Cambridge Assessment International Education

Cambridge International AS & A Level

26/27
30

CANDIDATE NAME Fuzail

CENTRE NUMBER

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2658768184

PHYSICS **9702/51**

Paper 5 Planning, Analysis and Evaluation **May/June 2020**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **8** pages. Blank pages are indicated.

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1 A student investigates springs made of metal wire, as shown in Fig. 1.1.

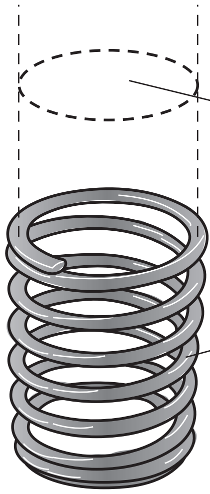

Fig. 1.1

The student constructs several springs from wire of thickness t. Each spring has a different cross-sectional area A.

The student investigates how the spring constant k varies with A.

It is suggested that the relationship between k and A is

$$k = \frac{\beta \rho t^4}{A^{\frac{3}{2}} N}$$

where ρ is the density of the metal, N is the number of turns of wire on the spring and β is a constant.

Design a laboratory experiment to test the relationship between k and A.
Explain how your results could be used to determine a value for β.

You should draw a diagram, on page 3, showing the arrangement of your equipment.
In your account you should pay particular attention to:

- the procedure to be followed
- the measurements to be taken
- the control of variables
- the analysis of the data
- any safety precautions to be taken.

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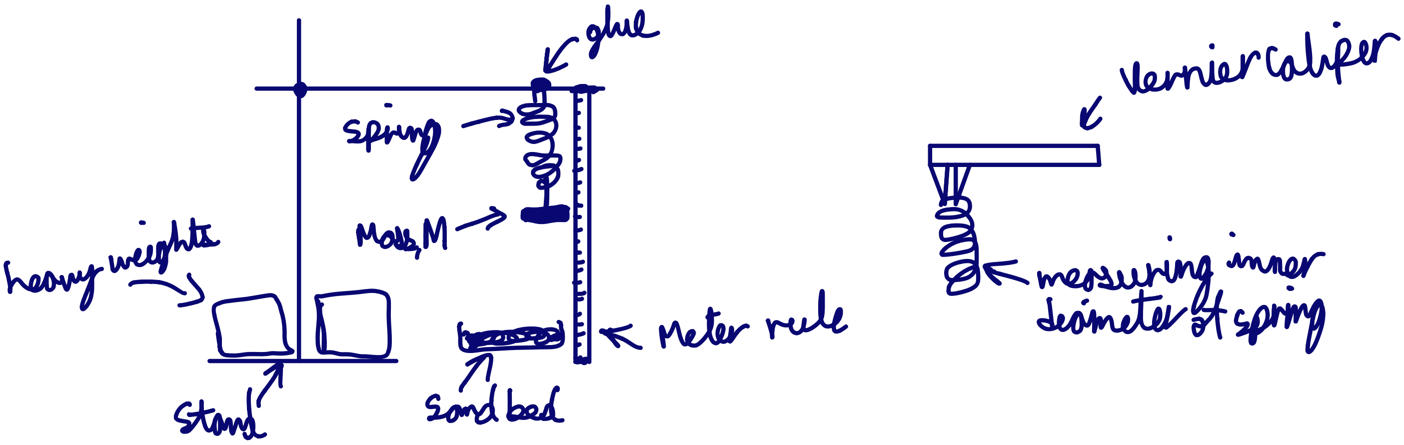
Diagram



In this experiment the cross sectional area, A, of the spring is the independant variable, the spring constant is the dependant variable. The same wire should be used to keep the density and thickness constant and the number of turns of the spring should be constant too.

The cross sectonal area, A, of the spring can be varied by making springs of different. The area can be calculated by firstly measuring the inner diameter with vernier calipers, $A = \pi \times \left(\frac{\text{diameter}}{2}\right)^2$. The spring constant should be measured by attaching a known mass, M, to the spring and measuring the increase in length using a meter ruler. $k = \frac{M \times 9.81}{x}$, when x is the increase in length.

