

1(a). A flute is a musical instrument made from a long tube that is open at both ends.

A stationary sound wave in the tube produces a musical note.

The lowest frequency note that a standard flute produces in air is 262 Hz.

The speed of sound in air at a temperature of 20°C is 340 m s⁻¹.

Show that a standard flute has an approximate length of 0.65 m.

[3]

(b). In an ideal gas, the speed v of sound is given by

$$v = \left(\frac{\gamma RT}{M} \right)^{1/2}$$

where

γ is a dimensionless constant that depends on the gas

R is the molar gas constant

T is the absolute temperature

M is the molar mass of the gas.

The table below shows values of γ and M for both air and helium.

Gas	γ	$M/\text{g mol}^{-1}$
Air	1.40	29.0
Helium	1.67	4.00

- i. The kinetic model of an ideal gas assumes that there are a large number of particles in rapid, random motion.

State **two** further assumptions for the kinetic model of an ideal gas.

1 _____

2 _____

[2]

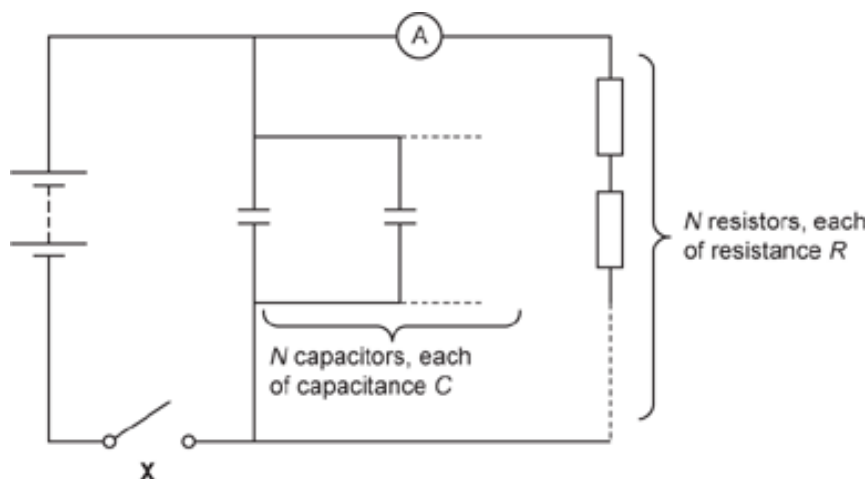
- ii. A standard flute is placed inside a sealed chamber.

The chamber is filled with helium at a temperature of -10°C .

Calculate the lowest frequency that the flute could produce inside the chamber.

frequency = Hz [4]

- 2(a).** A group of students investigate the circuit shown in the figure below.



There are N capacitors, each of capacitance C , connected in parallel.

There are N resistors, each of resistance R , connected in series.

Initially, the students close the switch **X**. They then note the reading on the ammeter.

The students then open the switch. They record the time T for the reading on the ammeter to fall to half of its initial value.

The table below shows the students' results.

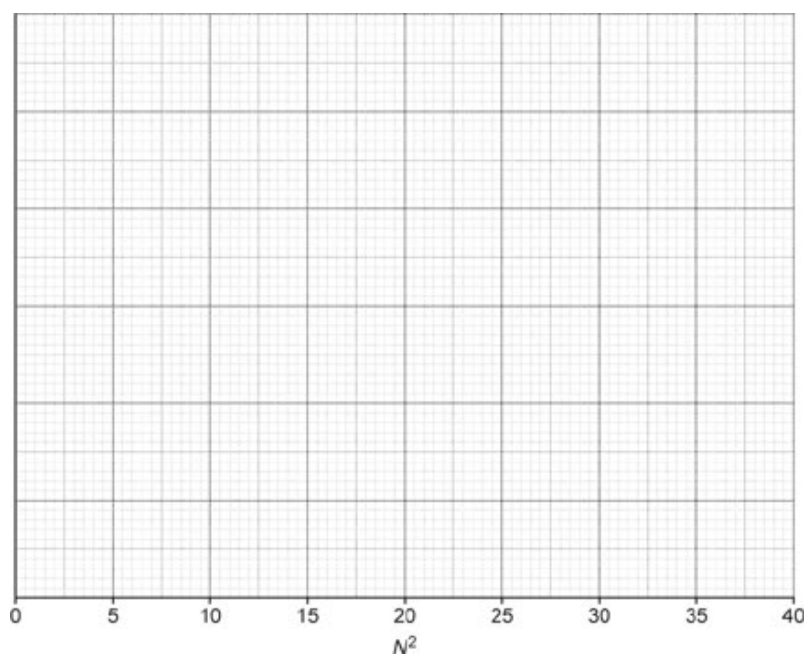
<i>N</i>	<i>T/s</i>			
	1	2	3	Mean
1	14.7	14.1	14.3	
2	50.3	49.6	50.1	
3	126.6	126.3	125.2	126.0
4	224.4	224.3	225.9	224.9
5	356.1	354.3	345.6	352.0
6	500.4	512.7	499.5	504.2

Complete the last column for *N* = 1 and *N* = 2 in the results table.

[1]

(b). The students begin to plot a graph of *T* (y-axis) against *N*² (x-axis).

- i. Complete the graph below and plot the 6 results from the table. You are **not** expected to include error bars.



[4]

- ii. Draw a straight line of best fit on the graph.

[1]

- iii. Calculate the gradient of the straight line of best fit.

gradient = s [2]

- iv. The value of C is known to be $1000\ \mu\text{F} \pm 5\%$.

Use your gradient value from (iii) to find a value for R , in units of $\text{k}\Omega$, including an **absolute** uncertainty.

$$R = \dots\dots\dots \pm \dots\dots\dots \text{ k}\Omega \text{ [2]}$$

(c). Following the investigation, the students discovered that the sixth $1000\ \mu\text{F}$ capacitor connected to the circuit was actually two $470\ \mu\text{F}$ capacitors connected in parallel.

- i. State the type of error caused by this mistake.

[1]

- ii. Explain the effect that this error would have had on the calculated value of R .

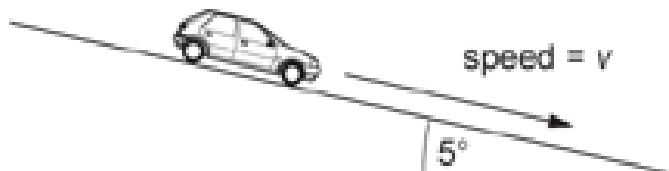
[1]

3(a). A car of weight $9300\ \text{N}$ is moving at speed v . The total resistive force, F , acting against the motion of the car is given by the formula

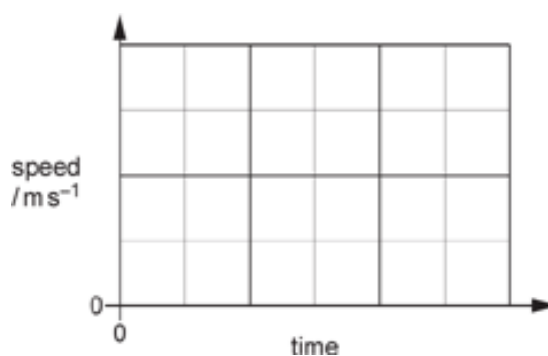
$$F = kv^2$$

where k is a constant.

The car is allowed to roll from rest down a slope of 5° to the horizontal. The engine of the car is not switched on. The car reaches a maximum speed of $30\ \text{m s}^{-1}$.



