SECTION A

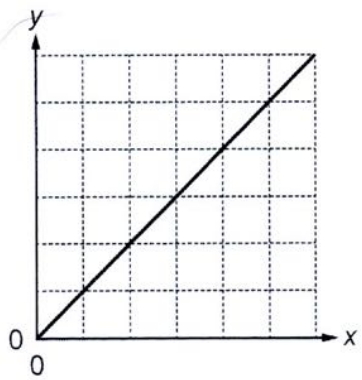
You should spend a maximum of 25 minutes on this section.

Answer **all** the questions.

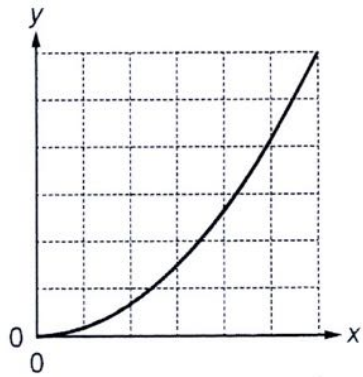
Write your answer to each question in the box provided.

Questions **1** and **2** are about these graphs.

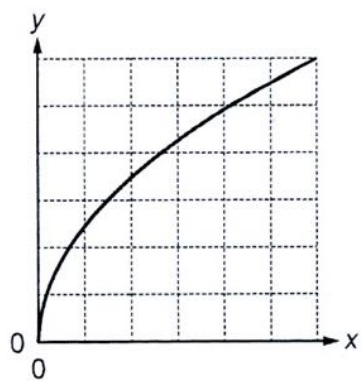
The graphs **A–D** represent different relationships between variables.



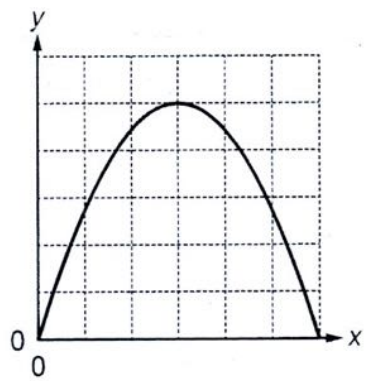
A



B



C



D

1 Which graph, **A**, **B**, **C** or **D**, best represents the relationship between the variables *x* and *y* where:

y is the velocity of an object falling freely from rest

x is the time taken?

Your answer A

$V = u + at$

$u = 0$

$\therefore V = at$

$y = mx$

[1]

2 Which graph, **A**, **B**, **C** or **D**, best represents the relationship between the variables x and y where:

y is the velocity of an object falling freely from rest

x is the distance fallen?

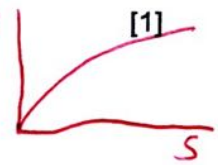
$v^2 - u^2 = 2as$

$u = 0 \therefore v^2 = 2as$

$v = \sqrt{2as}$

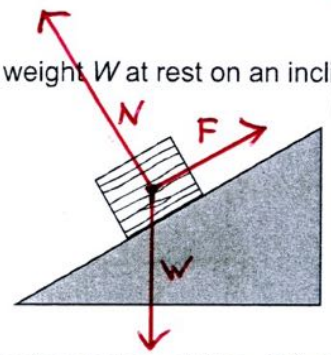
$v \propto \sqrt{s}$

Your answer C



[1]

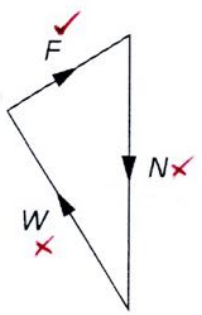
3 The diagram shows a block with weight W at rest on an inclined surface.



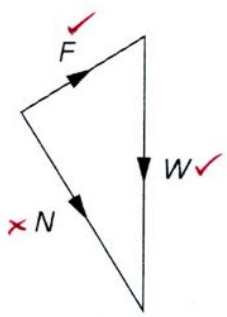
The frictional force, F, prevents the block from sliding. N is the normal contact force.

Which diagram shows the vector sum of the forces on the block?

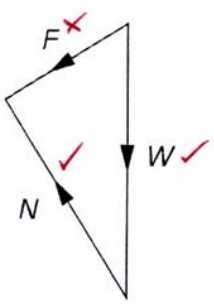
A



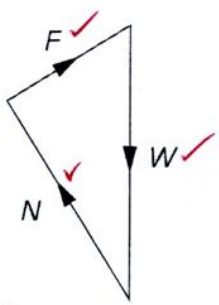
B



C



D

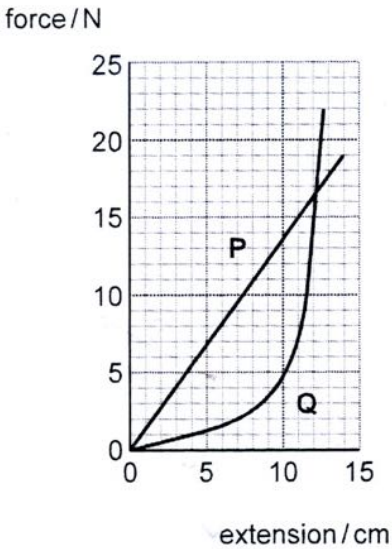


Your answer D

[1]

4 This is a force–extension graph for two cords, **P** and **Q**, made of different materials.

The cords had the same initial length and diameter and were stretched up to breaking point.



