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.

1 Which one of these ratios does **not** have units?

A $\frac{\text{acceleration}}{\text{gravitational field strength}}$ $ms^{-2} \equiv N kg^{-1}$ $F = ma \therefore \frac{F}{m} = a$ ✓

B $\frac{\text{Planck constant}}{\text{momentum}}$ $\frac{Js \text{ or } JHz^{-1}}{kg\,ms^{-1}} = J\,kg^{-1}m^{-1}s^2$ ✗

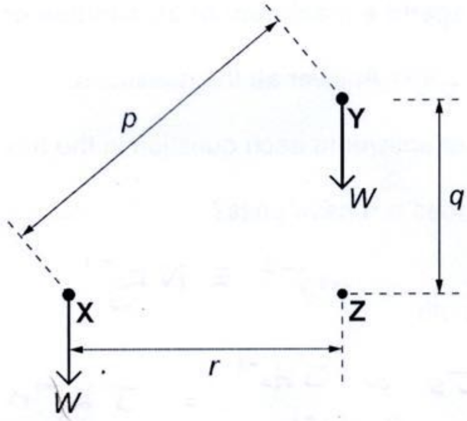
C $\frac{\text{resistance}}{\text{conductance}}$ $\frac{\Omega}{\Omega^{-1}} = \Omega^2$ ✗

D $\frac{\text{Young modulus}}{\text{strain}}$ $\frac{Pa}{\text{no unit}} = Pa$ ✗

Your answer | A |

[1]

2 A crane is used to lift a load directly from point **X** to point **Y**.



The weight of the load is *W*.
p, *q* and *r* are distances between points **X**, **Y** and **Z** as shown in the diagram.

What is the work done against the weight?

W = Fx
distance in direction of force
∴ Wk = Wq

A *Wp*

B *Wq*

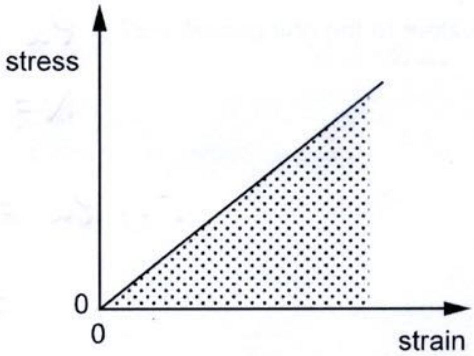
C *Wr*

D *W*(*q* + *r*)

Your answer B

[1]

3 The graph shows the variation in stress with strain for a sample of a material.



No it give the energy per unit volume.

$Nm^{-2} = Nm\ m^{-3}$
$= Jm^{-3}$

An F–x graph give E

Which of the following statements is **not** correct?

A The material shows elastic deformation. ✓ Hooke's Law stress ∝ strain

✗ **B** The area under the graph represents the energy stored in the stretched material.

C The gradient gives the Young modulus of the material. E = stress/strain ✓

D The graph would show the same gradient for a longer specimen of the same material. ✓

strain = extension/length so no change

Your answer B

[1]

4 Which word used to describe materials does **not** apply to ceramics?

A hard ✓

B stiff ✓

C strong ✓

D tough ✗ No ceramics are brittle

Your answer D

[1]

5 Here is a list of combinations of base units of the SI system.

Which combination is equivalent to the unit pascal, Pa?

A $kg\,m^{-1}\,s^{-2}$

B $kg\,m\,s^{-2}$

C $kg\,m\,s^{-1}$

D $kg\,m^{2}\,s^{-2}$

Your answer A

$Pa = Nm^{-2}$ $P = F/A$

$N = kg\,m\,s^{-2}$ $F = ma$

$\therefore Pa = kg\,m\,s^{-2}\,m^{-2}$

$= kg\,m^{-1}\,s^{-2}$

[1]

$1/-0.5 = -2\,D$ $1/0.2 = 5\,D$

6 Waves from an object 0.5 m away pass through a lens of focal length 0.2 m.

Which of the following give the curvature of the waves entering the lens and leaving the lens?

	Curvature entering lens / D	Curvature leaving lens / D
A	–2.0 ✓	+5.0 ✗
B	+2.0 ✗	+5.0 ✗
C	–2.0 ✓	+3.0 ✓
D	+2.0 ✗	+7.0 ✗

$C = \frac{1}{d}$

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

$-2D + 5D = 3D$

↑ = curvature entering + curvature added by lens.

Your answer C

[1]

7 The display of a laptop screen is viewed through a polarising filter by a student. The intensity of the light changes when the filter is rotated.

Which property of light is demonstrated in this experiment?

A It has wavelength of about 5×10^{-7} m. ✗

B It travels at the speed of light. ✗

C It is a transverse wave. ✓

D It is a longitudinal wave. ✗

Only transverse waves can be polarised

Your answer C

[1]

8 In which region of the electromagnetic spectrum is radiation of wavelength 50 μm?

A visible

B infra-red

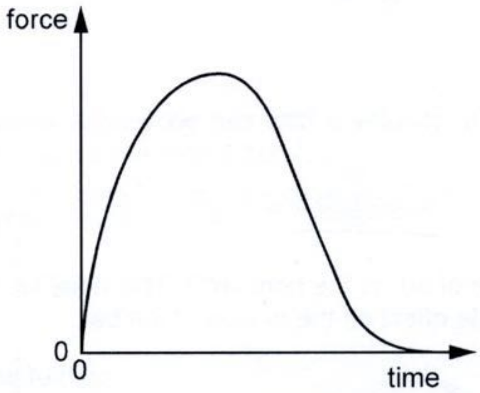
C microwave

D radio

Your answer B

[1]

9 The graph shows the resultant force on a football as it is kicked.



Which of the following graphs relating to this kick would have the same shape as the graph above?

