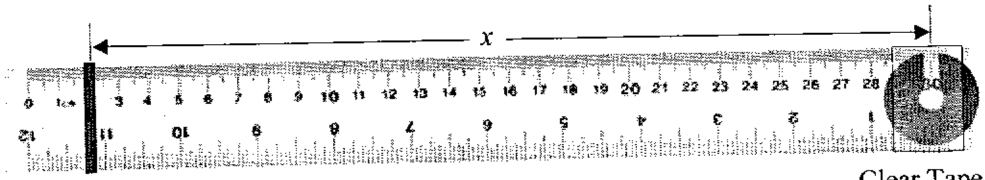


Fig. 1.1

Using the rubber band provided, make a loop across the 2 cm mark such that the distance x between the centre of gravity of the mass and the rubber band is around 28 cm.

(i) Record the value of x.

x =.................................cm [1]

(ii) Determine the percentage uncertainty in your value of x.

Percentage uncertainty in x =.................................. [1]

(iii) Place the setup over a flat edge of the lab bench such that the rubber band lies on the edge as shown in **Fig 1.2**. Hold down the shorter end firmly.

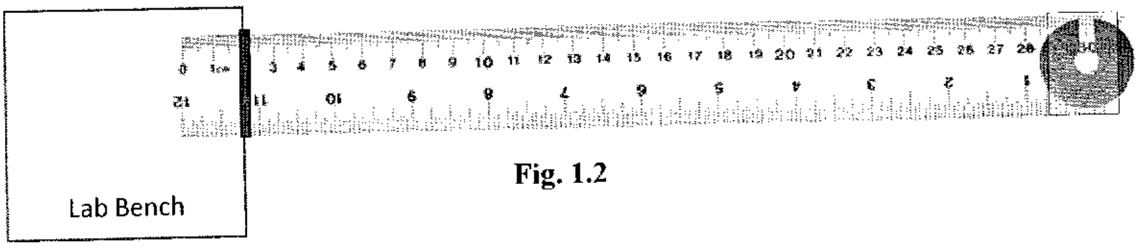


Fig. 1.2

Displace the mass downwards and determine the time taken for one period T.

T =................................. [2]

(iv) Estimate the percentage uncertainty in your value of T.

Percentage uncertainty in T =....................................... [1]

(b) Decrease x by approximately 2 cm and repeat **(a)(i)** and **(a)(iii)**.

x =.......................................cm

T =....................................... [1]

(c) It is suggested that the quantities x and T are related by the equation

$$T = k\,x^2$$

where k is a constant.

(i) Use your answers in **(a)(i)**, **(a)(iii)** and **(b)** to determine two values of k. Give your values of k to an appropriate number of significant figures with their units.

First value of k =.......................................

Second value of k =....................................... [2]

(ii) State whether the results of your experiment support the suggested relationship in **(c)** by referring to the result in (a)(iv).

....

....

....

.... [2]

(d) State one significant source of error in this experiment.

....

.... [1]

(e) It is suggested that the behaviour of the oscillating system also depends on the mass m taped at the end of the ruler, and that period T is proportional to m.

Explain how you would investigate the relationship using some additional masses.

Your account should include

- the experimental procedure
- control of variables
- how you would use your results to verify the relationship.

....

....

....

....

....

....

....

....

....

....

....

.... [4]

[15 marks]

2 In this experiment, you will determine the spring constant of a spring.

(a) You have been provided with three identical springs.

The length of an unstretched spring is S, as shown in **Fig. 2.1**.

Without disconnecting the springs, measure and record S for **one** of the springs.

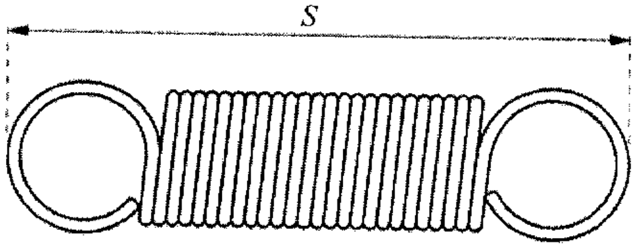


Fig. 2.1

S = ...

