



- 1 A ball rolls forwards and backwards on a curved track as shown in Fig. 1.1.

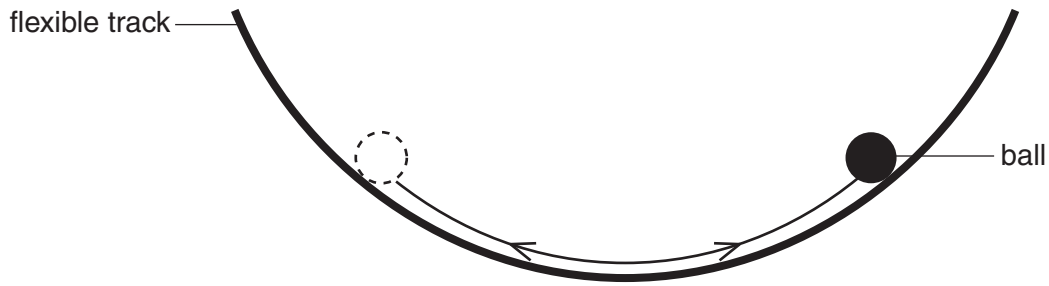


Fig. 1.1

It is suggested that the period  $T$  of the oscillations is related to the radius  $r$  of the ball and the radius of curvature  $C$  of the track by the relationship

$$T^2 = \frac{28\pi^2}{5g} (C - r)$$

where  $g$  is the acceleration of free fall.

You are provided with a flexible track. Design a laboratory experiment to test the relationship between  $T$  and  $r$ . Explain how your results could be used to determine a value for  $C$ . You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

- (a) the procedure to be followed,
- (b) the measurements to be taken,
- (c) the control of variables,
- (d) the analysis of the data,
- (e) the safety precautions to be taken.

[15]





- 2 A student is investigating a circuit containing an operational amplifier (op-amp).

The circuit is set up as shown in Fig. 2.1.

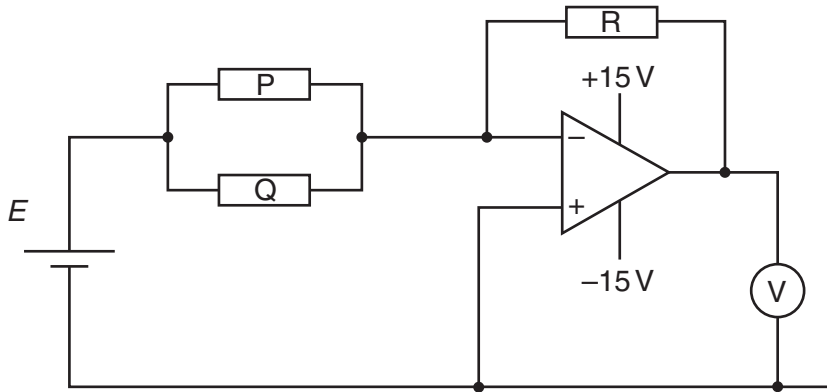


Fig. 2.1

The op-amp is connected to a +15V and –15V power supply.

An experiment is carried out to investigate how the reading  $V$  on the voltmeter varies with the resistance  $Q$  of resistor  $Q$ .

It is suggested that  $V$  and  $Q$  are related by the equation

$$V = -ER \left( \frac{1}{P} + \frac{1}{Q} \right)$$

where  $E$  is the e.m.f. of the cell,  $P$  is the resistance of resistor  $P$  and  $R$  is the resistance of resistor  $R$ .

- (a) A graph is plotted of  $\frac{V}{E}$  on the  $y$ -axis against  $\frac{1}{Q}$  on the  $x$ -axis.

Determine expressions for the gradient and the  $y$ -intercept in terms of  $P$  and  $R$ .

gradient = .....

$y$ -intercept = .....



[1]

- (b) The e.m.f.  $E$  of the cell has a value of  $1.6 \pm 0.1\text{V}$ .

Values of  $V$  and  $Q$  are given in Fig. 2.2.

$Q/10^3 \Omega$	$V/V$	$\frac{1}{Q}/10^{-3}\Omega^{-1}$	$\frac{V}{E}$
0.15	$-8.2 \pm 0.1$		
0.22	$-6.0 \pm 0.1$		
0.33	$-4.4 \pm 0.1$		
0.50	$-3.3 \pm 0.1$		
0.66	$-2.8 \pm 0.1$		
0.90	$-2.4 \pm 0.1$		