A acceleration of the ball against time

B kinetic energy of the ball against time

C momentum of the ball against time

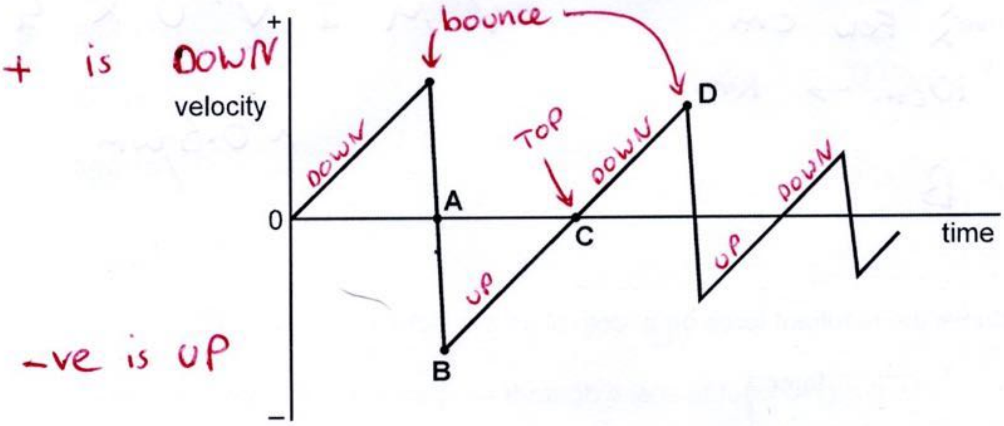
D velocity of the ball against time

Your answer A

[1]

10 A golf ball is dropped from rest onto a hard floor.
The graph shows how the velocity of the ball varies with time as it bounces, from the time of release.

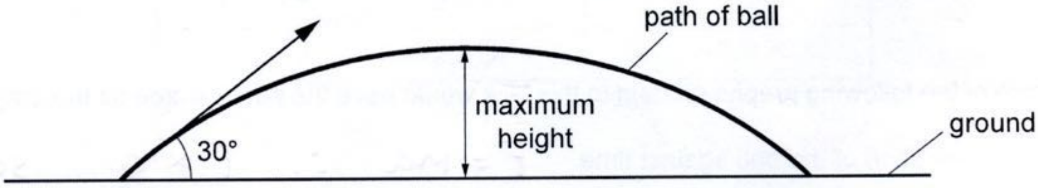
At which point does the ball reach its maximum height after the first bounce?



Your answer C

[1]

11 A ball is thrown at an angle of 30° to the horizontal. The initial kinetic energy of the ball is K.
Air resistance has negligible effect on the motion of the ball.



What is the kinetic energy of the ball at the maximum height?

A 0

B $0.25K$

C $0.75K$

D $0.87K$

Your answer C

[1]

Ball only has horizontal component of velocity at max height

$\therefore V_H = V\cos 30$

$= V \times 0.8660$

$E_K = \frac{mv^2}{2}$

$\therefore E_K = K \times 0.866^2$

$= 0.75K$

12 Ball **P** has mass m. Ball **Q** has mass $2m$. Both balls have the same kinetic energy, which is greater than zero.

What is the ratio $\frac{\text{momentum of } \mathbf{P}}{\text{momentum of } \mathbf{Q}}$?

A $\frac{1}{2}$

B $\frac{1}{\sqrt{2}}$

C $\sqrt{2}$

D 2

For Q m is double so to keep E_K the same v^2 must be half. ∴ v must be $\sqrt{1/2}$ × as big.

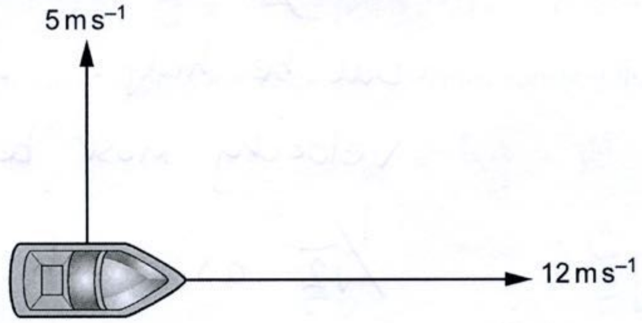
Since Q has double the mass the momentum must be $2\sqrt{1/2}$ × the momentum of P & $2\sqrt{1/2} = \sqrt{2}$

∴ ratio = $1/\sqrt{2}$

Your answer B

[1]

13 A boat is travelling eastwards across the sea with a velocity of $12\,\text{m s}^{-1}$. A wind from the south pushes the boat northwards at a velocity of $5\,\text{m s}^{-1}$.



What is the magnitude of the resultant velocity of the boat as it travels across the sea?

A $7\,\text{m s}^{-1}$

B $13\,\text{m s}^{-1}$

C $17\,\text{m s}^{-1}$

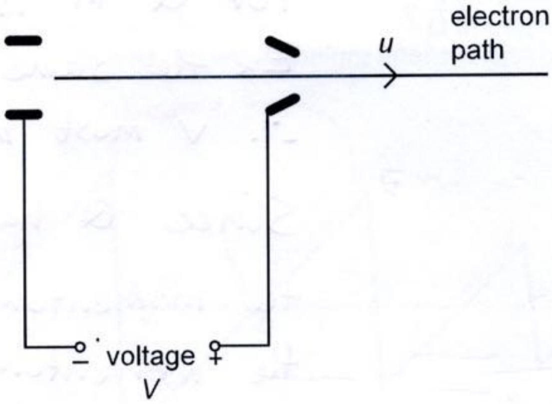
D $169\,\text{m s}^{-1}$

$\sqrt{5^2 + 12^2} = 13\,\text{ms}^{-1}$

Your answer B

[1]

14 An electron gun is used to accelerate electrons from rest through a voltage V. The electrons emerge with a speed u.



The voltage in the gun is halved to $\frac{V}{2}$. At what speed do the electrons emerge?

