1 A length x is 50 mm ± 2 mm. Length y is 100 mm ± 6 mm. The length z is given by $z = y - x$.

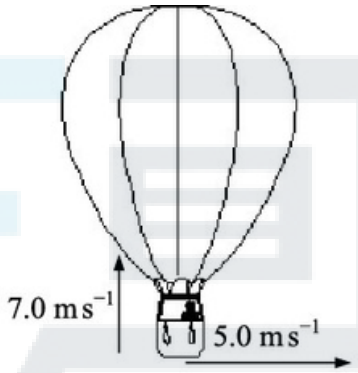
What is the best estimate of the uncertainty in z?

A ± 1 mm
B ± 4 mm
C ± 5 mm
D ± 8 mm

Your answer ☐

[1]

2 When a sandbag is dropped from a balloon hovering 1.3 m above the ground, it hits the ground at 5.0 ms–1. On another occasion, the sandbag is released from the balloon which is rising at 7.0 ms–1 when 1.3 m above the ground. There is also a crosswind of 5.0 m s–1.



At what speed does the sandbag hit the ground?

A 2.0 ms^{-1}
B 5.4 ms^{-1}
C 10 ms^{-1}
D 13 ms^{-1}

Your answer ☐

[1]

3 What is the correct unit for specific heat capacity?

A $m^2s^{-2}K^{-1}$

B msK^{-2} $^{-1}$

C $m^2s^{-1}K^{-1}$

D $m^2s^{-2}K$

Your answer

[1]

4 Which physical quantity has the same base units as energy?

A moment

B momentum

C force

D pressure

Your answer

[1]

5 A car travels a distance 166 ± 2 m in a time 5.2 ± 0.1 s.

What is the best estimate of the speed of the car?

A32 ± 1 m s^{-1}

B32.0 ± 2.1 m s

C32.0 ± 0.2 m s^{-1}

D32 ± 0.999 m s^{-1}

Your answer

[1]

6 Fig.16 shows typical thinking, braking and stopping distances for cars driven at different initial speeds. The speed is shown in miles per hour (mph).

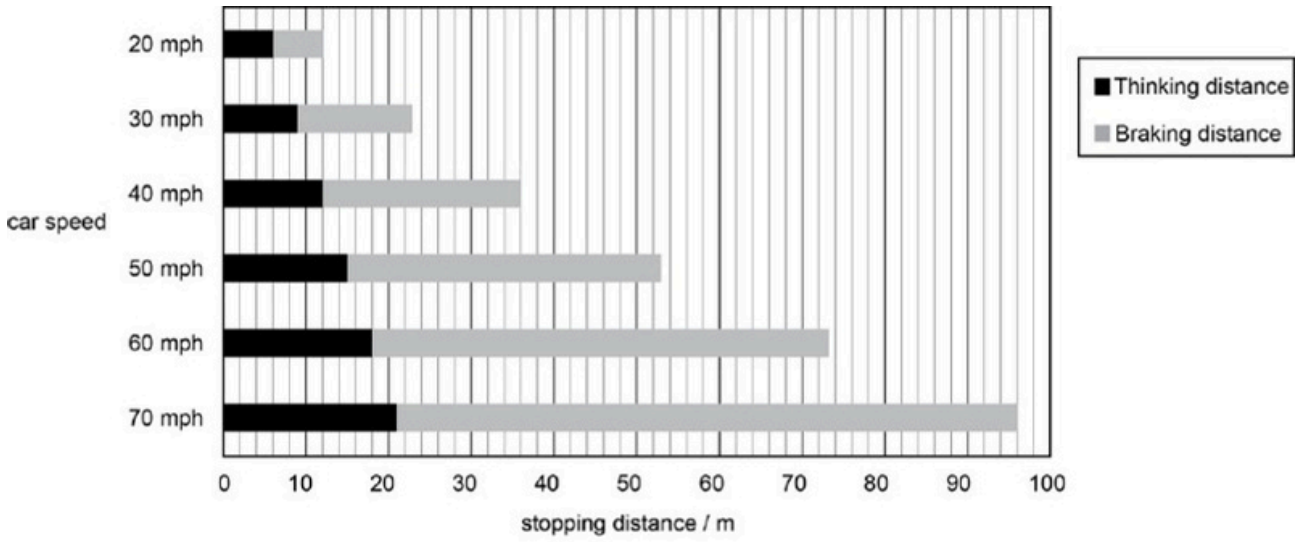


Fig. 16

A truck of mass 2300 kg is travelling at a constant speed of 22 m s−1 along a dry, level road. The driver reacts to a hazard ahead and applies the brakes to stop the truck. The reaction time of the driver is 0.97 s. The brakes exert a constant braking force of 8700 N.

(i)Calculate the magnitude of the deceleration of the truck when braking.

deceleration = _____ m s $^{-2}$ [2]

(ii)Show that the stopping distance of the truck is about 85 m.

[3]

(iii)Show that a speed of 22 m s $^{-1}$ is equivalent to about 50 mph (miles per hour). 1 mile = 1600 m

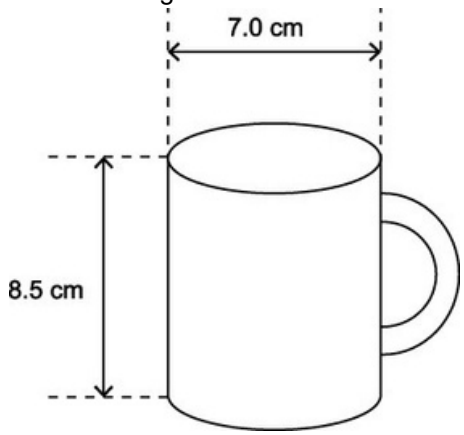
[1]

(iv)Use Fig. 16 and your answer to (ii) to compare the stopping distance of the car and the truck at 50 mph. Suggest relevant factors that may have affected the stopping distance of the truck.

---

[4]

7(a)A cylindrical cup of internal diameter 7.0 cm and height 8.5 cm is filled to the top with water.



The density of water is 1000 kg m−3. The mass of one mole of water is 18 g. The specific heat capacity of water is 4200 J kg−1 K−1.

Show that the minimum time taken for a 0.50 kW camping kettle to bring a cup of water at 20 °C to boiling point is about 200 s.

[3]

(b) In a laboratory test, the camping kettle was found to bring a cup of water to the boil in 320 seconds.

Explain why your previous answer is an underestimate and suggest two ways that you can refine the test to ensure that the time to boil is closer to 200 s.

---

[3]

8 Fig. 19 shows a crane lifting a car of mass 850 kg at constant velocity through a height of 12 m in a time of 40 s. The crane has a working efficiency of 60 %.

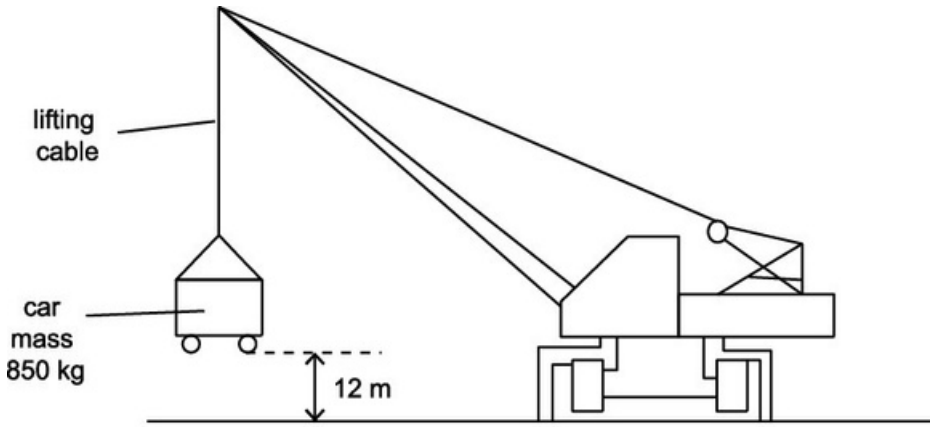


Fig. 19

(i)Calculate the tension in the lifting cable.

tension = _____N [1]

(ii)Calculate the total input power required by the crane to lift the car.

total input power = _____W [4]

(iii)Suggest and explain two ways the crane can be modified to improve its efficiency.

---

[2]

9 Hubble's law can be used to estimate the age of the universe. Fig. 23 shows some of Hubble's early measurements of nearby galaxies plotted on a v against d graph, where v is the recessional speed of a galaxy and d is its distance from us.

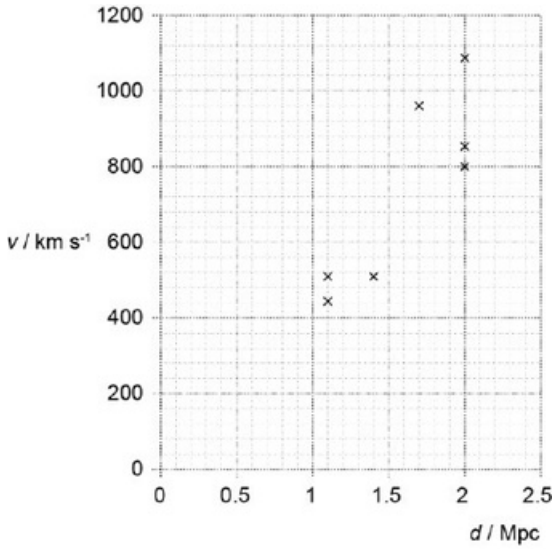


Fig. 23

(i) State how v was determined.

[1]

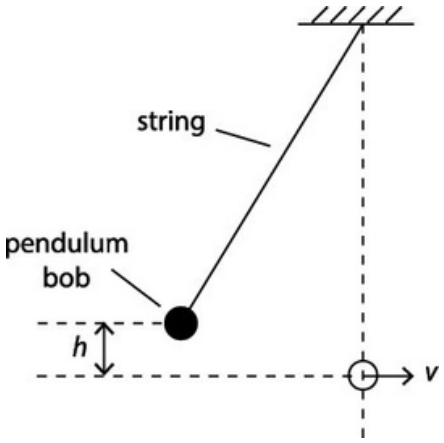
(ii) Use Fig. 23 to estimate a value for the Hubble constant H_0 in kms−1 Mpc^{-1}.

H_0 = _____ km s−1 Mpc^{-1} [3]

(iii) Use your answer to part (ii) to estimate Hubble's initial value for the age of the universe in years.

age = _____ years [3]

10(a)A group of students are conducting an experiment in the laboratory to determine the acceleration of free *g* using a simple pendulum as shown below.



The pendulum bob is released from rest from a height *h.* The speed of the pendulum bob as it passes through the vertical position is *v.* The speed *v* is measured using a light-gate and a computer.
The results from the students are shown in a table.

h / m	*v* / m s–1	*v*2 / m2 s–2
0.052	1.0 ± 0.1	1.0 ± 0.2
0.100	1.4 ± 0.1	2.0 ± 0.3
0.151	1.7 ± 0.1	2.9 ± 0.3
0.204	1.9 ± 0.1	
0.250	2.2 ± 0.1	4.8 ± 0.4
0.302	2.4 ± 0.1	5.8 ± 0.5

Complete the missing value of *v*2 in the table. [1]

(b)Fig. 24 shows the graph of *v*2 against *h.*

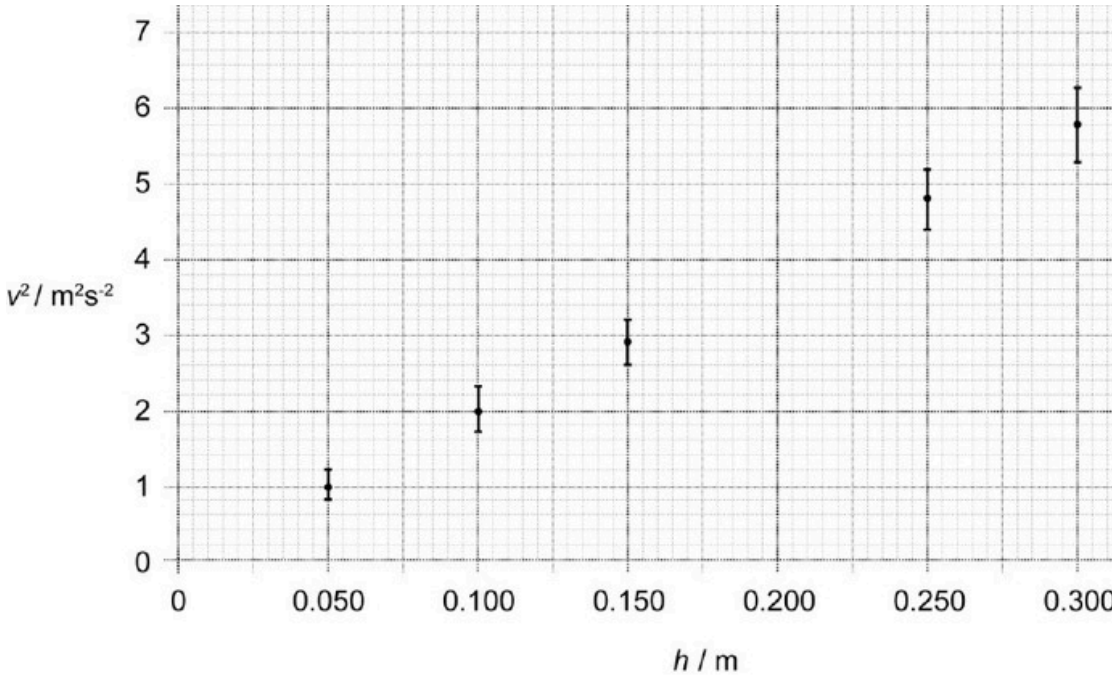


Fig. 24

(i)Plot the missing data point and error bar on Fig. 24.