- i. Sketch a graph on the axes below to show how the speed of the car changes over time. Add a suitable value to the vertical axis.



[2]

- ii. Explain why the car reaches a maximum speed.

[2]

- iii. Show that the value of k in the equation $F = kv^2$ is about 1.

[3]

(b). The car is now moving along a straight, level track. The engine of the car delivers a maximum power of 75 kW.

Calculate the maximum speed of the car.

maximum speed of car = m s⁻¹ [3]

(c). Changes are made to the engine of the car so that it can produce double the original maximum power.

Explain why the maximum speed of the modified car is **not** doubled.

[2]

4. Which row in the table shows two equivalent physical quantities?

A	0 °C	−273.15 K
B	1 kg m s ^{−1}	1000 N s
C	10 kW	10 000 N m
D	1.0 mPa	0.0010 N m ^{−2}

Your answer

☐

[1]

5. What are the SI base units of the Boltzmann constant k ?

- A** J K^{−1}
- B** kg m s^{−2} K^{−1}
- C** kg m² s^{−2} K^{−1}
- D** potential difference

Your answer

☐

[1]

6. Which is an S.I. base unit?

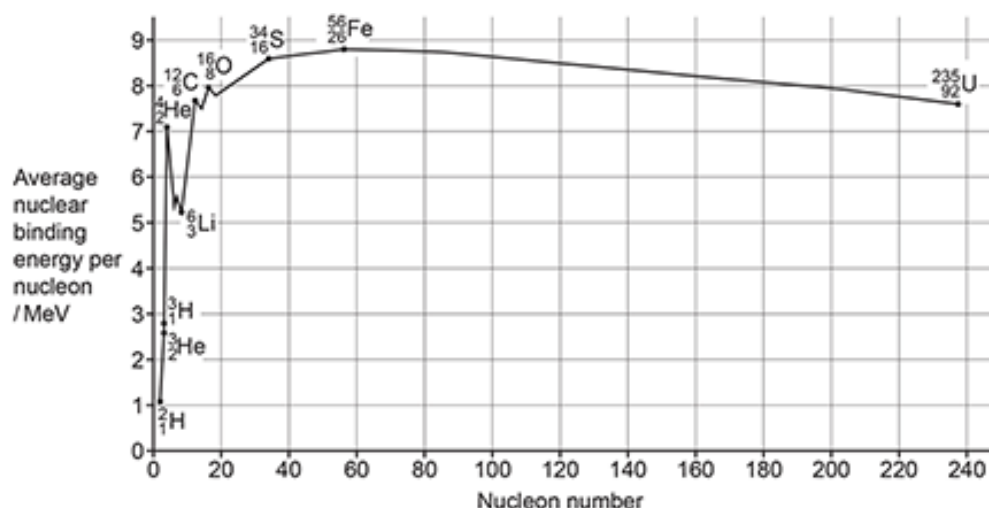
- A** amp
- B** coulomb
- C** ohm
- D** volt

Your answer

☐

[1]

7. The diagram below shows the average nuclear binding energy per nucleon for a number of different isotopes.



The main nuclear fusion reaction in the Sun is between nuclei of deuterium (^2_1H) and tritium (^3_1H).

This reaction can be written as shown below.



- i. Explain why isotopes with low mass numbers, such as hydrogen, are those which undergo nuclear fusion.

[1]

- ii. Use the diagram given at the start of this question to show that, for the reaction of deuterium and tritium, the energy released in each fusion event is approximately 3×10^{-12} J.

[3]

- iii. The Sun's mass decreases by 4.3×10^9 kg every second. Assume that the mass loss is only due to this reaction.

Calculate the number of fusion events per second occurring in the Sun.

number of fusion events per second = s^{-1} [2]

8. What are the base units of a kilowatt-hour?

- A J
- B kg m² s⁻¹
- C kg m² s⁻²
- D Ws

Your answer

[1]

9. The table shows the speed and wavelength of yellow light in air.

Quantity	Air	Glass
Speed of light / m s ⁻¹	3.00 × 10 ⁸	
Wavelength / nm	588	
Frequency / THz		

The refractive index at the air glass boundary is 1.52.

- i. Calculate the frequency, in THz, of yellow light in air.
Record your answer in the table.

[1]

- ii. Complete the table for yellow light in glass.

[2]

10(a). A stationary sound wave is set up in a closed resonance tube as shown in Fig. 6.1.

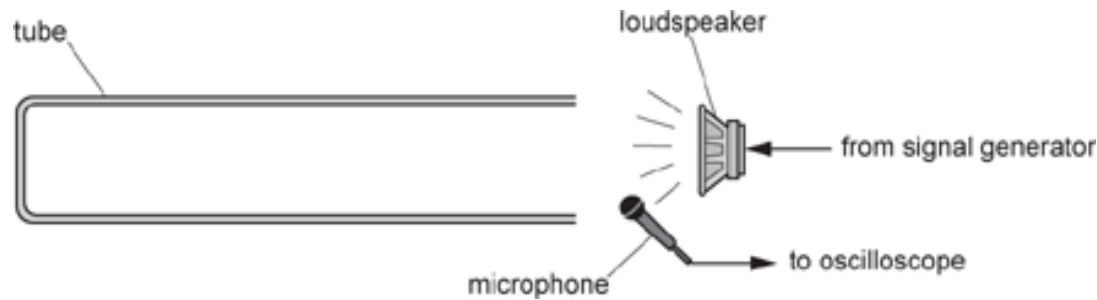


Fig. 6.1.

Sound is produced by a signal generator connected to a loudspeaker. The sound is detected by a microphone connected to an oscilloscope.

The time-base setting on the oscilloscope is 1 ms cm^{-1} .

The signal generator is adjusted until the fundamental mode of vibration is detected. **Fig. 6.2** shows the trace on the oscilloscope.

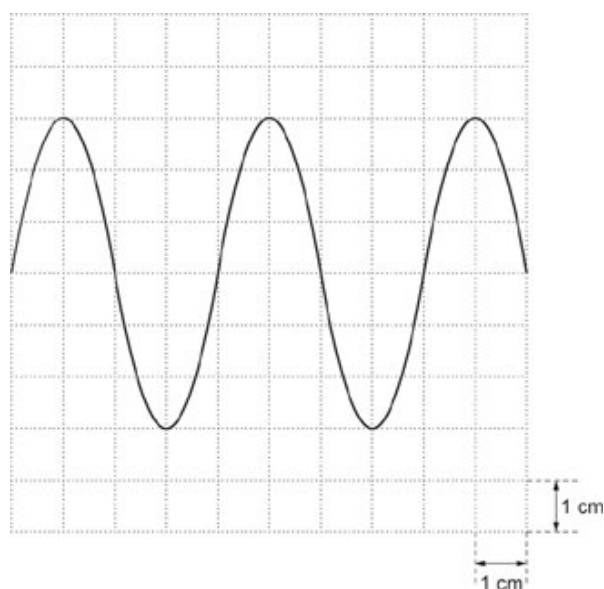


Fig. 6.2

Use **Fig. 6.2** to determine the frequency f_0 of the fundamental mode of vibration.

$$f_0 = \dots\dots\dots \text{ Hz [2]}$$

(b). Draw on Fig. 6.3 the stationary wave pattern for the fundamental mode of vibration.

Label on Fig. 6.3 the positions, if any, of any nodes **N** and any antinodes **A**.