A wire of metal of a known density should be used, and the thickness, t, of the wire can be measured using vernier calipers. The Number of turns, N, should be counted

$R = \frac{B \rho t^4}{N} \times \frac{1}{A^{3/2}}$, so a graph of R against $\frac{1}{A^{3/2}}$ should be made. The relationship is valid if the line of best fit is a straight line passing through the origin. To find the value of B, the gradient of this graph needs to be determined. $B = \frac{\text{gradient} \times N}{\rho \times t^4}$, where ρ is the density of the metal.

A sand bed should be placed under the spring for safety reasons.

For finding each value of R, those steps should be repeated and avg value of increase in length should be taken.

[15]

Question	Answer	Marks
1	**Defining the problem**	
	A is the independent variable and k is the dependent variable **or** vary A and measure k	1
	keep N constant	1
	Methods of data collection	
	labelled diagram of workable experiment including: • spring fixed at one end to a support • load attached to the other end of the spring • labelled load	1
	method to measure mass or weight of load: use top-pan balance to measure mass or newton meter to measure weight	1
	use of a micrometer/calipers to determine t **and** rule/calipers to measure the diameter of the spring	1
	method to measure extension, e.g. labelled ruler drawn parallel to spring, equilibrium position and displaced position indicated and x indicated **or** description of use of ruler to measure equilibrium position and displaced position and difference determined	1
	Method of analysis	
	plot a graph of k against $1/A^{3/2}$ (or $A^{-3/2}$) or equivalent e.g. lg k against lg A	1
	relationship valid if a straight line passing through the origin is produced (for lg k against lg A, relationship valid if a straight line with gradient –3/2)	1
	$\beta = \frac{\text{gradient} \times N}{\rho t^4}$ [for lg k against lg A, $\beta = 10^{y\text{-intercept}} \times N / (\rho t^4)$]	1

Question	Answer	Marks
1	**Additional detail including safety considerations**	6
	D1 use safety goggles/safety screen to prevent injury to eyes from (moving) spring/load **or** use cushion/sand box in case load falls	
	D2 keep t constant	
	D3 $k = \frac{mg}{x}$ or $\frac{F}{x}$	
	D4 use of set square when taking measurements to determine extension of spring	
	D5 repeat measurement of t along wire/spring and average	
	D6 repeat measurement of diameter D of spring (to determine A) in different directions and average	
	D7 use of $A = \frac{\pi D^2}{4}$	
	D8 method to ensure clamped rule to measure extension is vertical, e.g. correctly positioned set square indicated at right angles between the rule and the horizontal surface **or** plumb line shown in appropriate position	
	D9 method to determine the density of the wire **or** additional detail on construction of coil	
	D10 method to determine the mean diameter of the spring, e.g. subtract t from external diameter of spring	

2 A student investigates the discharge of a capacitor through a resistor using the circuit shown in Fig. 2.1.

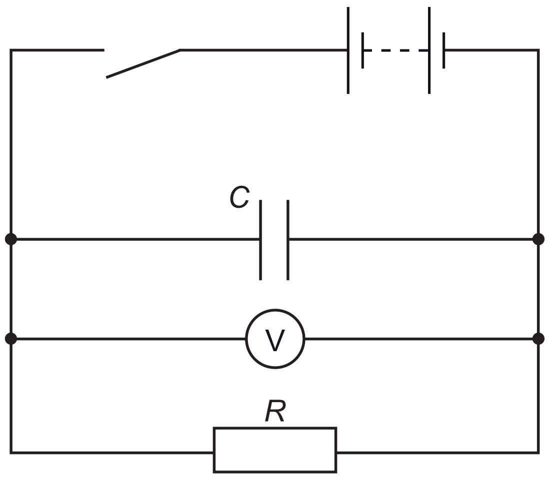


Fig. 2.1

The student initially closes the switch and charges the capacitor. The switch is then opened and a stop-watch is started. The capacitor discharges through the resistor. At time t the potential difference V across the capacitor is measured.