A $\frac{u}{4}$

B $\frac{u}{2}$

C $\frac{u}{\sqrt{2}}$

D $u\sqrt{2}$

Your answer C

$V = E/Q$ ∴ at half the voltage the kinetic energy will be half. ∴ the velocity must be $\sqrt{1/2}$ or $1/\sqrt{2}$ as much ∴ $u/\sqrt{2}$

[1]

15 The solar constant is the average power per square metre that the Sun provides at the surface of the Earth. The solar constant at the solar array on the International Space Station (ISS) is $1360\,W\,m^{-2}$. One section of the solar array has an area of $406\,m^2$.

Assuming that all of the solar energy is converted into electrical energy aboard the ISS, how much electricity is produced by one section of the solar array in one hour? = 3600 s

A 150 J

B 12 kJ

C 0.6 MJ

D 2.0 GJ

Your answer D

$1360\,Wm^{-2} \times 406\,m^2 = 552160$

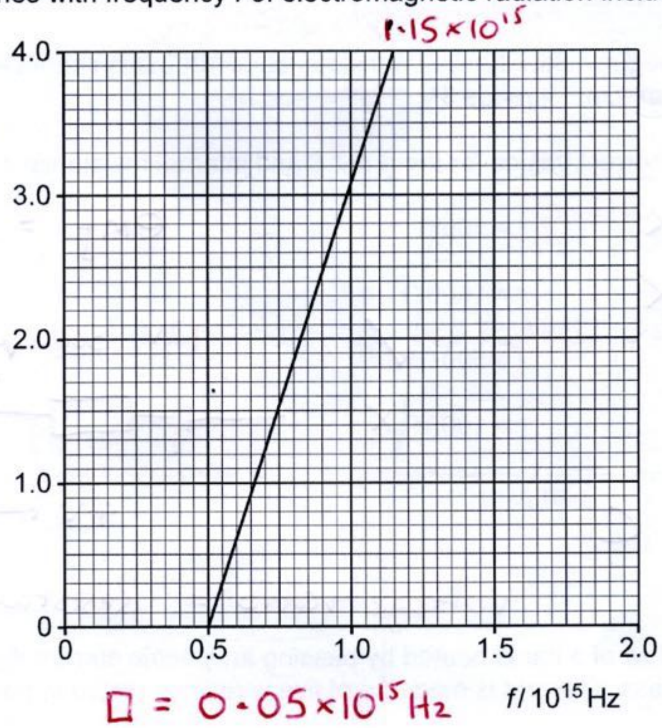
$E = Pt = 552160 \times 3600\,s$

$= 1.98 \times 10^9\,J$

$\approx 2\,GJ$

[1]

16 The graph below shows how the maximum kinetic energy *E* of electrons released from the surface of a potassium plate varies with frequency *f* of electromagnetic radiation incident on the plate.



To **two significant figures**, what is the value of the Planck constant that can be calculated from this graph?

A 6.2×10^{-34} J s

B 6.6×10^{-34} J s

C 6.2×10^{4} J s

D 1.6×10^{33} J s

Your answer C

[1]

$E_K = hf - \phi$

$y = mx + c$

$h = \text{gradient} = \frac{\Delta y}{\Delta x}$

$= \frac{4.0 \times 10^{-19}}{1.15 \times 10^{15} - 0.5 \times 10^{15}}$

$= 6.154 \times 10^{-34}$ Js

(You could guess that it is close to but not exactly the true value → C)

17 A digital voltmeter of very high resistance is connected across the terminals of a source of e.m.f. The voltmeter reads 12 V.

When an analogue voltmeter with a resistance of 1000 Ω is connected across the terminals of the same source of e.m.f, it reads 8 V.

What are the correct values for the e.m.f $\mathcal{E}$ and internal resistance r of the source?

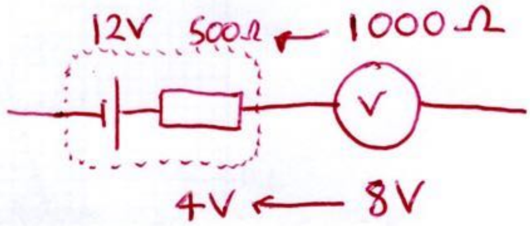
A $\mathcal{E}$ = 8 V ✗ r = 500 Ω

B $\mathcal{E}$ = 8 V ✗ r = 1000 Ω

C $\mathcal{E}$ = 12 V r = 500 Ω ✓

D $\mathcal{E}$ = 12 V r = 1000 Ω ✗

emf = 12V so rule out A & B



Your answer C

[1]

Voltage ratio = Resistance Ratio

18 The rear window of a car is heated by passing an electric current through a grid of wires that are fixed to the glass. The grid is made up of five wires connected in parallel.

Each wire is a thin rectangular strip of steel 80 cm long, 3.0 mm wide and 50 μm thick with resistivity 470 nΩ m.

What is the total resistance of the wires in the grid?