Fig. 6.3

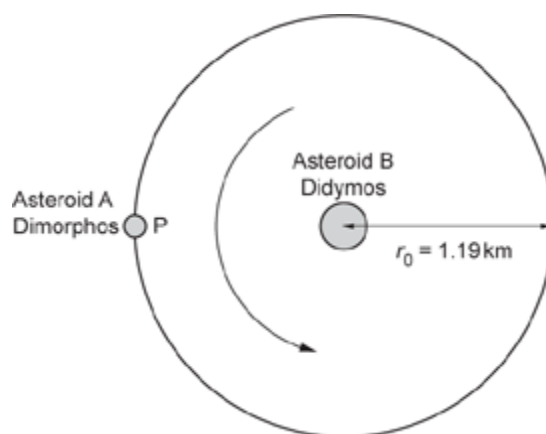
[2]

(c). The frequency of the signal generator is increased until the next harmonic is displayed on the oscilloscope.

Calculate the frequency f_n of the next harmonic.

$$f_n = \dots\dots\dots \text{ Hz [1]}$$

11. In space, Asteroid A, called Dimorphos travels at constant speed in a circle around a larger Asteroid B, called Didymos. The diagram shows Asteroid A at position P.



The distance r_0 between Asteroid A and Asteroid B is 1.19 km.

The time T_0 for Asteroid A to travel once around Asteroid B is $4.29 \times 10^4 \text{ s}$ (11 hours 55 minutes).

In 2022, the NASA DART mission impact caused Asteroid A to follow a different circular path round Asteroid B.

The new time T_N for Asteroid A to travel once around Asteroid B was reduced by 30 minutes.

- i. Show that the ratio

$$\frac{\text{new time to travel around Asteroid B } T_N}{\text{original time to travel around Asteroid B } T_0}$$

is approximately 0.958.

[1]

- ii. The relationship between the distance r from the centre of Asteroid B to the centre of Asteroid A and the time T for Asteroid A to travel around Asteroid B is

$$r^3 \propto T^2$$

Calculate the new distance r_N from the centre of Asteroid B to the centre of Asteroid A. Give your answer in km and to **3** significant figures.

$$r_N = \dots\dots\dots \text{ km [3]}$$

12. In an experiment, a trapdoor and electromagnet are used to determine the acceleration of free fall of a ball.

The distance the ball falls is h and the time taken for the ball to fall is t .

The experiment is repeated for different values of h .

The table shows the results. Values of $\sqrt{h}$ have been included.

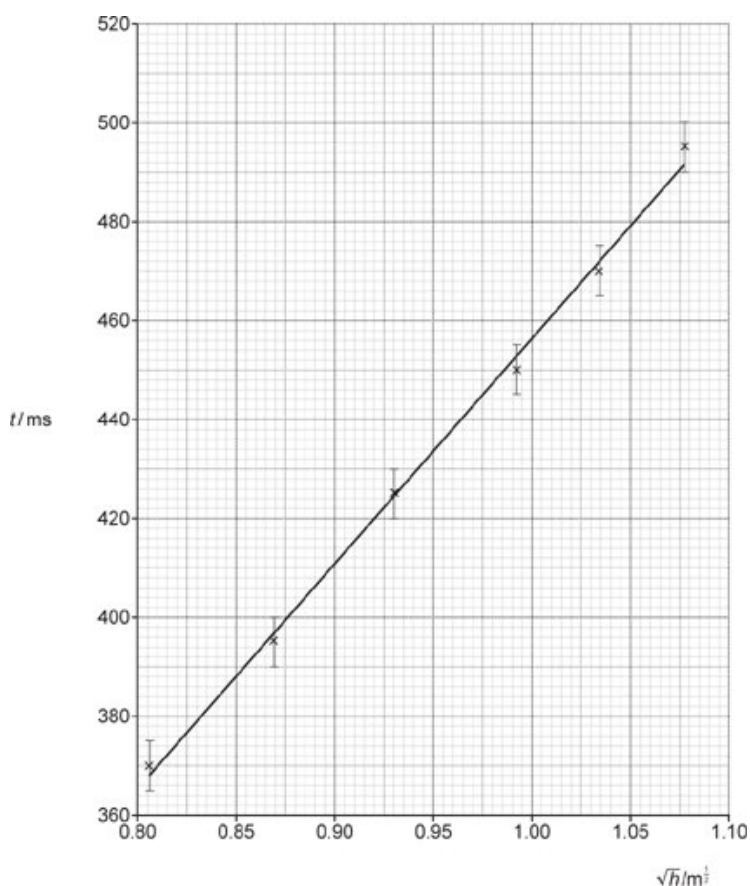
h/m	$\sqrt{h}/\text{m}^{\frac{1}{2}}$	t/ms
0.650	0.806	370 ± 5
0.755	0.869	395 ± 5
0.865	0.930	425 ± 5
0.985	0.992	450 ± 5
1.070	1.034	470 ± 5
1.160	1.077	495 ± 5

It is suggested that the relationship between t and h is

$$t = \sqrt{\frac{2}{g}}\sqrt{h} + k$$

where g is the acceleration of free fall and k is a constant.

A graph of t / ms on the y-axis against $\sqrt{h}/\text{m}^{\frac{1}{2}}$ on the x-axis is plotted.



- [illegible]

13. A pulsar is a rapidly rotating neutron star that emits radio waves.

A typical neutron star can be modelled as a sphere with mass $\approx 2 \times 10^{30}$ kg and radius ≈ 10 km.

Show that the average density of a neutron star is similar to the average density of an atomic nucleus.

- [3]**

14. A cloud is made up of droplets of water falling at terminal velocity.

- i. The terminal velocity v of a small sphere of density ρ_s and radius r falling through a fluid of density ρ_f is given by the formula:

$$v = \frac{2gr^2(\rho_s - \rho_f)}{9\eta}$$

where η is a constant for the fluid and g is the acceleration of free fall.

Water droplets of rain fall to the ground whereas water droplets in mist appear to float.

Use the formula above to suggest why.

[2]

- ii. A student models water droplets falling through air using small solid spheres in a liquid.

The table shows properties of the materials available to the student.

Material	Solid density, $\rho_s / \text{kg m}^{-3}$	Liquid density, $\rho_f / \text{kg m}^{-3}$	Approximate value of $\eta / 10^{-3} \text{ kg m}^{-1} \text{ s}^{-1}$
Water (liquid)		1000	1
Sunflower oil (liquid)		920	50
Steel (solid sphere)	7 800		
Lead (solid sphere)	11 300		

Describe an experiment to verify the expression given in (i) as accurately as possible. As part of your answer, estimate the **lowest** terminal velocity if the student uses a solid sphere of diameter = 1 mm.

[6]

15(a). Large power stations generate an electrical power of about 1 GW.

Current methods of energy production that use nuclear fusion are unable to produce enough energy for large-scale energy production. A proposed method of controlling nuclear fusion is inertial confinement fusion (ICF). ICF uses a large number of powerful lasers to create the high temperatures required for nuclear fusion to occur.

One ICF experiment uses a network of capacitors to store the energy needed to power the lasers. When the network is fully charged:

- potential difference across the network = 24 kV
 - total energy stored in the network = 400 MJ
- i. Calculate the total capacitance, C , of the network.

$C = \dots\dots\dots F$ [2]

- ii. Explain why the individual capacitors in the network should be connected in parallel in order to produce this total capacitance.