(b) **(i)** Set up the apparatus as shown in **Fig. 2.2**.

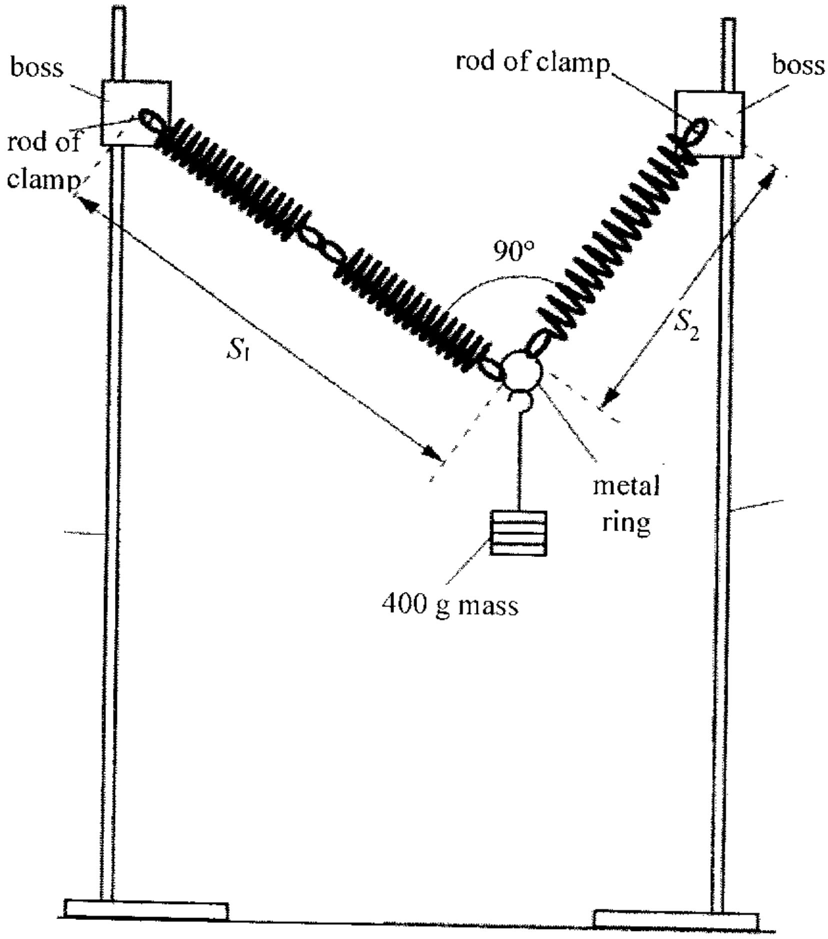


Fig. 2.2

Adjust the apparatus so that the angle between the springs is 90°.

The extended length of the double spring is S_1 and the extended length of the single spring is S_2.

Measure and record S_1 and S_2.

S_1 = ...

S_2 = ...

[1]

(ii) The extensions are p and q where

$$p = S_1 - 2S \text{ and } q = S_2 - S.$$

Calculate p and q.

p = ...

q = ...

[1]

(iii) Estimate the percentage uncertainty in your value of p.

percentage uncertainty of p = ...

[2]

(c) Theory suggests that

$$m^2g^2 = \frac{k^2p^2}{4} + k^2q^2$$

where m = 400 g, k is the spring constant of one of the springs and $g = 9.81$ m s^{-2}.

(i) Calculate k.

k = ... N m^{-1} [1]

(ii) If you were to repeat this experiment with other masses, describe the graph that you would plot to determine k.

....

....

....

....

[2]

(iii) Suggest one significant source of error in this experiment.

....

....

....

[1]

[8 marks]

3 In this experiment you will measure the potential difference across a length L of resistance wire joined to a series resistor **R**. You will use the results of your experiment to determine the current I in the circuit.