$F = kx$

$\therefore$ gradient = k

Which one of these statements is true?

A The stiffness of **Q** decreases as it is stretched. ✗ (increases)

B The work done to stretch **Q** by 12 cm and the work done to stretch **P** by 12 cm is the same. ✗ (Area under P > Q so no.)

C The stiffness of **P** is approximately 1.3 N m^{-1}. $k = F/x = 19\,N / 0.14\,m = 136\ N m^{-1}$ ✗

D **Q** is stronger than **P**. YES

Breaking force of Q > P

Your answer **D**

[1]

5 A spacecraft sends images of Pluto to Earth.
Each image consists of 1024 × 1024 pixels. Each pixel is coded by 12 bits.

The data transfers at a rate of 200 bytes per second. Approximately how long does it take to transmit one image?

A 700 seconds

B 5200 seconds

C 7800 seconds

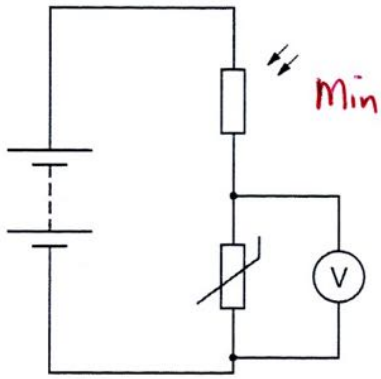
D 63 000 seconds

$$\frac{1024^2 \times 12}{8 \times 200} = 7864\ s$$

Your answer **C**

[1]

6 In the circuit below, the thermistor conducts better at higher temperatures.



Min R = high intensity

Max R = low temp

Which set of conditions produces the highest reading on the voltmeter?

A high light intensity, high temperature

B high light intensity, low temperature

C low light intensity, high temperature

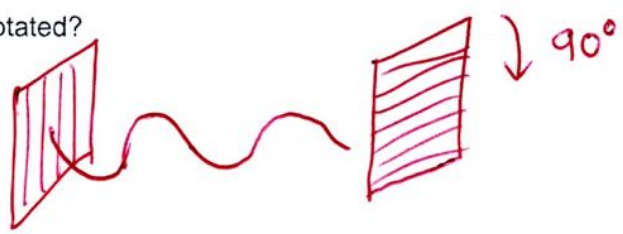
D low light intensity, low temperature

Your answer B

[1]

7 A plane-polarised light wave is passed through a single polarising filter. The filter is rotated and the intensity observed drops from a maximum to zero.

Through what angle was the filter rotated?



A 45°

B 90°

C 180°

D 360°

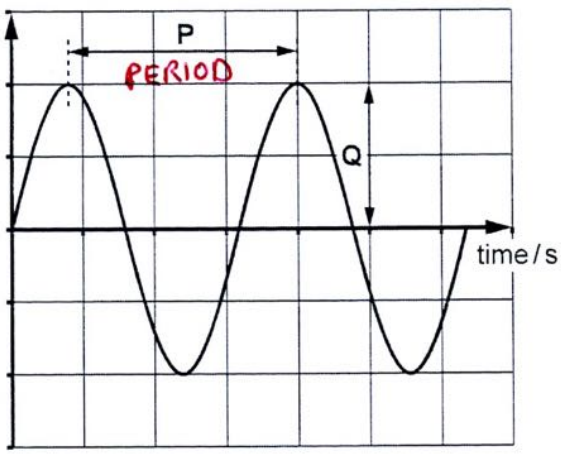
Your answer B

[1]

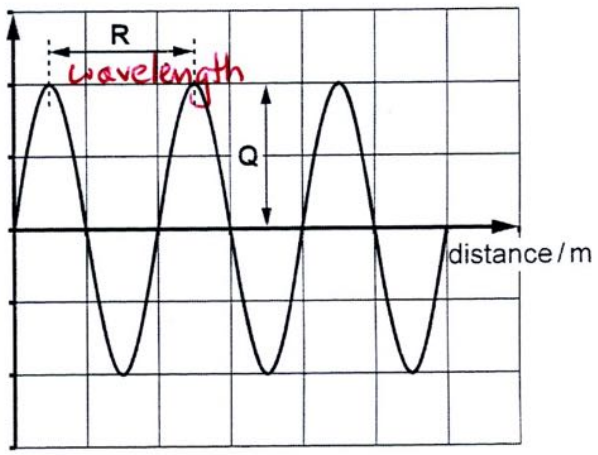
8 The graphs below describe a sound wave.

P, **Q** and **R** are intervals of time or distance as indicated on the graphs.

displacement / m



displacement / m



Which calculation gives the speed of this wave?