[1]

(ii)*Explain how Fig. 24 can be used to determine the acceleration of free fall *g*.

Find the value of *g* and include the uncertainty in your answer.

[6]

11(a)A cyclist moves along a horizontal road. She pushes on the pedals with a constant power of 250 W. The mass of the cyclist and bicycle is 85 kg. The total drag force is $0.4v2$, where v is the speed of the cyclist.

The cyclist now moves up a slope at a constant speed of 6.0 ms^{-1} and continues to exert a power of 250 W on the pedals.

Fig. 17.1 represents the cyclist and bicycle as a single point P on the slope.

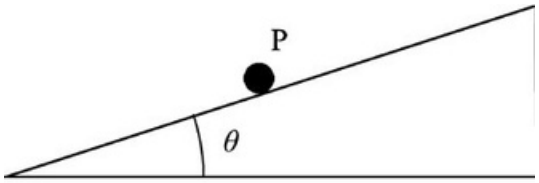


Fig. 17.1

(i)Draw arrows on Fig. 17.1 to represent the forces acting on P. Label each arrow with the force it represents.

[1]

(ii)Calculate the angle θ of the slope to the horizontal.

θ = _____ ° [2]

(b)The cyclist continues to move up the slope at 6.0 ms $^{-1}$ and approaches a gap of width 2.5 m as shown in Fig. 17.2.

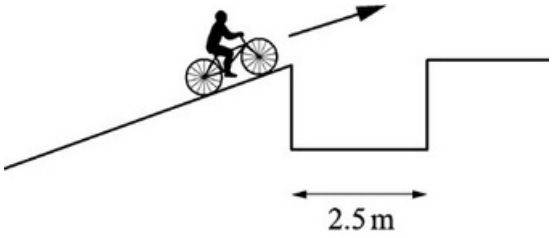


Fig. 17.2

A student has calculated that the cyclist will be able to clear the gap and land on the other side. Another student suggests that this calculation has assumed there is no drag and has not accounted for the effect caused by the front wheel losing contact with the slope before the rear wheel.

Without calculation, discuss how drag and the front wheel losing contact with the slope will affect the motion and explain how these might affect the size of the gap that can be crossed successfully.

[4]

12 A solar-powered ion propulsion engine creates and accelerates xenon ions. The ions are ejected at a constant rate from the rear of a spacecraft, as shown in Fig. 2.1.

The ions have a fixed mean speed of 3.2 × 104 ms−1 relative to the spacecraft.

The initial mass of the spacecraft is 5.2 × 103 kg.

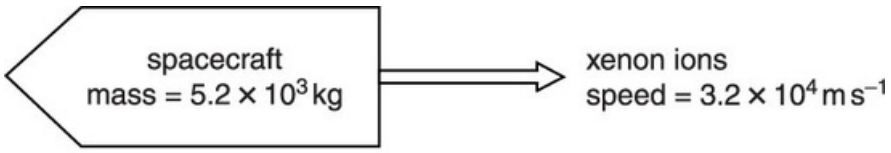


Fig. 2.1

(i)Calculate the mass of one xenon ion.

molar mass of xenon = 0.131 kg mol^{-1}

mass = _____kg [1]

(ii)The engine is designed to eject 9.5 × 1018 xenon ions per second.

Determine the initial acceleration of the spacecraft.

acceleration = _____m s^{-2} [3]

(iii)State in words the law that you have used to solve (ii).

In your answer, you should use appropriate technical terms spelled correctly.

---

[1]

(iv) State and explain how you would expect the acceleration of the spacecraft to change, if at all, while the engine is running.

---

[3]

13 To find the density ρ of a metal wire, a student makes the following measurements:

length l = 100 ± 1 mm
diameter d = 2.50 ± 0.05 mm
mass m = 4.00 ± 0.02 g

The equation $\rho = \frac{4m}{\pi d^2 l}$ is used to calculate the density of the metal.

What is the percentage uncertainty in the answer?

A ± 2.5%
B ± 3.5%
C ± 4.5%
D ± 5.5%

Your answer ☐

[1]

14 Fluorodeoxyglucose (FDG) is a radioactive tracer often used for PET scans. It contains radioactive fluorine-18, which is a positron-emitter. Some information about FDG and fluorine-18 is given below.

- 9.9% of the mass of FDG is fluorine-18.
- The half-life of fluorine-18 is 6600 s.
- The molar mass of fluorine-18 is 0.018 kg mol^{-1}.

A patient is injected with FDG. The initial activity of FDG is 400 MBq.

Use the information given to calculate the initial mass of FDG given to the patient.

mass = _____ kg [4]

15 What is the de Broglie wavelength in nm of a proton travelling at 1.5×10^{4} ms ?1?

A 2.6×10^{32} nm

B 2.6 nm

C 49 nm

D $4.9^{4} \times 10$ nm

Your answer ☐

[1]

16 A student records the following data during an experiment to determine the internal resistance of a battery.

e.m.f. = (4.5 ± 0.2) V

terminal p.d. = (3.0 ± 0.1) V

current = (2.0 ± 0.1) A

What is the percentage uncertainty in the value for the internal resistance of the battery?

A 5.0 %

B 6.1 %

C 13 %

D 25 %

Your answer ☐

[1]

17 What is the correct SI unit for acoustic impedance?

A kg s

B kg m−2 s^{-1}

C kg m−3 s^{-1}

D kg m−2 s^{-2}

Your answer ☐

[1]

18 This question is about the operation of an electrically powered shower designed by an electrical firm.

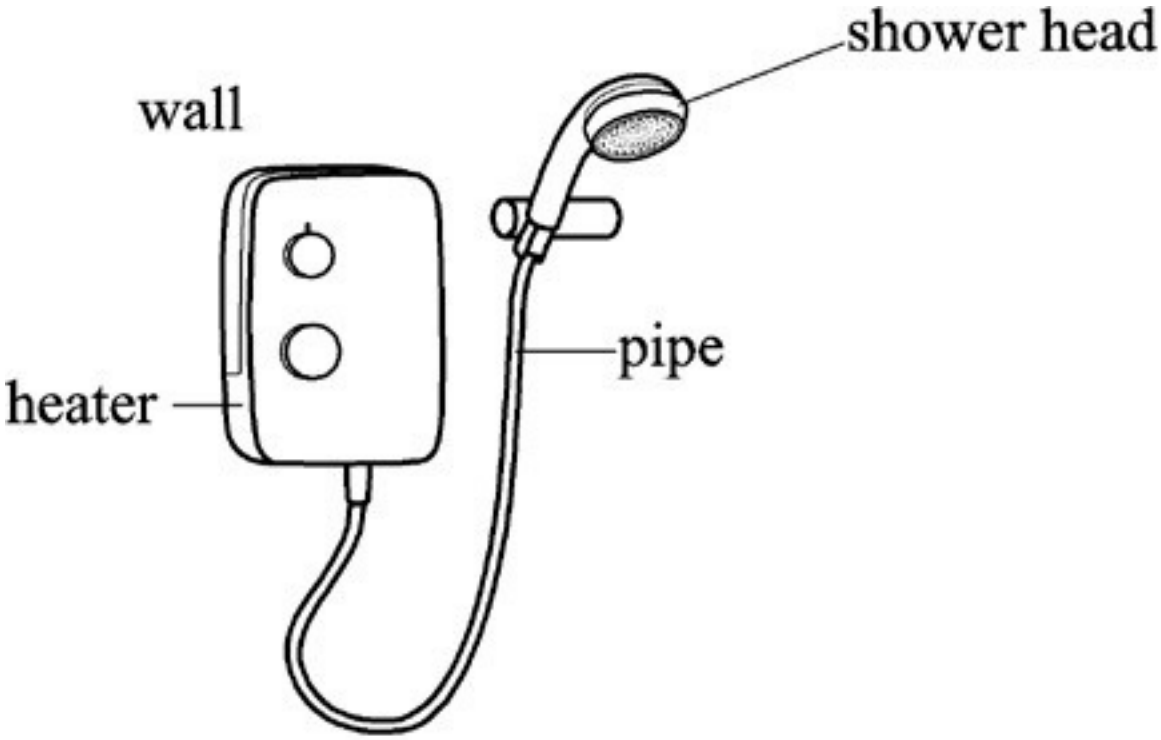


Fig.1.1

The water enters the heater at a temperature of 14 °C. At the maximum flow rate of 0.070 kg s^{-1}, the water leaves the shower head at a temperature of 30 °C.

Calculate the rate at which energy is transferred to the water. Give a suitable unit for your answer.

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

rate of energy transfer = _____unit _____[3]

19 The kilogram, metre and second are SI base units.

Determine the unit for *power* in terms of these SI units.

unit for power = _____[1]

20 Which quantity has the unit hertz (Hz)?

A frequency
B acceleration
C phase difference
D angular frequency

Your answer ☐

[1]

21 The cross-sectional area of a wire is recorded as 0.14 ± 0.01 mm2.
The length of the wire is recorded as 100 ± 1 mm.

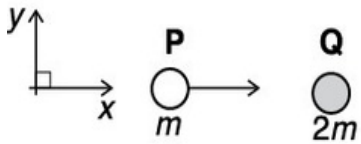
What is the percentage uncertainty in the volume of the wire?

A 1.0 %
B 4.6 %
C 7.1 %
D 8.1 %

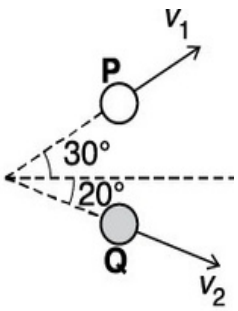
Your answer ☐

[1]

22 A ball P of mass *m* has a velocity in the positive *x*-direction. It makes a collision with a stationary ball Q of mass 2*m.* After the collision, the ball P has velocity *v*1, ball Q has velocity *v*2 and the balls travel in the directions shown in the diagram below.



before



after

After the collision, the total momentum of the balls in the *x*-direction is *p*x and the total momentum in the *y* -direction is *py*.

Which row is correct for *p*x and *py*?

	px	py 0
A	2*mv*2 cos 20° + *mv*1 cos 30°	0 2*mv*2 sin 30° + *mv*1 sin
B	2*mv*2 sin 20° + *mv*1 sin 30°	20°
C	2*mv*2 cos 20° + *mv*1 cos 30°	2*mv*2 cos 30° + *mv*1 cos
D	2*mv*2 sin 20° + *mv*1 sin 30°	20°

Your answer ☐

[1]

23 Fig. 16.1 shows an arrangement used by a group of students to determine the acceleration of free fall *g* in the laboratory.

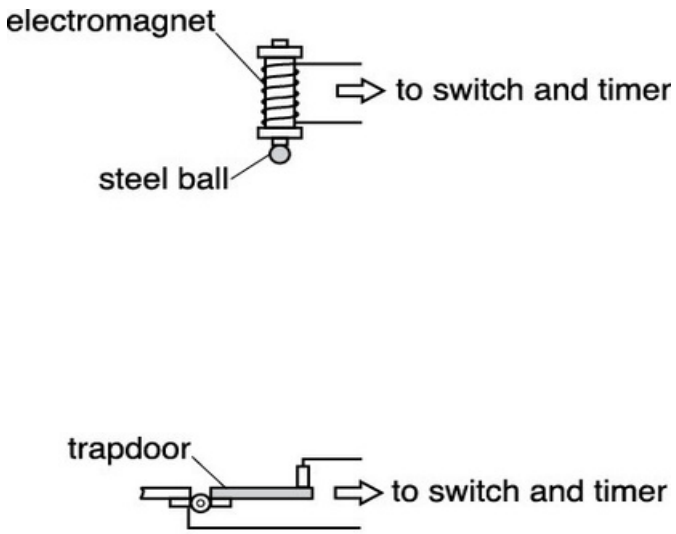


Fig. 16.1

An electromagnet is used to hold a small steel ball in position above a trapdoor. A timer starts as soon as the ball is released, and is stopped when the ball hits and opens the trapdoor. The clamp stands holding the trapdoor mechanism and the electromagnet are not shown in Fig. 16.1.

The distance between the bottom of the steel ball and the top of the trapdoor is 1.200 ± 0.001 m. The steel ball takes 0.50 ± 0.02 s to fall through this distance.

(i)Calculate a value for *g* using these results.

g = _____ m s $^{-2}$ [2]

(ii)Determine the percentage uncertainty in the value for *g*.

percentage uncertainty = _____ % [2]

24(a)The ball-release mechanism of a pinball machine is shown in Fig. 17.1.

