Answer **all** the questions.

Section A

1 Here is a list of electrical units.

A **S** **V** **Ω** **W**

State which of these units is correct for each of the following combinations of quantities:

(a) $\frac{\text{charge}}{\text{time}}$ ....A.......... $I = Q/t$

(b) $\frac{\text{energy}}{\text{charge}}$ ....V.......... $V = E/Q$

(c) $\frac{\text{current}}{\text{voltage}}$ ....S.......... $R = V/I \therefore S = I/V$ [3]

2 A student sets up a potential divider circuit with two 100 Ω resistors, intending to halve a potential difference of 10 V as shown in Fig. 2.1.

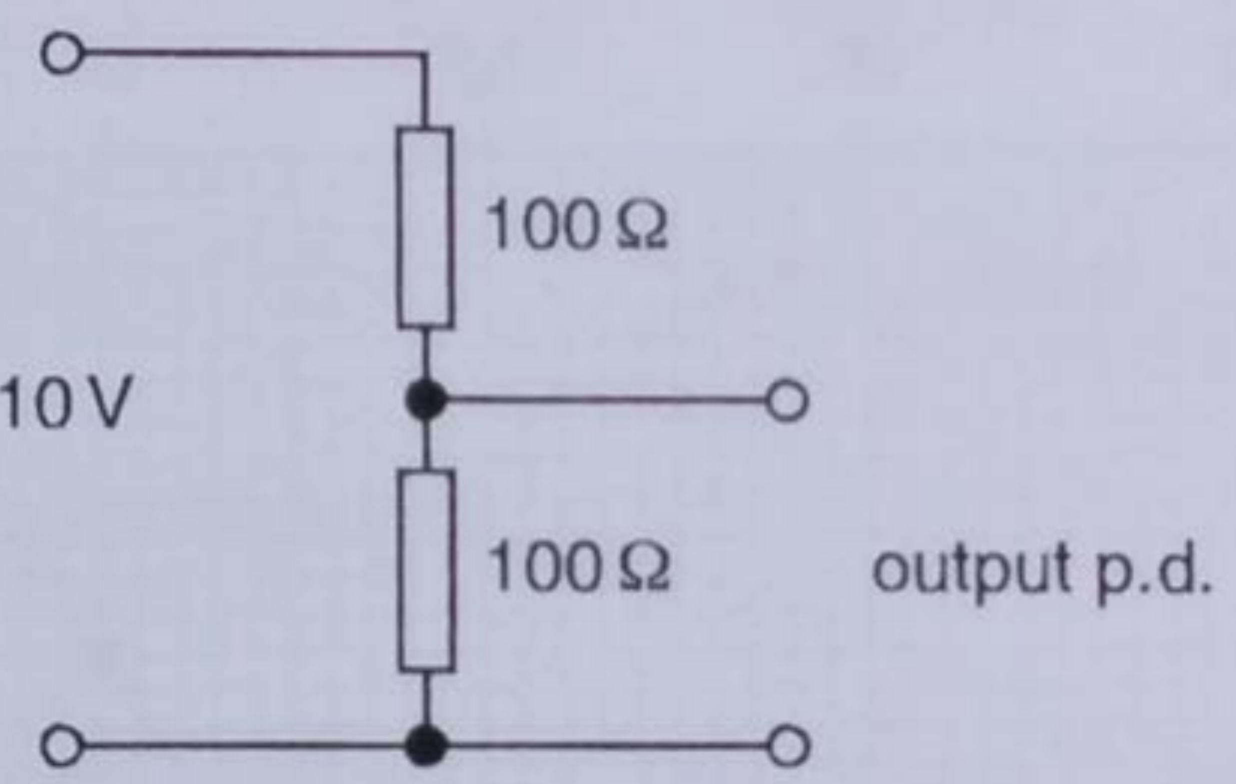


Fig. 2.1

The resistors are manufactured to a tolerance of ± 5%.

(a) State the smallest and largest possible values of each of the resistors that could be found within this tolerance.

smallest ....95.......... Ω largest ....105.......... Ω [1]

(b) Calculate the smallest possible output p.d. from the circuit in Fig. 2.1.

Make your method clear.

$10 \times \frac{95}{200} =$

output p.d. = ...4.75.......... V [2]

3 Fig. 3.1 shows the frequency spectrum of signals labelled **A**, **B**, **C** and **D** detected by a radio receiver.

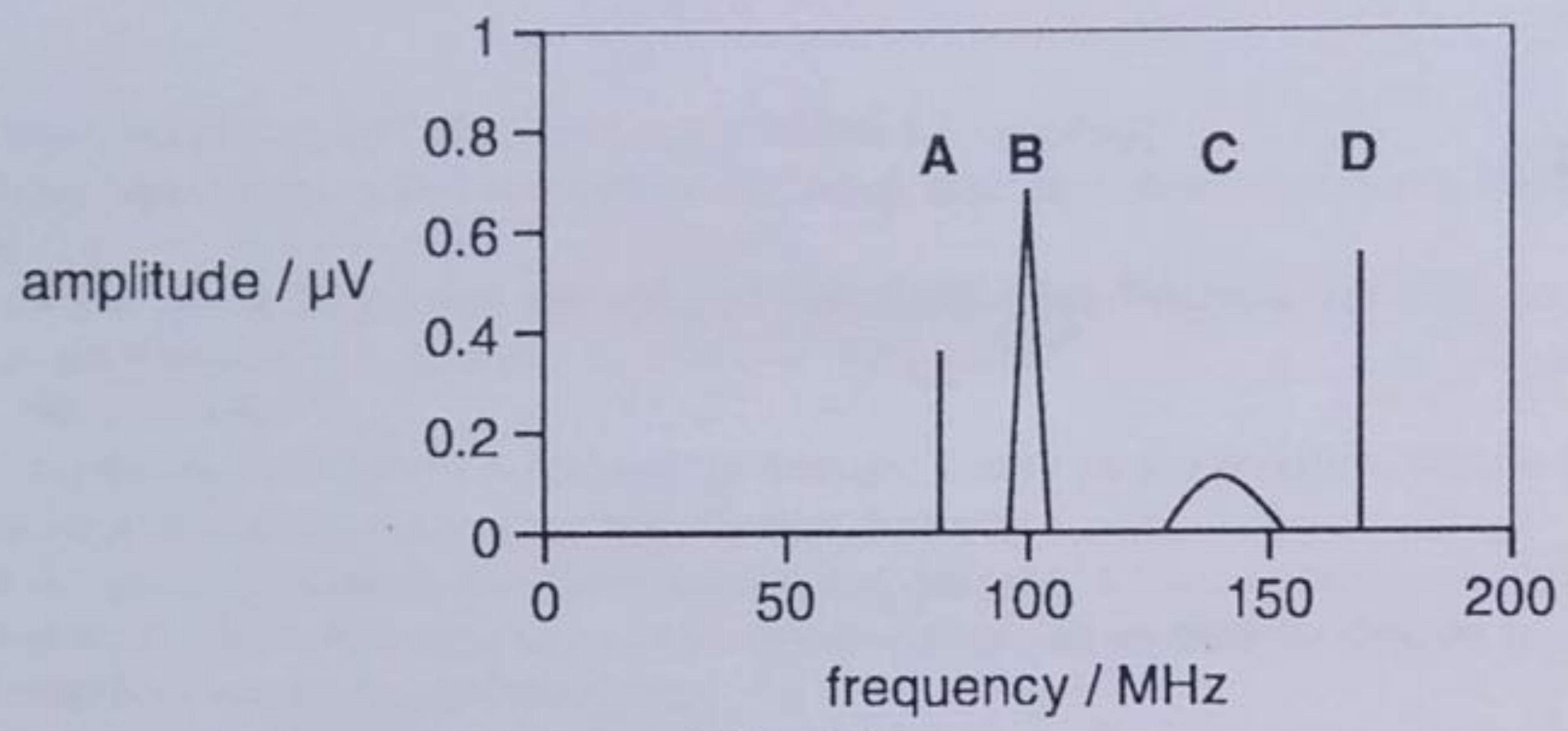


Fig. 3.1

State which signal has the largest

(a) wavelength ....A..........