A $P \times R$

B $\frac{P}{R}$

C $\frac{R}{P}$

D $R \times Q$

$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{\text{wavelength}}{\text{period}} = \frac{R}{P}$

Your answer C

[1]

9 A ball, initially at rest, is struck by a hockey stick. It leaves the hockey stick at speed v.

Which quantity, together with the mass of the ball, can be used to determine v?

Impulse = change in momentum

$Ft = \Delta mv$

A The time of the impact.

B The weight of the hockey stick.

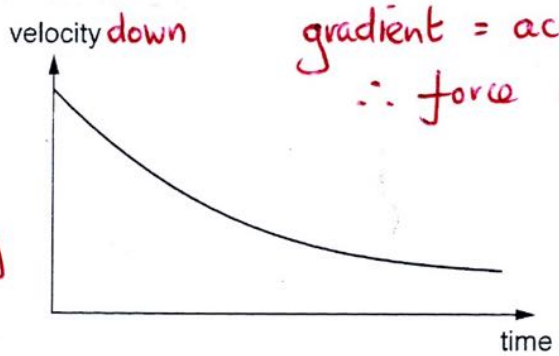
C The impulse of the force on the ball. ✓

D The final momentum of the hockey stick.

Your answer C

[1]

10 The velocity-time graph represents the motion of a parachutist after her parachute opens, but before she reaches terminal velocity.



gradient = acceleration ∝ force
∴ force decreasing

As v is decreasing force must be up.

Air resistance ∝ velocity so decreasing.

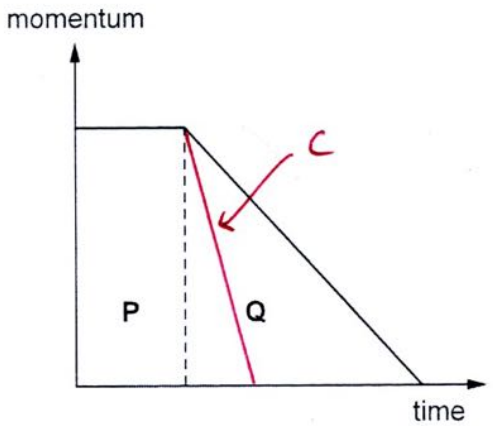
During the time shown in the graph, which row is correct?

	air resistance	resultant force	direction of resultant force
A	decreases	decreases	down ✗
(B)	decreases	decreases	up
C	increases ✗	decreases	down ✗
D	increases ✗	increases ✗	up

Your answer B

[1]

11 The graph represents the motion of a car stopping in an emergency. The driver takes a short time to react before applying the brakes.



Which statement is correct?

A ✗ Area **P** does not depend on the initial velocity. momentum = mv

B The braking force is the gradient of the graph in section **Q**. YES $F = \Delta mv/t$

C ✗ If the braking force is increased, the area **Q** will increase. No - t is less

D ✗ The total distance travelled before stopping is the sum of areas **P** and **Q**. No mvt does not have units of distance.

Your answer B

[1]

12 Which is an expression for energy?

A ✗ Fv where F is the force causing a body to move and v is its speed. $P = Fv$

B ✗ I^2R where I is the current in a resistance of value R. $P = I^2R$

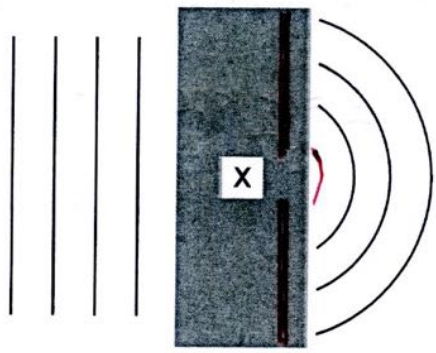
C ✗ mv where m is the mass of a body moving with velocity v. $P = mv$

D VIt where V is the potential difference across a conductor, I is the current through it and t is the time for which the current flows. $VIt = Pt = E$ ✓

Your answer D

[1]

13 The diagram shows plane wavefronts incident on a region **X**.
The contents of region **X** are hidden from view.



Region **X** is most likely to contain …

A a converging lens. No

B a narrow slit. ✓

C a polarising filter. ×

D a rectangular plastic block. ×

Your answer B

[1]

14 Two photons from the same monochromatic laser arrive at a detector via two possible paths.
The phasor representing each photon path is shown below.
The amplitude of each phasor is 1 unit.

The resultant phasor amplitude for these two possible paths at the detector is:

A 0

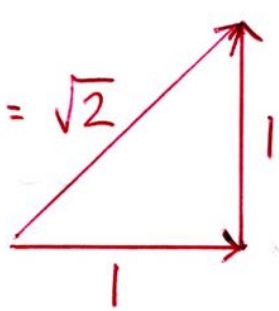
B 1.0 unit

C 1.4 units ≈ $\sqrt{2}$

D 2.0 units

tip to tail

$\sqrt{1^2+1^2} = \sqrt{2}$



Your answer C

[1]

15 An unextended spring is 0.2 m long and has a spring constant of 2500 N m^{-1}.
It is stretched to **three** times its original length and is still obeying Hooke's law.

└ 0.6m ∴ extension = 0.4m

What is the work done in stretching the spring?

