Answer **all** the questions.

Section A

1 Here is a list of electrical units:

A s **A V^{-1}** **C s^{-1}** **J s^{-1}** **J C^{-1}**

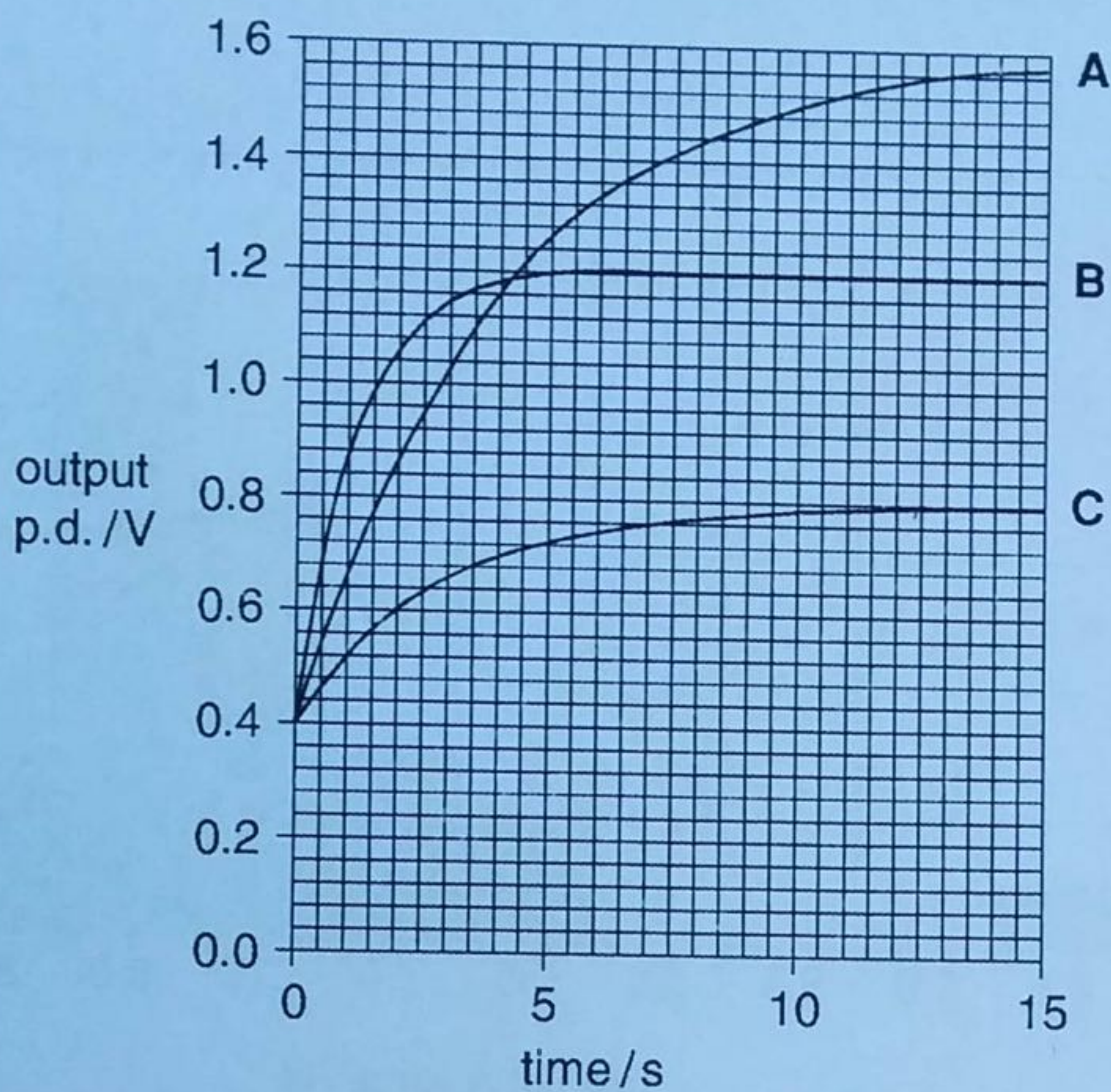
Choose the unit for

(a) electrical power ....J s⁻¹........

(b) electric charge ....A s........

(c) conductance ....A V⁻¹........ [3]

2 Three temperature sensors **A**, **B** and **C** were plunged into hot water at the same moment, time $t = 0$. The graph below shows their responses.



(a) State the sensor with the **shortest** response time. ....B.... [1]

(b) Estimate the response time of sensor **B**.

response time = ...5.... s [1]

(c) The temperature rise of each sensor was 75 °C.

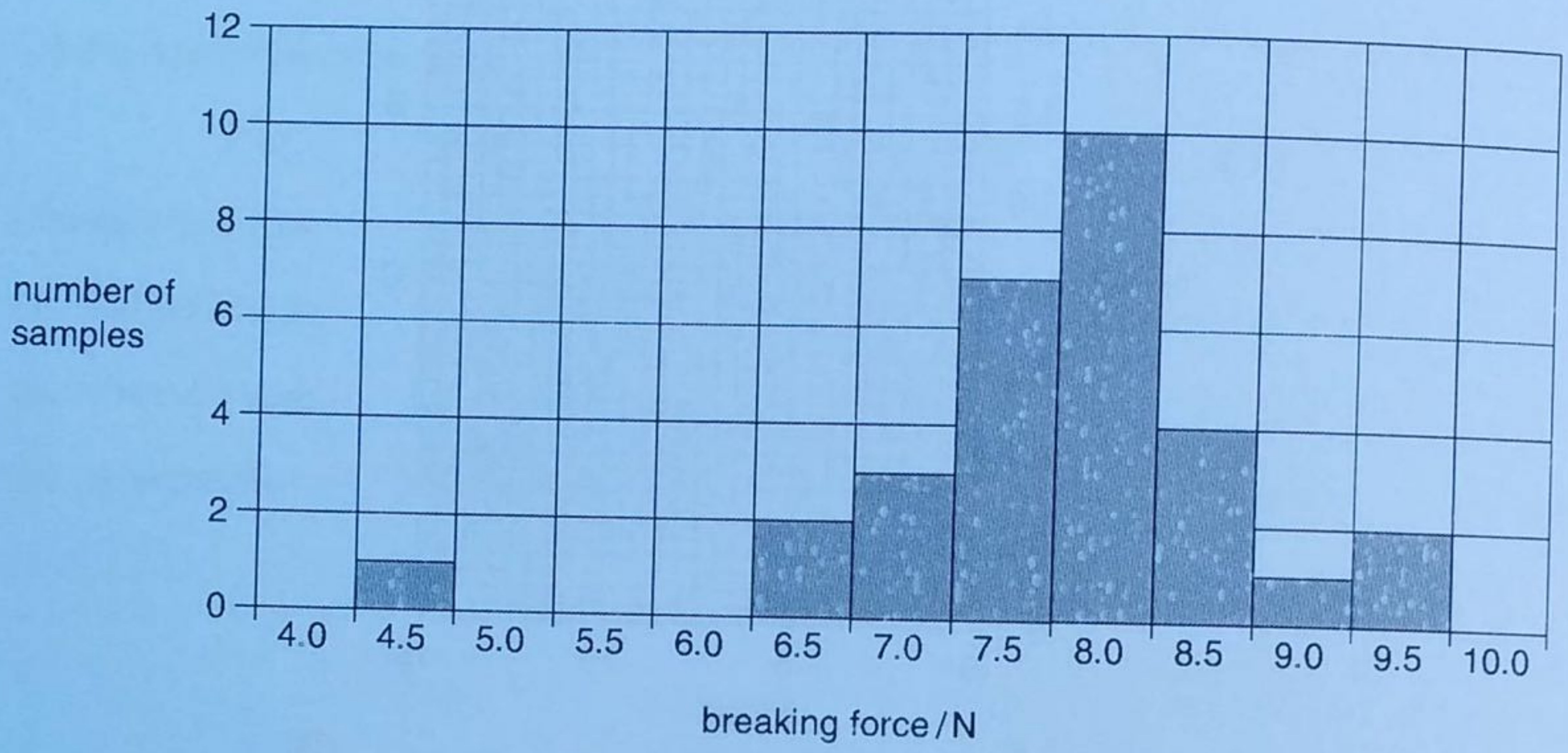
Calculate the average sensitivity of sensor **B** in this temperature range.
Make your method clear and give the units of sensitivity.