(b) bandwidth. ....C.......... **[2]**

4 Light reflected off the surface of water is partially polarised in the horizontal direction. The amount the light is polarised depends on the angle of reflection *r*, as shown in Fig. 4.1.

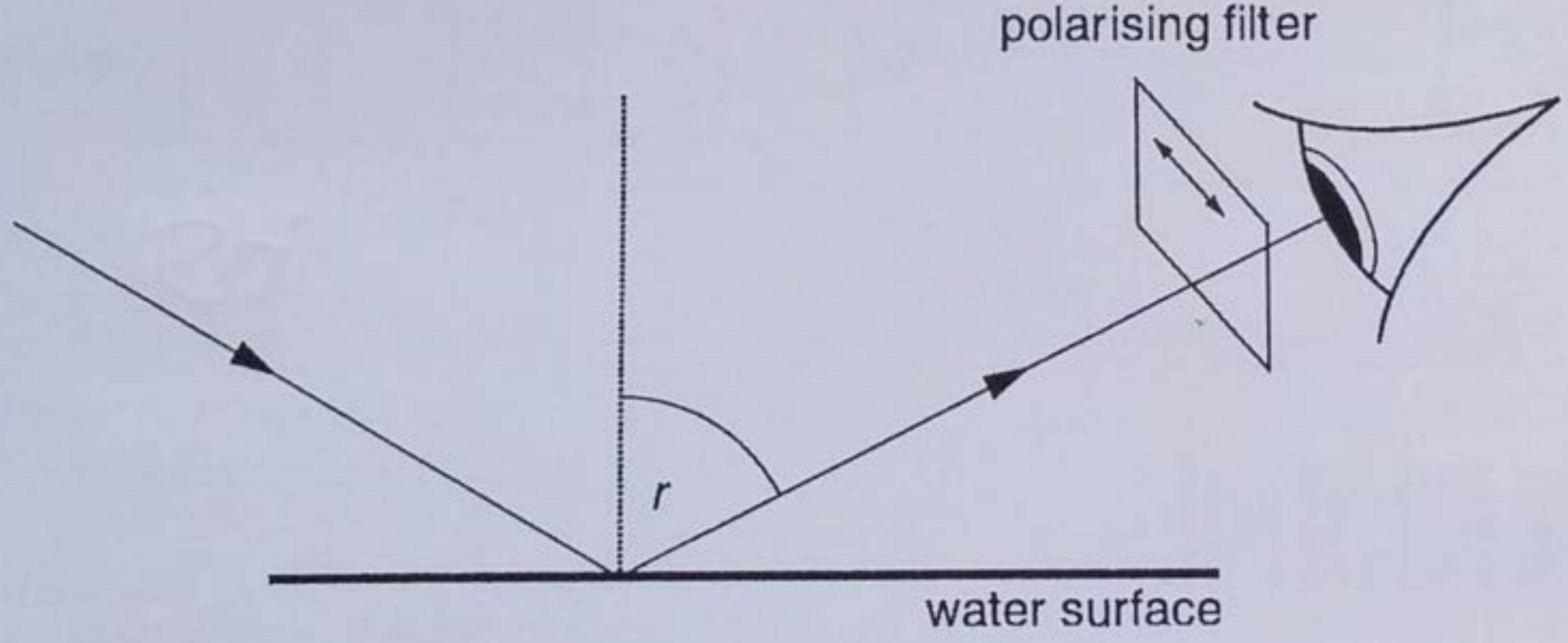


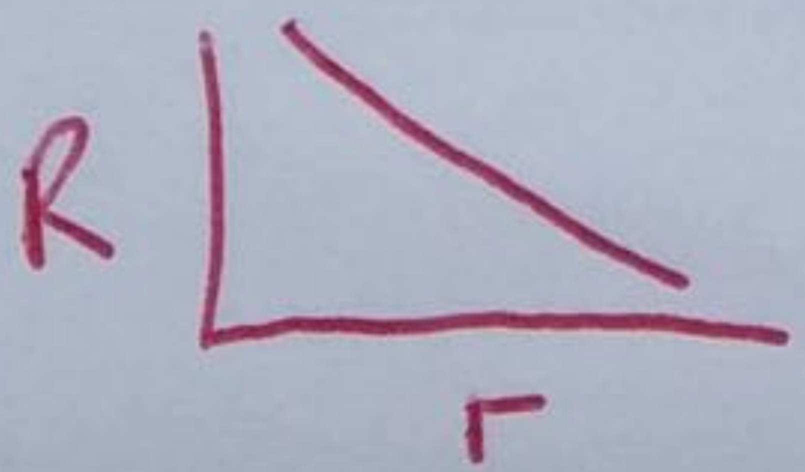
Fig. 4.1

Describe how students could use a polarising filter (sheet of Polaroid) to observe these effects. You may find it useful to refer to Fig. 4.1 in your answer.

In your answer, you should organise your description clearly and coherently.

Use polaroid & light meter. Set angle r & rotate polaroid recording lowest and highest intensities together with intensity with no polaroid. Plot graph of

[3]