(a) **(i)** Use a micrometer to *acccurately* measure the diameter d of the resistance wire. A small section of the wire has been left protruding from the ends of the rule for this purpose.

d = ... [2]

(ii) Hence determine the cross-sectional area A of the resistance wire.

A = ... m^2 [2]

(b) **(i)** Connect the circuit shown in **Fig. 3.1**. The lead X may be placed anywhere along the length of the wire.

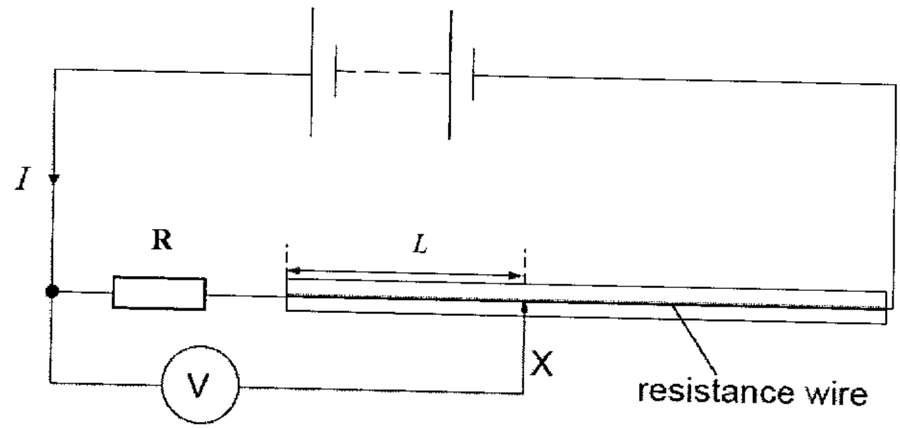


Fig. 3.1

(ii) Record the value of the potential difference V and length L of the wire.

V = ...

L = ...[1].

(c) Change the position of X to give a new length L and repeat **(b) (ii)** until you have a sufficient set of readings for V and L measured over a suitable range of L. Tabulate the results and include a column of values for L/A.

[5]

(d) **(i)** V and L are related by the equation

$$V = \frac{\rho L I}{A} + k$$

where ρ is the resistivity of the material of the wire, A is the cross-sectional area of the wire and k is a constant. The value of ρ is given on a card.

Using your measurements from (c), plot a suitable graph to determine values for k and I. You should include units where appropriate.

k = ...

I = ...

[7]

(ii) The quantity k is known to be the potential difference across the resistance of **R**. Without taking further readings, sketch a line on your graph grid to show the results you would expect if the experiment was repeated with a bigger value of **R**. Label this line A. Explain the shape of the line that you have sketched.

....

....

.... [2]

(iii) State what the voltmeter would read for various values of length L when the resistance of the wire is much smaller than that of the resistance of **R**.

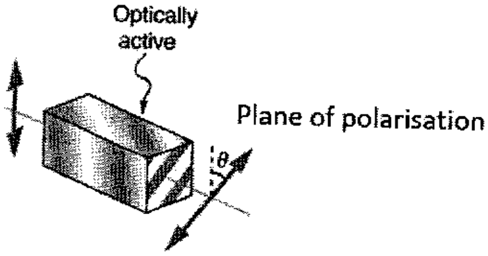
....

....

.... [1]

[20 marks]

4 When plane polarised light passes through an optically active solution of sugar in water, its plane of polarisation is rotated in the clockwise direction.



It is known that the angle θ through which the plane of polarisation of the light is rotated depends on both the wavelength λ of the light as well as the distance D that the light has travelled through the sugar solution.

The angle of rotation θ is given by the equation

$\theta = k\,\lambda^{a}\,D^{b}$ where k, a and b are constants.

Design an experiment to determine the values of a and b.

Assume that you are provided with sheets of polarising material, and several lasers which emit light of different but fixed and *unknown* wavelengths.