1·2 − 0·4 = 0·8V

$\frac{0\cdot 8V}{75°C}$ =

sensitivity = ...0·011.... unit ....V°C^{-1}.... [3]

3 A class experiment sets out to investigate the force needed to break a strip of paper. 30 sample strips, all cut to the same width, were tested. The breaking force for each was measured to the nearest 0.5 N. The histogram below shows the number of samples at each measured breaking force.



(a) The class are discussing whether to ignore the low result at 4.5 N.

Suggest a possible reason for this low result.

sample is torn or damp etc.

[1]

(b) The result at 4.5 N was ignored. Estimate the breaking force of the paper. Estimate also the variability in the measurements for this set of samples.

Make your method for making the estimates clear.
Give your answers to a sensible number of significant figures.

mean = 228.5/29 = 7.9 N

mode & median = 8 N

spread = $\frac{\text{range}}{2}$ = ±1.5

breaking force = ...8.... ± ....1.5.... N [3]

4 Here are five mechanical properties of materials:

brittleness hardness toughness stiffness strength

For each of the following descriptions of mechanical properties of materials write down the property being described from the list.

the ratio stress/strain when a material is stretched elastically ....stiffness....

the tendency to break by crack propagation ....brittleness....

[2]

5 The highest frequency in a film soundtrack is 6.0 kHz. The soundtrack is to be sampled and digitised. The sampling frequency should be at least 12 kHz.

(a) State one problem produced by sampling at less than 12 kHz.

loss of high frequencies

aliases

[1]

(b) The soundtrack contains some random electrical noise. The variation of the noisy signal is 2000 times larger than the noise alone.

$$V_{total} / V_{noise} = 2000$$

Thus when the signal is digitised, there is no point distinguishing more than 2000 digital levels.

Show that it would be pointless to use more than 11 bits to digitise each sample.

$\log_2 2000 = 10.96$

$\therefore$ >11 bits codes noise

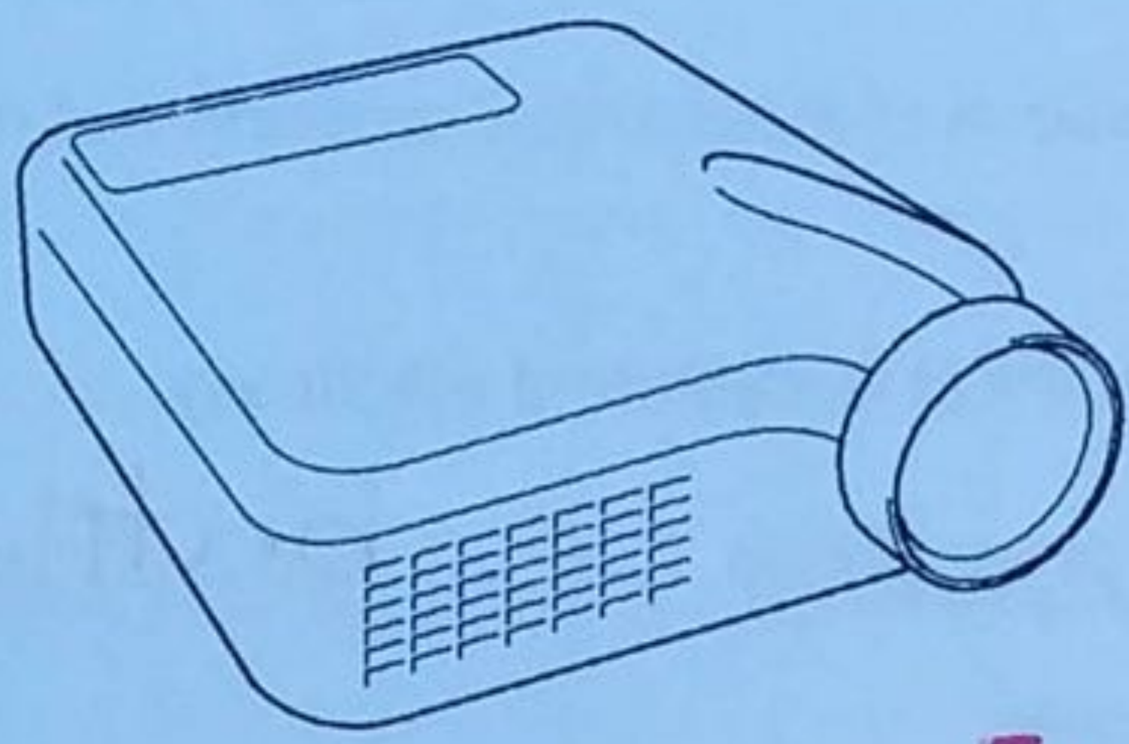
[1]

(c) Estimate the rate of information transfer that this digitised soundtrack uses.

$11 \times 12 \times 10^3$

rate of information transfer = ...132000.... bit s^{-1} [1]

6 Inside a data projector the illuminated object display is 45 mm wide.
The focused real image on a distant screen is 1.35 m wide.



$= 1.35 / 45 \times 10^{-3}$

(a) Calculate the linear magnification of the image.

magnification = ...30...... [1]

(b) The image distance *v* from the projector lens is 2.10 m.