where $R = \frac{\text{Lowest Int.}}{\text{Highest Int.}}$

5 Fig. 5.1 shows the calibration curve for the output potential difference (p.d.) for an electrical wind speed sensor.

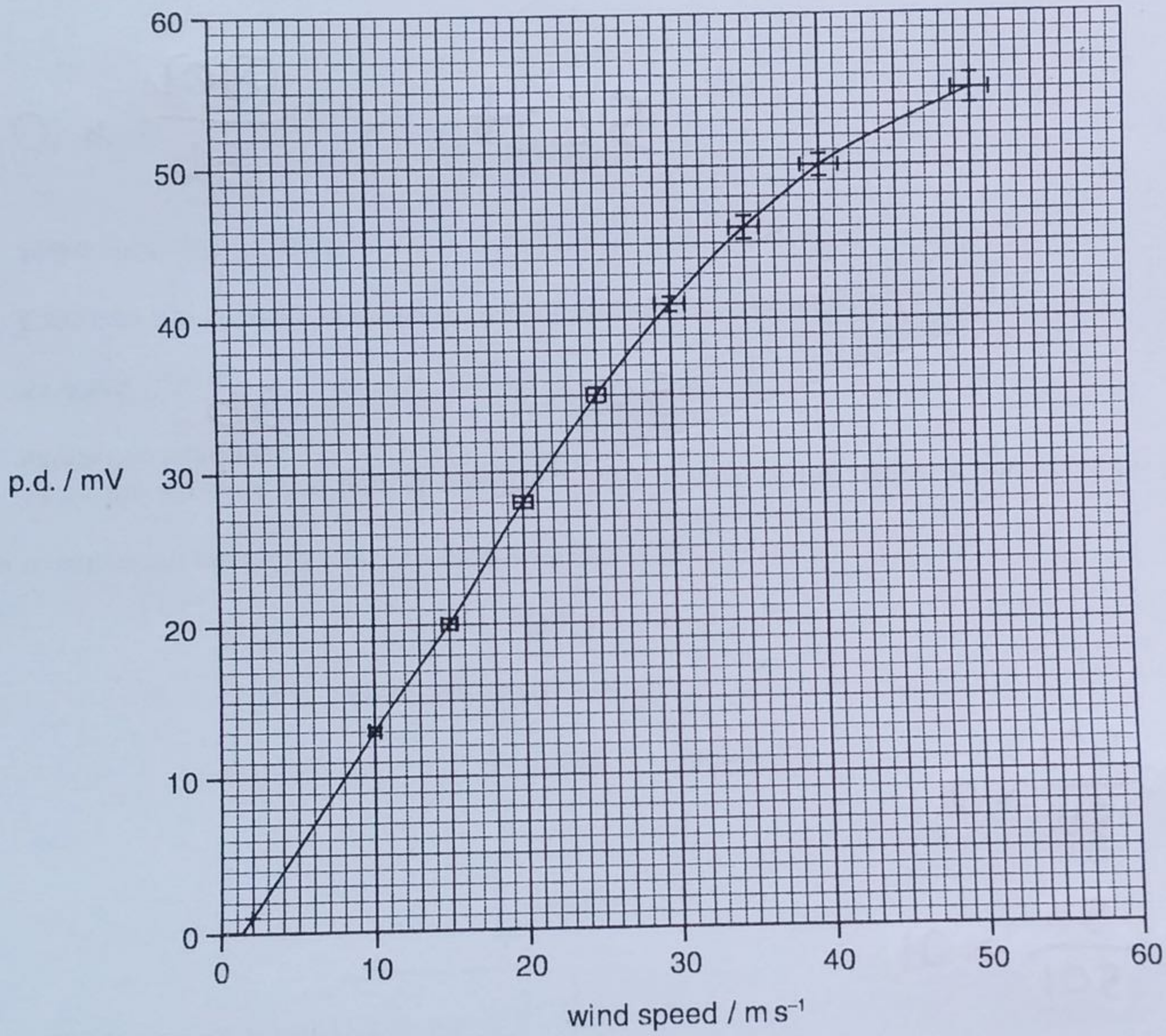


Fig. 5.1

(a) At 55 mV the wind speed is 50 m s^{-1}.
Use the graph to estimate the ± % uncertainty of this wind speed.

$\frac{\pm 1.2}{50} \times 100$

± % uncertainty = ...3...... % [1]

(b) Describe **one** feature of the uncertainties indicated by the uncertainty bars.

uncentainties inceace as p.d & speed increase

[1]

(c) Fig. 5.1 shows that the sensor output increases with wind speed.

State **two** other features of how the sensor output varies with wind speed as shown by the graph.

No output until speed > 1.5 m/s

From 1.5 to 25 m/s output is linear

At higher speeds sensitivity decreases

[2]

An electronic display of a company logo is to be designed to fit into an array of 12 × 12 pixels. Each pixel is either ON or OFF (1 / 0).

(a) State how many bits will be needed to store the logo. 144 bits [1]

(b) State the amount of information in the logo in bytes. 18 bytes [1]

(c) Calculate the total possible number of alternative logos the designer could consider. Assume that a change to any pixel forms a different logo.

$2^{144} = 2.2 \times 10^{43}$

number of alternative logos = ... [1]

7 A long-sighted person needs a corrective lens of power + 5.5 D for reading. One corrective lens is rather thick and heavy. The optician suggests a lighter, less curved lens of a material with a higher refractive index, as shown in Fig. 7.1. The density of the materials for both lenses is the same.

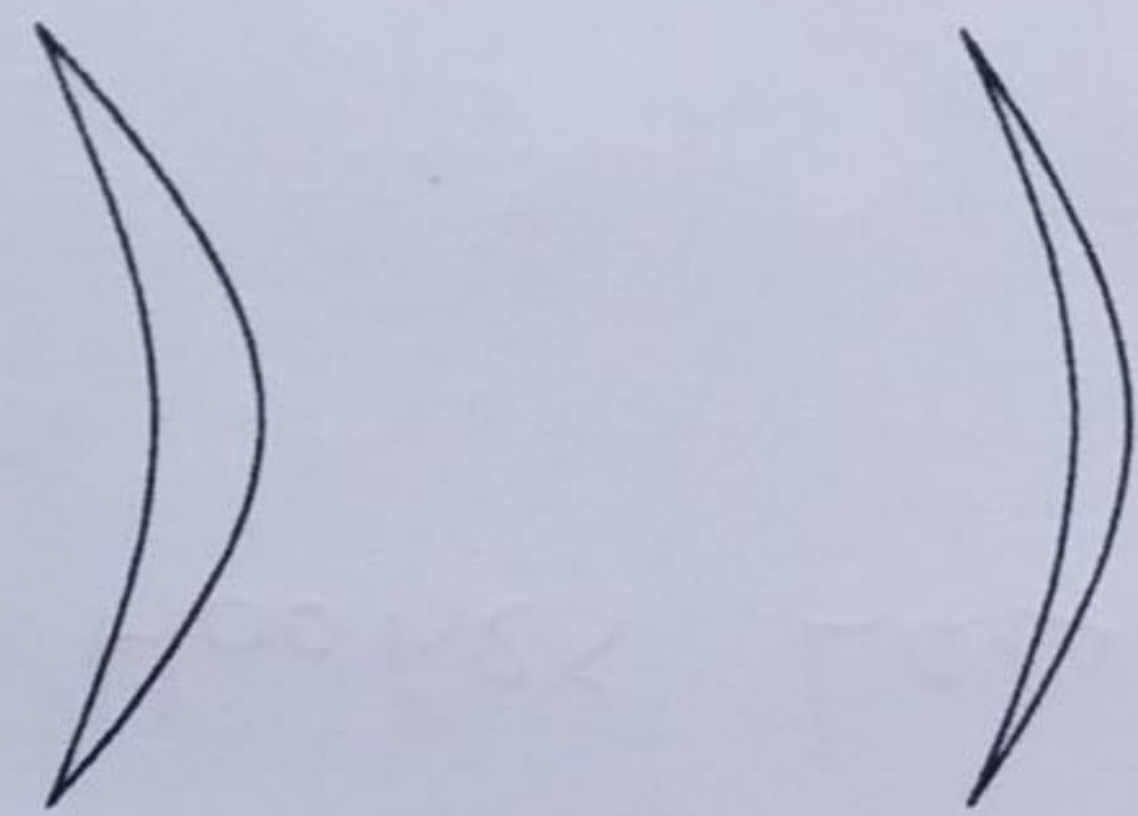


Fig. 7.1

Explain how the higher refractive index lens can

(a) be less heavy than the thick lens

Same density but lower volume as lens is thinner so mass less. $(m = d \times V)$

[1]

(b) have the same power as the thick lens.

Higher refractive index material slows light down more so thinner lens can add same amount of curvature

[1]

[Total Section A: 20]

Section B

8 Fig. 8.1 shows the graph of force against extension for a metal wire **A**.

Fig. 8.1

(a) **(i)** Draw on Fig. 8.1 the graph you would expect for a wire of the same material and diameter as **A**, but of **twice** the original length. Label this graph **B**.

2× L ∴ 2× extension

[1]

(ii) Draw on Fig. 8.1 the graph you would expect for a wire of the same material and length as **A**, but of **double** the original diameter. Label this graph **C**.