A 50 J

B 200 J

C 450 J

D 800 J

$E = \frac{1}{2}kx^2 = \frac{1}{2} \times 2500 \times 0.4^2$

$= 200\,J$

Your answer B

[1]

16 The length of a square paving stone is 0.500 ± 0.002 m.
The percentage uncertainty in this measurement is 0.4%.
The area of the paving slab is 0.250 m^2.

What is the uncertainty in the value for the area?

A ± 0.0004 m^2

B ± 0.0010 m^2

C ± 0.0020 m^2

D ± 0.0040 m^2

Max value =

$0.500 + 0.002 = 0.502$

$0.502^2 = 0.252\ m^2$

which is $0.25 + 0.002\ m^2$

∴ C

Your answer C

[1]

OR $A = l \times l$

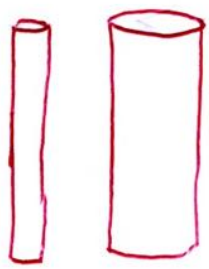
∴ $0.4 \times 2 = 0.8\%$

$\frac{0.8}{100} \times 0.250 = 0.002\ m^2$

∴ C

17 Two wires of the same material are of equal unstretched length. One of the wires has double the diameter of the other wire. Equal weights are suspended from both wires. The thinner wire has strain ε.

What is the strain in the thicker wire?



×2 diameter
= ×4 Area
so like four wires
∴ ε is 1/4

A $\frac{\varepsilon}{4}$

B $\frac{\varepsilon}{2}$

C 2ε

D 4ε

Your answer A

[1]

18 A student uses an ohmmeter and obtains five readings all of 1.89 kΩ. Resolution = 0.01 kΩ → 1.89 ± 0.005 kΩ

The student changes the range from 0–20 kΩ to 0–2 kΩ.

The student takes five new readings as shown in the table.

Resistance / kΩ	1.888	1.892	1.887	1.889	1.891

Resolution = 0.001 kΩ ∴ better

Which line in the table correctly describes the effects of this change?

	Meter	Results
A	Better resolution	More precise
B	Better resolution	More accurate ✗
C	Better precision ✗	More accurate
D	Better precision ✗	More precise

A → Yes *

B → can't tell accuracy unless you have a way of knowing the true value.

Your answer A

[1]

* In the first five readings R is clustered between 1.885 → 1.895 but in the second set R is clustered between 1.8865 – 1.8925 which is more precise.

19 The ratio $\frac{\text{height of a person}}{\text{wavelength of visible light}}$ is of the order of:

$\rightarrow 10^0$

$\sim 800\,nm \rightarrow 1000\,nm = 10^{-6}$

$10^0 / 10^{-6} = 10^6$

A 10^2

B 10^4

C 10^6

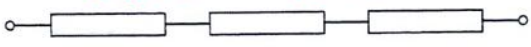
D 10^8

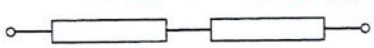
Your answer C

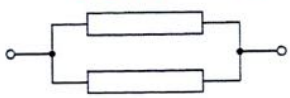
[1]

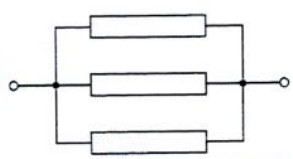
20 The resistors below are identical. Each combination is connected in a circuit to a 6 V battery of negligible internal resistance.

For which combination is the most power dissipated?

A 

B 

C 

D 

Your answer D

[1]

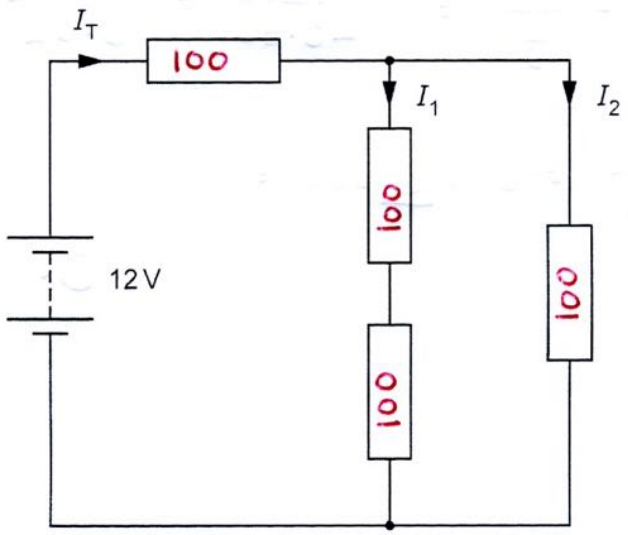
$P = I^2 R$ ∴ I has biggest impact

so D

SECTION B

Answer **all** the questions.

21 In the circuit shown, all resistors have the same resistance of 100 Ω.
Assume the battery has negligible internal resistance.



(a) State the relationship between the currents I_T, I_1 and I_2.

$I_T = I_1 + I_2$ ..... **[1]**

(b) Explain why I_2 is twice as large as I_1.