Draw a diagram to show the arrangement of your apparatus. You should pay particular attention to

(a) the equipment you would use

(b) the procedure to be followed

(c) how the angular change θ and the wavelength λ of the transmitted light are determined

(d) the control of variables

(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram

[12]

[Total: 12]

Mark Scheme for 2021 Prelim Practical Exam

Experiment 1

		Marking point	Code	Mark	Remarks
(a)	(i)	x is measured to 1 dp in cm.	A1	1	Award mark even if no repetition
		x = 28.0 cm			
(a)	(ii)	Percentage uncertainty to 2sf. Δx = 0.2 cm to 0.3 cm (due to thickness of rubber band and uncertainty of C.G. of 20 g mass)	A2	1	
		$\frac{\Delta x}{x}\text{x}100 = \frac{0.2}{28.0}\text{x}100 = 0.71\%$			
(a)	(iii)	N oscillations chosen such that total time t > 10s t recorded to 1 or 2 dp	A3	1	
		Repeated readings of t clearly shown. Period calculated by taking $\frac{t_{average}}{n} = T$	A4	1	
		N = 20 oscillations **t_1 = 12.1 s** **t_2 = 12.2 s** $<t> = \frac{12.1+12.2}{2} = 12.2\ s \Rightarrow T = \frac{12.2}{20} = 0.610\ s$			
(a)	(iv)	Percentage uncertainty to 2sf. Uncertainty $\frac{\Delta t}{t} \times 100\% = \frac{\Delta T}{T} \times 100\%$ Δt = 0.2 s to 0.5 s (human reaction time (HRT))	A5	1	Note, do not allow ΔT as HRT
		$\frac{\Delta t}{t}\text{x}100 = \frac{0.3}{12.2}\text{x}100 = 2.5\% = \frac{\Delta T}{T} \times 100\%$			
(b)		T accurately calculated as in (a)(iii)	B1	1	
		x= 26.0 cm **N = 25 oscillations** **t_1 = 13.5 s** **t_2 = 13.6 s** $<t> = \frac{13.5+13.6}{2} = 13.6\ s \Rightarrow T = \frac{13.6}{20} = 0.680\ s$			
(c)	(i)	Values of k accurately calculated to correct sf. (3sf) Units of k indicated [s cm^{-2} or s m^{-2}]	C1 C2	1 1	
		$k_1 = \frac{T_1}{{x_1}^2} = \frac{0.610}{0.280^2} = 7.78\ \text{s m}^{-2}$ $k_2 = \frac{T_2}{{x_2}^2} = \frac{0.680}{0.260^2} = 10.1\ \text{s m}^{-2}$			

(c)	(ii)	Referring to (a)(iv), Test for logical conclusion. $\frac{\Delta k}{k} = \frac{k_2 - k_1}{k_2}$calculated from (c)(i) If $\frac{\Delta k}{k} > \frac{\Delta T}{T}$ then relationship is not supported. If $\frac{\Delta k}{k} < \frac{\Delta T}{T}$ then relationship is supported.	C3 C4	1 1	
(d)		Any of the following - human reaction time is significant especially when length x is short - Oscillation is damped and thus displacement can become too small, thus making it hard to observe. - Oscillations are very fast making it difficult to count the oscillations	D1	1	
(e)		1. Set up experiment in the same way as this experiment. 2. Fix the length x at a certain length. Eg $x = 28.0$ cm 3. Oscillate the ruler as before. 4. Time N oscillations using a stopwatch such that total time $t > 10$s. 5. Repeat and take average for the time for N oscillations. 6. Divide time taken by N to obtain period of oscillation 7. Repeat steps 2 to 6 varying mass from approximately 10 g to 60 g measured by an electronic balance to obtain 6 data points.	E1 E2	1 1	*Steps 4 to 7 must be mentioned to get 1 mark for experimental procedure.* *Stopwatch and electronic balance must be mentioned for the other mark.*
		Control of variables 1. Same ruler is used since different rulers have different stiffness factors which will affect the period. 2. Ensure length x is fixed.	E3	1	Either one of the two factors to be mentioned to get mark.
		Showing relationship [1m] 1. Since it is suggested that $T \propto mass$, plot T vs m. 2. If the graph is a straight line passing through the origin, the relationship holds. Otherwise, it does not.	E4	1	