∴ 4× area ∴ ¼ extension

[1]

(b) **(i)** State **one** piece of evidence from the graph which suggests that the stretching of the wire (by a force of 10 N) is elastic.

Force ∝ extension

ie Hooke's Law obeyed

[1]

(ii) Wire **A** has a cross-sectional area of $7.8 \times 10^{-8}\ m^2$ and an original length of 2.00 m.

Calculate the Young modulus of the material of the wire.

$$E = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{x/L} = \frac{FL}{xA}$$

At point (A)

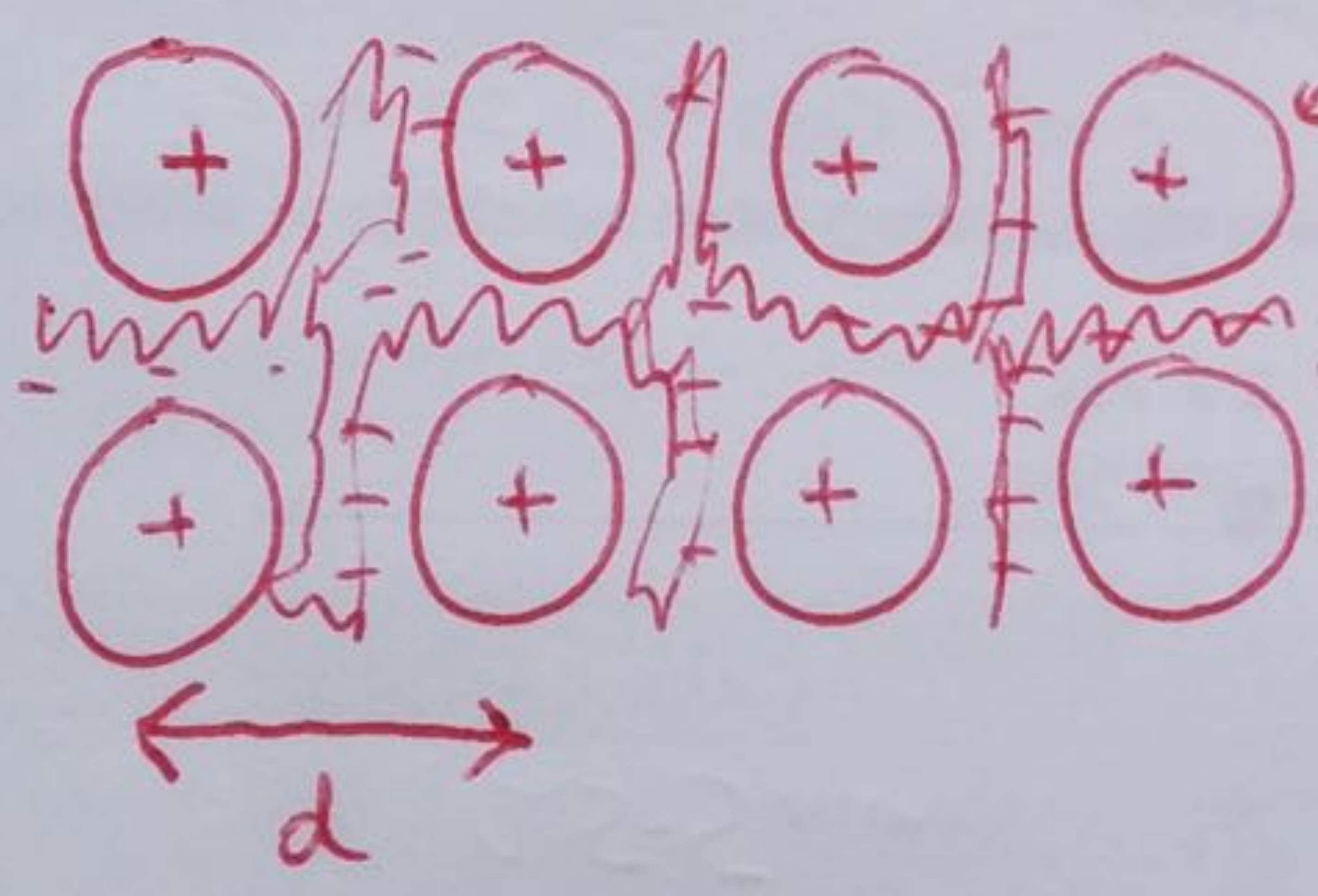
$$= \frac{10N \times 2.00m}{1.4 \times 10^{-3} m \times 7.8 \times 10^{-8} m^2}$$

Young modulus = 1.83×10^{11} Pa **[3]**

(c) Describe metallic bonding on the atomic scale. Include in your description an explanation of how metals such as wire **A** can show elastic behaviour.

In your explanation, you should make clear how the bonding between atoms can account for the large-scale elastic behaviour of the material.

You should use appropriate technical terms in your answer. You may wish to use diagrams.



Regular lattice of metal ions (positive)

mobile electrons, e^-

electrostatic force between (+) & [electrons] hold structure together.

d increases on application of force.

$\Delta d \propto F$

Returns when force removed.

[4]

[Total: 10]

9 This question is about some uses of a piezoelectric crystal. A potential difference develops across the piezoelectric crystal when put under stress. A crystal microphone contains a piezoelectric crystal. It produces the electrical signal shown in Fig. 9.1 when stressed by the pressure changes in a sound wave.