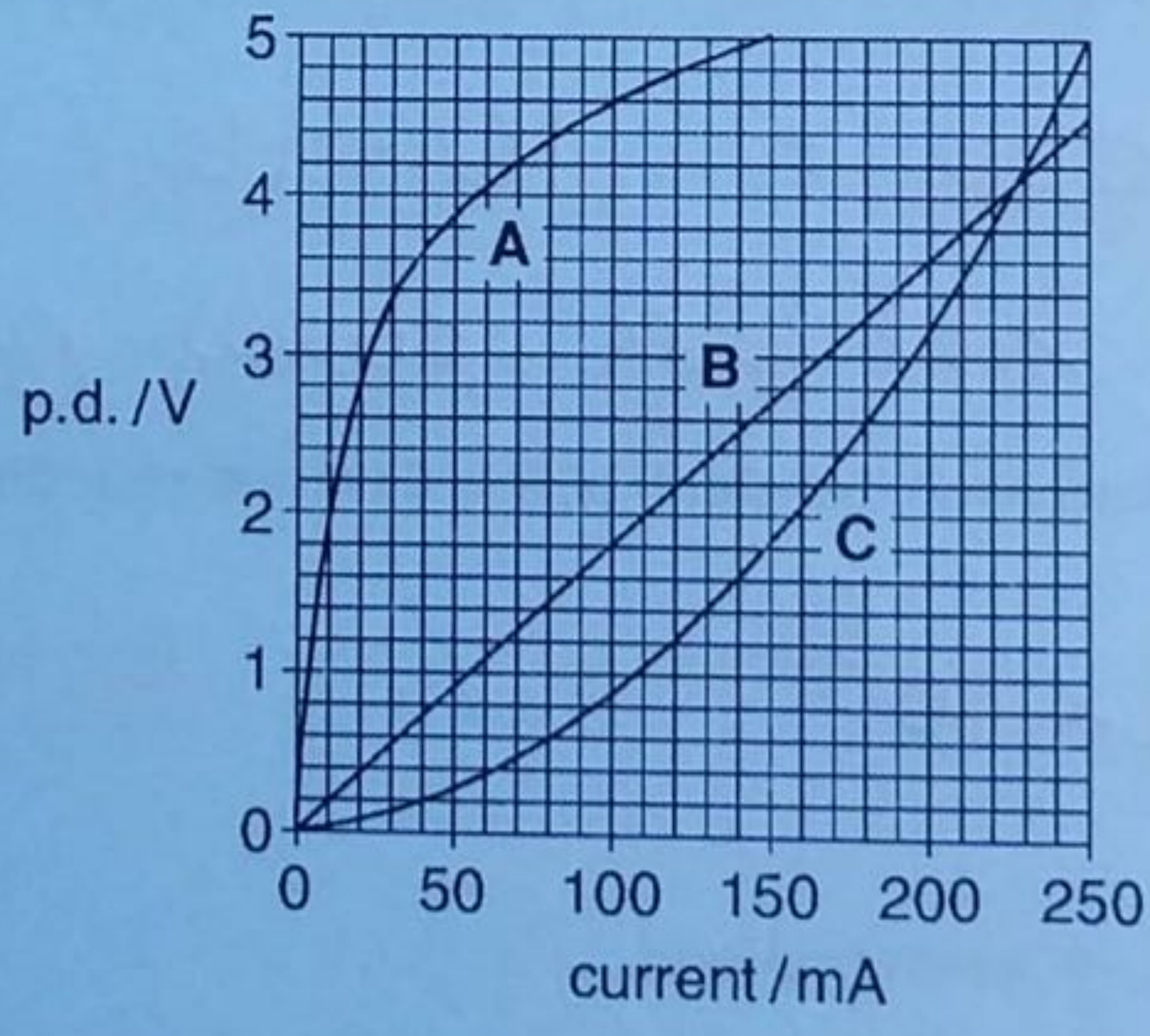
Calculate the object distance *u* and hence show that the power of the projector lens is about 15 D.

$m = v/u \therefore u = v/m = 2.1\text{m}/30 = 0.07\text{m}$

$P = \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{2.1} - \frac{1}{-0.07} = 14.8\ D$

[3]

7 The graph shows the characteristics of 3 different electrical conductors **A**, **B** and **C**.



(a) State which conductor obeys Ohm's Law. ......B...... [1]

(b) State which graph shows decreasing resistance at higher current. ......A...... [1]

[Section A Total: 23]

Section B

8 Fig. 8.1 shows an image of part of the South Atlantic seafloor.
The image is 480 pixels wide × 580 pixels high, and the resolution is 10 km $pixel^{-1}$.

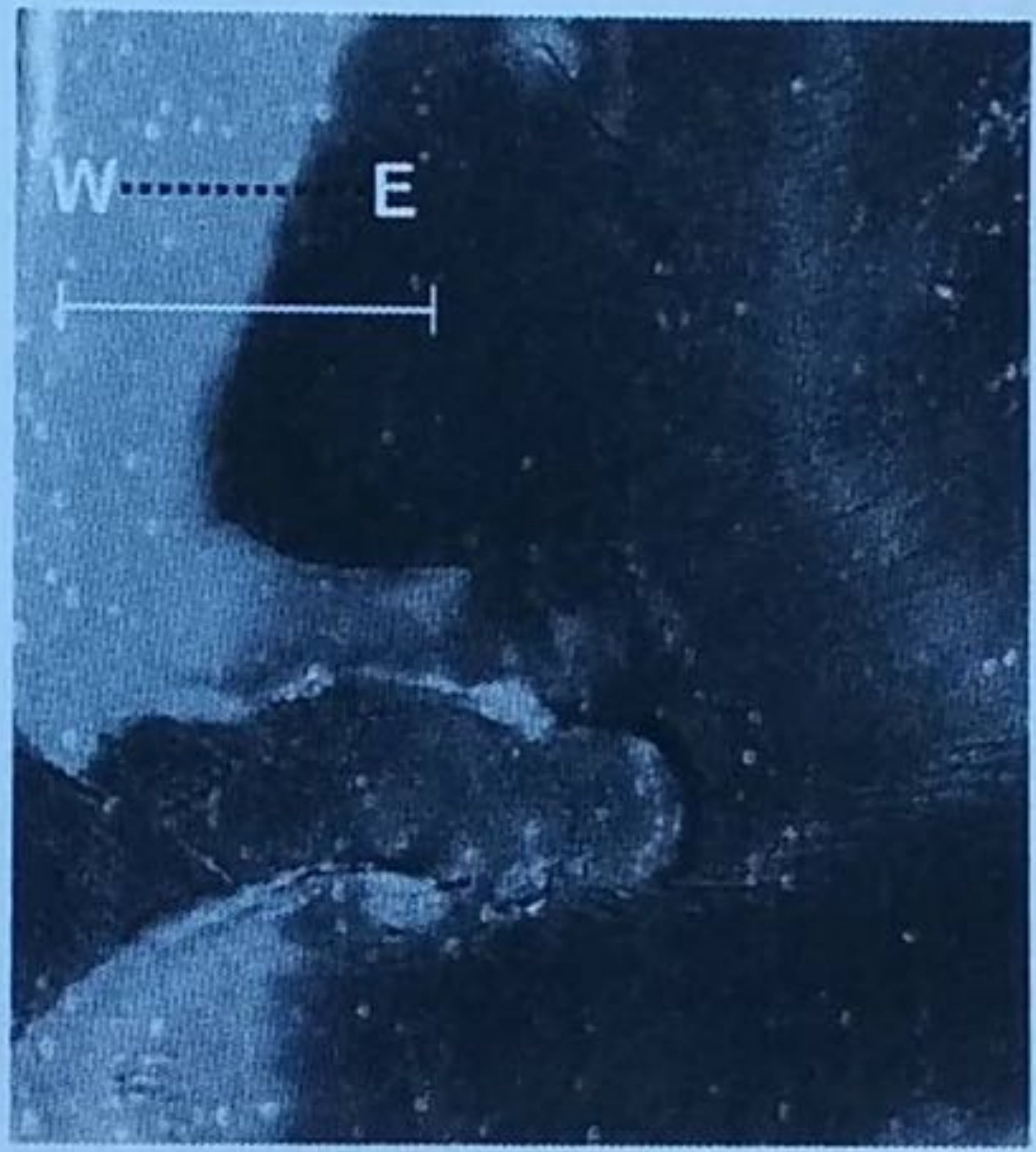


Fig. 8.1

(a) Calculate the area of seafloor that the image represents.