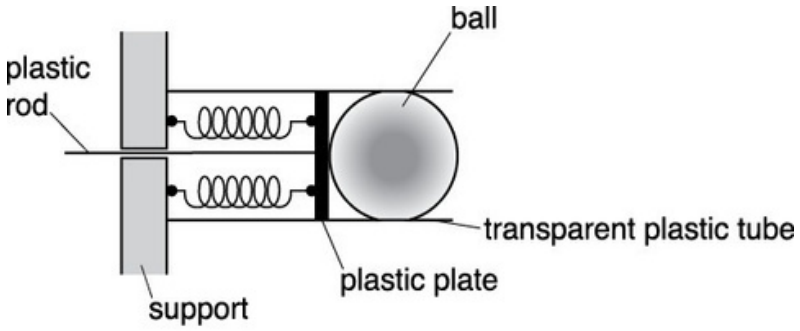


Fig. 17.1

A pair of identical compressible springs are fixed between a plastic plate and a support. The springs are in parallel. A plastic rod attached to the plate is pulled to the left to compress the springs. A ball, initially at rest, is fired when the plate is released.

A group of students are conducting an experiment to investigate the ball-release mechanism shown in Fig. 17.1.
The students apply a force *F* and measure the compression *x* of the springs.
The table below shows the results.

F / N	x / cm
1.1 ± 0.2	2.0
2.0 ± 0.2	4.0
2.9 ± 0.2	6.0
4.0 ± 0.2	8.0
5.1 ± 0.2	10.0

Fig. 17.2 shows four data points from the table plotted on a *F* against *x* graph.

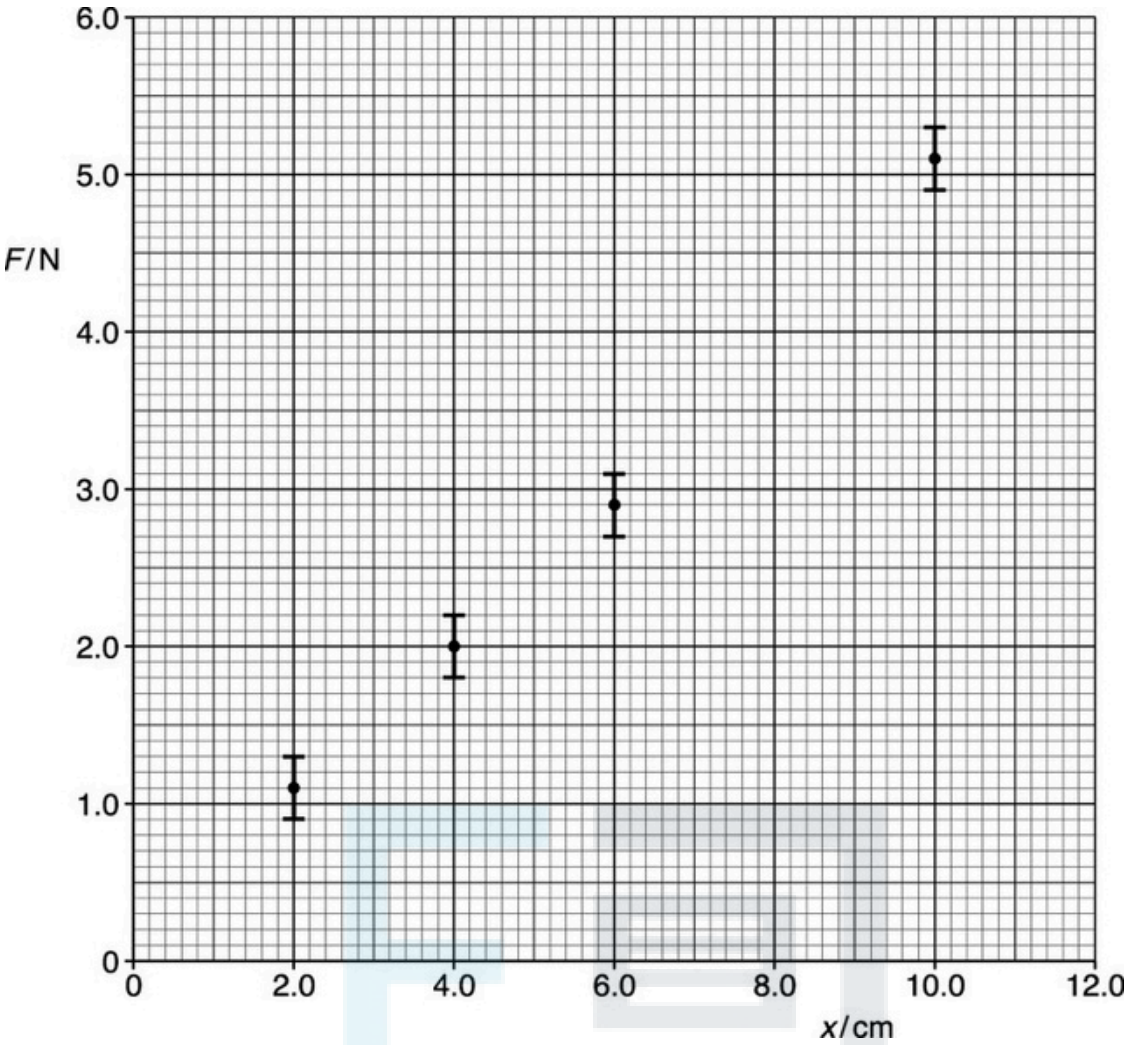


Fig. 17.2

(i)Plot the missing data point and the error bar on Fig. 17.2.

[1]

(ii)Describe how the data shown in the table may have been obtained in the laboratory.

---

[2]

(iii)Draw the best fit and the worst fit straight lines on Fig. 17.2.

Use the graph to determine the force constant *k* for a single spring and the absolute uncertainty in this value.

k = _____ ± _____ N m−1 [4]

(iv)State the feature of the graph that shows Hooke's law is obeyed by the springs.

_____

_____ [1]

(v)The mass of the ball is 0.39 kg.

Use your answer from (iii) to calculate the launch speed v of the ball when the plastic plate shown in Fig. 17.1 is pulled back 12.0 cm.

v = _____ m s^{-1} [3]

(b)Anew arrangement for the ball-release mechanism using three identical springs is shown in Fig. 17.3.

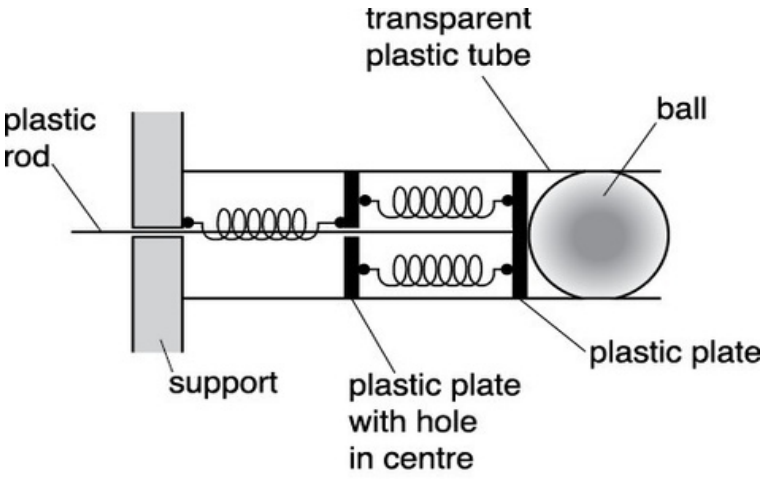


Fig. 17.3

The force constant of each spring is *k*.

The same ball of mass 0.39 kg is used. The plastic rod is pulled to the left by a distance of *x*.

Show that initial acceleration *a* of this ball is given by the equation

$$a = 1.7\,kx.$$

[2]

25 The Big Bang theory explains the origin and the evolution of the early Universe.

The table below shows the distance *d* and recession velocity *v* of some galaxies close to our own galaxy.

Galaxy	d / Mpc	v / km s^{-1}
NGC-5357	0.45	200
NGC-3627	0.90	650
NGC 4151	1.7	960
NGC-4472	2.0	850

The chemical composition of the stars in our galaxy can be determined by analysing in the laboratory the absorption spectral lines for these stars.

The closest star to us is the Sun. The wavelength of the hydrogen-beta spectral line from the Sun is 486 nm.

(i) Use the information from the table to calculate the observed wavelength λ of the hydrogen-beta spectral line from a star in the galaxy NGC-4151.

λ = _____ nm [3]

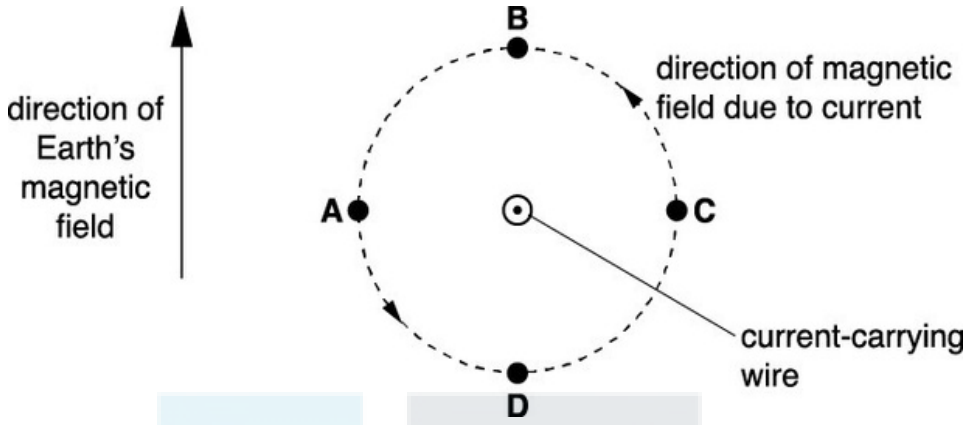
(ii) A diffraction grating with 800 lines per mm is used to observe and analyse the light from the Sun in the laboratory.

A narrow beam of light from the Sun is incident normally at the diffraction grating.

Calculate the angle θ between the central beam of light through the grating and the hydrogen-beta spectral line in the second order spectrum.

θ = _____ ° [2]

26 The diagram below shows a current-carrying wire coming out from the plane of the paper. The current in the wire produces a magnetic field in an anticlockwise direction around the wire.



The direction of the Earth's magnetic field is also shown.
The Earth's magnetic field interacts with the magnetic field of the current-carrying wire.

At which point A, B, C or D is the resultant magnetic field strength a minimum?

Your answer ☐

[1]

27 In Fig. 18.1 the solid line represents the displacement *s* against distance *x* graph for a progressive transverse wave on a stretched string at time *t* = 0. The dotted line shows the graph for the same wave at a later time *t* = 2.5 ms.

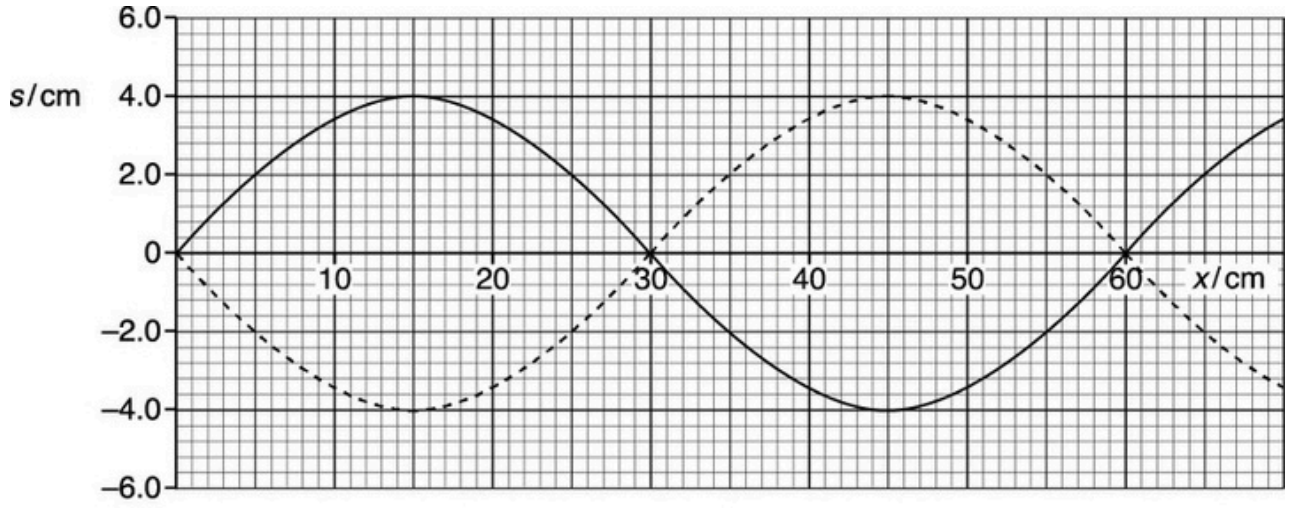


Fig. 18.1

Determine the frequency *f* of this wave.

f = _____ Hz [3]

28(a) Electromagnetic radiation of wavelength 300 nm is incident on the surface of two metals X and Y. Metal X has work function 2.0 eV and metal Y has work function 5.0 eV.