A 0.50 Ω

B 2.5 Ω

C 13 Ω

D 50 Ω

$R = \frac{\rho L}{A} = \frac{470 \times 10^{-9} \times 0.8}{3 \times 10^{-3} \times 50 \times 10^{-6}}$

$= 2.51\ \Omega$

Your answer A

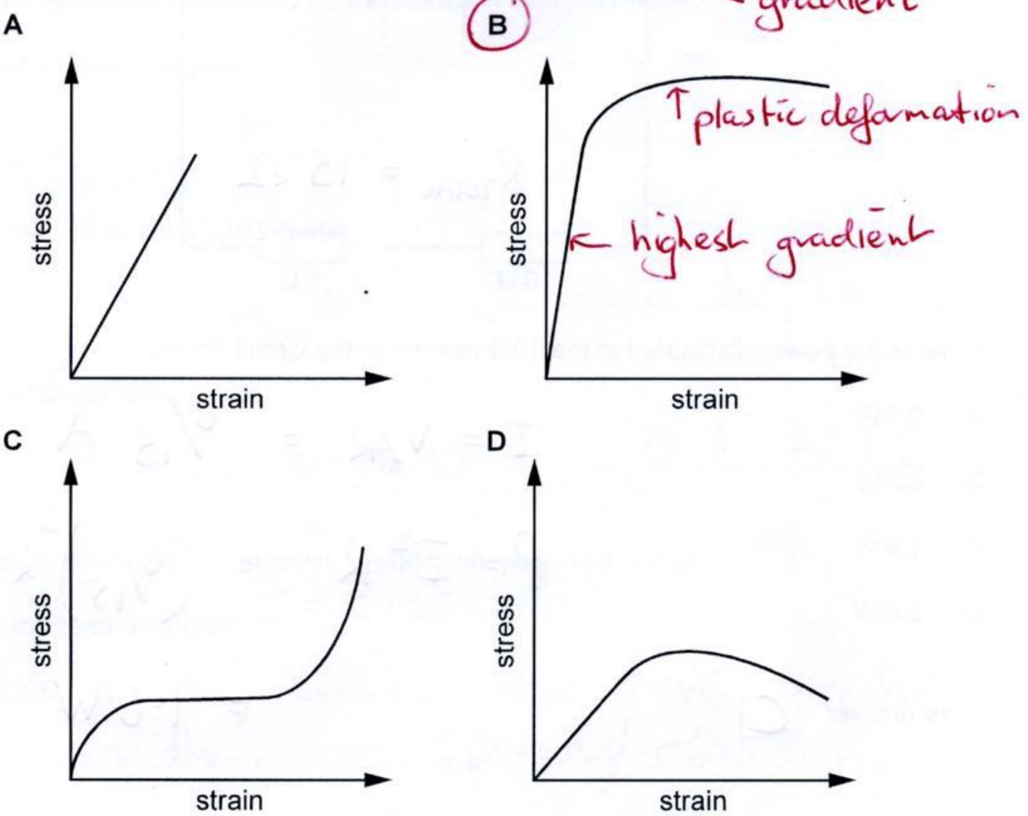
[1]

5 wires in parallel so

$R_{TOTAL} = 2.51/5 = 0.50\ \Omega$

19 The graphs below show the stress against strain relationships for four different materials, **A**, **B**, **C** and **D**. Each graph has the same scales.

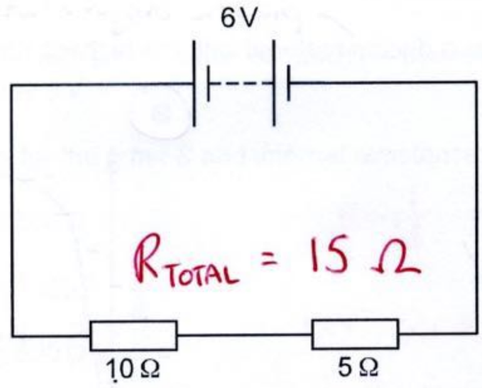
Which of the graphs shows a ductile material with the highest Young modulus?



Your answer B

[1]

20 In the diagram below, the battery of e.m.f 6 V has negligible internal resistance.



What is the power dissipated in the 10 Ω resistor in the circuit shown?

A 0.4 W

B 0.9 W

C 1.6 W

D 3.6 W

$I = V/R = 6/15\ A$

$P = I^2 R = (6/15)^2 \times 10$

$= 1.6\ W$

Your answer C

[1]

SECTION B

Answer **all** the questions.

21 Write down an estimated magnitude for the following everyday quantities:

(a) weight of a fist-sized apple

or 10^0 0.9 to 5 N **[1]**

(b) electric current to run a 230 V kettle

or 10^1. 3 to 13 A **[1]**

(c) volume of water to fill a bath

or 10^{-1} to 10^0 0.1 to 1.0 m^3 **[1]**

22 A microwave transmitter and a receiver operate with polarised waves.

(a) Explain the term *polarised*.

(transverse) waves that have oscillations all in the same plane / direction **[1]**

(b) The transmitter **T** faces the receiver **R** as shown in Fig. 22.

The signal received is a maximum.

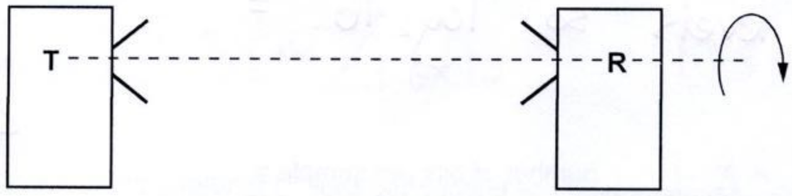


Fig. 22

State what happens to the intensity of the signal received as the receiver is rotated by 180° about the axis **TR**.