480 × 10 km × 580 × 10 km =

area = 2.78×10^7 km^2 **[1]**

(b) Pixel values in the image represent a measurement of average sea depth.
These have been calibrated at 33 m depth per step of the grey scale from 0 (white) to 255 (black).

(i) Calculate the greatest depth that could be represented in the image.

255 × 33

greatest depth = 8415 m **[1]**

(ii) Explain why pixel values represent an **average** sea depth.

Depth varies within each km^2 **[1]**

(c) Fig. 8.2 shows a West-East cross-section **W E** through part of the image data.

33 m/pixel

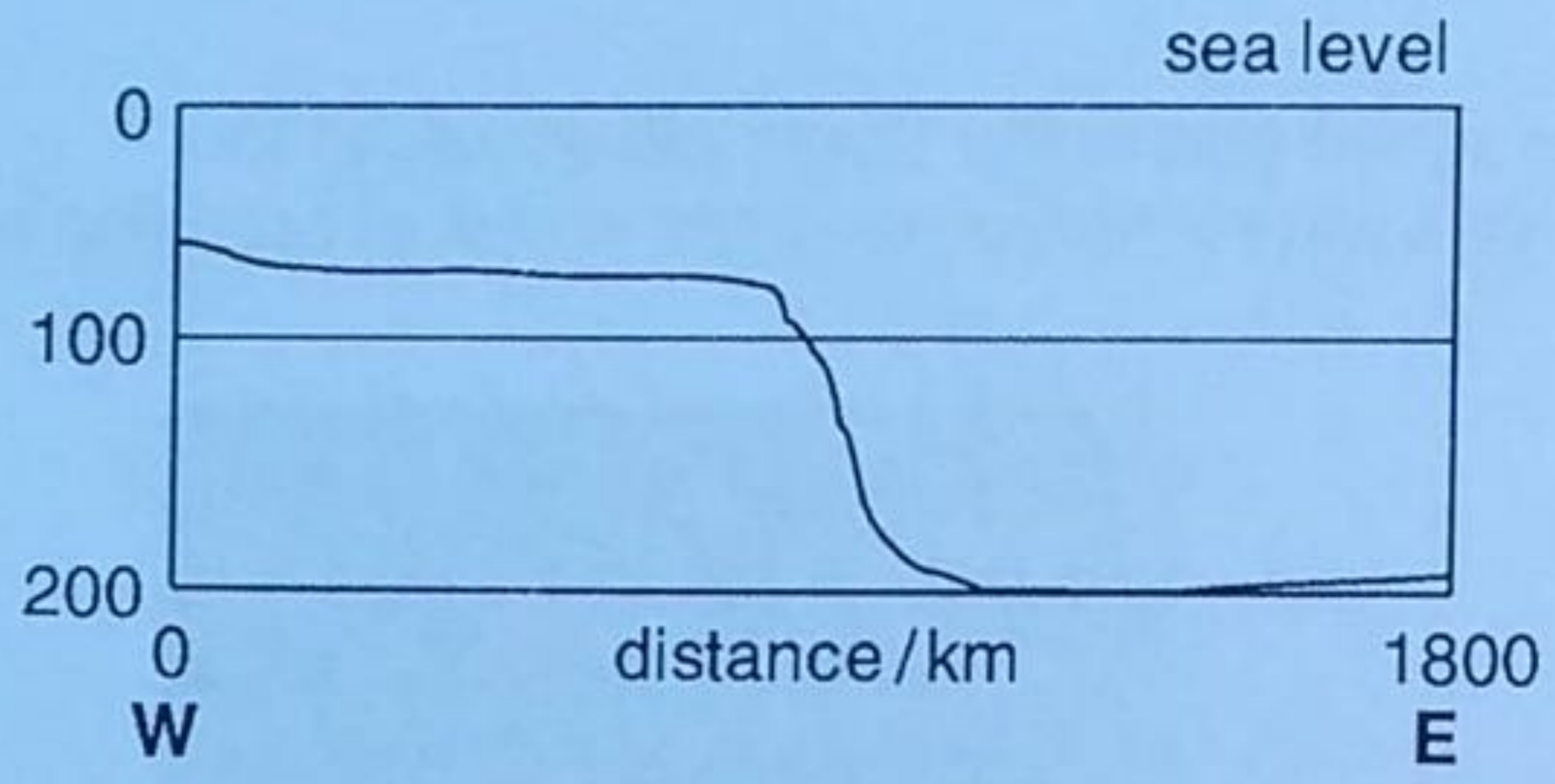


Fig. 8.2

Use numerical information from Fig. 8.2 to describe **two** features of the seafloor that this cross-section reveals.

seafloor is ~ 2 km deep out to ~ 900 km, it then plummets to ~ 6.6 km deep.

[2]

(d) Fig. 8.3 shows the number of pixels in the whole image at each greyscale value.