It is suggested that V and t are related by the equation

$$V = \left(\frac{Q_0}{C}\right)e^{-\left(\frac{t}{RC}\right)}$$

where Q_0 is the charge of the fully charged capacitor, C is the capacitance of the capacitor and R is the resistance of the resistor.

(a) A graph is plotted of ln V on the y-axis against t on the x-axis.

Determine expressions for the gradient and y-intercept.

$$\ln V = \ln\left(\frac{Q_0}{C}\right) + \left(\frac{-t}{RC}\right)$$

gradient = $-\frac{1}{RC}$

y-intercept = $\ln\left(\frac{Q_0}{C}\right)$

[1]

(b) Values of *t* and *V* are given in Table 2.1.

Table 2.1

t / s	*V* / V	ln (*V* / V)
0	6.2 ± 0.2	1.82 ± 0.03
6	4.6 ± 0.2	1.53 ± 0.04
12	3.4 ± 0.2	1.22 ± 0.06
18	2.6 ± 0.2	0.96 ± 0.07
24	2.0 ± 0.2	0.69 ± 0.10
30	1.4 ± 0.2	0.34 ± 0.13

Calculate and record values of ln (*V* / V) in Table 2.1.
Include the absolute uncertainties in ln (*V* / V). [2]

(c) **(i)** Plot a graph of ln (*V* / V) against *t* / s.
Include error bars for ln (*V* / V). [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

gradient of Line of best fit

$= \dfrac{1.82 - 0.14}{-35} = -0.048$

gradient of Line of worst fit

$\dfrac{1.85 - 0.04}{0 - 35} = -0.0517$

$\Delta m = -0.048 - (-0.0517)$

$= 0.0037$

gradient = -0.048 ± 0.004 [2]

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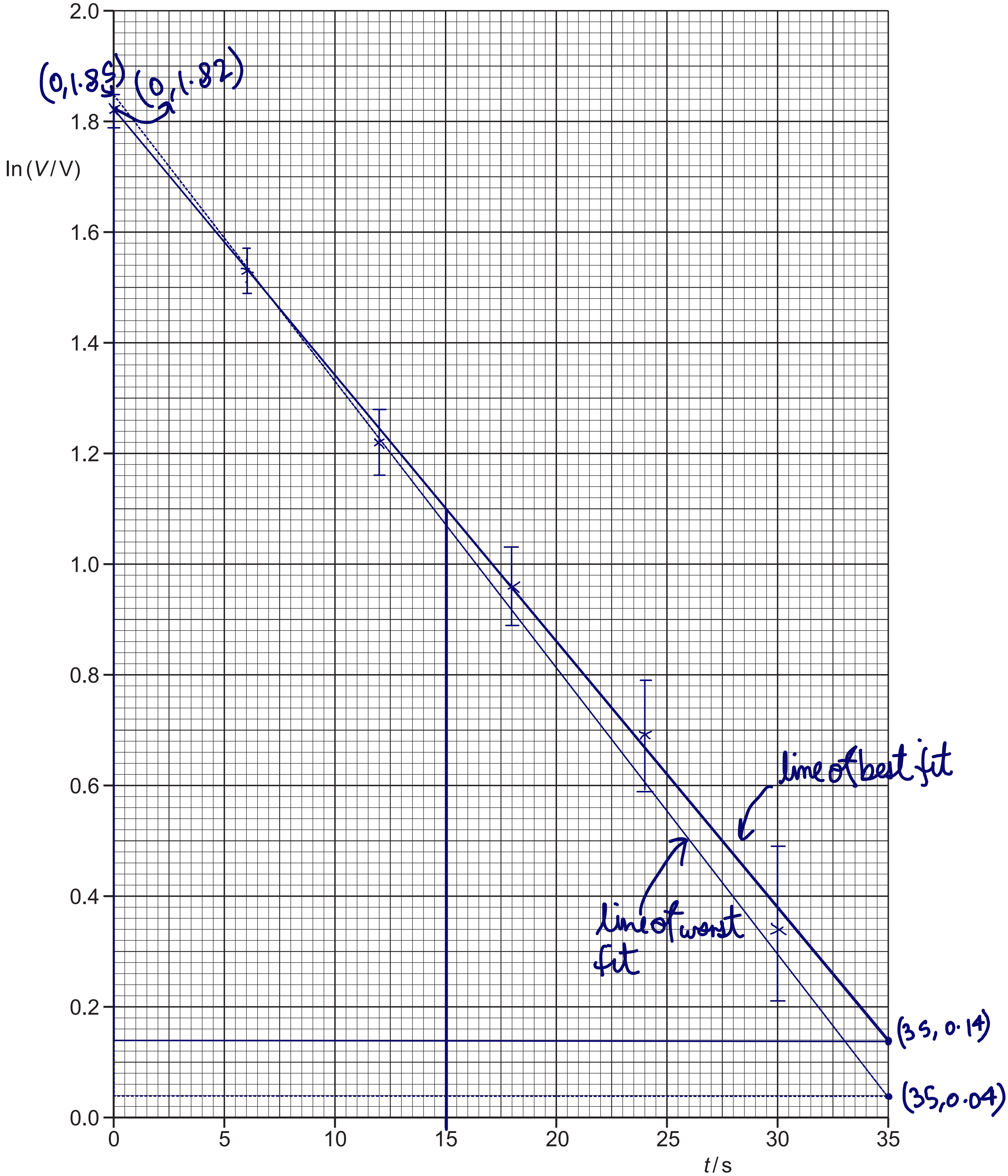