Falls to a minimum at 90° and then increases back to maximum at 180° **[1]**

23 Fig. 23 shows the graph of an analogue signal varying in time, together with the digitised sampled signal.

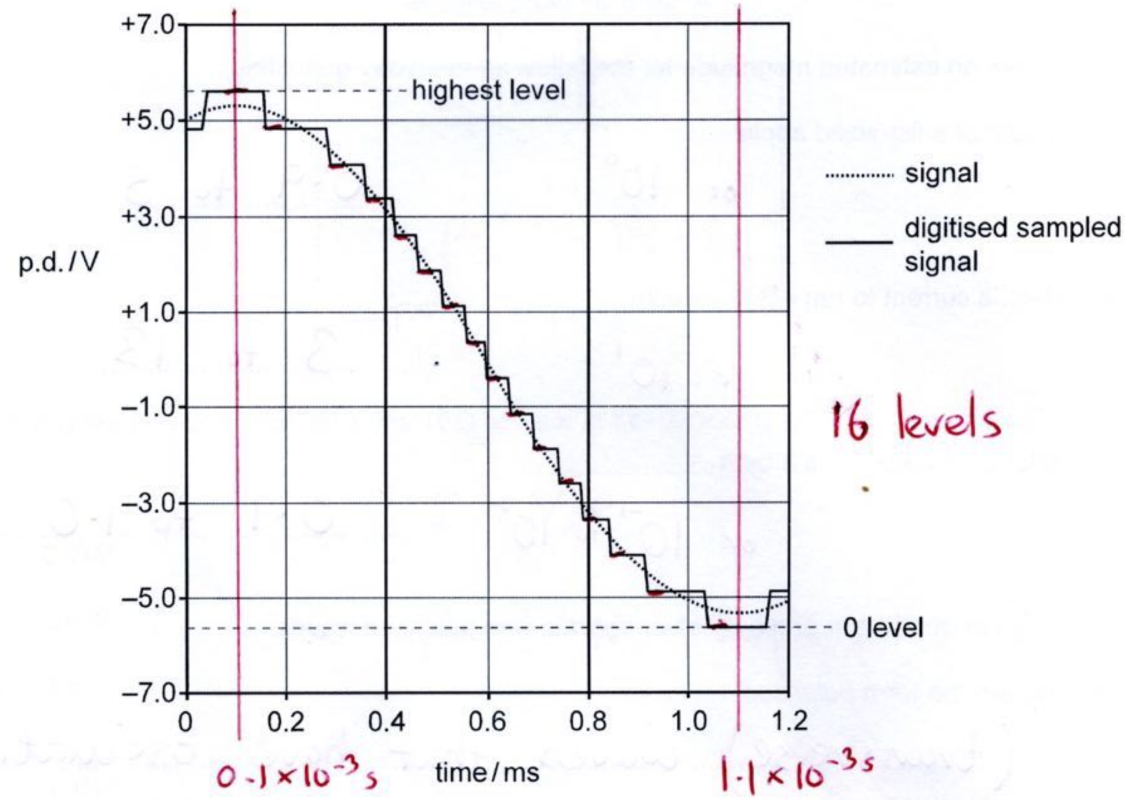


Fig. 23

(a) Determine the number of bits per sample that have been used to digitise the signal.

Explain your reasoning.

16 levels so $\log_2 16$ =

number of bits per sample = ...4.......... **[2]**

(b) Estimate the frequency of the analogue signal shown in Fig. 23.

Make your method clear.

$T = 2 \times (1.1 - 0.1) \times 10^{-3}$ s $= 2 \times 10^{-3}$ s

$f = \frac{1}{T} = \frac{1}{2 \times 10^{-3}} =$ frequency = ...500.......... Hz **[1]**

24 A lit candle is placed between two parallel metal plates. It burns with a vertical orange flame. The orange colour is due to carbon C^+ ions. When the 5 kV power supply is switched on, the plates become charged and the flame bends towards the negatively charged plate as shown in Fig. 24. The current rises from zero to 28 μA between the plates.

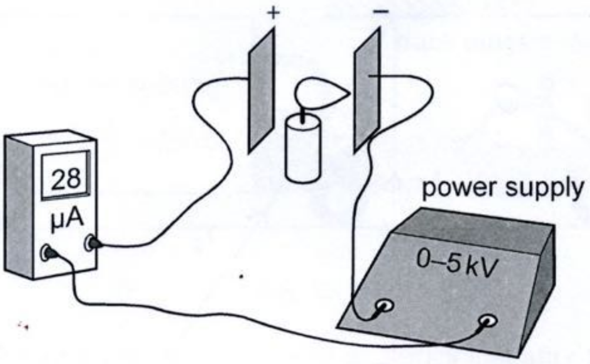


Fig. 24

(a) Explain why there is a current when the power supply is switched on.

The C^+ ions flow between the plates and a flow of charged particles is an electric current (a flow of charge) **[2]**

(b) The charge on a carbon C^+ ion is $+1.6 \times 10^{-19}$ C.

Calculate how many carbon C^+ ions arrive per second at the negative plate when the current is 28 μA.

$28 \mu A = 28 \times 10^{-6}\ C s^{-1}$

$\therefore\ n = 28 \times 10^{-6} / 1.6 \times 10^{-19} = 1.75 \times 10^{14}\ s^{-1}$

number of C^+ ions per second = 1.8×10^{14} s^{-1} **[2]**

25 Fig. 25.1 shows a wrecking ball of weight 4600 N, hanging at rest.
It hangs vertically with the support chain under tension T_1.
It is then deflected through angle θ by the horizontal force H, as shown in Fig. 25.2.
The new tension in the support chain is T_2.