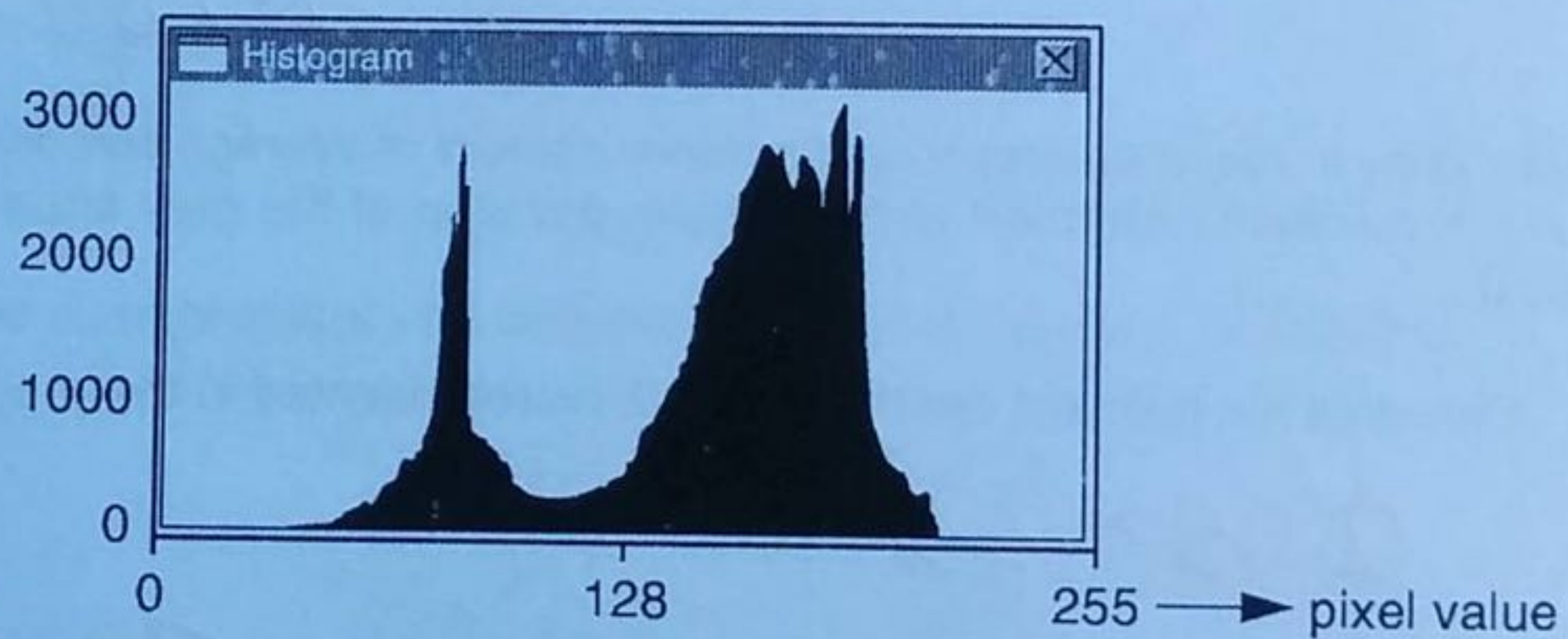


Fig. 8.3

Explain how you could use Fig. 8.3 to estimate the fraction of the area of the seafloor in the image that was less than 4 km deep.

In your answer, you should ensure that your explanation is clear with correct spelling and punctuation.

4000/33 = pixel value of 121

Fraction = $\frac{\text{area of histogram} < 121}{\text{total area of histogram}}$

[2]

(e) The original image is processed by edge detection and the result is shown below in Fig. 8.4.

Fig. 8.4

Describe how this image process highlights details in the image.

it highlights large changes in pixel value over short distances

[1]

[Total: 8]

9 Fig. 9.1 shows a cell with an emf ε of 1.55 V and an internal resistance r of 0.40 Ω. The cell delivers a current I of 250 mA into a constant load resistance R of 5.8 Ω.

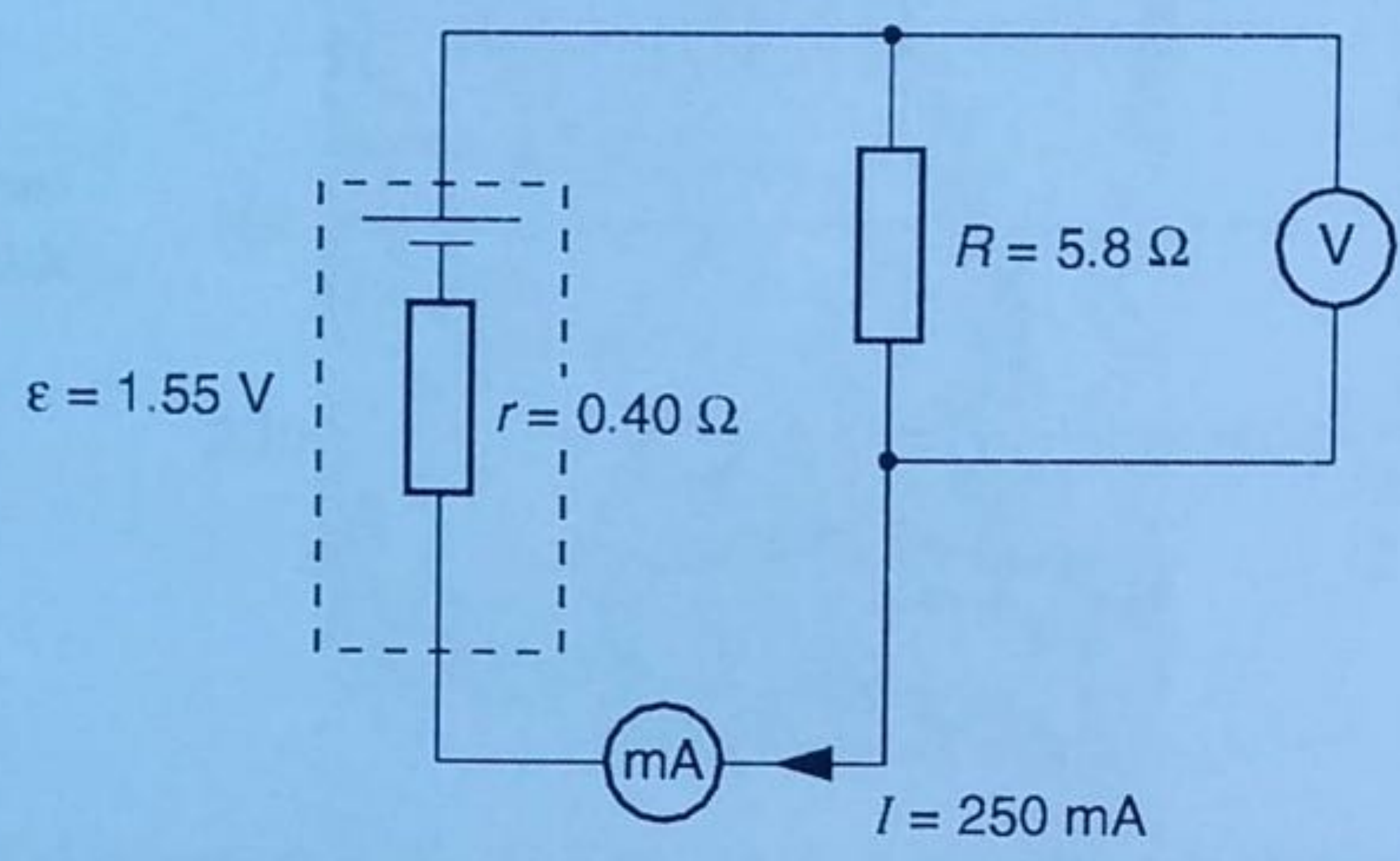


Fig. 9.1

(a) **(i)** Calculate the p.d. across the load resistance R.

$V = \mathcal{E} - Ir = 1.55 - 0.25 \times 0.4$

p.d. = 1.45 V **[2]**

(ii) Explain why the p.d. across the load resistance is less than the emf of the cell.

Some p.d. is lost across the internal resistance

[1]

(b) The cell is left connected to the 5.8 Ω load resistance for several hours.
Fig. 9.2 shows how the current from the cell varies with time.