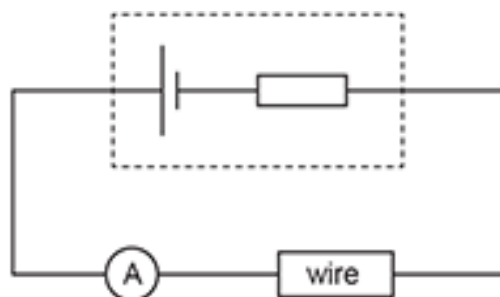
[1]

(b). The total stored energy must be released in a time of less than 1 millisecond.

Explain, using a calculation, why the lasers are powered by the network of capacitors instead of being connected directly to the mains electricity supply.

[2]

16. A student uses the circuit below to investigate the resistivity of a wire.



The cell has e.m.f. ε and internal resistance r . The wire has resistivity ρ and diameter d .

The student takes five measurements of the diameter of the wire, which are shown in the table below.

Diameter / mm	0.460	0.450	0.455	0.495	0.455
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- i. Suggest how the student made these measurements.

[2]

- ii. The student calculates the value of the diameter as $d = 0.455 \pm 0.005$ mm.

Explain how the student calculated the value of the diameter, and its uncertainty, from the data in the table above.

[3]

17. A student carries out an experiment to determine the speed v of sound in air. The student forms stationary sound waves in a resonance tube with water at the bottom as shown in **Fig. 7.1**.

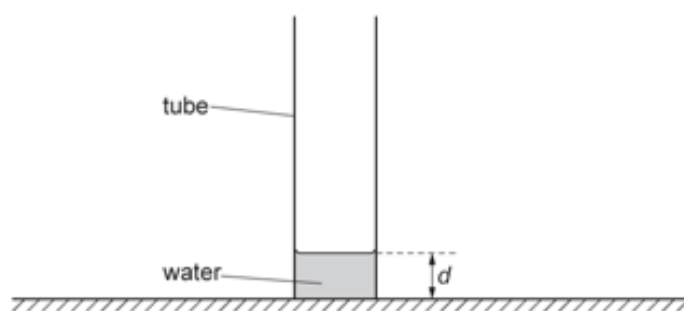


Fig. 7.1

The depth of the water is d .

Sound is produced by a signal generator connected to a loudspeaker. The sound is detected by a microphone connected to an oscilloscope.

The signal generator is adjusted. The frequency f of the fundamental mode of vibration of the sound in air is determined.

The experiment is repeated for different values of d .

The table shows the results. Values of $\frac{1}{f}$ have been included.

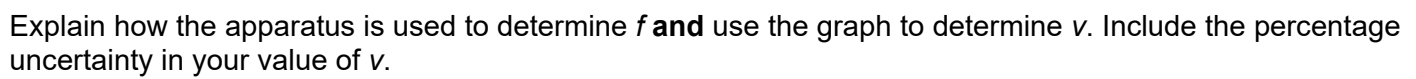
d / cm	f / Hz	$\frac{1}{f} / 10^{-3} \text{Hz}^{-1}$
5.0	140	7.1 ± 0.2
15.0	170	5.9 ± 0.2
25.0	210	4.8 ± 0.2
35.0	280	3.6 ± 0.2
45.0	420	2.4 ± 0.2
55.0	840	1.2 ± 0.2

It is suggested that the relationship between f and d is

$$\frac{1}{f} = -\frac{4d}{v} + c$$

where v is the speed of sound in air and c is a constant.

A graph of $\frac{1}{f} / 10^{-3} \text{Hz}^{-1}$ on the y-axis against d / cm on the x-axis is plotted as shown below.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

[6]

18(a). Electromagnetic radiation is incident on a metal plate. Photoelectrons are emitted.

The maximum kinetic energy of the emitted photoelectrons is 1.9 eV.

- i. Show that the maximum kinetic energy of the emitted photoelectrons, is about 3.0×10^{-19} J.

[1]

- ii. Determine the wavelength λ of the incident electromagnetic radiation.

$\lambda = \dots\dots\dots$ m [3]

(b). The intensity of the incident radiation is doubled.

State the change, if any, on

- i. the maximum kinetic energy of the photoelectrons emitted from the surface of the metal plate

[1]

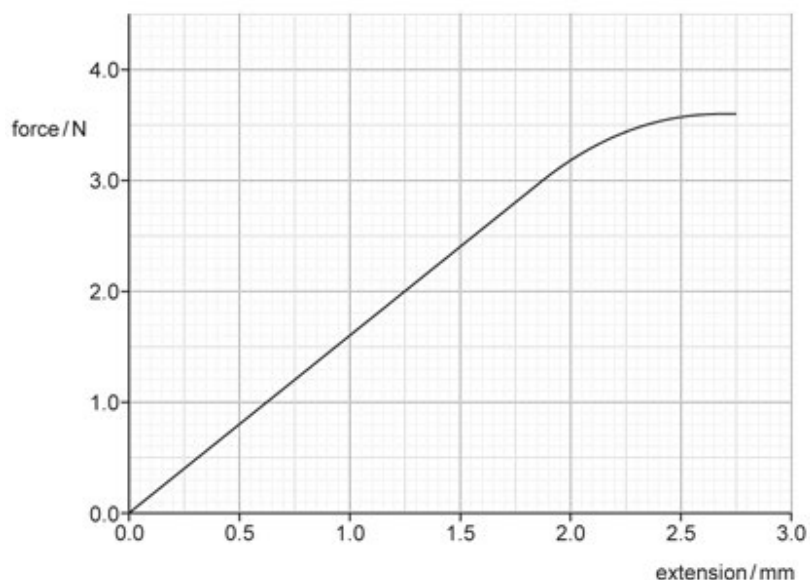
- ii. the rate of emission of the photoelectrons.

[1]

19. A metal wire has a length of 4.4 m. The Young modulus of the metal is 120 GPa.

In an experiment force is applied to the wire and the extension is measured.

The graph shows the variation of the extension of the wire with the force applied.



- i. The gradient of the linear section of the graph is 1.6 N mm^{-1} .

Determine the cross-sectional area A of the wire.

$$A = \dots\dots\dots \text{m}^2 \text{ [3]}$$

- ii. Use the graph to determine an estimate of the work done E_w in stretching the wire when a 3.5 N force is applied.

$$E_w = \dots\dots\dots \text{J [3]}$$

20. The figure below shows a stationary glider of mass m on an air track.

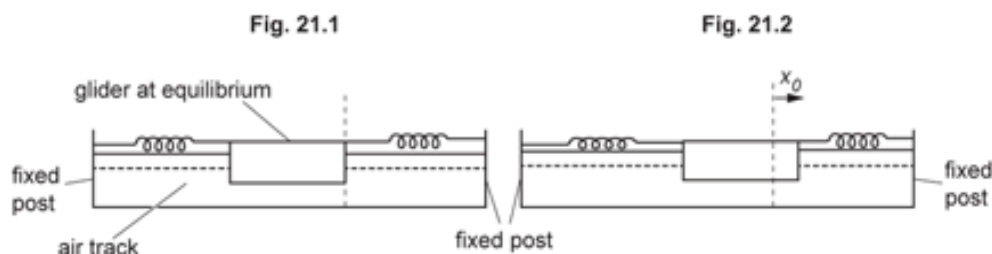
The glider has identical springs with force constant k attached to each end which are secured to fixed posts.

The air track blower is turned on and the glider is displaced a small distance x_0 , as seen in the figure. It is then released.