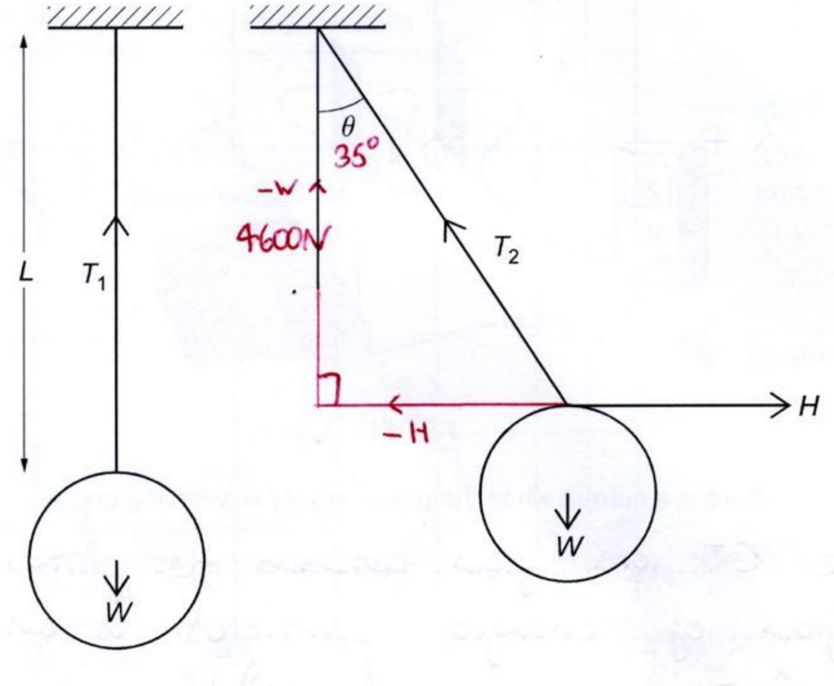


Fig. 25.1 **Fig. 25.2**

(a) Explain why the magnitude of T_1 is 4600 N.

No acceleration so no resultant force $T_1 = -W$ **[1]**
$\therefore T_1 = -4600$ N

(b) Calculate the magnitude of T_2 when $\theta = 35°$.

Vertic component = 4600N = $T_2 \cos 35°$

$\therefore T_2 = \frac{4600}{\cos 35} = 5616$ N

T_2 = ...5600........ N **[2]**

(c) Calculate the magnitude of H when $\theta = 35°$.

H = horizontal component of T_2

$\tan 35° = \frac{H}{4600}$

H = ...3200........ N **[1]**

$\therefore H = 4600 \tan 35° = 3221$ N

(or $5616 \sin 35° =$
or $\sqrt{5616^2 - 4600^2} =$)

26 Fig. 26 shows the head-on collision between a lorry and a truck.
The lorry has mass 8000 kg and initial velocity 30 m s^{-1}.
The truck has mass 1500 kg and initial velocity −4.0 m s^{-1}.

$p = mv$

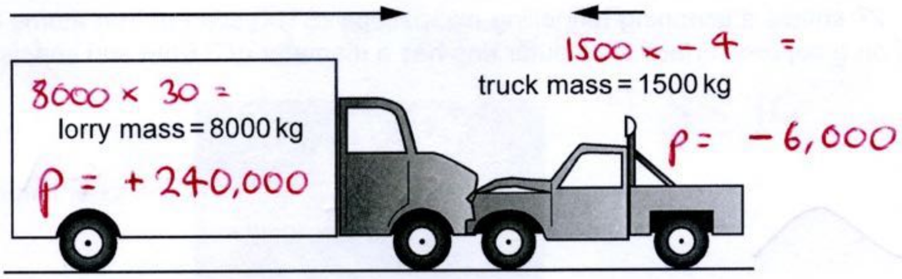


Fig. 26

(a) Show that the combined velocity of the lorry and truck just after the collision is greater than 24 m s^{-1}.

Initial $p = 240{,}000 + -6{,}000 = +234000$ kgms^{-1}

∴ Final $p = +234000$ kgms^{-1}

$V = P/m = +234000/(8000+1500) = +24.63$ ms^{-1} **[2]**

(b) Calculate the mean force acting between the lorry and truck during the collision which lasts 20 ms.

Forces on truck & lorry are equal & opposite so just need to calculate for one.

$$F = \frac{\Delta mv}{\Delta t} = m\frac{\Delta v}{\Delta t}$$

mean force = 2.15×10^{6} N **[2]**

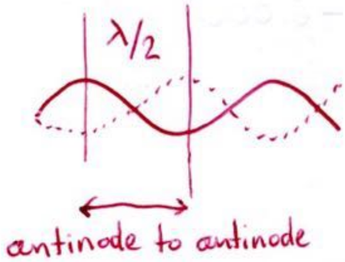
For lorry $F = 8000 \times (30 - 24.63)/20 \times 10^{-3} = 2.15 \times 10^{6}$ N

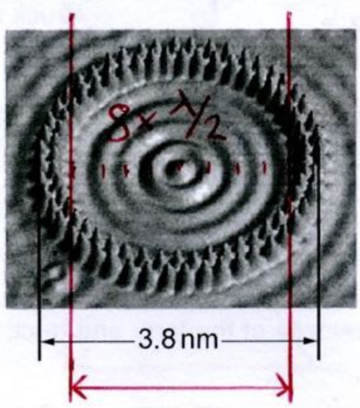
or truck $F = 1500 \times (-4 - 24.63)/20 \times 10^{-3} = -2.15 \times 10^{6}$ N

SECTION C

Answer **all** the questions.