Experiment 2

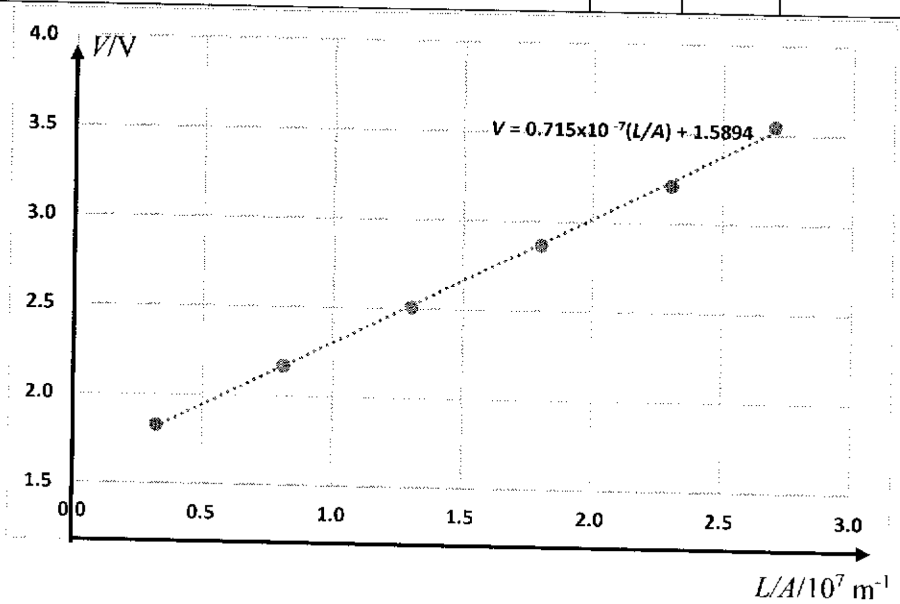
		Marking point	Code	Mark	Remarks
(b)	(i)	Length recorded to the nearest 1 mm or 0.1 cm Consistent unit. Unit needed.	B1	[1]	
		S = 5.0 cm; S_1 = 29.0 cm; S_2 = 17.4 cm			
(b)	(ii)	Correct calculation to determine p and q	B2	[1]	p and q were calculated when S = 5.0 cm
		p = 19.0 cm; q = 12.4 cm			
(b)	(iii)	Actual uncertainty for p must be 0.3 cm to 0.7 cm because of unsteady measurements in air	B3	[1]	Working must be shown clearly
		Correct calculation of percentage uncertainty	B4	[1]	2 s.f. for percentage uncertainty.
		$\frac{\Delta p}{p} \text{x}100 = \frac{0.6}{19.0} \text{x}100 = 3.2\%$			
(c)	(i)	Value of k is calculated correctly and within the range.	C1	[1]	Range: 20.0 – 30.0 N m^{-1}
		$m^2g^2 = \frac{k^2p^2}{4} + k^2q^2$ $0.400^2(9.81^2) = k^2\left(\frac{0.190^2}{4} + 0.124^2\right) \Rightarrow k = 25.0 \text{ N m}^{-1}$			
	(ii)	Plot m^2 against $\left(\frac{p^2}{4} + q^2\right)$	C2	[1]	Do not accept m^2 vs p^2, as q^2 is a variable
		The graph obtained should be a straight line passing through the origin, and the gradient is equal to $\frac{k^2}{g^2}$. Hence, $k = g\sqrt{\text{gradient}}$	C3	[1]	
	(iii)	The set up might not be aligned in a vertical plane, affecting the extension of the springs Measurements of length and angle are done in air without any equipment to ensure verticality, affecting the accuracy of the readings. The springs might not be identical, affecting the accuracy of p and q. Any other reasonable source of error.	C4 C5 C6 C7	[1]	Any one is acceptable