The glider moves horizontally in simple harmonic motion.

The springs remain in tension throughout the motion.

The time taken for 20 complete oscillations is measured, and the period T calculated.



The relationship between the period T , the mass of the glider m and the force constant k is described by the equation $T^2 = \frac{2\pi^2 m}{k}$.

- i. Show that the equation above is homogeneous by reducing the equation to SI base units.

[2]

- ii. Explain why the magnitude of the resultant force F on the glider is given by $F = 2kx$ where x is the displacement at any time.

[2]

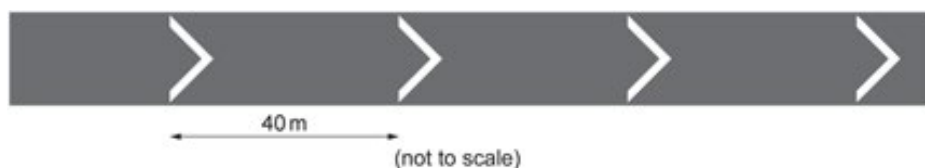
- iii. State and explain the effect, if any, of increasing the initial displacement on the period of the subsequent motion.

[2]

21(a). The diagram shows a road where vehicles travel at high speeds.

Markings painted on the road surface are spaced 40 m apart.

Drivers are advised to keep at least two markings visible on the road between them and the vehicle in front.



The maximum speed vehicles travel at on the road is 110 km / hr. The table shows data from a driving manual for a vehicle travelling on a straight, horizontal road.

Speed (km / hr)	Braking distance (m)	Stopping distance (m)
110	75	96

- i. Calculate the maximum speed v of vehicles on the road in S.I. units.

$$v = \dots\dots\dots \text{Unit} = \dots\dots\dots \text{[2]}$$

- ii. A vehicle passes over one of the markings.

Calculate time taken to travel the 40 m distance between the two markings.

$$t = \dots\dots\dots \text{s [1]}$$

- iii. Using the table, explain why having markings 40 m apart helps prevent collisions.

.....[3]

(b). A vehicle with mass 1600 kg is travelling at 110 km / hr.

The driver sees an obstruction and applies the brakes to bring the vehicle to rest in 5.6 s.

- i. Estimate the magnitude of the average resultant force F required to bring the vehicle to rest.

$$F = \dots\dots\dots \text{N [2]}$$

- ii. Explain the effect on the distance required to bring the vehicle to rest if the road has an upwards slope.

[2]

22. Which of these units is a base unit?

- A** A
B J
C m²
D N

Your answer

☐

[1]

23. A student experiments with microwaves emitted from a transmitter. The frequency f of the microwaves from the transmitter can be adjusted.

The microwaves are produced by an alternating current in the transmitter.

In one experiment, f is 11 GHz. In a wire in the transmitter, the magnitude of the **maximum** alternating current is 20 mA. The wire has cross-sectional area $1.4 \times 10^{-8} \text{ m}^2$ and is made of a metal with free electron number density $8.0 \times 10^{28} \text{ m}^{-3}$.

- i. Show that the maximum drift velocity of each free electron in the wire is about 0.1 mms^{-1} .

[3]

- ii. The student models the average motion of the free electrons in the wire as simple harmonic motion.

Use your answer to (i) to calculate the amplitude A of this motion.

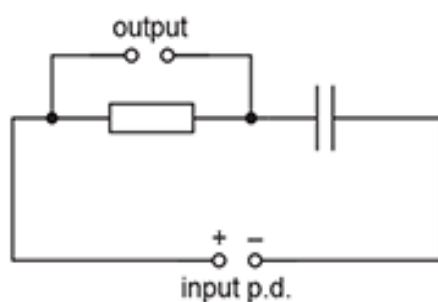
$A = \dots\dots\dots \text{ m}$ [3]

- iii. Without further calculation, explain how the maximum acceleration of a free electron varies as the frequency f is adjusted, provided that the maximum alternating current remains constant.

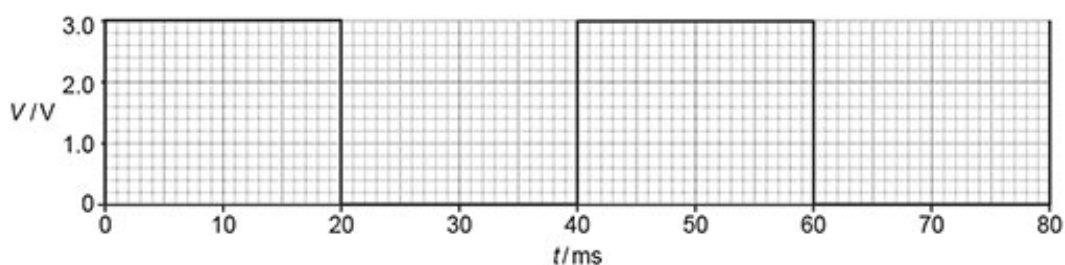
[2]

24.

The capacitor circuit shown in **Fig. 6.1** can be used to smooth oscillating electrical signals.

**Fig. 6.1**

- i. **Fig. 6.2** shows the input signal of potential difference (p.d.) V against time t .

**Fig. 6.2**

Calculate the frequency f of this input signal.

$f = \dots\dots\dots$ Hz [2]

- ii. **Fig. 6.3** shows the variation of the charge Q on the positive plate of the capacitor with time t .

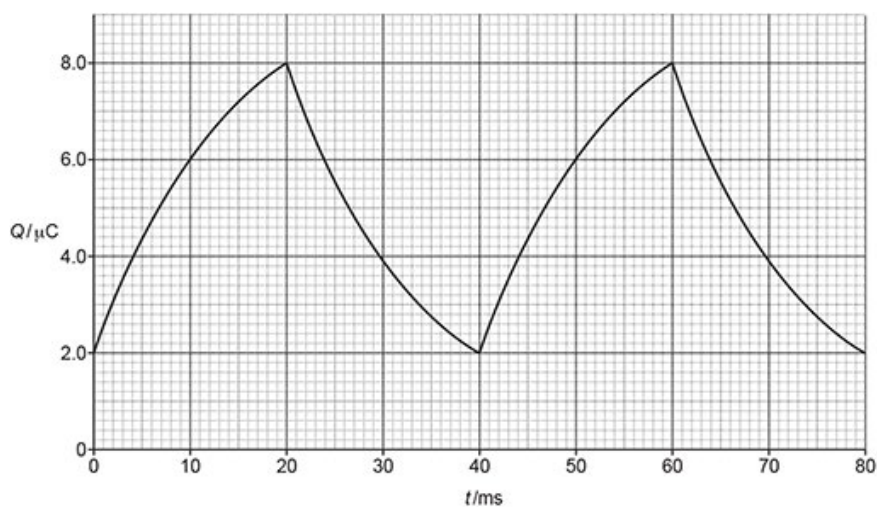


Fig. 6.3

Use a discharging section of the graph in **Fig. 6.3** to determine the time constant of the circuit. Give your answer in ms.

time constant = ms **[2]**

- iii. By drawing a suitable tangent to the graph in **Fig. 6.3**, calculate the maximum current in the resistor.

maximum current =A **[2]**

- iv. On **Fig. 6.4** below, sketch the variation of the current I in the resistor with time t . Include an appropriate label and scale on the vertical axis.