27 Fig. 27 shows a scanning tunnelling microscope (STM) scan of iron atoms formed into a double ring on a copper surface. The outer ring has a diameter of 3.8 nm and consists of 48 iron atoms.





$= 4\lambda$

Fig. 27

37mm = 3.8 nm

29mm = $29 \times \frac{3.8}{37} = 2.98$nm

(a) Use the data from the STM to calculate the diameter of an iron atom.

$C = \pi d = \pi \times 3.8 \times 10^{-9} = 1.194 \times 10^{-8}$ m

$\therefore d_{atom} = 1.194 \times 10^{-8} / 48 =$ diameter = 2.49×10^{-10} m **[2]**

or 2.5×10^{-10} m

(b) **(i)** Describe evidence from Fig. 27 that indicates that free electrons trapped inside the ring of iron atoms have a wavelength.

The waves are equally spaced indicating a fixed wavelength / Need fixed λ for standing waves. **[1]**

(ii) Using **Fig. 27**, make appropriate measurements to show that the wavelength of these free electrons is about 0.7 nm.

From diagram $4\lambda = 2.98$nm

$\therefore \lambda = \frac{2.98\text{nm}}{4} = 0.745$ nm **[2]**

≈ 0.7nm

(iii) Calculate the momentum of each electron.

$h = 6.6 \times 10^{-34}$ J s

$\lambda = h/p$

$p = h/\lambda = 6.63 \times 10^{-34} / 0.7 \times 10^{-9} =$

momentum = 9.5×10^{-25} kg m s^{-1} **[1]**

(iv) Calculate the kinetic energy of each electron.

$p = mv$

$\therefore \; p^2 = m^2 v^2$

kinetic energy = 5.0×10^{-19} J **[2]**

$\frac{p^2}{m} = mv^2$

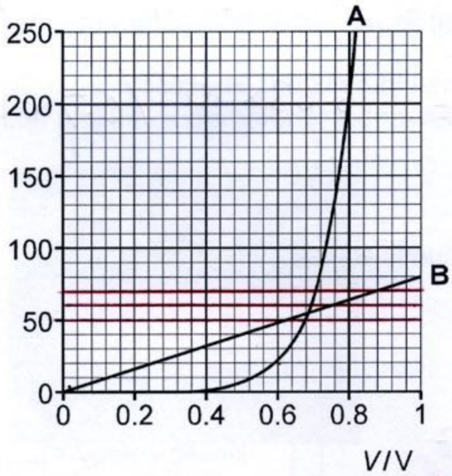
$\frac{p^2}{2m} = \frac{1}{2}mv^2 = E_K$

$E_K = \frac{(9.5 \times 10^{-25})^2}{2 \times 9.11 \times 10^{-31}} = 4.95 \times 10^{-19}$ J

Can also do by calculating V.

28 Fig. 28.1 shows two *I-V* graphs **A** and **B**, for a diode and a resistor of fixed resistance.

□ = 10mA



□ = 0.04

Fig. 28.1

(a) (i) State which of the two graphs relates to the diode.
Explain your decision.

A is the diode as it is not linear.

[1]

(ii) Calculate the resistance of the fixed resistor.

$R = V/I = 1/80\times10^{-3} =$

resistance = 12.5 Ω **[1]**

(b) (i) Suggest why the diode should **not** be connected directly across a 1.5 V supply in its conducting direction.

The current will become too high and overheat the diode

[1]

(ii) The diode and resistor are connected in series across a 1.5 V supply. The diode is connected in its conducting direction.
Use **Fig. 28.1** to predict the current drawn from the supply.
Make your method clear.

In series so currents must be the same and voltages must add up to 1.5V. Need horizontal line where two V values add to 1.5V.

current = 65mA mA **[2]**

I/mA	V_R	V_D	V_T
50	0.64	0.68	1.32
60	0.76	0.69	1.45
70	0.88	0.70	1.58

so around 65 mA

i.e. For full scale deflection ↓ so $V_{max} = IR = 100 \times 10^{-6} \times 1000 = 0.1\text{V}$

(c) A sensitive ammeter has a full scale deflection of 100 µA and a resistance of 1000 Ω. The meter remains undamaged for voltages across it of up to 0.6 V.

To protect the meter against accidental misconnection, two diodes are connected in parallel across the meter as shown in Fig. 28.2. The diodes have the same *I-V* graph as the diode shown in Fig. 28.1.

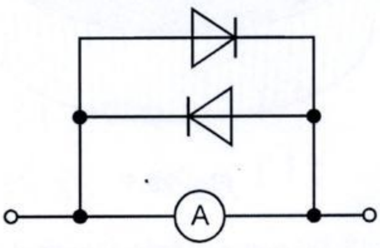


Fig. 28.2

Suggest how the diodes protect the meter from accidental current overload, and why they have little effect during normal operation. You may wish to make numerical calculations with your reasoning.

At full scale reading on ammeter the p.d. across it is 0.1 V. At 0.1V the diodes are non-conducting so have no effect. At 0.6V the resistance of the diode drops to $R = V/I = 0.6/20 \times 10^{-3} = 30\ \Omega$ which is much less than the 1000 Ω meter. so the current bypasses the meter **[4]** protecting it. Two diodes are needed to allow the current to bypass the meter in both directions.

29 This question is about an experiment to find the terminal velocity of a large paper cake case, as shown in Fig. 29.1, falling in air.