Experiment 3

		Marking point	Code	Mark	Remarks
(a)	(i)	Diameter of wire. 2 d.p. (mm) in raw data. Consistent unit. Unit needed. Accept 0.18 mm to 0.22 mm for *d*.	A1	[1]	Value must have been already corrected for zero error; no need to show. If 3 marks are allocated, show zero error.
		Repeat measurement	A2	[1]	
		d_1 = 0.20 mm **d_2 = 0.20 mm** $d = \frac{d_1+d_2}{2}$ **= 0.20 mm**			
(a)	(ii)	Correct formula $A = \frac{\pi d^2}{4}$	A3	[1]	
		S.f. in *A* the same as s.f. in *d*.	A4	[1]	
		$A = \frac{\pi d^2}{4} = \frac{\pi(0.20\text{x}10^{-3})^2}{4} \approx 3.1\text{ x }10^{-8}\text{ m}^2$			
(b)	(ii)	Values of *V* and *L* with units and correct dec. pl	B1	[1]	
		V = 2.76 V **L = 50.0 cm**			
(c)		Minimum six sets of readings of *V* and *L*	C1	[1]	Unreasonable values of *V* : minus1 (e.g. Voltage values areabout the same ($V_{max} - V_{min}$ < 0.5 V), wrong trend (L↑, V↓) or if any one value of V < 0.5V; *V* cannot exceed 4.5 V (emf of battery)
		Range of *L* should be equal or more than 70.0 cm	C2	[1]	
		Column headings: *V*/V; *L*/cm; *L*/*A*/10^7 m^{-1}. Each column heading must contain a quantity and a unit where appropriate. Ignore units in the body of the table. There must be some distinguishing mark between the quantity and the unit (i.e. solidus is expected, but accept, for example, *L* (cm)).	C3	[1]	
		Consistency of presentation of raw readings All values of *L* must be given to the same number of decimal places. *L* read to 1 mm or 0.1 cm or 0.001 m	C4	[1]	
		Significant figures. Apply correctly to *L*/A. Check a single value of *L*/A for correct calculation. Correct unit for *L/A*.	C5	[1]	

L/m	**V/V**	**L/A/10^7 m^{-1}**
0.100	**1.83**	**0.32**
0.250	**2.17**	**0.81**
0.400	**2.51**	**1.3**
0.550	**2.87**	**1.8**
0.700	**3.21**	**2.3**
0.850	**3.55**	**2.7**