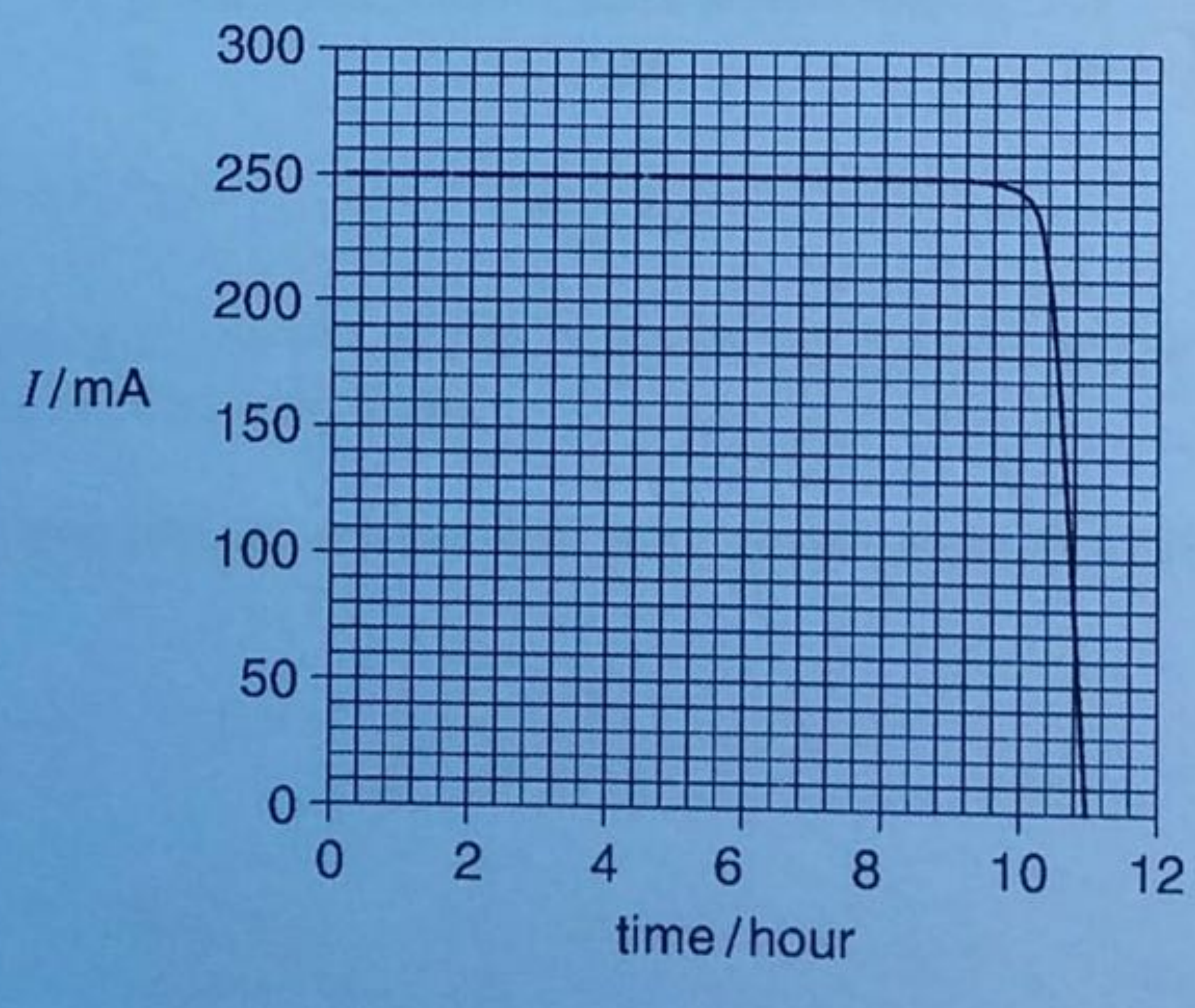


Fig. 9.2

(i) Describe how the current varies with time.

constant for ~10h then falls to zero over final hour

[2]

(ii) Suggest reasons why the current varies with time in this way.

Internal resistance is constant for first 10h. In final hour it rises rapidly as the cell's chemical energy is used up.

[2]

(iii) Use Fig. 9.2 to estimate the total charge delivered by the cell.

Make your method clear.

$Q = It$ ∴ Area under graph

$= 0.25 \times 10 \times 60 \times 60$
$+ 0.125 \times 1 \times 60 \times 60$

charge = 9450 C **[3]**

[Total: 10]

10 A red LED starts conducting when the p.d. across it is greater than 1.6 V.
Fig. 10.1 shows the circuit used to run the LED from a 9.0 V battery of negligible internal resistance.

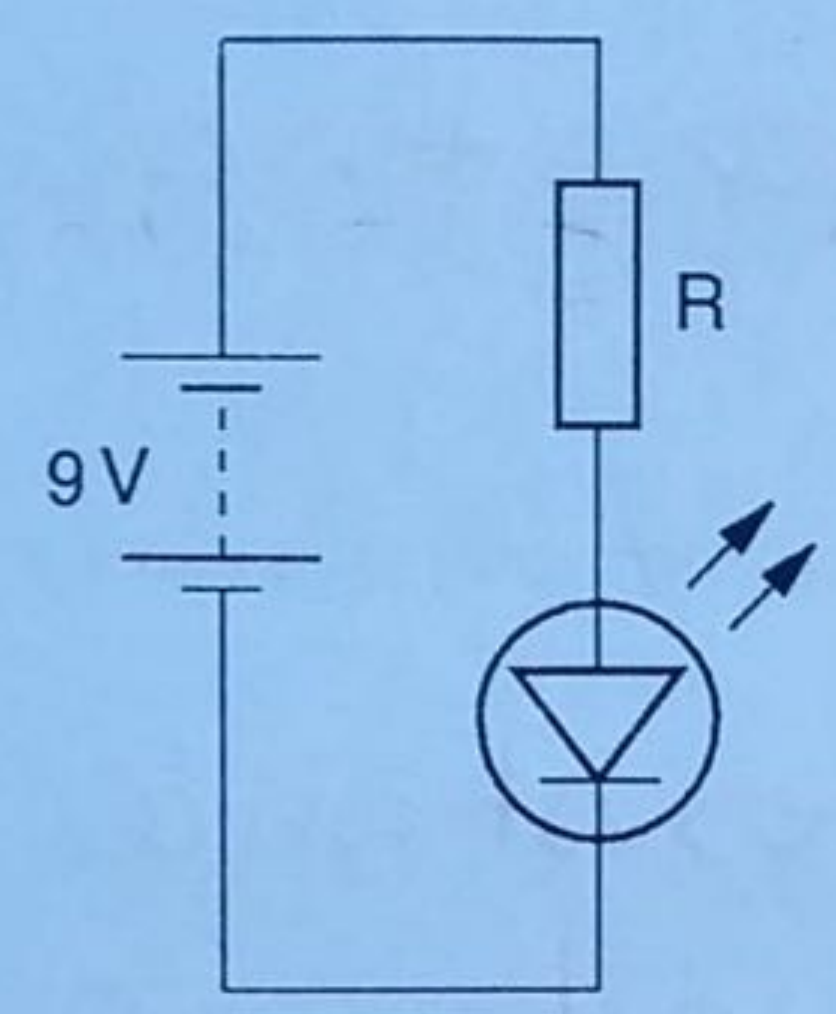


Fig. 10.1

(a) (i) State the purpose of the resistor R in this circuit.

protect LED from too high a current

[1]

(ii) When operating at its normal current of 25 mA the p.d. across the LED is 2.1 V.