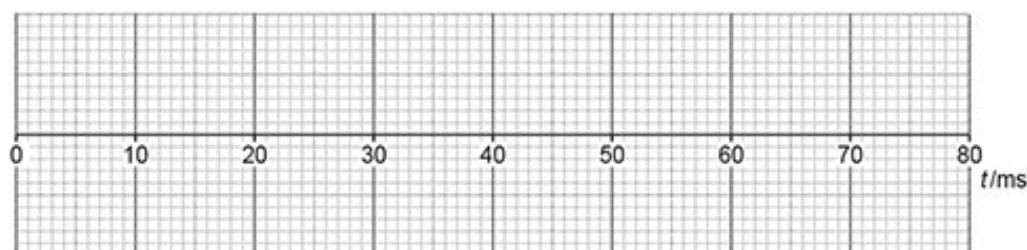


Fig. 6.4

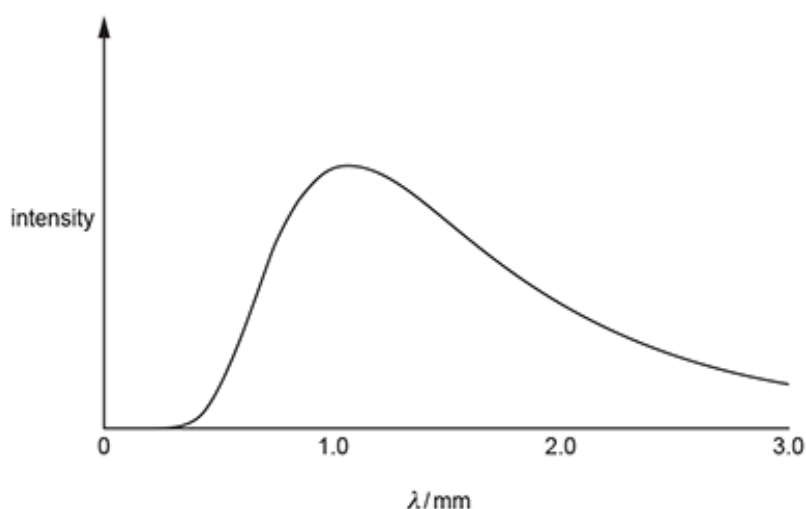
[3]

25. Astronomers can detect microwave background radiation coming from space in every direction.

The temperature of this microwave radiation is 2.7 K and its **total** intensity is about $3 \times 10^{-6} \text{ W m}^{-2}$.

The figure below shows how the intensity of the microwave background radiation varies with its wavelength λ .

The **peak** intensity is at a wavelength of 1.1 mm.



This spectrum of microwave background radiation changes with temperature according to Wien's displacement law.

- i. Suggest and explain how the spectrum might have looked in the distant past. You may draw on the figure to support your answer.

[2]

- ii. Calculate the energy of a photon which has a wavelength of 1.1 mm.

energy = J [2]

- iii. Estimate the number of photons of microwave background radiation incident per second on the back of your hand.

Assume that all emitted photons have the energy calculated in (ii), and that the back of your hand has a surface area of 150 cm^2 .

number of photons per second = s^{-1} [2]

- iv. A scientist suggests that the microwave background radiation could be used as an energy source.

The scientist proposes using large tanks of water to absorb the microwave radiation.

Estimate the maximum rise in temperature that could be produced per second for a large cylindrical tank of depth 5.0 m. Assume that all microwave radiation incident on the top of the tank is absorbed.

density of water = 1000 kg m^{-3}

specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$

maximum rise in temperature per second = $^{\circ}\text{C s}^{-1}$ **[3]**

26(a). The table shows some data on the planet Venus.

Mass / kg	4.87×10^{24}
Radius / km	6050
Density of atmosphere at surface / kg m^{-3}	65
Period of rotation about its axis / hours	5830

Calculate the magnitude of the gravitational field strength g at the surface of Venus.

Give your answer to **3** significant figures.

$g = \dots\dots\dots \text{N kg}^{-1}$ **[3]**

(b). Two identical space probes, **A** and **B**, land on a flat surface on Venus.

Probe **A** lands at the north pole. Probe **B** lands on the equator.

Each probe has mass 760 kg and volume 1.7 m^3 .

- i. Calculate the centripetal acceleration a of probe **B** at the equator due to the rotation of Venus about its axis.

$a = \dots\dots\dots \text{ms}^{-2}$ **[3]**

- ii. The atmosphere exerts the same upthrust on each probe.

Using your answer to **(a)**, calculate the upthrust acting on each probe.

upthrust = N **[3]**

- iii. Explain which probe will experience the greater normal contact force from the surface of Venus.

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

27(a). A gamma camera has several important components including a collimator, scintillator and photomultiplier tubes.

Suggest why the collimator needs to be long and narrow.

..... **[1]**

(b). State the function of the scintillator.

..... **[1]**

(c). In a single photomultiplier tube, a photon of light produces a $0.32 \mu\text{A}$ pulse of current for a duration of 1.2 ns .

Calculate the number of electrons responsible for this pulse of current.

number of electrons = **[2]**

(d). State one diagnostic application of a gamma camera.

..... **[1]**

28. A light-emitting diode (LED) can be used to determine the Planck constant h . When the LED just starts to emit light, the equation below is valid

$$eV = \frac{hc}{\lambda}$$

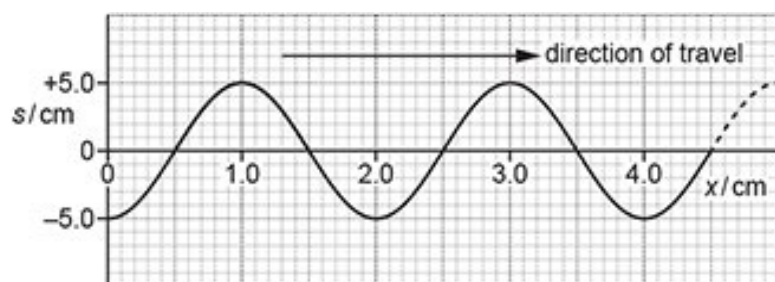
where V is the potential difference (p.d.) across the LED, λ is the wavelength of the light emitted, c is the speed of light in vacuum and e is the elementary charge.

In the equation above, $\frac{hc}{\lambda}$ is the energy of a photon emitted from the LED. Determine the S.I. base units for h .

base units = [2]

29.

A graph of displacement s against distance x for a **progressive** wave at time $t = 0$ is shown below.



Determine:

- i. the phase difference ϕ in radians between the points on the wave at $x = 1.5$ cm and $x = 2.5$ cm

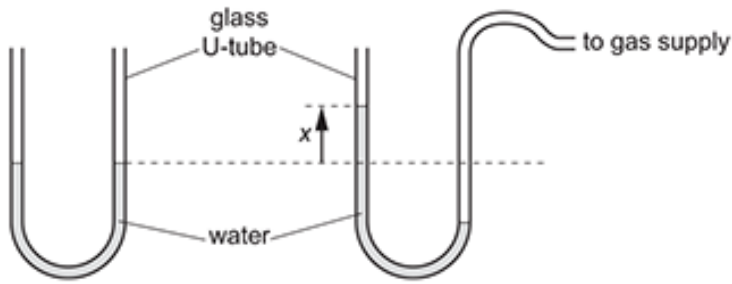
$\phi = \dots\dots\dots$ rad [1]

- ii. the displacement s at time $t = \frac{3}{4}T$ at $x = 1.5$ cm, where T is the period of the oscillations of the wave.