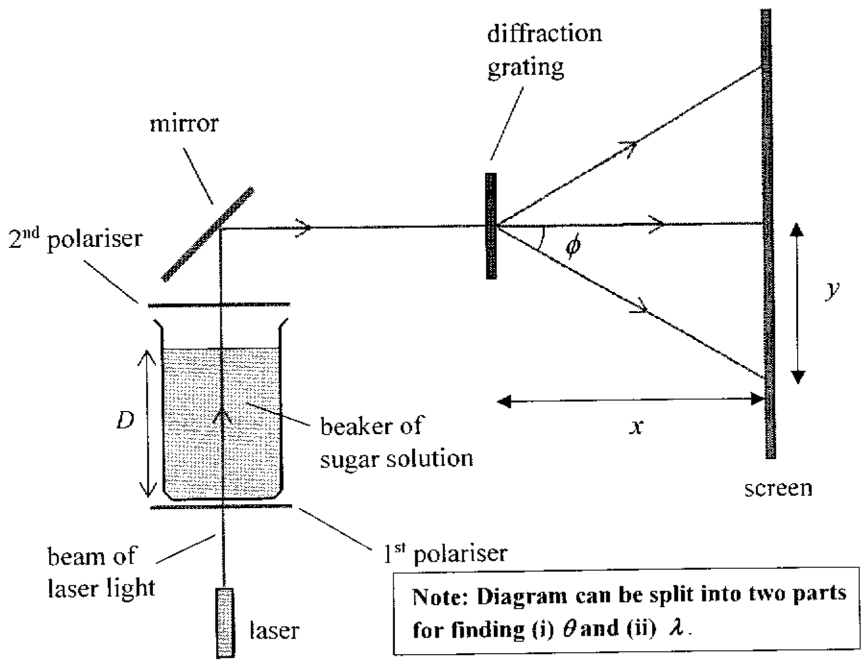
(d)	(i)	Axes. Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Scales must be labelled with the quantity which is being plotted. Include units.	D1	[1]	If wrong graph plotted (e.g. *L* against *L*/A) do not award mark.
		All observations must be plotted. Check 3 random plots. Tick if correct.	D2	[1]	Work to an accuracy of half a small square.
		Line of best fit. Allow 1 point off (anomalous). All 6 plots needed. There must be a fair scatter of points either side of the line.	D3	[1]	Do not award mark if large scatter.
		Gradient The hypotenuse of the Δ must be at least half the length of the drawn line. Read-offs must be accurate to half a small square.	D4	[1]	Do not allow table values unless on the line of best fit.
		Value for k, $0.5\text{ V} \le k \le 2.5\text{ V}$ Should be y-intercept. Unit required. 2 or 3 sf.	D5	[1]	The value must be read to the nearest half square. The value can be calculated using y = mx + c.
		Working for I must be checked. Gradient = ρI	D6	[1]	
		Value for I, $0.05\text{ A} \le I \le 0.20\text{ A}$	D7	[1]	Unit required A (V Ω^{-1}). 2 or 3 sf.



Gradient = ρI **or** $0.715 \times 10^{-7} = 5.2 \times 10^{-7} I \Rightarrow I = 0.138$ **A or 0.14 A**
k **= y- intercept = 1.59 V**

(d)	(ii)	k has the unit V for homogeneity of equation. It is actually IR. If R increases in the circuit, I will decrease in the circuit. Gradient = ρI will decrease. The voltage k will increase by the potential divider principle.	D8	[1]	
		Graph A must have a gentler gradient with a bigger vertical intercept.	D9	[1]	
(d)	(iii)	When the resistance of the wire is much smaller than that of R, the voltmeter will read practically the same value (terminal p.d. of cell) regardless of the value of L. This will be the p.d. across **R**.	D10	[1]	

PLANNING QUESTION



Note: Diagram can be split into two parts for finding (i) θ and (ii) λ.

Procedure:

Experiment 1: Finding the relationship between θ and wavelength λ:

1. Prepare the sugar solution in a beaker, keeping the depth D at a fixed value through the experiment.
2. Position two polarisers above and below the beaker.
3. Position a laser below the beaker and polarisers so that it emits a beam of monochromatic light which passes vertically through them.

Measurement of λ

4. Temporarily remove the beaker of sugar solution. Use a mirror inclined at 45° to reflect the light beam so that it travels horizontally, so as to facilitate its analysis with a spectrometer.
5. Position a diffraction grating and screen in the path of the light beam from the second polariser to serve as a spectrometer.
6. Measure the angle of diffraction ϕ of the transmitted light using one of the beams transmitted by the grating. Calculate ϕ by measuring the distances x and y with a ruler and using $\phi = \tan^{-1}\left(\frac{y}{x}\right)$.
7. Calculate the wavelength λ of the laser light using $d \sin\phi = n\,\lambda$ where d is the distance between adjacent slits in the diffraction grating.