With the help of calculations, explain any difference between the emission of photoelectrons from the surfaces of the metals X and Y.

[4]

(b) *Two groups of researchers, A and B, conduct photoelectric effect experiments on a new material. The maximum kinetic energy KEmax of the photoelectrons emitted from the material is determined for different frequencies f of the electromagnetic radiation incident on the material.

Fig. 19 shows incomplete graphs of KE^{max} against f from the groups A and B.

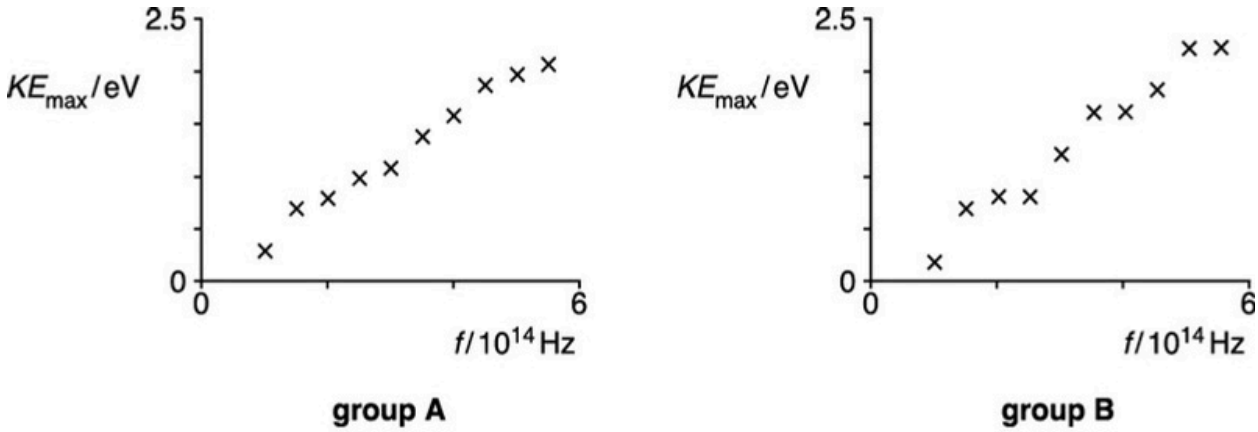


Fig. 19

The value of the Planck constant h is determined from the completed KE_{max} against f graphs.
The result from each group is shown below.

group A: $h = (6.3 \pm 0.3) \times 10^{-34}$ J s
group B: $h = (6.6 \pm 0.6) \times 10^{-34}$ J s

Explain how a graph of KE_{max} against f can be used to determine h. Discuss the accuracy and precision of the results from each group.

[6]

29 Fig. 21.1 shows two oppositely charged ions to the left of a point X.

Fig. 21.1

The separation between the centres of the ions is 3.0×10^{-10} m. Each ion has charge of magnitude 1.6×10^{-19} C.

(i)Explain why the direction of the resultant electric field strength at point X is to the left.

---

[2]

(ii)Calculate the minimum energy in eV required to completely separate the ions.

energy = _____ eV [3]

30 Apatient with a blood clot in his muscle is having an ultrasound A-scan.

Fig. 24.1 shows an ultrasound transducer placed on the patient's skin.

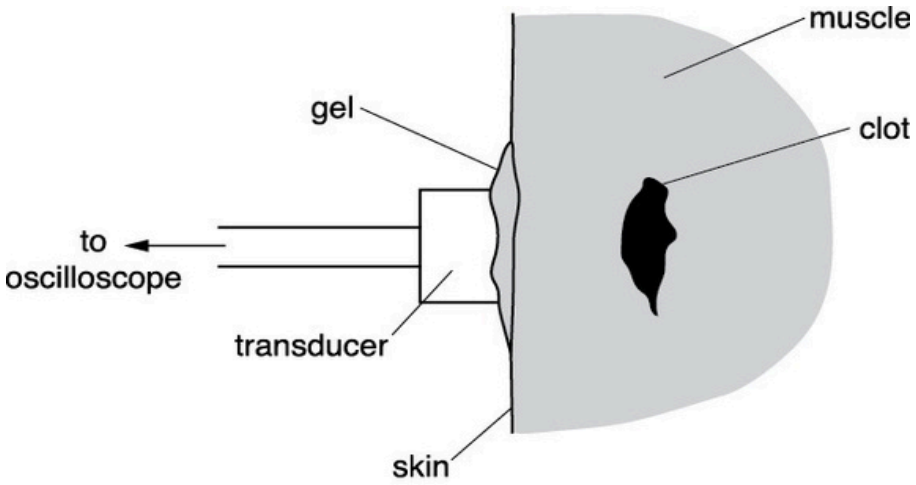


Fig. 24.1 (not to scale)

The ultrasound transducer produces pulses of ultrasound. An oscilloscope is connected to the transducer. Fig. 24.2 shows part of the oscilloscope display.

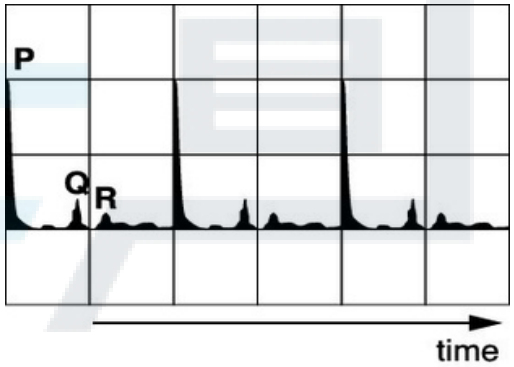


Fig. 24.2

The front of the blood clot is 1.5 cm from the skin.

The density of the patient's muscle is 1070 kg m−3.

The time difference between pulses P and Q in Fig. 24.2 is 19 μs.

Determine the acoustic impedance *Z* of patient's muscle. State an appropriate unit for your answer.

Z = _____ unit: _____ [4]

31 Which is not a unit of energy?

A kW h

B eV

C J

D W

Your answer ☐ [1]

32(a)

State one S.I. base quantity other than length, mass and time.

[1]

(b)Fig. 17 shows two resistors X and Y connected in series.

Fig. 17

The resistors are wires. Both wires have the same length L and diameter d. The material of X has resistivity ρ and the material of Y has resistivity 2ρ.

(i)Show that the total resistance R of the wires is given by the equation

$$R = \frac{12\rho L}{\pi d^2}.$$

[2]

(ii)A student uses the equation in (i) to determine R.

The table below shows the data recorded by the student in her lab book.

Quantity	Value
ρ	4.7 × 10−7 Ωm
L	9.5 ± 0.1 cm
d	0.270 ± 0.003 mm

1 Name the likely instruments used by the student to measure *L* and *d*.

L:

---

d:

---

[1]

2 Use the data in the table and the equation in (i) to determine *R* and the absolute uncertainty. Write your answer to the correct number of significant figures.

R = _____ ± _____ Ω [4]

3 The instrument used to measure *d* has a zero-error. The measured *d* is much larger than the actual value.

Discuss how the actual value of *R* compares with the value calculated above.

---

[1]

33(a)

Fig. 20.1 shows a positively charged metal sphere and a negatively charged metal plate.

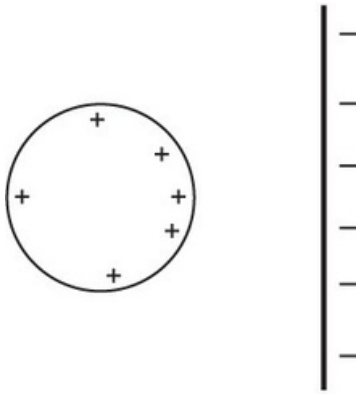


Fig. 20.1

On Fig. 20.1, draw a minimum of five electric field lines to show the field pattern between the sphere and the plate.

[2]

(b)Define *electric potential* at a point in space.

---

[1]

(c)A metal sphere is given a positive charge by connecting its surface briefly to the positive terminal of a power supply. The electric potential at the surface of the sphere is + 5.0 kV. The sphere has radius 1.5 cm.

(i)Show that the charge Q on the surface of the sphere is 8.3×10^{-9} C.

[2]

(ii)Fig. 20.2 shows the charged sphere from (i) suspended from a nylon thread and placed between two oppositely charged vertical plates.

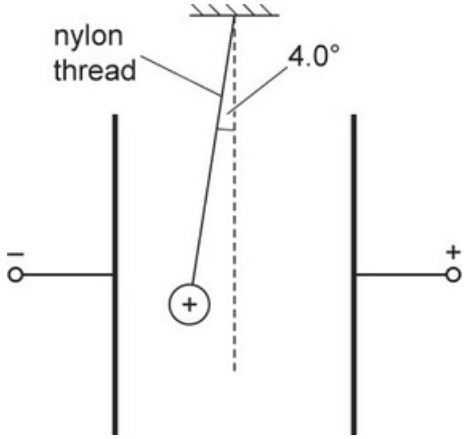


Fig. 20.2 (not to scale)

The weight of the sphere is 1.7×10^{-2} N. The string makes an angle of 4.0° with the vertical.

1Show that the electric force on the charged sphere is 1.2×10^{-3} N.

[1]

2Calculate the uniform electric field strength *E* between the parallel plates.

E = _____N C $^{-1}$ [2]

34(a)

A capacitor of capacitance 7.2 pF consists of two parallel metal plates separated by an insulator of thickness 1.2 mm. The area of overlap between the plates is 4.0 × 10−4 m2. Calculate the permittivity of the insulator between the capacitor plates.

permittivity = _____ F m^{-1} [2]

(b)Fig. 21 shows a circuit.

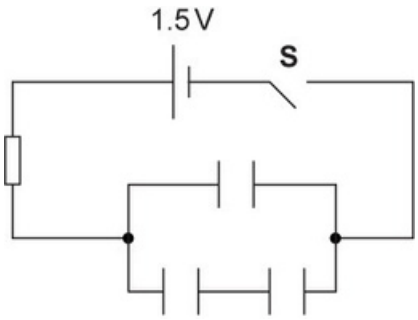


Fig. 21

The capacitance of each capacitor is 1000 μF. The resistance of the resistor is 10 kΩ. The cell has e.m.f. 1.5 V and negligible internal resistance.

(i)Calculate the total capacitance *C* in the circuit.

C = _____μF [2]

(ii)The switch S is closed at time *t* = 0. There is zero potential difference across the capacitors at *t* = 0.

Calculate the potential difference *V* across the resistor at time *t* = 12 s.

V = _____V [2]

A student conducts an experiment to confirm that the uniform magnetic flux density *B* between the poles of a magnet is 30 mT.

A current-carrying wire of length 5.0 cm is placed perpendicular to the magnetic field.

The current *I* in the wire is changed and the force *F* experienced by the wire is measured. Fig. 22.1 shows the graph plotted by the student.

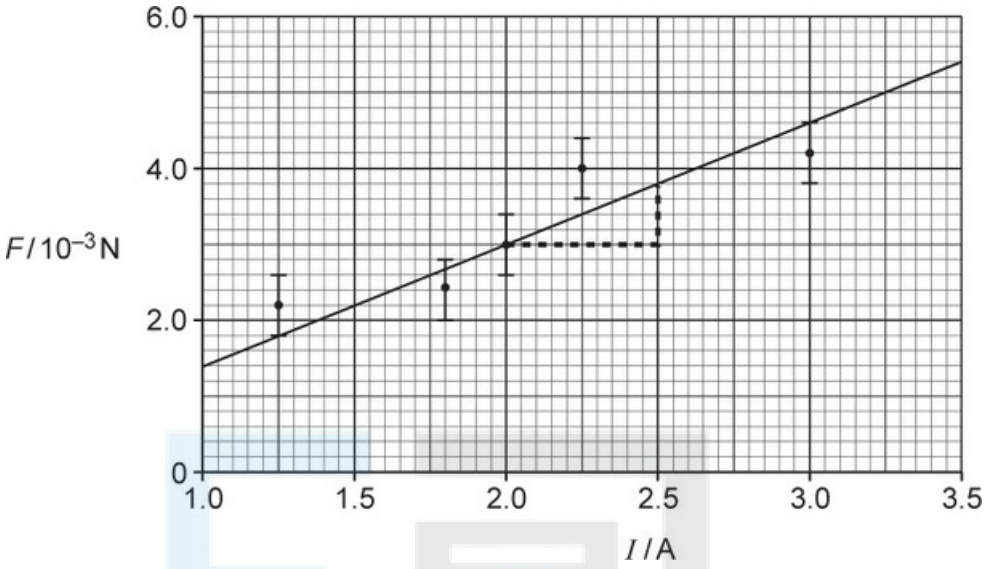


Fig. 22.1

The student's analysis is shown on the graph of Fig. 22.1 and in the space below.

$F = BIL$

$$\text{gradient} = BL = \frac{(3.8 - 3.0) \times 10^{-3}}{2.5 - 2.0} = 0.0016$$

$$B = \frac{0.0016}{0.05} = 0.032\,\text{T} = 32\,\text{mT}$$

This is just 2 mT out from the 30 mT value given by the manufacturer, so the experiment is very accurate.