$s = \dots\dots\dots$ cm [1]

30.

The diagram shows a glass U-tube partially filled with a mass of water.



One end of the U-tube is connected to a gas supply of **constant** pressure and the other end is open to the atmosphere. The displacement of the water from its equilibrium position is x .

The density ρ of water is 1000 kg m^{-3} .

- i. The pressure from the gas supply raises the water in the U-tube. The vertical distance between the two levels of water in the two vertical sections of the U-tube is 10.0 cm ($x = 5.0 \text{ cm}$).

Δp is the difference between the gas pressure and atmospheric pressure. Calculate Δp .

$\Delta p = \dots\dots\dots \text{ Pa [2]}$

- ii. When the gas supply is disconnected, the water levels in the U-tube oscillates with simple harmonic motion. The acceleration a of the water level in the left-hand side of the U-tube is given by the equation

$$a = -\frac{2\rho g A}{m} x$$

where m is the mass of the water in the U-tube, A is the internal cross-sectional area of the U-tube, ρ is the density of water, g is the acceleration of free fall and x is the displacement of the water level in the left-hand side of the U-tube.

For this U-tube, $A = 1.0 \times 10^{-4} \text{ m}^2$ and $m = 0.052 \text{ kg}$.

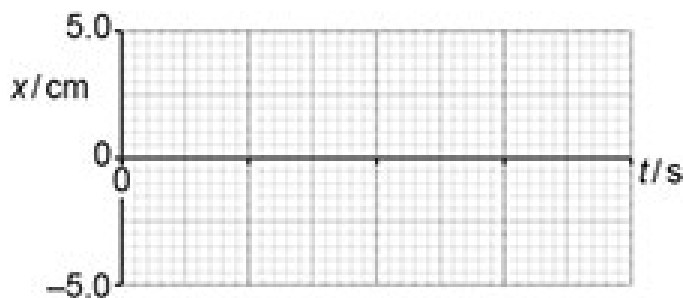
Show that the period T of the oscillations is about 1 second.

The oscillations of the water level are slightly **damped**.

At time $t = 0$, $x = 5.0$ cm.

2

Sketch a suitable graph of displacement x against time t for the oscillating water level. Add suitable values to the time t axis.



[3]

The U-tube is now connected to another gas supply where the pressure oscillates at a frequency of about 1 Hz.

3

Explain the effect this will have on the water in the U-tube.

[2]

31. An electric engine of mass 17 000 kg has a constant power output of 280 kW and it can reach a maximum speed of 42 ms^{-1} on horizontal rails. The maximum kinetic energy of the engine is 15 MJ.

The engine is initially at rest on long horizontal rails.

Show that the minimum time taken for the engine to reach its maximum speed is about 1 minute.

[1]

32.

A power supply of electromotive force (e.m.f.) 14.4 V and negligible internal resistance is connected by two identical metal wires to two filament lamps, as shown in **Fig. 25.3**.

**Fig. 25.3**

The current in the circuit is 3.0 A.

The potential difference across **each** lamp is 6.0 V.

The **total** length of the metal wire is 25.0 m. The cross-sectional area of the wire is 0.54 mm².

- i. Calculate the resistivity ρ of the metal from which the wire is made.

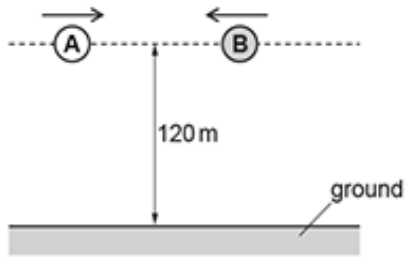
$$\rho = \dots\dots\dots \Omega \text{ m} \text{ [4]}$$

- ii. The number of electrons per unit volume n in the metal wire is $8.5 \times 10^{28} \text{ m}^{-3}$.

Calculate the mean drift velocity v of the electrons in the metal.

$$v = \dots\dots\dots \text{ m s}^{-1} \text{ [2]}$$

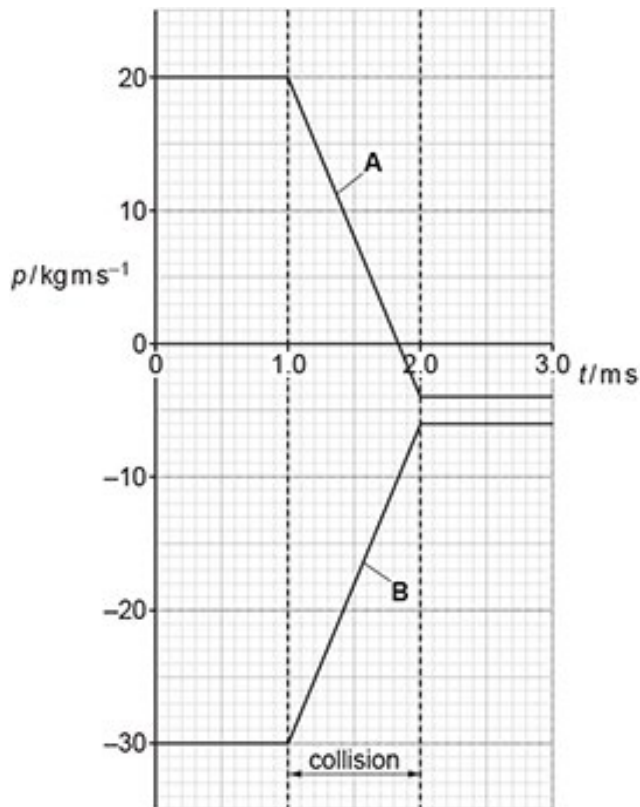
33(a). Two objects **A** and **B** are travelling horizontally and in opposite directions. The objects collide in mid-air at a height of 120 m above the horizontal ground, as shown below.



The mass of **A** is 2.0 kg and the mass of **B** is 3.0 kg.

After the collision the objects are joined together.

The momentum p against time t graphs for each object before, during and after the collision are shown below.



Calculate the magnitude of the horizontal velocity v of the combined objects immediately after the collision.

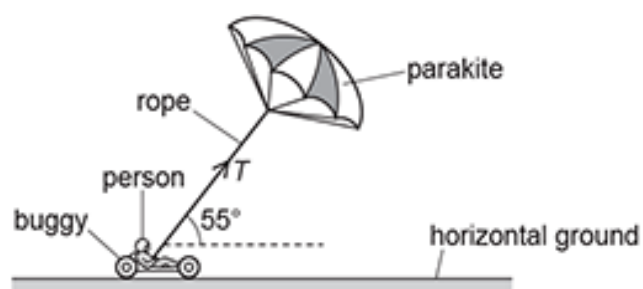
$$v = \dots\dots\dots \text{ m s}^{-1} \quad [2]$$

(b). Air resistance has negligible effect on the motion of the objects.