Measurement of θ

8. With the beaker still removed, position two polarisers, one above the other. Rotate the two polarisers relative to each other until the intensity of the transmitted laser light is maximum. This indicates that their polarising directions are aligned.
9. Replace the beaker. As the sugar solution rotates the direction of polarisation of the laser light, the light that is now transmitted by the second polariser is reduced in intensity.
10. Rotate the second polariser until the intensity of the transmitted light is again maximum.
11. Measure the angle of rotation θ using a protractor. This is the angular change in the plane of polarisation of the light caused by the sugar solution.
12. While keeping D constant, vary the wavelengths λ of laser light by using different lasers, so as to obtain a series of corresponding values of λ and θ.
13. From

$$\theta = k\,\lambda^a\,D^b$$

we linearise to get $ln\theta = lnk + aln\lambda + blnD$.

Plot a grah of $ln\theta$ against $ln\lambda$ while keeping D constant. The gradient of the straight line is a.

Experiment 2: Finding the relationship between θ and distance D:

1. For this experiment, keep the wavelength λ of the light constant by using only one laser for the whole experiment.
2. Obtain values of θ for various values of D. Measure D with a ruler.
3. Plot a graph of lg (θ) against lg D.The gradient of this graph is equal to the constant b.

Control of Variables

Keep the concentration of the sugar solution constant as changes in concentration will affect θ.

Precautions for accuracy:

1. Ensure that the laser beam enters the sugar solution perpendicular to the solution surface, as otherwise the distance travelled will not be accurately measured.
2. Use a light intensity meter to measure the intensity of the transmitted light so as to detect the point at which maximum intensity has been reached, instead of relying on human judgment.

3. Use the higher orders of the diffracted beams from the grating to maximise the diffraction angle ϕ, so as to reduce the percentage error in the calculated value of the wavelength λ.
4. Perform the experiment away from strong electric and magnetic fields as these may affect the behaviour of the sugar molecules in rotating the plane of polarisation.

Precautions for safety:

1. Wear safety goggles (dark glasses) while working with lasers as the laser light may cause injury to eyes.
2. Mop up any spillage of the sugar solution as it can cause a person to slip and fall.

Marking scheme:

Diagram [2]	D1	Labelled diagram showing: - a method of polarising the light before it enters the sugar solution. - a second polariser to analyse the transmitted light.
	D2	Labelled diagram showing method of: - a diffraction grating to determine the wavelength.
Procedure [4]	P1	Workable methods to vary D and λ.
	P2	Correct method to determine θ (by rotating polarisers w.r.t. each other and finding point of maximum transmitted intensity).
	P3	Workable method to determine λ (using diffraction grating)
	P4	Correct instruments used to measure distance D (ruler) and θ (protractor) and ϕ using measurements of x and y (use ruler). Note: If students already missed out D2 and P3 because they didn't think about using a diffraction grating, shouldn't penalise for this point. i.e. award P4 for mentioning instruments to measure D and θ
Control of variables [1]	C1	Ensure that the concentration of the sugar solution is kept constant for the experiment.
Analysis [3]	A1	Linearising the equation into: $\lg(\theta) = a\lg\lambda + b\lg D + \lg k$
	A2	• Plot a graph of lg (θ) against lg λ (when D is kept constant). • Equate gradient to a.
	A3	• Plot a graph of lg (θ) against lg D (when λ is kept constant). • Equate gradient to b.
Accuracy precaution [1]	R1 R2	Any one precaution for accuracy: • Ensure that the laser beam enters the sugar solution perpendicular to the solution surface, as otherwise the distance travelled will not be accurately measured.

	R3 R4 R5	• Use a light intensity meter to measure the intensity of the transmitted light so as to detect the point at which maximum intensity has been reached, instead of relying on human judgment. • Use the higher orders of the diffracted beams from the grating to maximise the diffraction angle ϕ, so as to reduce the percentage error in the calculated value of the wavelength λ. • Perform the experiment away from strong electric and magnetic fields as these may affect the behaviour of the sugar molecules in rotating the plane of polarisation. • Any other reasonable precaution for accuracy
Safety precaution [1]	S1 S2 S3	• Wear safety goggles (dark glasses) while working with lasers as the laser light may cause injury to eyes. • Mop up any spillage of the sugar solution as it can cause a person to slip and fall. • Any reasonable precaution for safety