Evaluate the information from Fig. 22.1 and the analysis of the data from the experiment. No further calculations are necessary.

---

[6]

(b)Fig. 22.2 shows a transformer circuit.

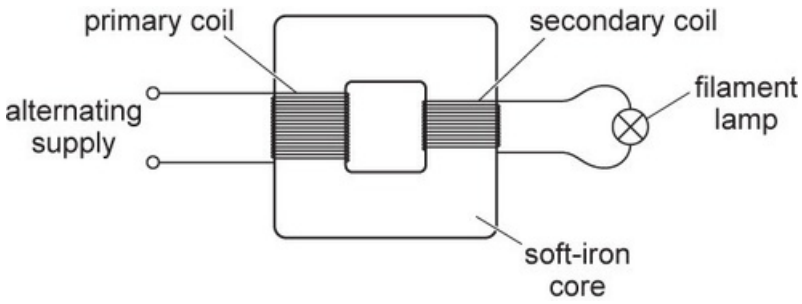


Fig. 22.2

The primary coil is connected to an alternating voltage supply. A filament lamp is connected to the output of the secondary coil.

(i)Use Faraday's law of electromagnetic induction to explain why the filament lamp is lit.

---[3]

(ii)The primary coil has 400 turns and the secondary coil has 20 turns. The potential difference across the lamp is 12 V and it dissipates 24 W. The transformer is 100% efficient.

1Calculate the current in the primary coil.

current = _____A [2]

2The alternating voltage supply is replaced by a battery and an open switch in series. The switch is closed. The lamp is lit for a short period of time and then remains off. Explain this observation.

---[2]

36 Which is the best estimate of the area of a rectangular field of length 98 ± 3 m and width 47 ± 2 m?

A 4600 ± 5 m2

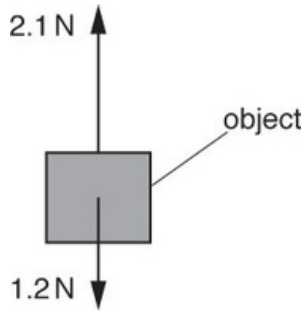
B 4600 ± 6 m2

C 4600 ± 300

D m2 4606 ± 337 m2

Your answer [1]

37 The diagram shows two opposite vertical forces of magnitude 1.2 N and 2.1 N acting on an object.



Which of the following statements could be correct?

1 The object is accelerating and moving up.

2 The object is decelerating and moving down.

3 The magnitude of the resultant force is 0.9 N.

A Only 3 Only

B 1 and 3 Only

C 2 and 3 1, 2

D and 3

Your answer ☐ [1]

38(a) A group of students are conducting an experiment in the laboratory to determine the value of absolute zero by heating a fixed mass of gas. The volume of the gas is kept constant.

Fig. 17.1 shows the arrangement used by the students.

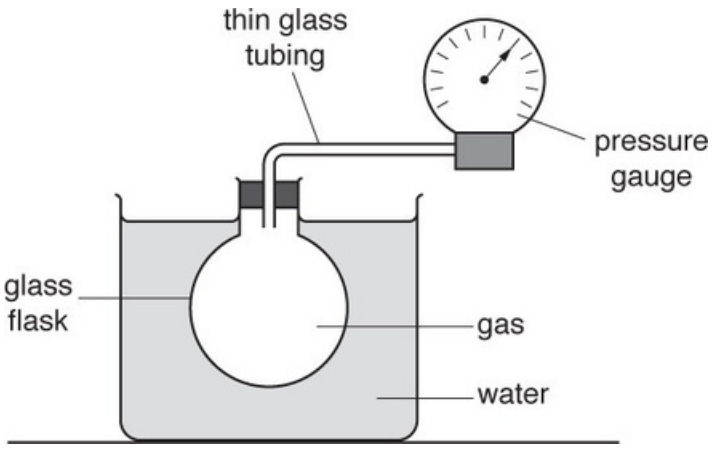


Fig. 17.1

The gas is heated using a water bath. The temperature θ of the water is increased from 5 °C to 70 °C.
The temperature of the water bath is assumed to be the same as the temperature of the gas. The pressure p of the gas is measured using a pressure gauge.

The results from the students are shown in a table.

θ / °C	p / kPa
5 ± 1	224 ± 3
13 ± 1	231 ± 3
22 ± 1	238 ± 3
35 ± 1	248 ± 3
44 ± 1	
53 ± 1	262 ± 3
62 ± 1	269 ± 3
70 ± 1	276 ± 3

Describe and explain how the students may have made accurate measurements of the temperature θ.

---

[2]

(b)Fig. 17.2 shows the pressure gauge. Measurements of p can be made using the kPa scale or the psi (pounds per square inch) scale. The students used the psi scale to measure pressure and then converted the reading to pressure in kPa.

Fig. 17.2

(i)Suggest why it was sensible to use the psi scale to measure p.

---

[1]

(ii)The students made a reading of p of 37.0 ± 0.5 psi when θ was 44 ± 1°C.
Convert this value of p from psi to kPa. Complete the table for the missing value of p. Include the absolute uncertainty in p.

1 pound of force = 4.448 N

1 inch = 0.0254 m

[2]

(c) Fig. 17.3 shows the graph of p against θ.

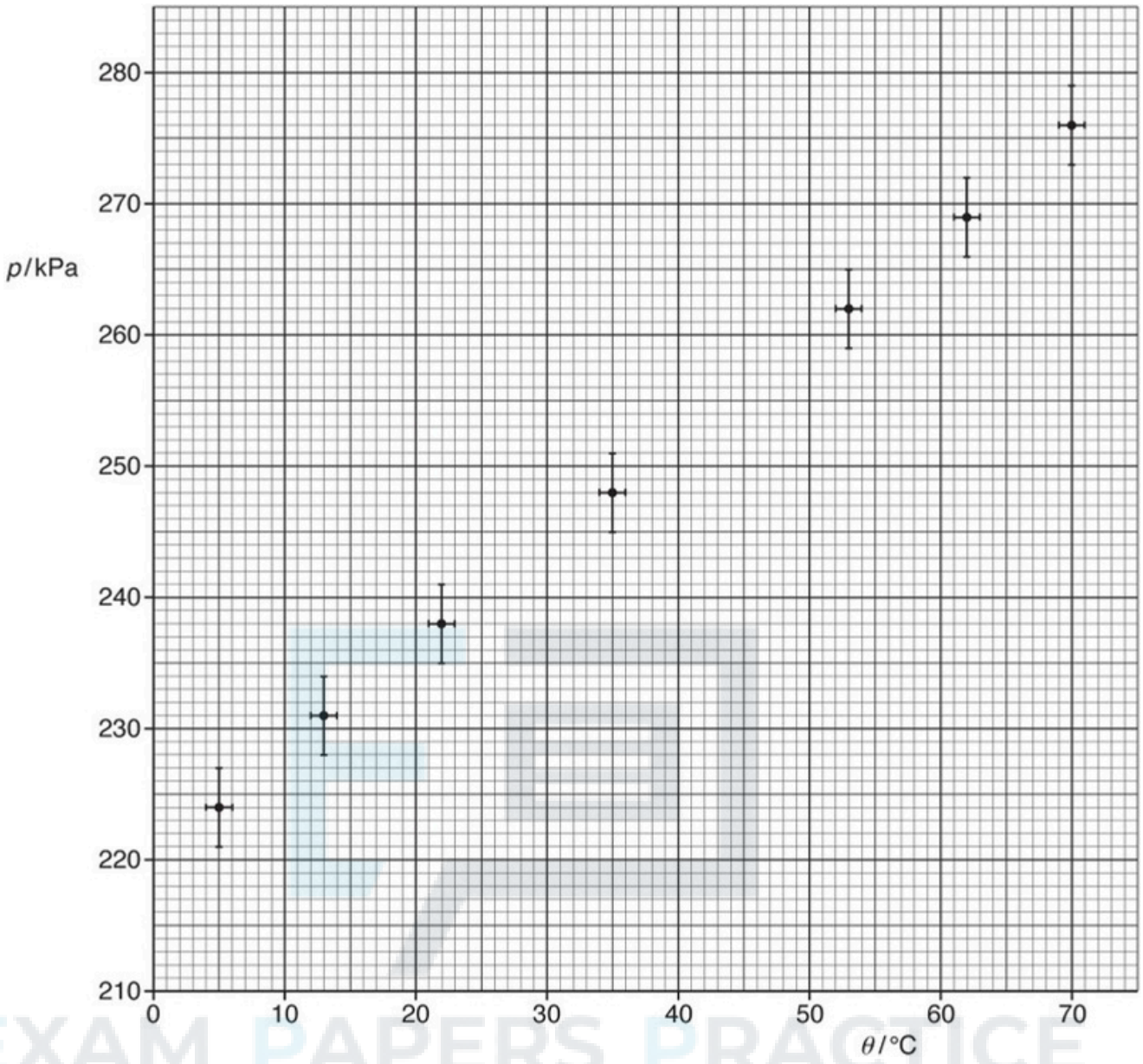


Fig. 17.3

(i)Plot the missing data point and the error bars on Fig. 17.3.

[1]

(ii) Explain what is meant by *absolute zero*. Describe how Fig. 17.3 can be used to determine the value of absolute zero.

Determine the value of absolute zero. You may assume that the gas behaves as an ideal gas.

[6]

(d)Describe, without doing any calculations, how you could use Fig. 17.3 to determine the actual uncertainty in the value of absolute zero in (c)(ii).

[2]

(e)The experiment is repeated as the water bath quickly cools from 70 °C to 5 °C. Absolute zero was found to be −390°C.

Compare this value with your value from (c)(ii) and explain why the values may differ. Describe an experimental approach that could be taken to avoid systematic error in the determination of absolute zero.

[4]

39(a)Fig. 16 shows a hydraulic jack used to lift a car which has a mass of 1200 kg. A mechanic exerts a downwards force of 400 N on the handle of the jack, moving it 80.0 cm downwards. As he moves the handle, the car rises 2.0 cm.

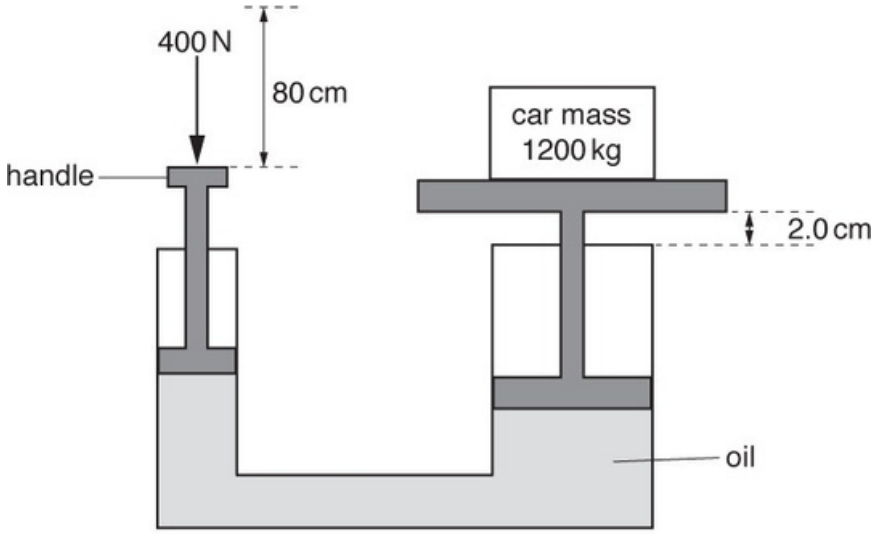


Fig. 16

Calculate the work done by the 400 N force exerted by the mechanic.

work done = _____ J [2]

(b)Calculate the ratio

$$\frac{\text{speed of handle moving down}}{\text{speed of car moving up}}.$$

ratio = _____[2]

(c) Calculate the useful work done on the car and hence the percentage efficiency of the jack.

efficiency = _____% [2]

40 Which of the following units is not an S.I. base unit?

A ampere
B mole
C volt
D kilogram

Your answer [1]

41 Which set of quantities are all scalar?

A acceleration, displacement, velocity
B energy, mass, power
C extension, force, gravitational potential energy
D weight, kinetic energy, work done

Your answer [1]

42 The latent heat of vaporisation of a liquid is 2300 kJ kg^{-1} and it has a molar mass of 0.018 kg mol^{-1}.

What is the energy required to change 30 moles of the liquid to gas?

A 4.1 × 104
B J 1.2 ×
C 106 J 6.9
D × 107 J
3.8 × 109
J

Your answer [1]

43(a)

A tennis ball is struck with a racket.

The initial velocity v of the ball leaving the racket is 30.0 m s $^{-1}$ and it makes an angle of 70° to the horizontal as shown in Fig. 16.