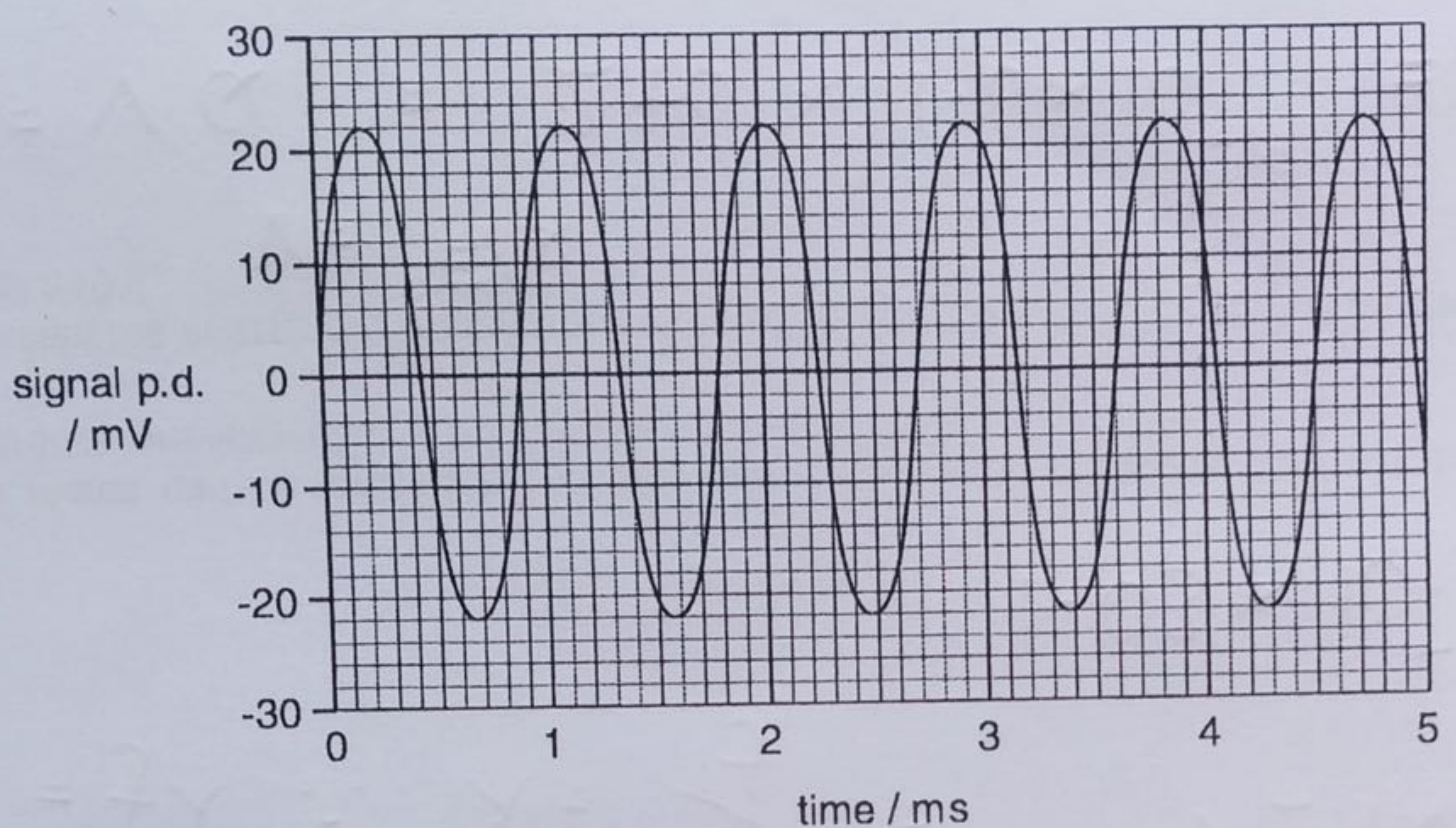


Fig. 9.1

(a) Write down the amplitude of the electrical signal. 22 mV **[1]**

(b) Calculate the frequency of the electrical signal. Make your method clear.

5 cycles in 4.5 ms

$\therefore T = \frac{4.5 \times 10^{-3}}{5} = 9 \times 10^{-4}$ s

$f = \frac{1}{T} =$

frequency = 1100 Hz **[3]**

(c) The amplitude of the pressure wave that produces the stress in the crystal is 2.0 Pa.

The Young modulus (E) of the piezoelectric crystal is 72 GPa.

Show that the peak strain in the crystal caused by this stress is about 3×10^{-11}.

$E = \frac{\text{stress}}{\text{strain}} \quad \therefore \quad \text{strain} = \frac{\text{stress}}{E} = \frac{2}{72 \times 10^{9}}$

$= 2.8 \times 10^{-11}$

[2]

(d) Fig. 9.2 shows an image of the tip of a Scanning Tunnelling Microscope (STM).

68mm

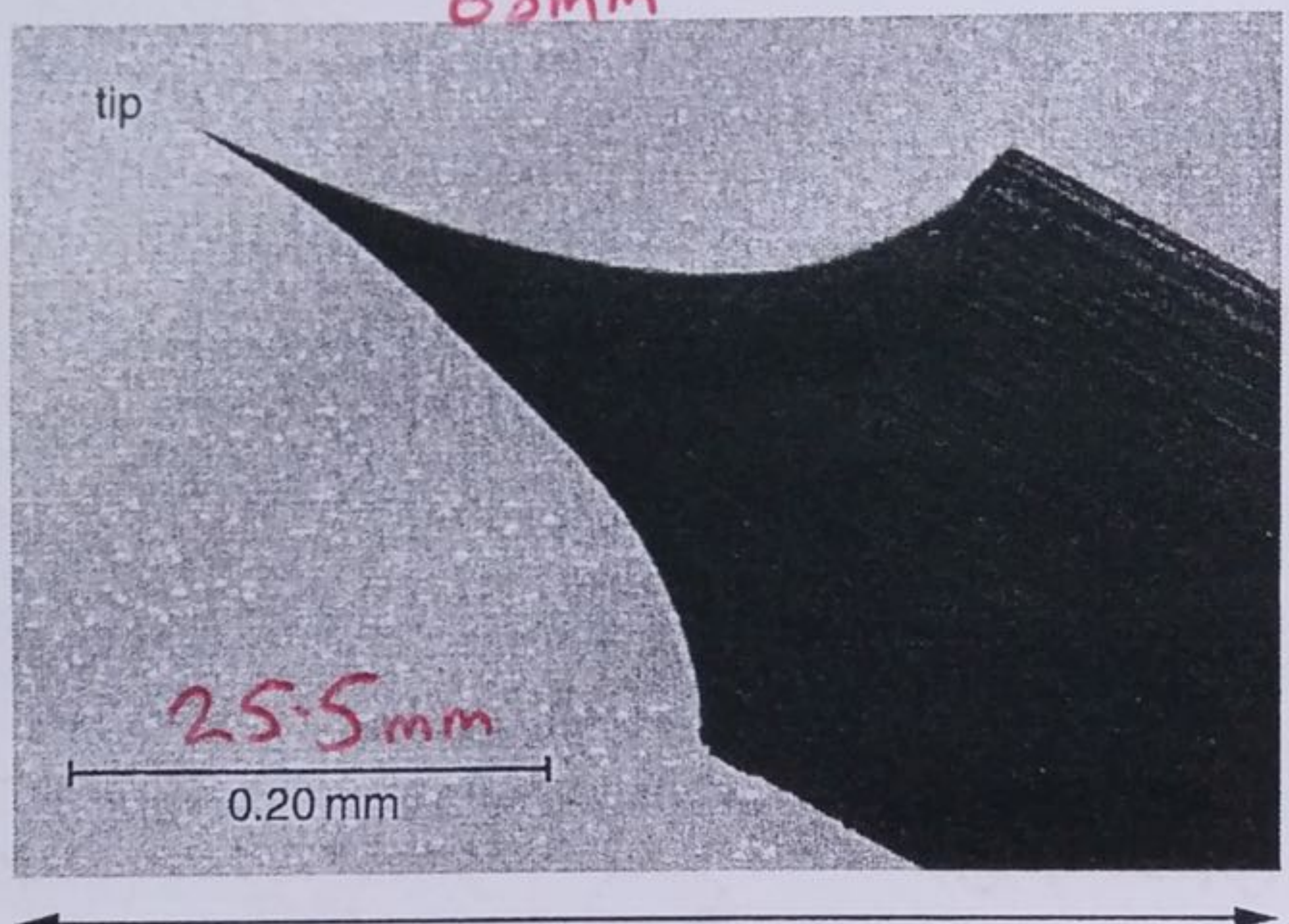


Fig. 9.2

$\frac{25.5}{68} \times 400$

$= 150$ pixels in 0.2 mm

$Res = \frac{0.2 \times 10^{-3}}{150}$

The image is 400 pixels wide. Calculate the resolution of this image.

resolution = 1.3×10^{-6} m **[1]**

(e) The STM tip is attached to a piezoelectric crystal, to make a nano-manipulator. When a p.d. is applied across the crystal a strain is produced which moves the tip through a molecular sized distance. The strain ε in the crystal is proportional to the p.d. V applied across it, with a constant of $1.3 \times 10^{-9}\,V^{-1}$.

$$\varepsilon = 1.3 \times 10^{-9}\,V$$

(i) Calculate the extension of a crystal that is 8.0 mm in length when a p.d. of 900 V is applied across it. Make your method clear.

strain = $1.3 \times 10^{-9} \times 900\,V = 1.17 \times 10^{-6}$

ext = strain × length = $1.17 \times 10^{-6} \times 8 \times 10^{-3} =$

extension = 9.36×10^{-9} m **[3]**

(ii) Calculate the number of atomic diameters that the crystal extends when the 900 V is applied. Take an atomic diameter to be 260 pm.