$I = V/R$

The resistance in path I_2 is half I_1 so the current is double as V is the same. ..... **[2]**

(c) Show that the total resistance of the circuit is less than 170 Ω.

For parallel paths $\frac{1}{R} = \frac{1}{200} + \frac{1}{100} = \frac{3}{200}$ $\therefore R = 66.67\ \Omega$

$\therefore R_T = 100 + 66.67 = 166.7\ \Omega$ ..... **[2]**

(d) Calculate the power supplied by the battery.

$P = VI = V^2/R = 12^2/166.7 =$

power = 0.86 W **[2]**

22 The lens in a digital camera has focal length, $f = 2.0\,\text{cm}$. $= 0.02\,\text{m}$
The camera is used to take a picture of a cat that is 50 cm away. $u = -0.50\,\text{m}$

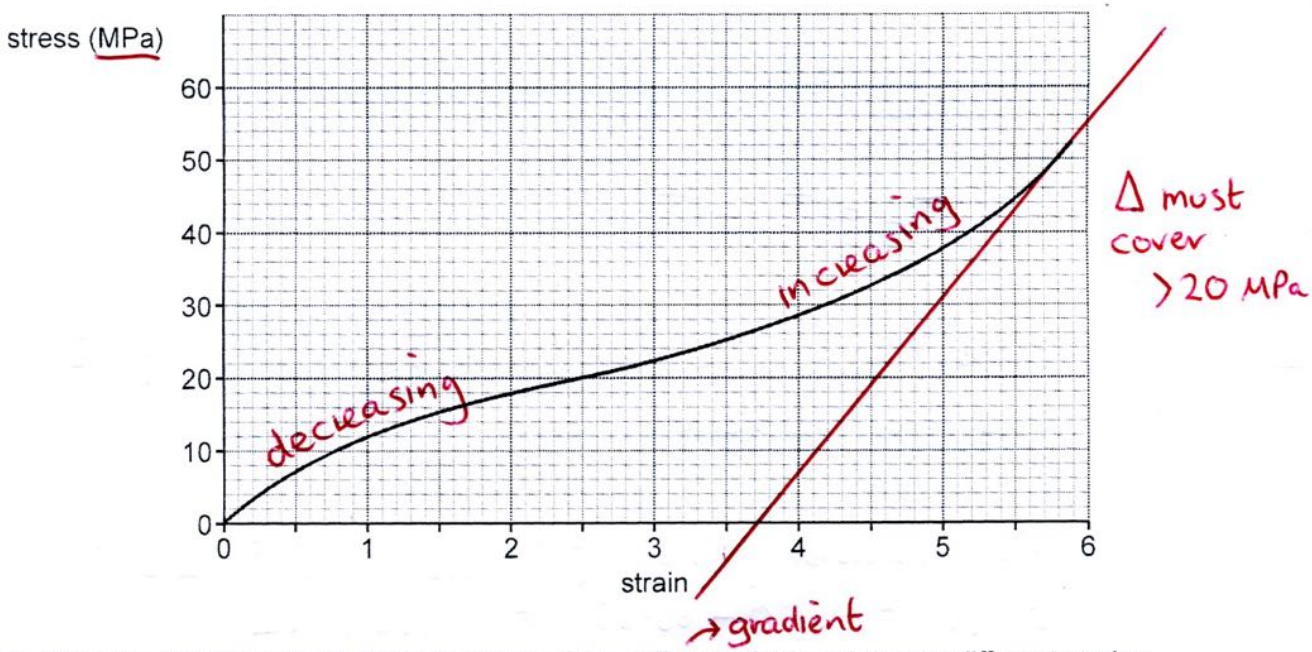
Calculate the distance between the lens and image sensor (CCD) in the camera. calc v
Give your answer to 2 significant figures.

$$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{-0.50} + \frac{1}{0.02} = 48$$

$$v = \frac{1}{48} = 0.020833 =$$

image distance = 0.021 m **[3]**

23 The graph shows the stress-strain graph for a polymer material up to fracture.



(a) Describe what the graph shows in terms of the stiffness of this polymer at different strains.

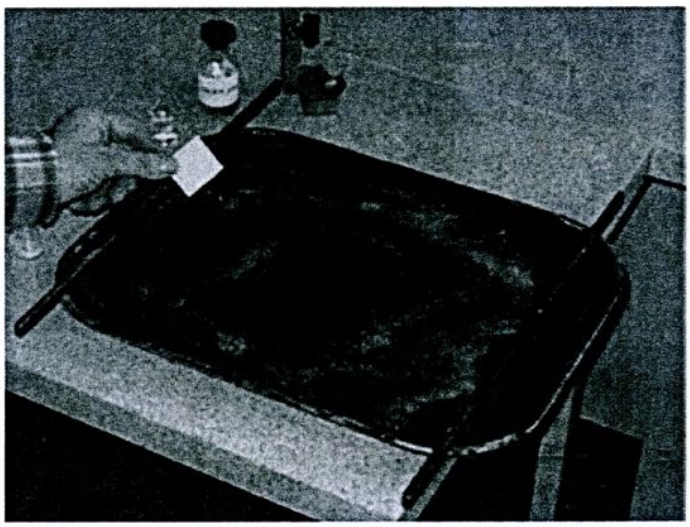
It decreases as strain goes from 0 to 2.5 and from 2.5 to ~6 it increases **[2]**