Air resistance is negligible

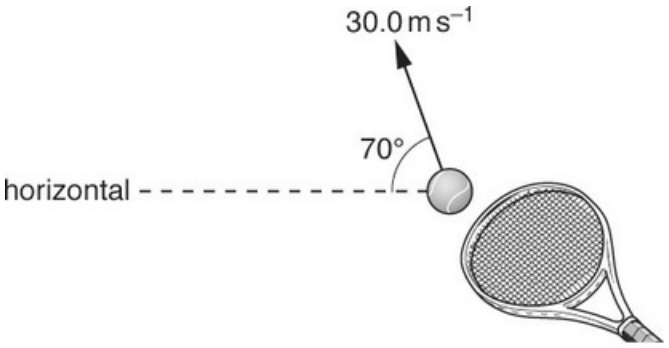


Fig. 16

(i)Calculate the vertical component of the initial velocity of the ball.

vertical component =_____m s^{-1} [1]

(ii)Use your answer in (i) to show that the ball reaches a maximum height *h* of about 40 m.

h =_____ m [2]

(iii)Explain why the kinetic energy of the ball is not zero at maximum height.

---

[1]

(iv)The mass *m* of the ball is 57.0 g.

Calculate the kinetic energy *Ek* of the ball when it is at its maximum height.

Ek = _____ J [2]

(b)

A metal ball is rolled off the edge of a horizontal laboratory bench. The initial horizontal velocity of the ball is *v*. The ball travels a horizontal distance *x* before it hits the level floor.

Use your knowledge of projectile motion to suggest the relationship between *v* and *x*. Describe how an experiment can be safely conducted to test this relationship and how the data can be analysed.

---

[6]

44(a)

The gravitational field strength at a distance *r* from the centre of Mars is *g*.

The table below shows some data on Mars.

g / N kg−1	r / km	lg (g / N kg^{-1})	lg (r / km)
1.19	6000	0.076	3.78
0.87	7000		
0.67	8000	−0.174	3.90
0.53	9000	−0.276	3.95
0.43	10000	−0.367	4.00

(i) Complete the table by calculating the missing values. [1]

(ii)Fig. 17.2 shows the graph of lg (*g* / N kg $^{-1}$) against lg (*r* / km).

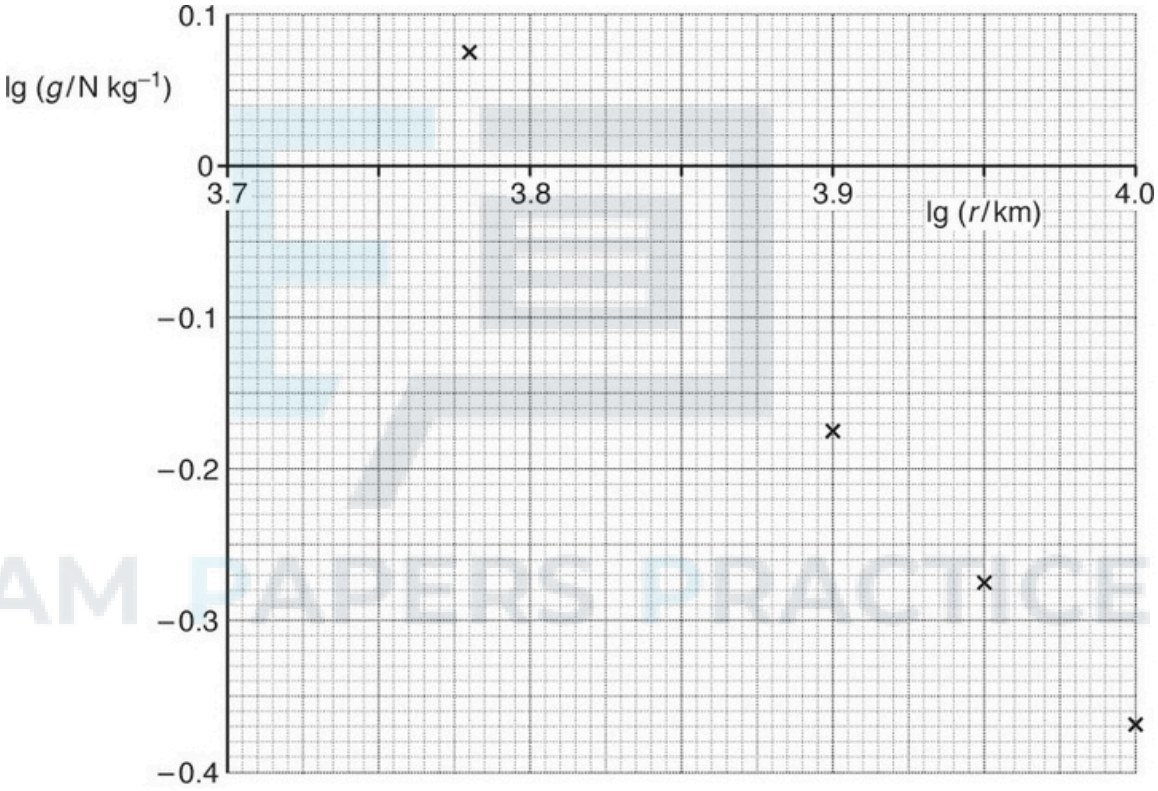


Fig. 17.2

1 Plot the missing data point on the graph and draw the straight line of best fit. [2]

2 Use Fig. 17.2 to show that the gradient of the straight line of best fit is −2.

[1]

3 Explain why the gradient of the straight line of best fit is −2.

[2]

(b) In July 2018, the closest distance between the centre of Mars and the centre of Earth will be 5.8 × 1010 m.

Fig. 17.3 shows the variation of the resultant gravitational field strength *g* between the two planets with distance *r* from the centre of the Earth.

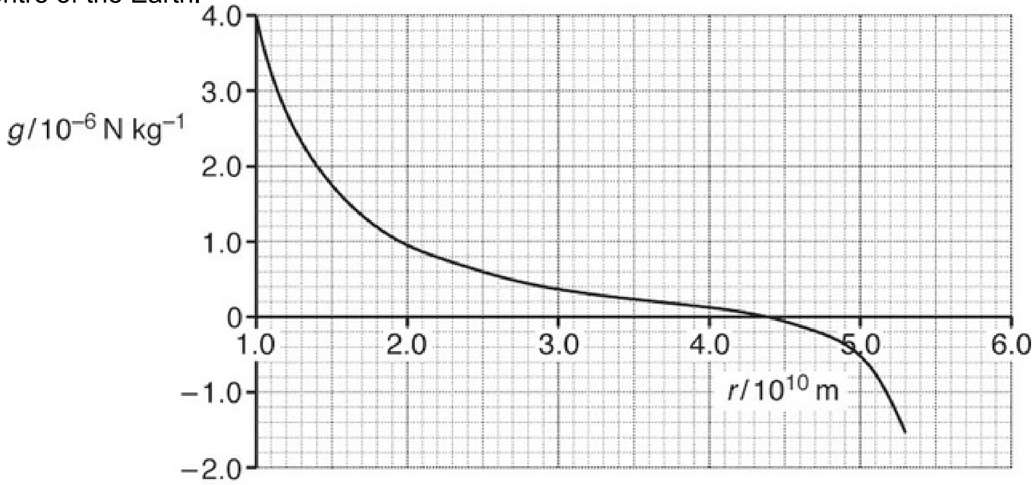


Fig. 17.3

(i)Explain briefly the overall shape of the graph in Fig. 17.3.

-- [2]

(ii)Use the value of *r* when *g* = 0 from Fig. 17.3 to determine the ratio

$$\frac{\text{mass of Earth}}{\text{mass of Mars}}.$$

$$\frac{\text{mass of Earth}}{\text{mass of Mars}} = $$ ------------------------------------ [2]

45 Wind turbines convert the kinetic energy of the wind into electrical energy.
Fig. 18 shows a wind turbine.

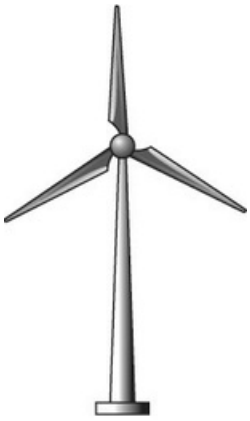


Fig. 18

When the wind speed is 8.0 m s−1, the kinetic energy of the air incident at the turbine per second is 1.2 MJ s^{1}.
Calculate the mass of the air incident at the turbine per second.

mass per second =_____ kg s^{-1} [2]

46 Fig. 21 shows the drum of a washing machine.

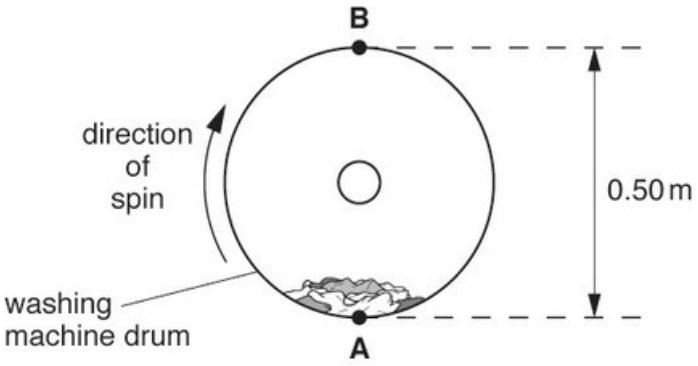


Fig. 21

The clothes inside the drum are spun in a vertical circular motion in a clockwise direction.

The drum has diameter 0.50 m. The manufacturer of the washing machine claims that the drum spins at 1600 ± 100 revolutions per minute.

Calculate the speed of rotation of the drum and the absolute uncertainty in this value.

speed = _____ ± _____ ms^{-1} [3]

47(a) A group of students are conducting an experiment to determine the wavelength of monochromatic light from a laser.

Fig. 24.1 shows the laser beam incident normally at a diffraction grating.

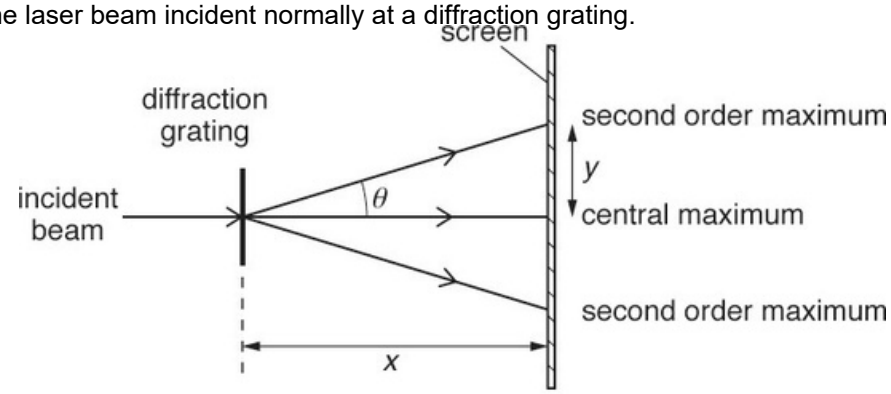


Fig. 24.1

The students use a diffraction grating with 600 lines mm−1. They vary the distance *x* between the grating and the screen from 1.000 m to 2.000 m. They measure the distance y from the *central* maximum to the *second order* maximum.

The students decide to plot a graph of *y* against $\sqrt{x^2 + y^2}$.

Show that the gradient of the graph is equal to sin *θ*, where *θ* is the angle between the central maximum and the *second* order maximum.

[1]

(b)Fig. 24.2 shows the graph plotted by the students.

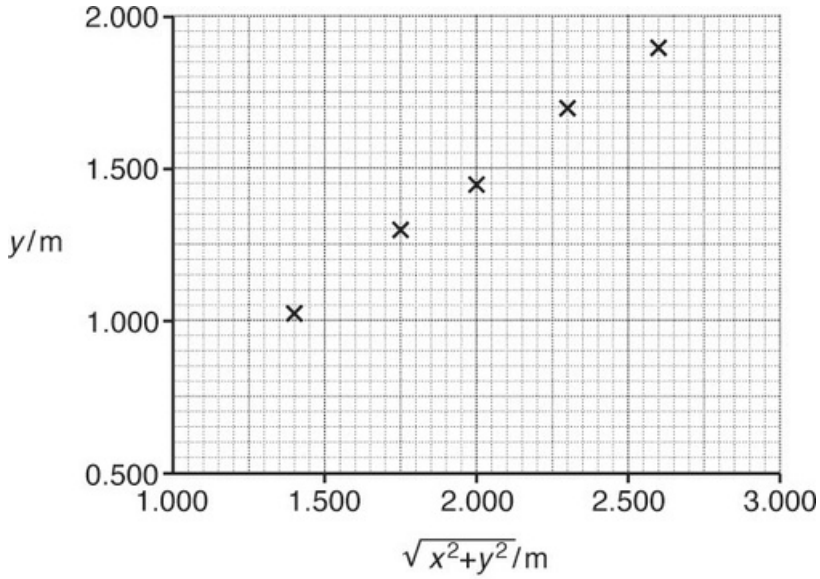


Fig. 24.2

(i)Use Fig. 24.2 to determine an accurate value of the wavelength λ of the light from the laser.

λ =_____ m [2]

(ii)Suggest why there are no error bars shown in Fig. 24.2.

_____

_____ [1]

(iii)Suggest how the precision of this experiment may be affected by using a protractor to measure the angle θ.