$\frac{9.36 \times 10^{-9}}{260 \times 10^{-12}} =$

number of diameters = 36 **[1]**

[Total: 11]

Turn over

10 This question is about the operation of a gas-filled pixel in a plasma TV screen. A plasma is a conducting ionised gas. It is formed by a high voltage pulse across a pair of electrodes in the pixel as shown in Fig. 10.1.

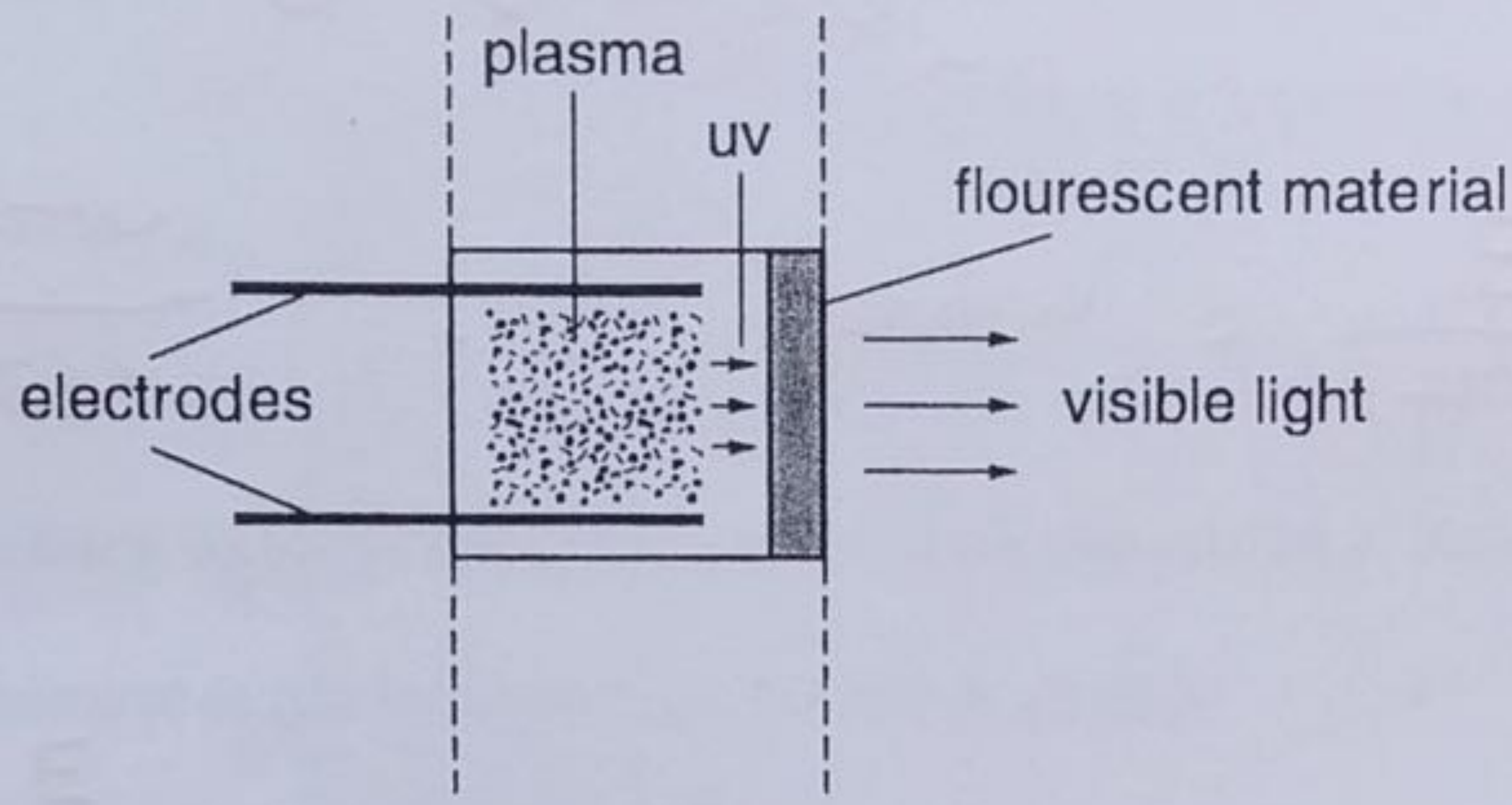


Fig. 10.1 (schematic diagram of a pixel in plasma display)

(a) Describe what is meant by an ionised gas.

molecules have lost electrons

$M_{(g)} \rightarrow M^{+}_{(g)} + e^{-}$

and become positive ions **[2]**

(b) Plasma emits uv radiation at a frequency of 2.9×10^{15} Hz.

Calculate the wavelength of this radiation.

speed of light $= 3.0 \times 10^{8}\,\text{m s}^{-1}$

$c = f\lambda \therefore \lambda = \frac{c}{f} = 3 \times 10^{8} / 2.9 \times 10^{15}$

wavelength = 1.03×10^{-7} m **[1]**

(c) Gas atoms can be ionised by collision with fast-moving electrons. The p.d. between the electrodes provides energy for these electrons.

Calculate the energy gained by an electron of charge 1.6×10^{-19} C when it passes through a p.d. of 240 V.

$V = E/Q$

$E = VQ = 240 \times 1.6 \times 10^{-19} =$

energy = 3.84×10^{-17} J **[2]**

(d) Once started by a high voltage pulse the plasma in a pixel can be maintained at a lower voltage. The plasma can be ended by switching off the voltage. Fig. 10.2 shows how the current in the gas in a pixel changes as the p.d. is raised to 290 V and lowered back to 0 V.