(b) Estimate the gradient of the graph just before fracture. Make your method clear. → tangent at 5.9

$$\text{gradient} = \frac{55}{6 - 3.7} = 23.9$$

gradient = 24 MPa **[2]**
(16–28 OK)

24 An experiment to estimate the size of an oil molecule is shown below.



radius = 0.25×10^{-3} m

A drop of oil with diameter (0.5 ± 0.1) mm is dropped into water dusted with powder.
The oil spreads out to a diameter of 20 cm in a layer that is assumed to be one molecule deep.

radius = 0.10 m

Estimate the size of a molecule using this data.
One mark is for stating an assumption you make in your calculation.

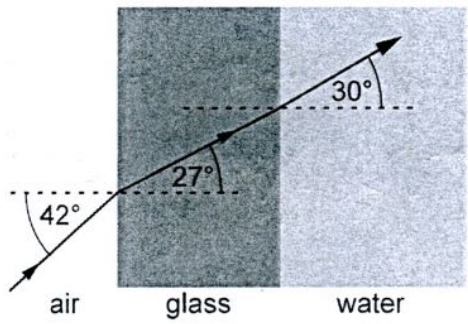
volume of drop = volume of disc

$$\frac{4}{3}\pi r^3 = \pi R^2 h$$

$$\therefore h = \frac{4r^3}{3R^2} = \frac{4 \times (0.25 \times 10^{-3})^3}{3 \times 0.10^2} =$$

size of molecule = 2.08×10^{-9} m **[3]**

25 A glass tank contains water. A ray of light travels from the air through the glass into the water as shown.



(a) Show that the speed of light in glass is about two-thirds of that in air.

$n = \frac{\sin i}{\sin r} = \frac{c_{air}}{c_{glass}}$ $\therefore$ $c_{glass}/c_{air} = \frac{\sin r}{\sin i} = \frac{\sin 27^\circ}{\sin 42^\circ}$

$= 0.68 \approx 2/3$

[2]

(b) Without calculation, explain what the diagram shows about the speed of light in water.

As $r > i$ ie $30^\circ > 27^\circ$ then the speed of light in water is higer than in glass.

[2]

SECTION C

Answer **all** the questions.

26 **Fig. 26.1** shows an aeroplane flying horizontally and towing a flag.

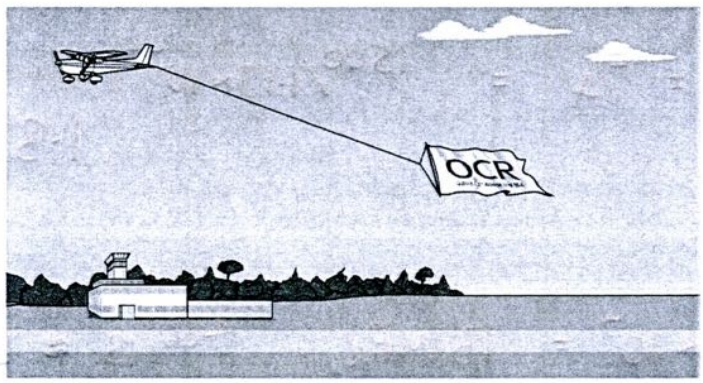
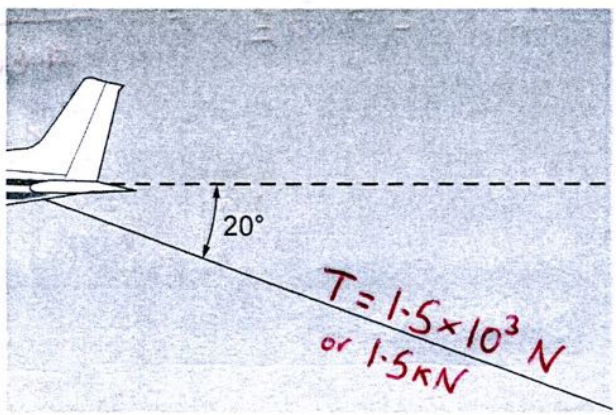


Fig. 26.1

The flag is attached to the aeroplane using a metal cable. **Fig. 26.2** shows that the cable is at an angle of 20° below the line of flight of the aeroplane.



or $1.5\cos 20$ kN

$F_H = 1.5\times10^3 \cos 20$ N

20°

1.5×10^3 N

Fig. 26.2

When the aeroplane is travelling at a steady speed of 40 m s^{-1} the tension in the cable is 1.5 kN.

(a) Show that the work done in towing the flag when the aeroplane travels 1 m in the line of flight is about 1.4 kJ.