Calculate the value of the resistor R for operation of the LED at 25 mA from the 9.0 V battery. Make your method clear.

p.d. across R = 9 − 2.1 = 6.9 V

R = V/I = 6.9/0.025 =

resistance = 276 Ω **[2]**

(iii) Calculate the power dissipated in the resistor R in this circuit.

P = IV = 6.9 × 0.025 =

power = 0.17 W **[2]**

(b) Fig. 10.2 shows how the p.d. across LEDs varies with current for a red and a green LED.

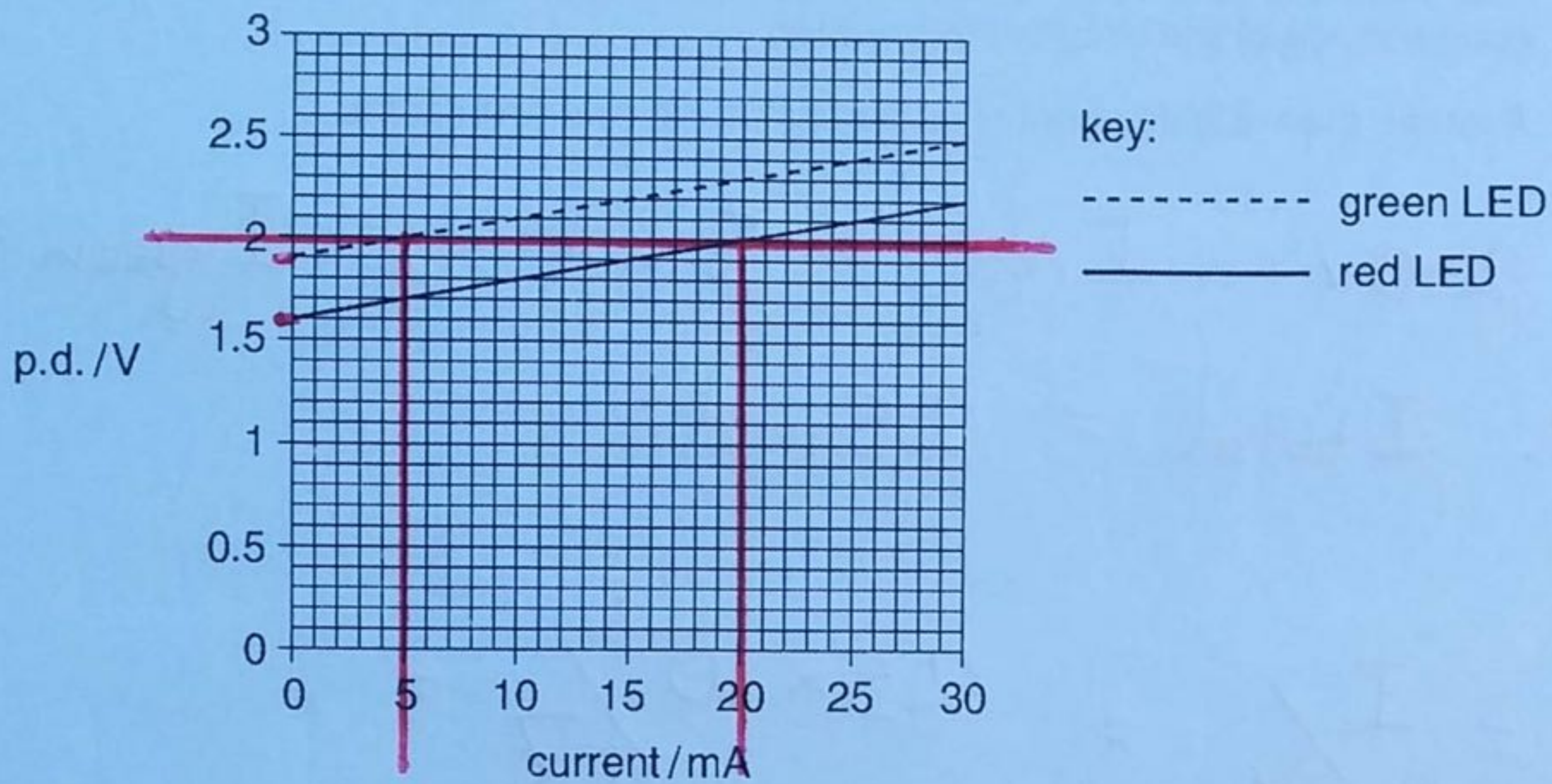


Fig. 10.2

(i) Describe a difference shown in the graphs between the behaviour of the red and green LEDs.

a higher p.d. is needed for green LED to conduct

[1]

(ii) A red and a green LED are connected in parallel with a suitable series resistor to a supply of variable p.d. as in Fig. 10.3.