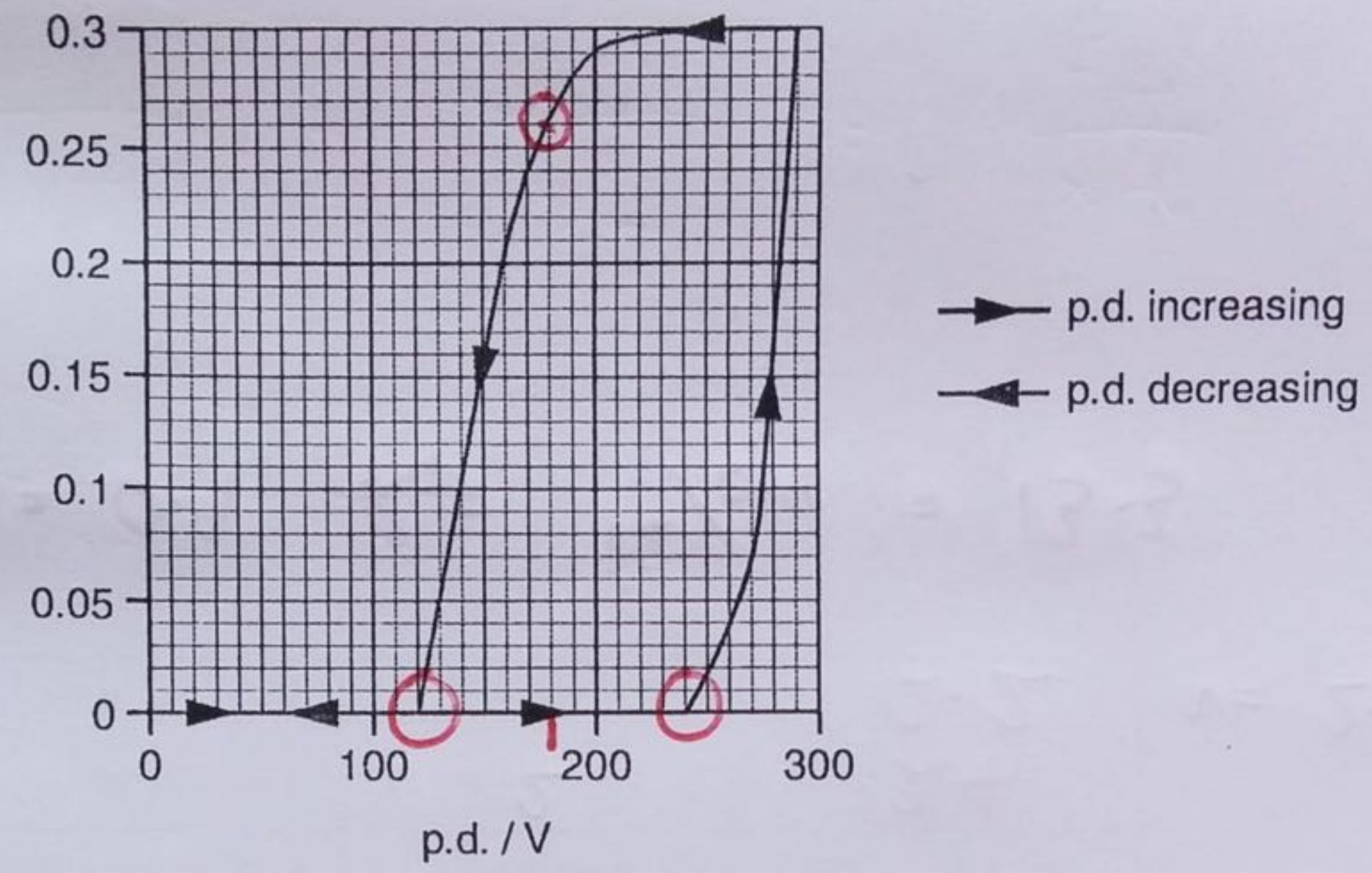


Fig. 10.2

(i) **1** State the voltage at which ionisation starts. 240 V

2 State the voltage at which ionisation stops. 120 V **[2]**

(ii) There are 6.2×10^6 pixels in the display. When emitting visible light pixels operate at 180 V.

Use data from Fig. 10.2 to calculate the total operating power of the display with all the pixels on.

at 180V current = 0.26×10^{-6} A

$P = IV = 180\text{V} \times 0.26 \times 10^{-6}\text{A}$

$= 4.68 \times 10^{-5}$ A per pixel

Total = $6.2 \times 10^6 \times 4.68 \times 10^{-5}$ =

power = 290 W **[3]**

[Total: 10]

11 Fig. 11.1 shows the variation of p.d. against current for two circuit components **X** and **Y**. **X** is a variable resistor set to its maximum value, **Y** is a filament lamp.

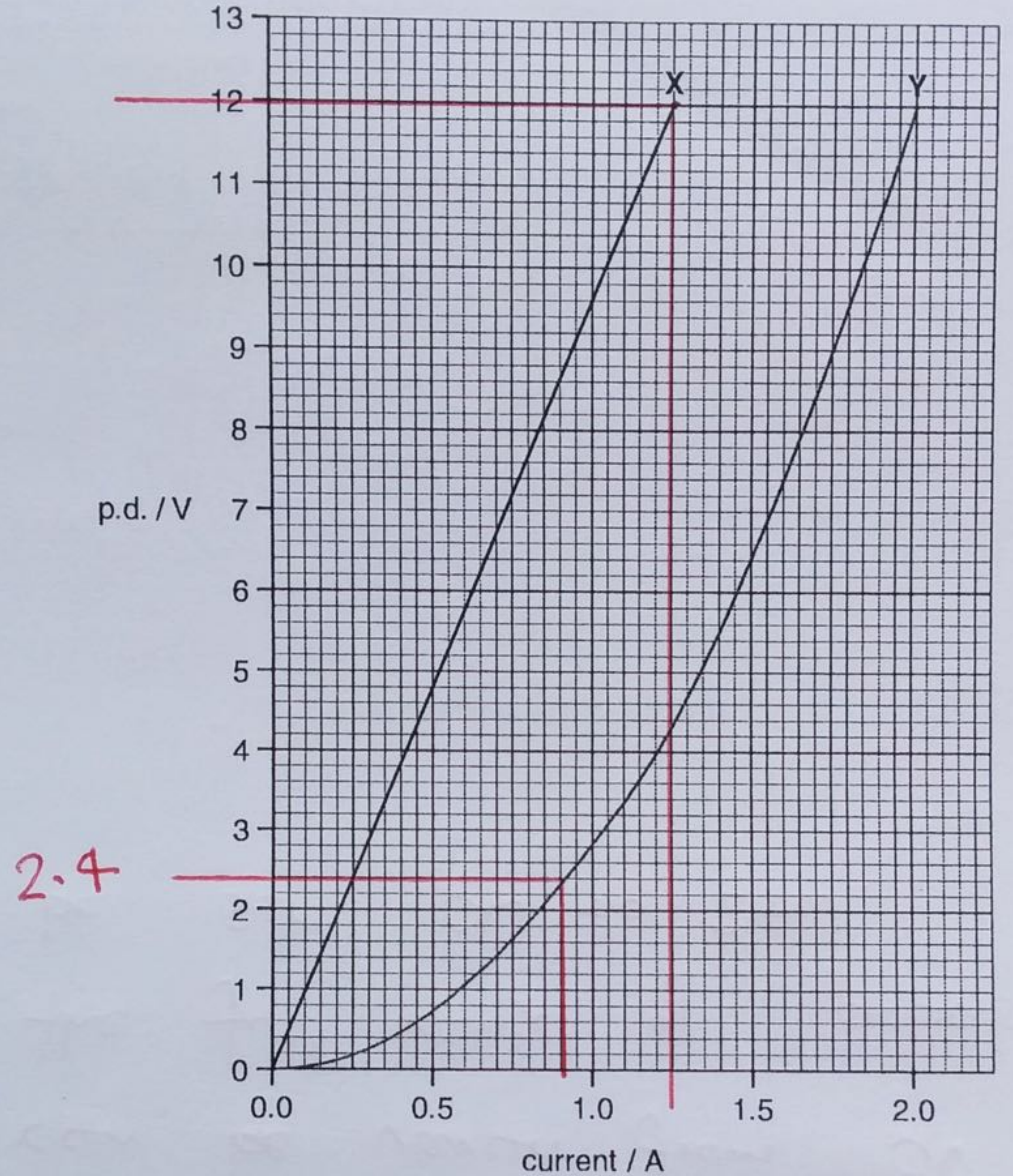


Fig. 11.1

(a) **(i)** Calculate the resistance of resistor **X** at this setting.

$R = V/I = 12/1.25 =$

resistance of **X** = ...9.6...... Ω **[1]**

(ii) Describe how the graph indicates that **Y** is a filament lamp.

As current increases the gradient and hence resistance increases. **[1]**

(Filament gets hotter)

(b) The variable resistor **X** is used to control the power dissipated in lamp **Y**, as shown in Fig. 11.2. The power supply is 12 V and has negligible internal resistance.