t / s	V / V	ln (V / V)
0	6.2 ± 0.2	1.82 ± 0.03
6	4.6 ± 0.2	1.53 ± 0.04
12	3.4 ± 0.2	1.22 ± 0.06
18	2.6 ± 0.2	0.96 ± 0.07
24	2.0 ± 0.2	0.69 ± 0.10
30	1.4 ± 0.2	0.34 ± 0.13

(iv) Determine the y-intercept of the line of best fit. Do **not** include the absolute uncertainty in your answer.

$c = y - mx$
$= 0.14 - (-0.048)35$
$= 1.82$

y-intercept = ...1.82.... [1]

(d) **(i)** Using your answers to **(a)**, **(c)(iii)** and **(c)(iv)**, determine values of C and Q_0. Include appropriate units.

Data: $R = 39\,\text{k}\Omega$

$\ln\left(\frac{Q_0}{C}\right) = 1.82$
$Q_0 = C \times e^{1.82}$
$Q_0 = 0.000534 \times e^{1.82}$
$= 0.0032969$

$\frac{-1}{39000C} = -0.048$
$C = \left(\frac{1}{0.048}\right) \div 39000 = 0.000534$

C = ...5.34×10^{-4}....

Q_0 = ...3.29×10^{-3}....

[3]

(ii) The percentage uncertainty in the value of R is 5%.

Determine the absolute uncertainty in C.

$\%C = \%R + \%M$
$= 5\% + \left(\frac{0.0037}{0.048} \times 100\right)\%$
$= 5\% + 7.70833\%$

$\frac{\Delta C}{C} \times 100 = 12.7083\%$
$\Delta C = 0.127083 \times 5.34 \times 10^{-4}$
$= 6.786 \times 10^{-5}$

absolute uncertainty in C = ...6.8×10^{-5}.... [1]

(e) Using your results, determine the value of V when the time t is 1.0 minute.

$$V = \left(\frac{Q_0}{C}\right) e^{-\left(\frac{t}{RC}\right)}$$

$\left(\frac{3.29 \times 10^{-3}}{5.34 \times 10^{-4}}\right) \times e^{\frac{-60}{39000 \times 5.34 \times 10^{-4}}}$

$= 0.345$

V = ...0.35.... V [1]

[Total: 15] 15

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