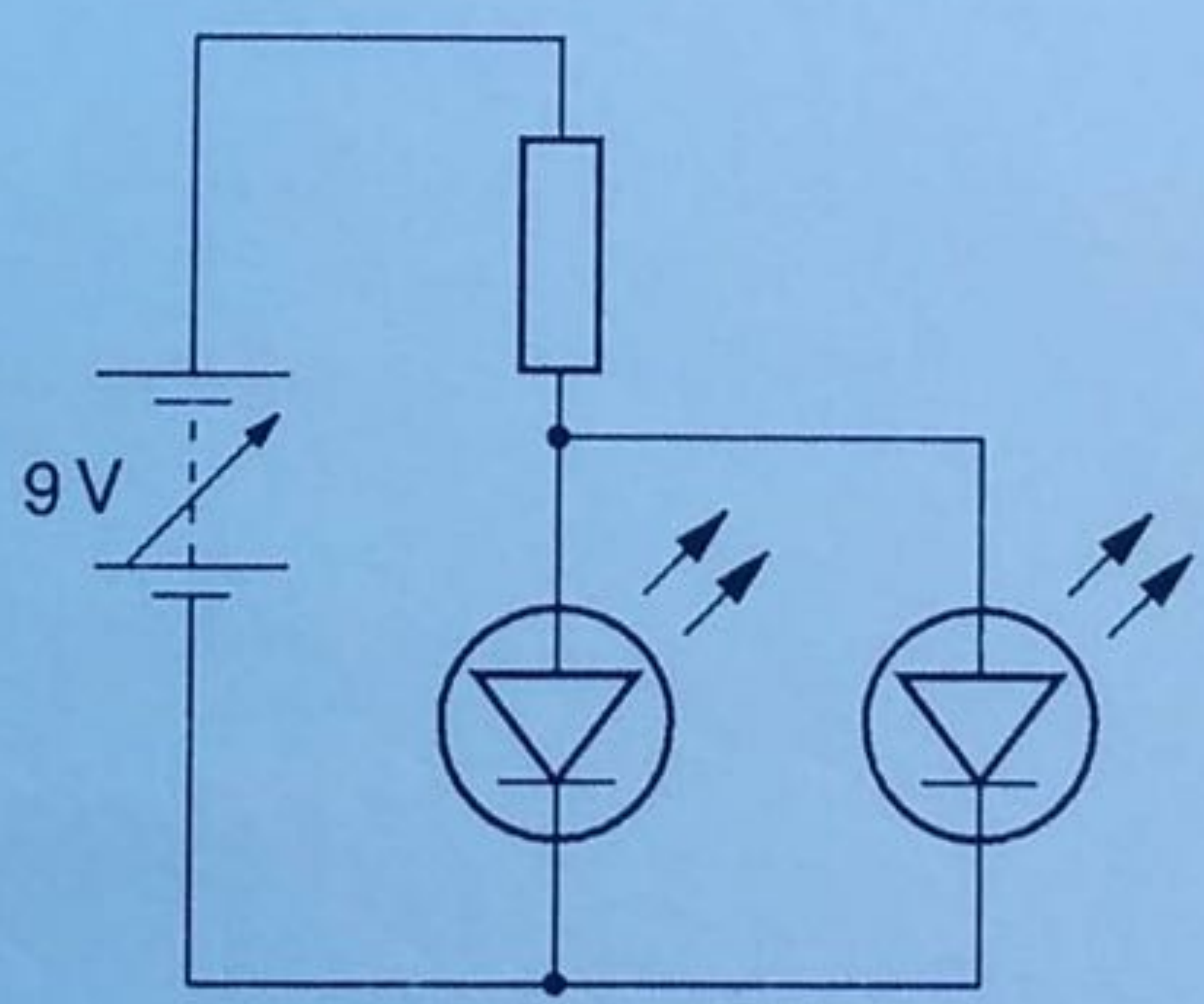


Fig. 10.3

State and explain what happens in the circuit when the p.d. across the diodes is gradually increased from 0 V to over 2.1 V.

red LED turns on first at 1.6V followed by green at 1.9V

[2]

(iii) The output of the variable supply is set to 7.0 V.
This makes a p.d. of 2.0 V across both LEDs. Use data from Fig. 10.2 to find the total conductance of the circuit at this setting.

Assume the variable supply has negligible internal resistance.

At 2.0V $I_{red} = 5mA$ & $I_{green} = 20mA$

$\therefore I_{total} = 25mA$

$G = I/V = 25\times10^{-3}/7 =$

conductance = 3.6×10^{-3} S **[2]**

[Total: 10]

11 Fig. 11.1 shows the structure of glass.

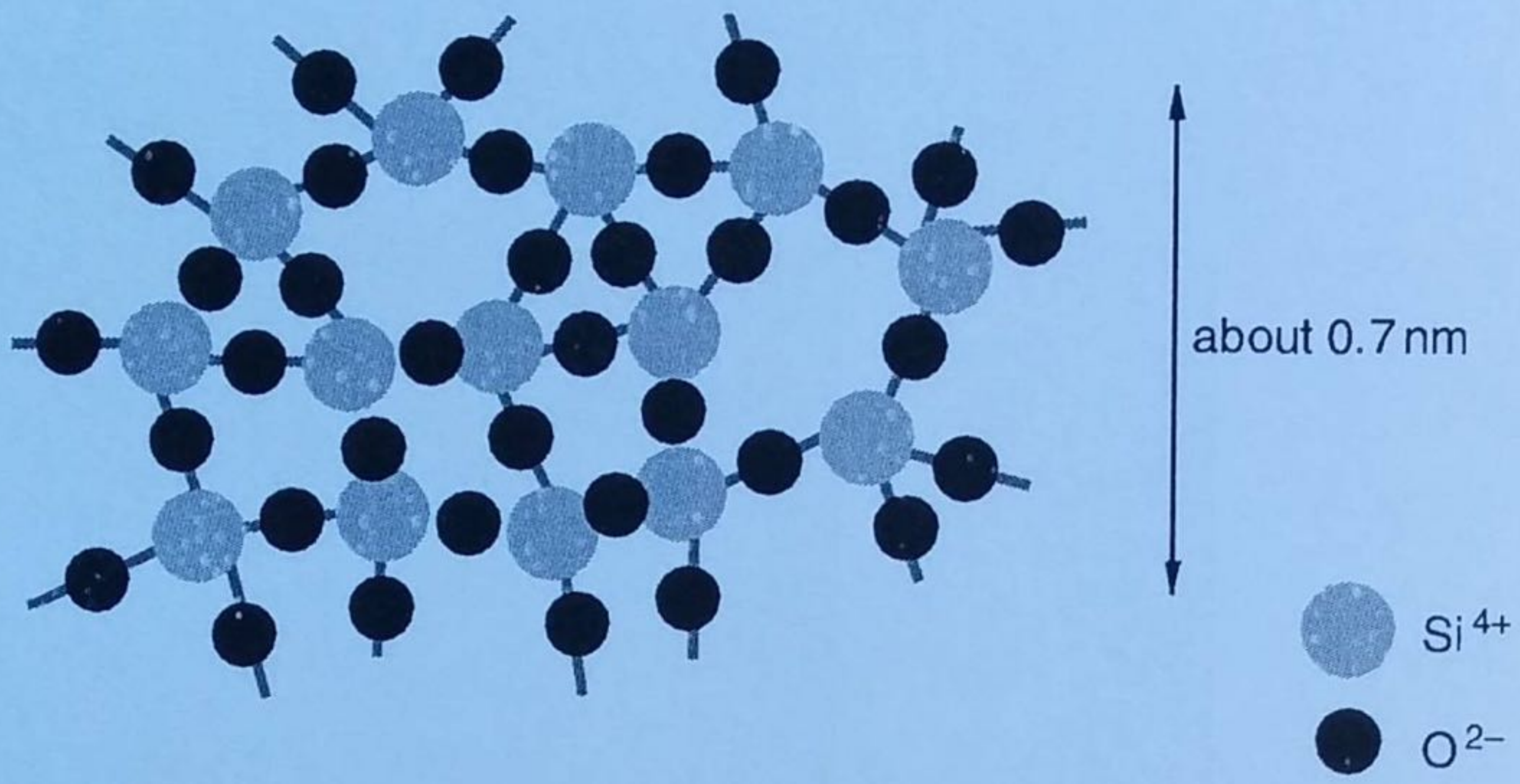


Fig. 11.1

The bonding is strong, stiff and directional within groups of ions, but with random orientations between neighbouring groups. There is little short range order in the structure.

Use features of this micro-structure of glass to suggest **explanations** for the following macroscopic properties of glass.

(a) Glass fibres are strong but show no plastic deformation before fracture.

bonds are strong

no slip as no dislocations & structure is random

(b) A sheet of glass can be broken cleanly and accurately into two pieces, if a scratch is drawn across its surface and the glass is slightly bent.

☐ *In your answer, you should use appropriate technical terms, spelt correctly.*

stress concentrated at tip of scratch on bending; crack propagates as no plastic flow to reduce stress at tip.

because of random structure

[3]

(c) Solid glass at room temperature is a good electrical insulator, but when heated near its melting temperature it can conduct electricity.

In a solid ions are fixed, but become mobile on melting so can carry charge through material by moving.

[3]

[Total: 9]

[Section B Total: 37]

END OF QUESTION PAPER