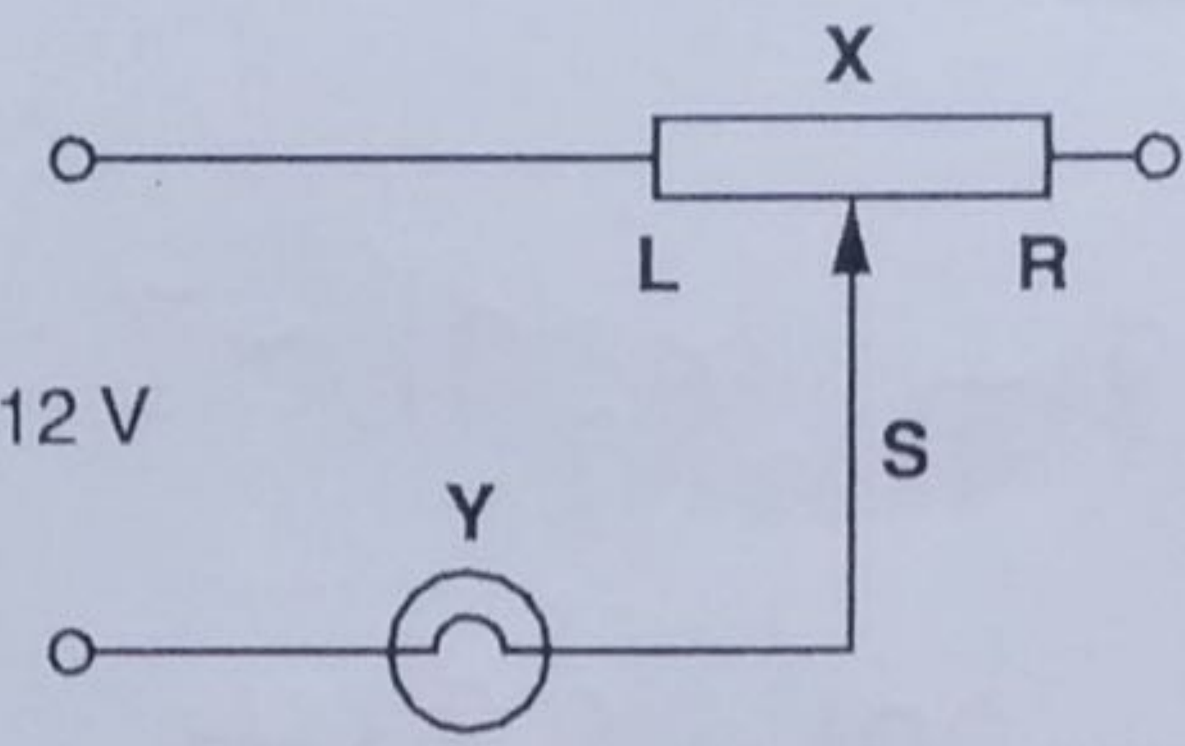


Fig. 11.2

(i) Explain how the variable resistor **X** controls the power dissipated in lamp **Y**.

As resistance of X ~~[illegible]~~ increases the lamp gets a smaller share of the voltage. Also the total resistance goes up so the current falls. P = VI so power will also fall.

[2]

(ii) Complete the following table showing the current in the circuit and the power dissipated in lamp **Y** for the positions of the variable contact **S** labelled in Fig. 11.2. You will need to use data from Fig. 11.1 to calculate the values, one value has been inserted already.

From Graph

position of **S** on **X**	current / A	power in **Y** / W
at **L**	2	24
at **R**	0.90	2.2

V= 2.4V

[3]

TURN OVER FOR PART (c)

(c) Another way of controlling the power dissipated in lamp **Y** is to use the variable resistor **X** as a potential divider as shown in Fig. 11.3.

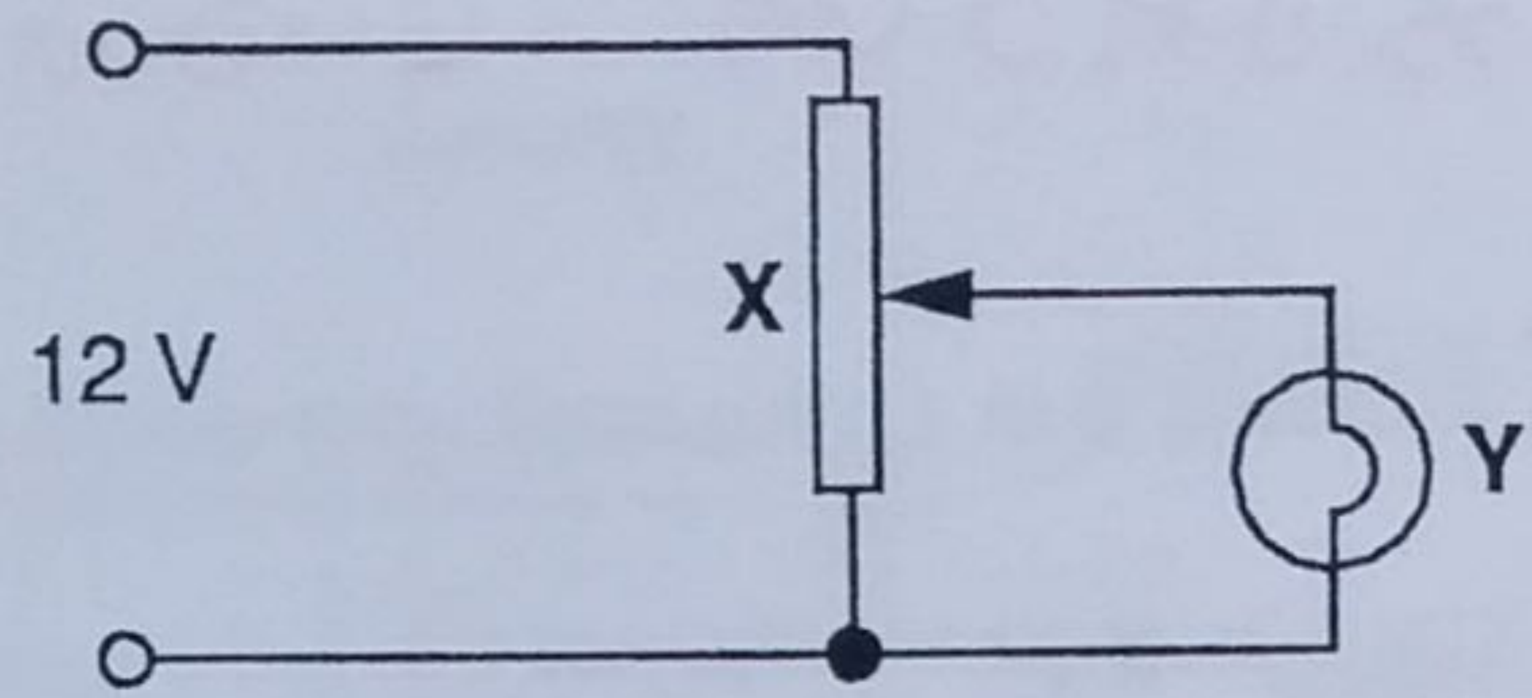


Fig. 11.3

Explain clearly **one** advantage of this potential divider circuit compared to the series resistor circuit of Fig. 11.2.

As the voltage across the lamp can be varied from 0V to 12V the full range of powers can be set. 0W to 24W.

[2]

[Total: 9]

[Total Section B: 40]

END OF QUESTION PAPER