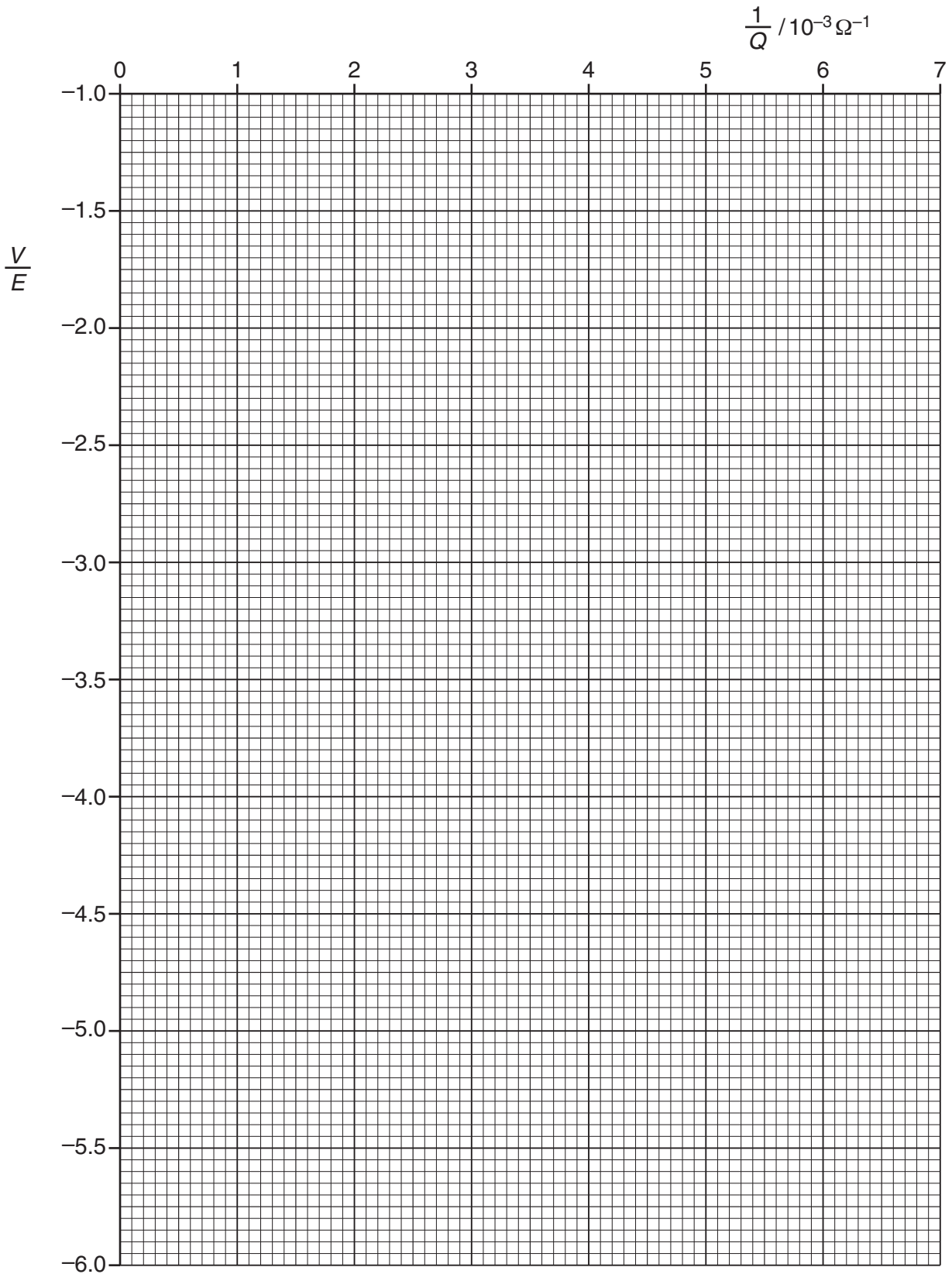
**Fig. 2.2**

Calculate and record values of  $\frac{1}{Q}/10^{-3}\Omega^{-1}$  and  $\frac{V}{E}$  in Fig. 2.2.

Include the absolute uncertainties in  $\frac{V}{E}$ . [3]

- (c) (i) Plot a graph of  $\frac{V}{E}$  against  $\frac{1}{Q}/10^{-3}\Omega^{-1}$ . Include error bars for  $\frac{V}{E}$ . [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 uncertainty in your answer.

gradient = ..... [2]




- (iv) Determine the  $y$ -intercept of the line of best fit. Include the uncertainty in your answer.

$y$ -intercept = ..... [2]


- (d) (i) Using your answers to (c)(iii) and (c)(iv), determine the values of  $P$  and  $R$ . Include appropriate units.

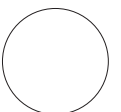
$P$  = .....

$R$  = ..... [2]


- (ii) Determine the percentage uncertainty in  $P$ .

percentage uncertainty = .....% [1]

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