[1]

48(a)Fig. 4.1 shows an arrangement used by a student to determine the acceleration of free fall.

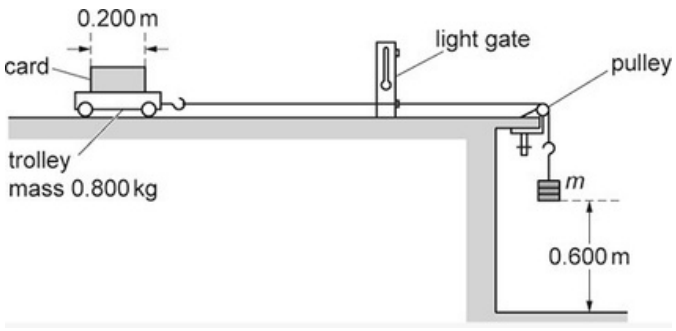


Fig. 4.1

A trolley is attached to a variable mass *m* by a string which passes over a pulley.

The mass *m* is released from rest and falls through a fixed height of 0.600 m accelerating the trolley of mass 0.800 kg. When the mass *m* hits the floor, the trolley then continues to move at a constant velocity *v*.

This constant velocity *v* is determined by measuring the time *t* for the card of length 0.200 m to pass fully through a light gate connected to a timer.

Frictional forces on the trolley and the falling mass *m* are negligible.

Show that the relationship between *v* and *m* is

$$v^2 = \frac{1.20mg}{(m + 0.800)}$$

where *g* is the acceleration of free fall.

[2]

(b)The student records the information from the experiment in a table. The column headings and just the last row for m = 0.600 kg from this table are shown below.

m/kg	$t/10^{-3}$ s	$\frac{m}{(m+0.800)}$	v/m s^{-1}	v^2/m^{2}s^{-2}
0.600	90 ± 2	0.429	2.22 ± 0.05	

(i) Complete the missing value of $v2$ in the table including the absolute uncertainty. [2]

(ii)Fig. 4.2 shows some of the data points plotted by the student. Plot the missing data for m = 0.600 kg on Fig. 4.2 and draw the straight line of best fit.

[2]

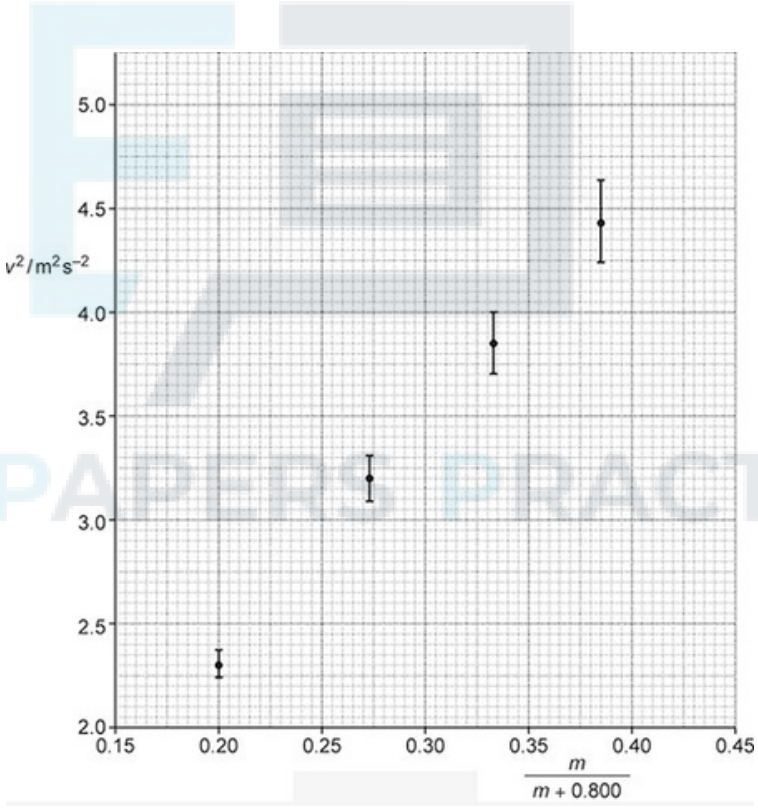


Fig. 4.2

(c)

(i)Use the equation given in (a) to show that the gradient of the graph of $v2$ against $\frac{m}{(m+0.800)}$ is equal to 1.20 g.

[1]

(ii)Assume that the best-fit straight line through the data points gives 9.5 m s−2 for the experimental value of g. Draw a worst-fit line through the data points on Fig. 4.2 and determine the absolute uncertainty in the value for g.

absolute uncertainty = ± ---------- ms^{-2} [4]

(d) It is suspected that the card on the trolley did not pass at right angles through the light beam.
Discuss, without doing any calculations, the effect this may have on the experimental value for the acceleration of free fall *g*.

[4]

49 Which electrical quantity has S.I. units ampere-second (A s)?

A charge current
B resistance potential
C difference
D

Your answer [1]

50 Which is the best value for the elementary charge *e* in terms of both accuracy and uncertainty?

A $(1.5 \pm 0.5) \times 10^{-19}$ C
B $(1.5 \pm 0.4) \times 10^{-19}$ C
C $(1.7 \pm 0.2) \times 10^{-19}$ C
D $(1.8 \pm 0.2) \times 10^{-19}$ C

Your answer [1]

51 The acoustic impedance Z of a material in the shape of a cube can be determined using the equation

$$Z = \frac{Mc}{L^3}$$

where M is the mass of the material, L is the length of each side of the cube and c is the speed of ultrasound in the material.

The percentage uncertainty in L is 1.2 % and the percentage uncertainty in c is 1.8 %. The percentage uncertainty in M is negligible.

What is the percentage uncertainty in Z?

A 2.2 %
B 3.0 %
C 4.2 %
D 5.4 %

Your answer [ ] [1]

52

Derive the S.I. base units for resistance.

base units: ---------- [2]

An approximate value of the Planck constant h can be determined in the laboratory using light-emitting diodes (LEDs). An LED suddenly starts to conduct and emit monochromatic light when the potential difference across an LED exceeds a minimum value $V0$.

The potential difference $V0$ and the wavelength λ of the emitted light are related by the equation

$$V_0 = \left(\frac{hc}{e}\right) \times \frac{1}{\lambda}$$

where e is the elementary charge and c is the speed of light in a vacuum.

Fig. 20.1 shows some data points plotted by a student on a $V0$ against $\frac{1}{\lambda}$ graph for five different LEDs.

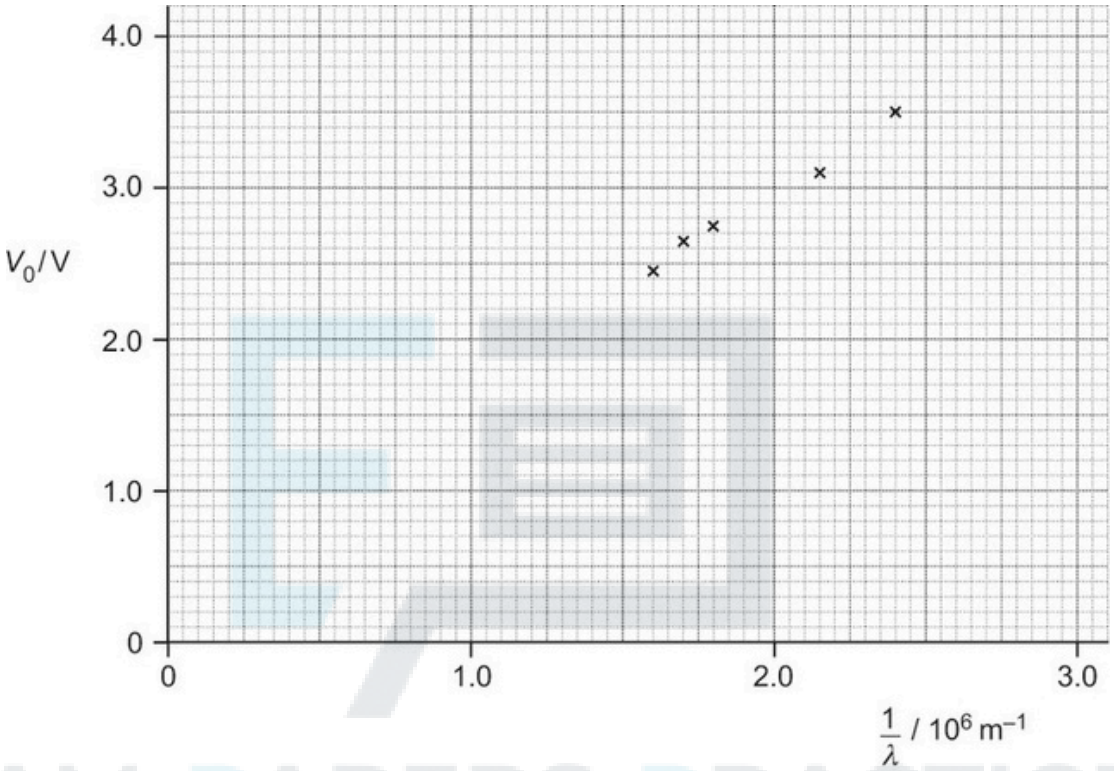


Fig. 20.1

The potential difference across each LED was measured using a digital voltmeter with divisions ± 0.01 V. The values for the wavelengths are accurate and were provided by the manufacturer of the LEDs.

The value of $V0$ was determined by directly observing the state of the LED in the brightly lit laboratory.

(i)Draw the straight line of best fit on Fig 20.1 and determine the gradient of the line.

gradient = ---------- V m [2]

(ii)Use your answer in (i) and the equation above to determine a value for *h* to 2 significant figures. Show your working.

h = ---------- J s [3]

(iii)Calculate the percentage difference between your value in (ii) and the accepted value of the Planck constant.

difference = ... % [1]

(iv)Identify the two types of errors shown by the data in Fig. 20.1 and suggest how you could have refined the experiment to reduce or eliminate these errors.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[4]

$^{60}_{27}Co$ is produced by irradiating the stable isotope $^{59}_{27}Co$ with neutrons.

Each nucleus of $^{60}_{27}Co$ then decays into a nucleus of nickel (Ni) by the emission of a low energy beta-minus particle, one other particle and two gamma photons.

Students want to carry out an investigation into gamma photon absorption using a source of $^{60}_{27}Co$.
They add sheets of lead between the source S and a radiation detector T, to give a total thickness *d* of lead. S and T remain in fixed positions, as shown in Fig. 2.1.

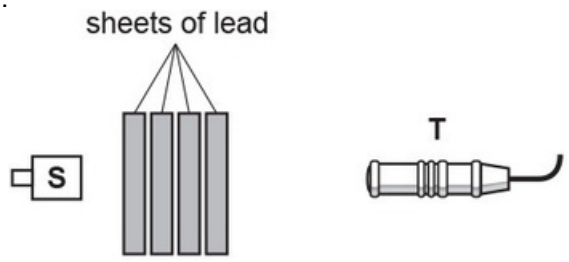


Fig. 2.1

(i) The $^{60}_{27}Co$ source emits beta radiation as well as gamma radiation.

Explain why this would not affect the experiment.

---

[1]

(ii)The students record the number *N* of gamma photons detected by T in 10 minutes for each different thickness *d* of lead. The background count is negligible.

The results are shown in a table. The table includes values of ln *N*, including the absolute uncertainties.

N	d / mm	ln N
4300 ± 440	0	8.37 ± 0.10
2500 ± 250	0	7.82 ± 0.10
1400 ± 150	20	7.24 ± 0.11
800 ± 90	30	6.68 ± 0.11
500 ± 60	40	6.21 ± 0.12

300 ± 40	50	

N and d are related by the equation $N = N_0 e^{-\mu}$ where N_0 and μ are constants.

1 The students decide to plot a graph of ln N against d.

Show that this should give a straight line with gradient = $-\mu$ and y-intercept = ln N_0.

[1]

2 Complete the missing value of ln N in the table, including the absolute uncertainty.

Show your calculation of the absolute uncertainty in the space below.

[2]

3 In Fig. 2.2, five of the data points have been plotted, including error bars for ln N

- Plot the missing data point and error bar.
- Draw a straight line of best fit and one of worst fit.