Need component in direction of motion (horizontal)

Work = Force × distance

$= 1.5\cos 20 \times 1 = 1.41$ kJ [2]

(b) Calculate the power required for towing the flag. (F in direction of v)

$P = FV = 1.5\times10^3 \cos 20 \times 40 =$

power = 5.6×10^4 W **[1]**

radius = 0·006m

(c) The diameter of the metal cable is 12 mm.
The Young modulus of the metal cable is 210 GPa.

(i) Calculate the operating stress in the cable during towing.

Area = πr^2 = $\pi \times 0.006^2$ = 1.13×10^{-4} m^2

stress = F/A = $1500 / 1.13 \times 10^{-4}$

stress = 1.33×10^7 Pa [3]

(ii) The breaking stress of the metal is 460 MPa.

Comment on the safety of the procedure.

1.33×10^7 = 13 MPa 460/13 ≈ 35

The breaking stress is > 35× the tension so it is safe. [1]

(iii) Calculate the strain in the cable.

$E = \frac{\sigma}{\varepsilon}$ ∴ $\varepsilon = \sigma / E$ = $1.33 \times 10^7 / 210 \times 10^9$

strain = 6.32×10^{-5} [2]

27 A student is investigating a smartphone app which records voice messages. The sound is converted into an analogue electrical signal (input p.d.) by the microphone. The signal is shown in **Fig. 27.1**.

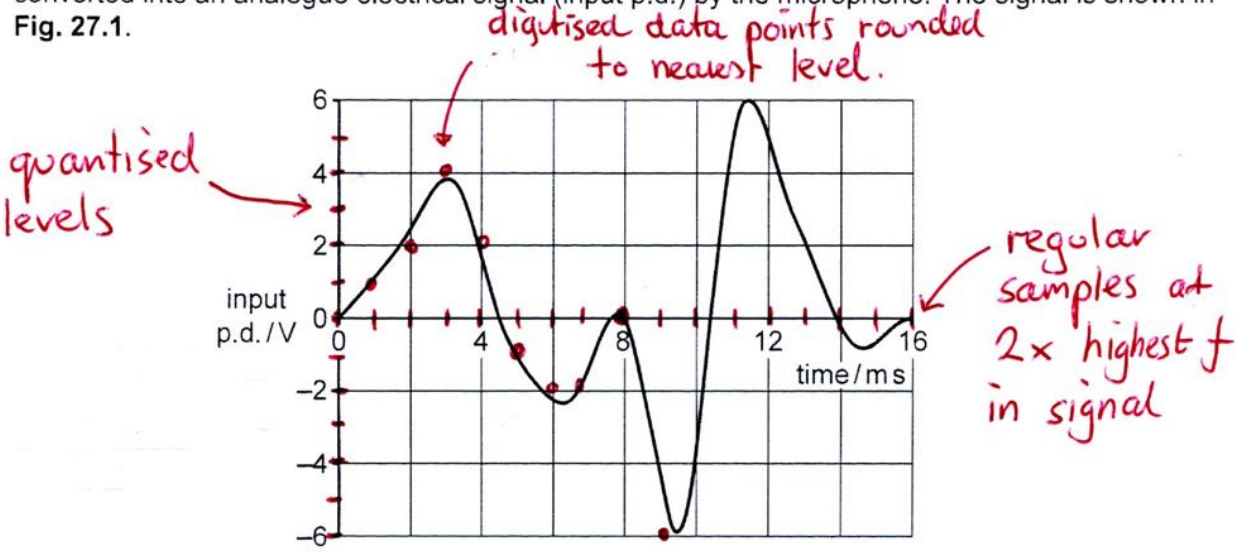


Fig. 27.1

(a) Explain how this signal can be digitised.
You may draw on **Fig. 27.1** to support your answer.

.....

.....

.....

.....

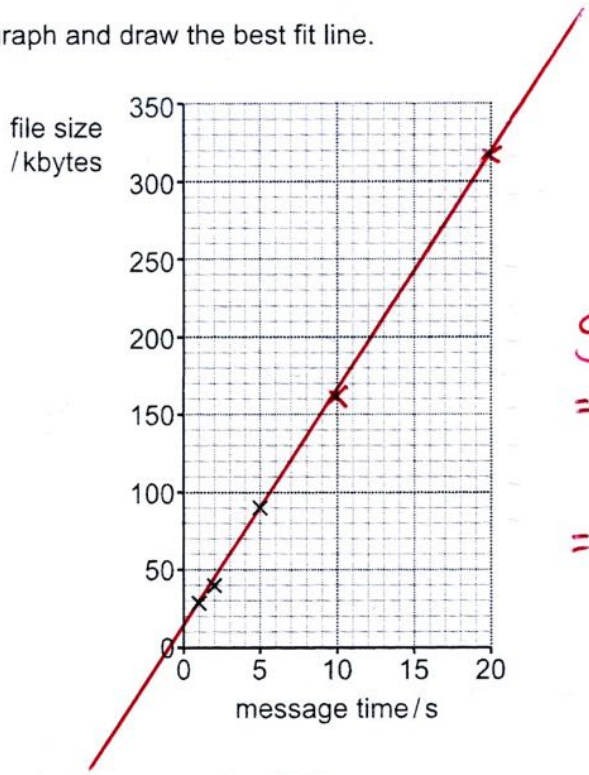
..... **[3]**

(b) The student records a number of messages of different lengths and records the size of the resulting (uncompressed) sound files. Her results are tabulated below.