Calculate the time taken for the combined objects to reach the ground after the collision.

time taken = s **[3]**

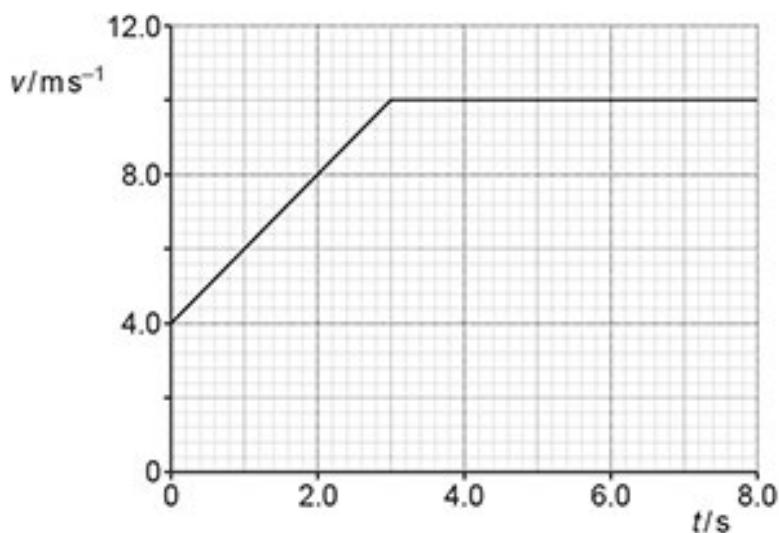
34. A person in a buggy is attached to a large parakite by a rope, as shown below.



Strong wind acting on the parakite moves the buggy along horizontal ground.

The rope makes an angle of 55° to the horizontal. The total mass of the buggy and person is 150 kg.

The velocity v against time t graph for the buggy is shown below.



At $t = 1.0$ s the buggy is accelerating.

- i. Use the graph to show that the acceleration of the person at $t = 1.0$ s is 2.0 m s^{-2} .

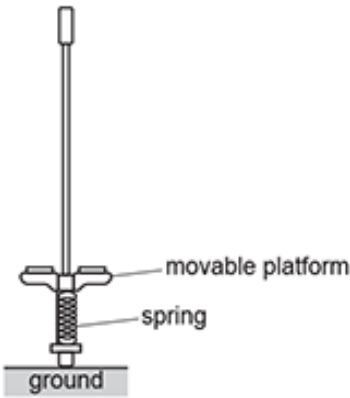
- ii. At $t = 1.0\text{ s}$ the tension T in the rope is 680 N and the total **horizontal** resistance acting on the buggy and person is R .

Calculate R by resolving the tension in the rope horizontally.

$R = \dots\dots\dots\text{ N [3]}$

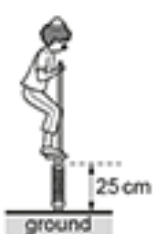
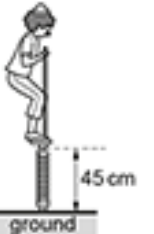
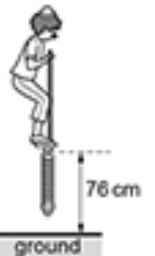
35. A pogo stick is a spring-based toy used by a circus clown for jumping vertically up and down.

A **compression** spring is fixed to the bottom of the pogo stick. The upper end of the spring is attached to a movable platform.



The force constant of the spring is $1.7 \times 10^4\text{ N m}^{-1}$.
The mass of the clown is 68 kg .
The mass of the pogo stick is negligible compared with the mass of the clown.

The table below shows the state of the spring and the clown in three different positions.

	Position A	Position B	Position C
			
State of spring	fully compressed	original length	original length
State of clown	stationary	Moving vertically upwards at maximum speed	stationary
Height of platform above the ground/cm	25	45	76

Describe how the force constant of the compression spring in the pogo stick can be verified in the laboratory.

[2]

36. A total of 3.8×10^7 electrons flow through a wire in a time of $1.2 \mu\text{s}$.

What is the current in the wire?

- A $6.1 \times 10^{-12} \text{ A}$
- B $7.3 \times 10^{-12} \text{ A}$
- C $5.1 \times 10^{-6} \text{ A}$
- D $3.2 \times 10^{13} \text{ A}$

Your answer

[1]

37. An electric cooker has two independent heating rings **A** and **B** as shown in **Fig. 7.1**.



Fig. 7.1

The cooker rings **A** and **B** are connected in parallel to a 230 V power supply. At maximum power, ring **A** has a power of 1100 W and ring **B** has a power of 1700 W.

- i. Show that the maximum current in the cooker is less than 13 A.

[2]

- ii. The cost of 1 kW h of energy is 18p.
Calculate the cost of using the cooker at maximum power for 30 minutes.

cost = p [1]

38(a). A student investigates the motion of a steel ball in oil in a laboratory.

The radius r of the ball is 8.1 mm.

The student uses a measuring cylinder and a digital balance to determine the density of the oil.
The student records the following measurements:

- mass of empty measuring cylinder = 96 g
- volume of oil added to measuring cylinder = 87 cm³
- total mass of measuring cylinder and oil = 169 g

Show that the density of the oil is about 840 kg m⁻³.

[2]

(b). The steel ball is submerged in the oil.

Show that the upthrust acting on the steel ball is 1.8×10^{-2} N.

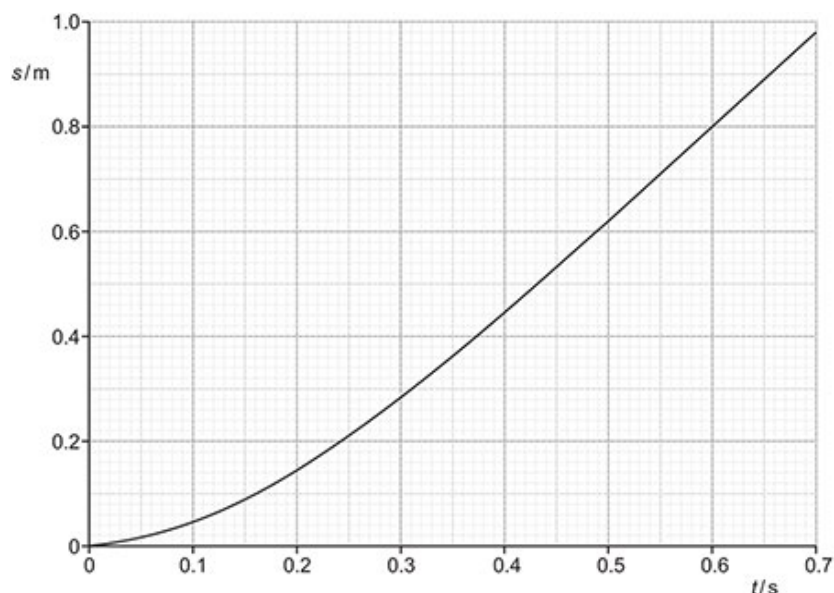
[2]

(c). The student fills a long tube with the oil.

The student drops the steel ball from rest at the surface of the oil at time $t = 0$.

The displacement s of the ball is measured from the surface of the oil.

The graph shows the displacement s against time t for the steel ball from the instant it enters the oil.



- i. The terminal velocity v of the steel ball is 1.8 m s^{-1} .

Describe and explain how this can be determined from the graph.

[3]

- ii. Use the graph to calculate the velocity u of the steel ball at time $t = 0.20 \text{ s}$.

$u = \dots\dots\dots \text{ m s}^{-1}$ [2]

- (d). The mass of the steel ball is 17 g .

The drag F acting on the steel ball falling through the oil is given by the equation $F = 6\pi\eta rv$

where η is a constant for the oil, r is the radius of the steel ball and v is the speed of the steel ball through the oil.

At $v = 1.8 \text{ ms}^{-1}$, the force F is equal to the **difference** between the weight of the steel ball and the upthrust acting on the steel ball.

Calculate η .

Include an appropriate unit.

$\eta = \dots\dots\dots$ unit $\dots\dots\dots$ **[3]**

END OF QUESTION PAPER