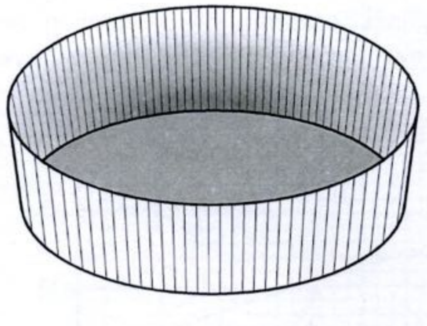


Fig. 29.1

(a) The paper case is dropped from rest and falls a vertical distance of 1.85 m.
13 students use ± 0.1 s stop clocks to time the fall. Fig. 29.2 shows a dot plot of the data obtained.

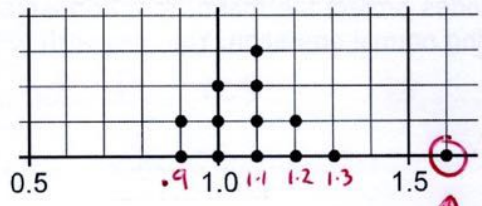


Fig. 29.2

(i) The single 1.6 s reading was treated as an outlier.

Calculate the mean time of drop for the remaining data and estimate the uncertainty.

(2× 0·9) + (3×1) + (4×1·1) + (2×1·2) + 1·3/12 =

range = 1·3 − 0·9 = 0·4

spread = 0·4/2 = ± 0·2

mean time of drop = 1·1 ± 0·2 s **[2]**

(ii) Explain why the 1.6 s reading was treated as an outlier.

It is greater than 2× spread from the mean. **[1]**

(iii) The vertical distance is measured as 1.85 ± 0.02 m due to the uncertainty in the release position.

Calculate your best estimate for the terminal velocity of the paper case and the uncertainty, using the data.

Make your method clear and justify how you estimated the uncertainty.

$V_t = 1.85/1.1 = 1.682 \text{ ms}^{-1}$

%U in t = $0.2/1.1 \times 100 = 18\%$

%U in d = $0.02/1.85 \times 100 = 1.1\%$

Overall %U ≈ 20% $20/100 \times 1.682 = 0.34 \text{ ms}^{-1}$

terminal velocity = 1.7 ± 0.3 m s^{-1} **[3]**

(iv) Suggest **one** systematic error that exists in this method of finding the terminal velocity, and how it affects the estimate.

This method assumes the cake case reaches terminal velocity instantly. For some of the drop it will be below Vt so the value arrived at will be systematically low. **[2]**

Question 29 continues on page 26

(b) An improved method for finding the terminal velocity for the same falling paper case gives the data table and distance fallen against time graph shown in Fig. 29.3.

time / s	distance fallen / s	
0	0.43	
0.1	0.43	0.00
0.2	0.43	0.00
0.3	0.43	0.00
0.4	0.44	0.01
0.5	0.49	0.05
0.6	0.60	0.11
0.7	0.72	0.12
0.8	0.94	0.22
0.9	1.17	0.23
1.0	1.38	0.21
1.1	1.61	0.23
1.2	1.84	0.23
1.3	2.08	0.24
1.4	2.28	0.20
1.5	2.28	0.00
1.6	2.28	0.00

mean = 0.2267m

$v = \frac{0.2267}{0.1}$

$= 2.27 ms^{-1}$

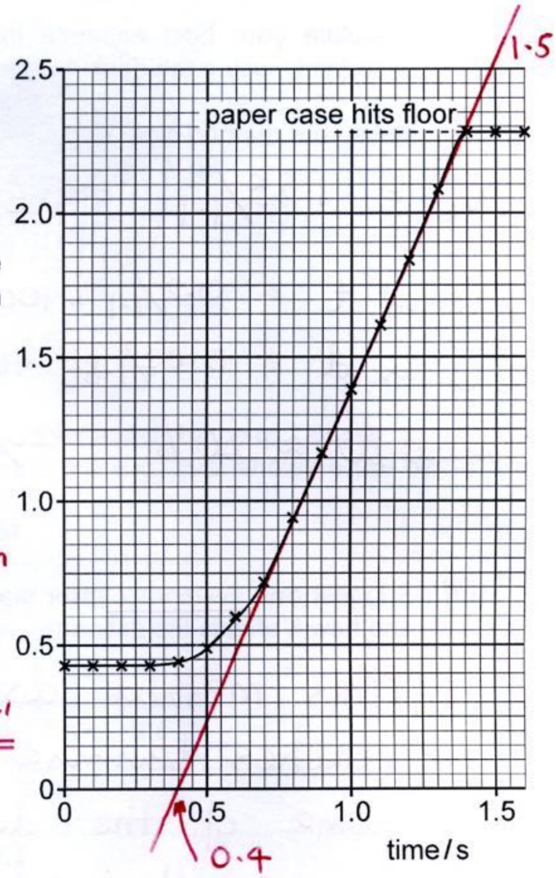


Fig. 29.3

(i) Use the data from the table or the graph to make a new estimate for the terminal velocity. The table has a blank column for you to use, if required. Make your method clear.

$v = \Delta s / \Delta t$ = gradient $= \frac{\Delta y}{\Delta x}$ $2.5m / 1.5 - 0.4 = \frac{2.5}{1.1} =$

terminal velocity = 2.27 m s^{-1} **[2]**

(ii) Describe an experiment that could give the data in Fig. 29.3 and justify **one** way in which this method is better than that in **(a)**.

Video the falling case infront of a ruler with a stop clock in the frame. Record the position every 0.1s. The advantage is you can see when terminal velocity is reached so eliminating the systematic error.

[3]

END OF QUESTION PAPER