Message Time/s	File Size/10^3 bytes
1	29
2	40
5	88
10	162
20	317

(i) **Fig. 27.2** shows a graph of the file size plotted against message time for the first three data points.

Complete the graph and draw the best fit line. **[2]**



gradient
$= \frac{320 - 15}{20}$
$= 15.25$ kbyte s^{-1}

Fig. 27.2

(ii) State how the graph shows that there is a fixed amount of information transmitted with each file that is independent of the message time.

When message time is 0 sec the file size is ~ 15 kbytes. **[1]**

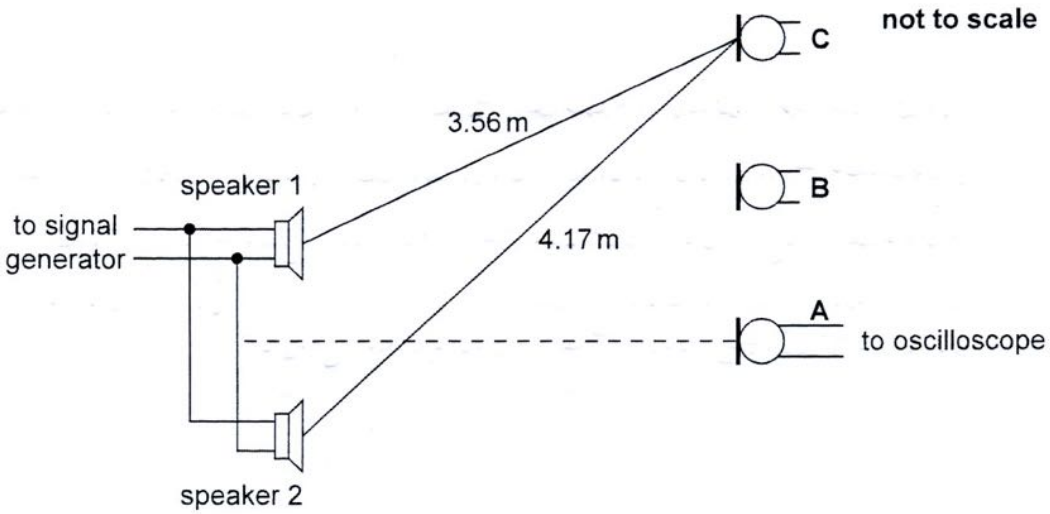
(iii) Use the data to estimate the number of **bits** stored in the file per second of sound recorded.

= gradient × 8000
as kbytes per sec × 8000 = bits per second

$15.25 \times 8000 = 122000$

bits per second = 1.22×10^5 **[2]**

28 A student is attempting to measure the wavelength of sound waves using interference.
She sets up the apparatus shown. There are **two** identical loudspeakers connected in parallel to a signal generator and a microphone connected to an oscilloscope.



The student finds that a maximum signal is measured with the microphone at position **A**.
She moves the microphone to position **B** where the signal is a minimum.

(a) Suggest one reason why it would be difficult:

(i) to locate position **B** precisely → small variation in repeated measurements.

Hard to consistently judge the quietest position [1]

(ii) to measure the distance between position **A** and the speakers precisely.

Hard to consistently measure distance as speaker and microphone are not points. [1]

(b) The student continues to move the microphone to position **C** where the signal is again a maximum.

(i) Calculate the wavelength of the sound waves. Show how you arrive at your answer.

As it is a maximum the path difference must be one wavelength

$\lambda = 4.17 - 3.56 =$

wavelength = 0.61 m **[2]**

(ii) Another student suggests a method for improving the wavelength measurement.
He suggests using a laser to measure the distance between the speakers and microphone very accurately.

Evaluate this suggestion in terms of the likely effect on the percentage error in the calculated wavelength.

The laser will reduce the uncertainty in the speaker – microphone distance but the main source of uncertainty is in judging the speaker position so no change in overall uncertainty in the wavelength. [2]

(c) The student measured the frequency of the sound wave at 560 ± 30 Hz.
The uncertainties in the distances from each speaker to position **C** are ± 0.02 m.

Calculate the speed of sound in air from this data and your answer in part **(b)** and make an estimate of the uncertainty. Make your method clear.

speed = $f\lambda$ = 560×0.61 = 342 ms^{-1}

highest poss speed = $560 + 30 \times 0.61 + (0.02 \times 2)$

= 590×0.65 = 384 ms^{-1} (two measurements are needed to get λ)

384 − 342 = 42

which is 40 to 1 s.f.

speed of sound = 340 ± 40 $m\,s^{-1}$ [4]

(d) The student now reverses the connections to speaker 2 but keeps the connections to speaker 1 unchanged.

State and explain the effect this would have on the signal measured by the microphone at positions **A** and **C**.

The maxima now become minima as the speakers are now in antiphase. (180° out of phase) [2]

END OF QUESTION PAPER