[2]

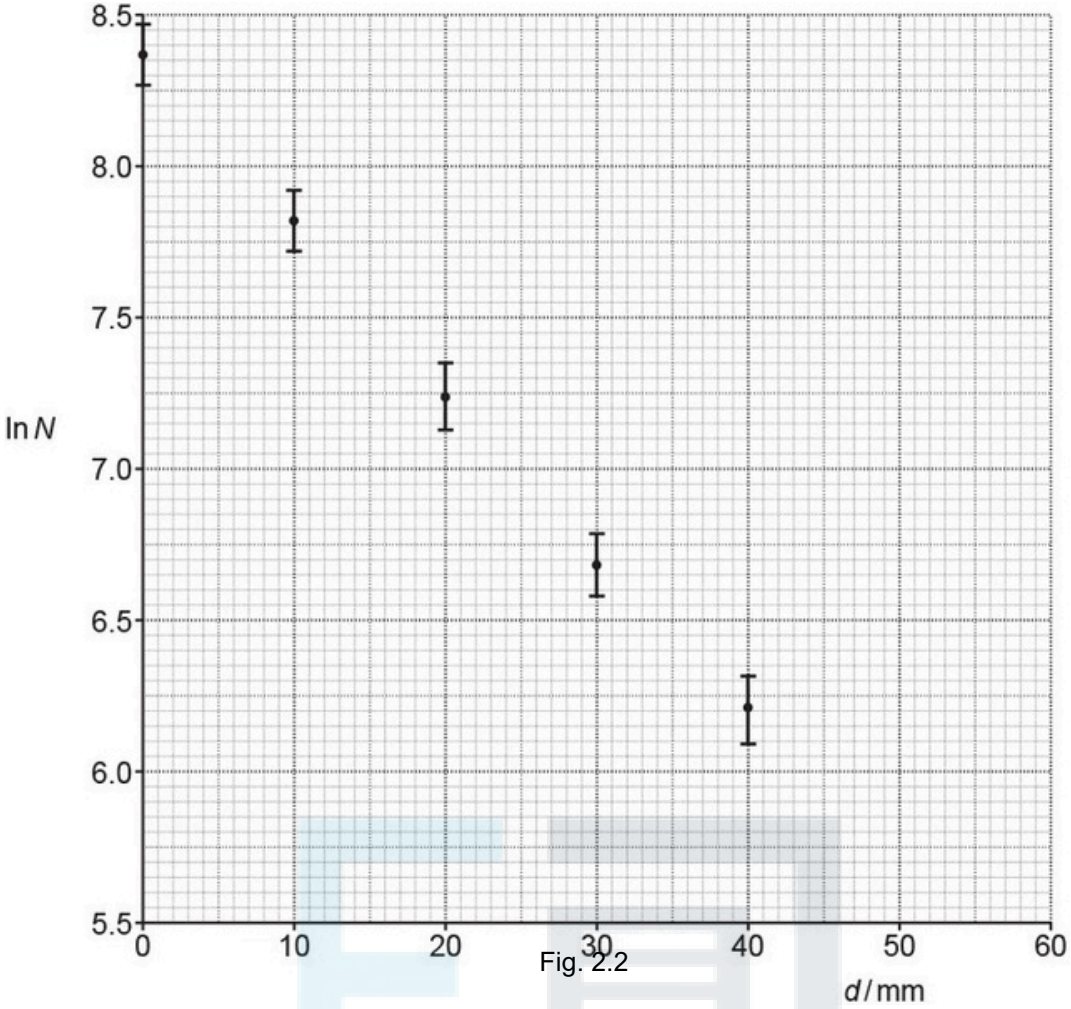


Fig. 2.2

4Use Fig. 2.2 to determine the value of μ in m–1, including the absolute uncertainty.

μ =.....± ..... m–1[4]

5Determine the thickness, $d_{½}$, of lead which halves the number of gamma photons reaching T.

$d_{½}$ = ... m [2]

55(a)At an airport, the conveyor belt for suitcases moves at a constant speed of 1.5 m s^{-1}.

In Fig. 4.1, a suitcase of mass 8.0 kg has reached the line labelled XX'.

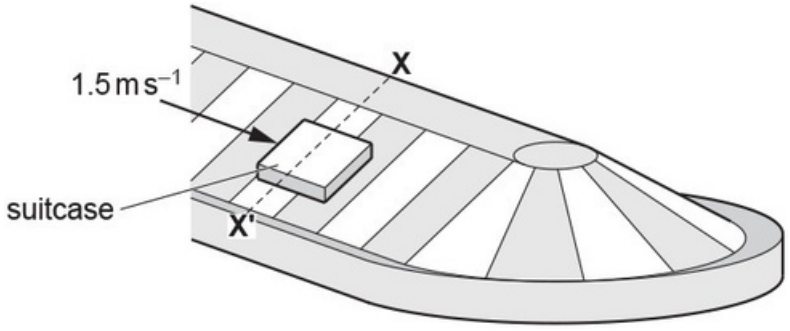


Fig. 4.1

Fig. 4.2 shows the situation in vertical cross-section. The frictional force *F* prevents the suitcase of weight *W* from sliding to the bottom of the belt.

The normal contact force on the suitcase is *R*.

The belt is inclined at an angle of 30° to the horizontal.

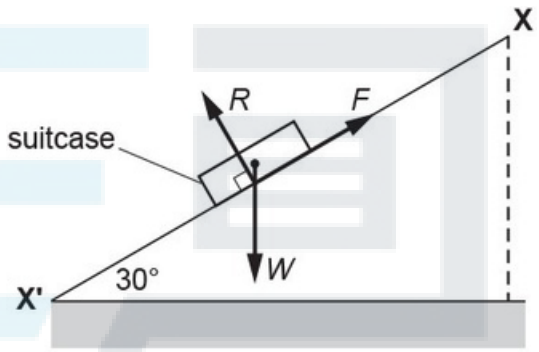


Fig. 4.2 (not to scale)

By using a vector triangle, or by resolving forces, calculate the magnitude of forces *F* and *R*.

F = ... N

R = ... N

[3]

(b)Fig. 4.3 shows the suitcase and the forces acting on it at the line labelled YY'.

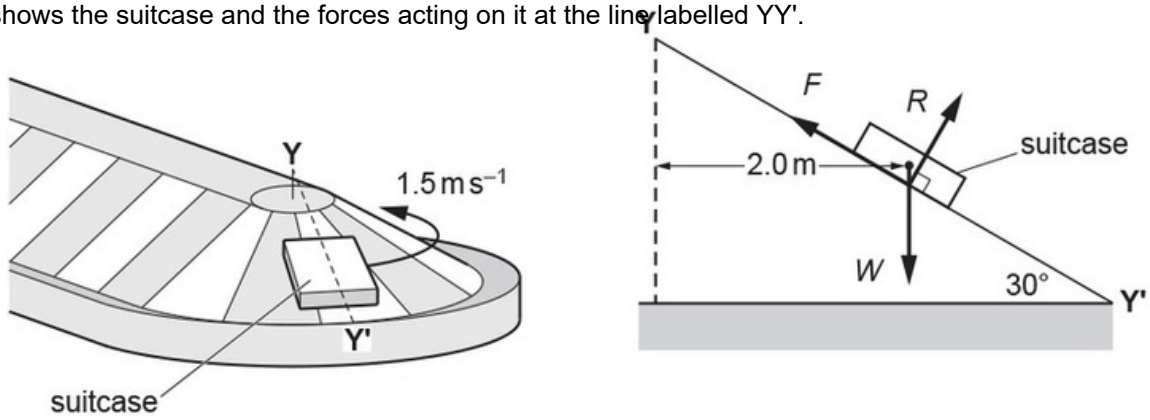


Fig. 4.3

The centre of mass of the suitcase is now moving at 1.5 m s^{-1} along a semi-circular arc of radius 2.0 m.

(i)Calculate the magnitude of the centripetal force acting on the suitcase.

centripetal force = ... N [2]

(ii)When the suitcase is at line YY', the magnitude of force *F* is larger and the magnitude of force *R* is smaller than at XX'.

Explain why this is so.

---

[4]

56 Hydrogen atoms excited in a discharge tube only emit four different discrete wavelengths of visible photons.

*In a semi-darkened room, a single slit is placed in front of the discharge tube. A student holds a diffraction grating which has 300 lines per millimetre.

The student looks through the grating at a 15 cm plastic ruler placed 0.50 m away, as shown in Fig. 5.1.

The paths of the different colours of light from the slit to the student's eye are shown in Fig. 5.2.

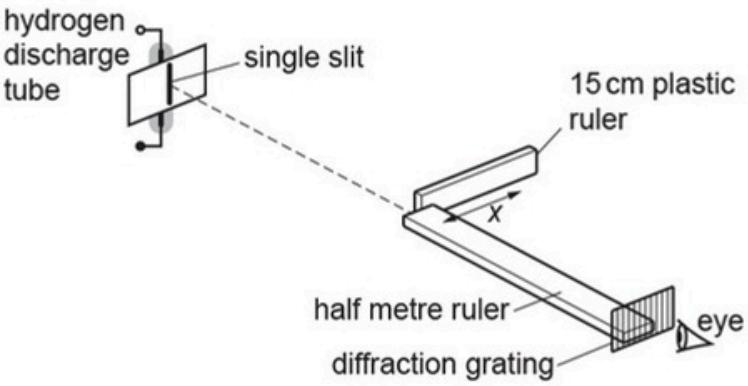


Fig. 5.1 (not to scale)

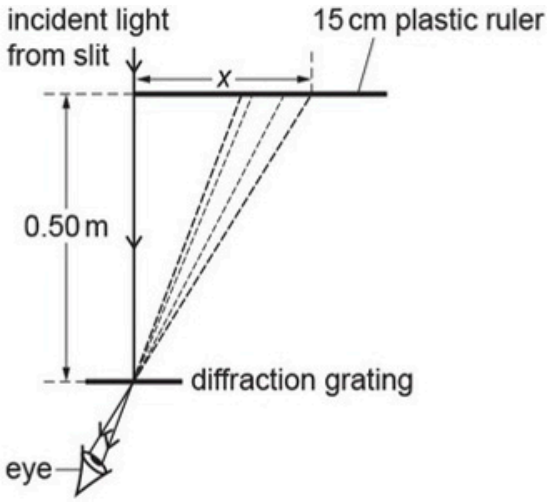


Fig. 5.2 (not to scale)

Four first order images of the slit, one at each photon wavelength, are observed as vertical lines against the background of the plastic ruler, as shown in Fig. 5.3.

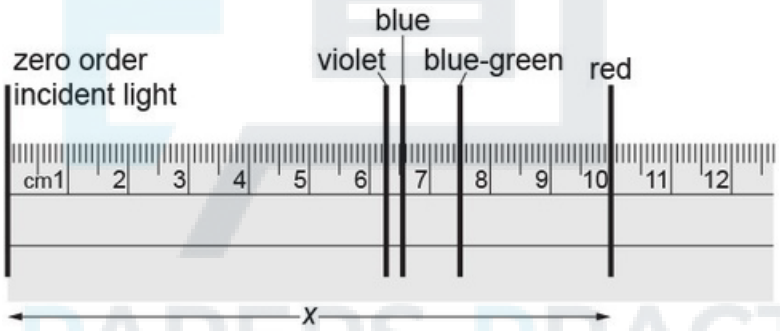


Fig. 5.3

The student decides to determine the wavelength of the photons which form the red line observed at x = 10 cm on the ruler.

- Describe how the information that has been given can be used to determine the wavelength of the red photons.
- Estimate the percentage uncertainty in the measured value of the wavelength.

[6]

57 In their laboratory notes, one student writes about the accuracy of the measurements whereas the other writes about their precision.

Define these terms.

accuracy: .....

.....

precision: .....

.....

[2]

58 Which set of prefixes A, B, C or D are in order of increasing magnitude?

A micro, milli, centi, kilo

B milli, centi, micro, kilo

C kilo, centi, milli, micro

D centi, micro, milli, kilo

Your answer ☐ [1]

59 A solid cylindrical glass rod has length 20.0 ± 0.1 cm and diameter 5.00 ± 0.01 mm.

What is the percentage uncertainty in the calculated volume of this rod?

A 0.1%

B 0.2%

C 0.7%

D 0.9%

Your answer ☐ [1]

60 An object is falling.
The weight of the object is 4.5 N.
The wind provides a horizontal force of magnitude *F* on the object.
The resultant force on the object is 5.8 N.
Air resistance and upthrust on the object are negligible.

What is the value of *F*?

A 1.3 N

B 3.7 N

C 7.3 N

D 13 N

Your answer ☐ [1]

61 Which of the following shows the correct base units for pressure?

A kg m–2

B kg m–2 s^2

C kg m–1 s^2

D kg m2 s^{-3}

Your answer ☐ [1]

62(a)The S.I. base units for the ohm (Ω) are kg m2 s–3 A–2.
Use the equation $R = \frac{\rho L}{A}$ to determine the S.I. base units for resistivity ρ.

base units for ρ ..... [2]

(b)Fig. 18.1 shows a circuit used by a student to determine the resistivity of the material of a wire.

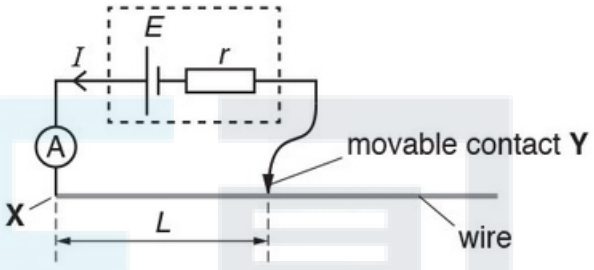


Fig. 18.1

The wire is uniform and has diameter 0.38 mm. The cell has electromotive force (e.m.f.) E and internal resistance r. The length of the wire between X and Y is L.

The student varies the length L and measures the current I in the circuit for each length.

Fig. 18.2 shows the data points plotted by the student.

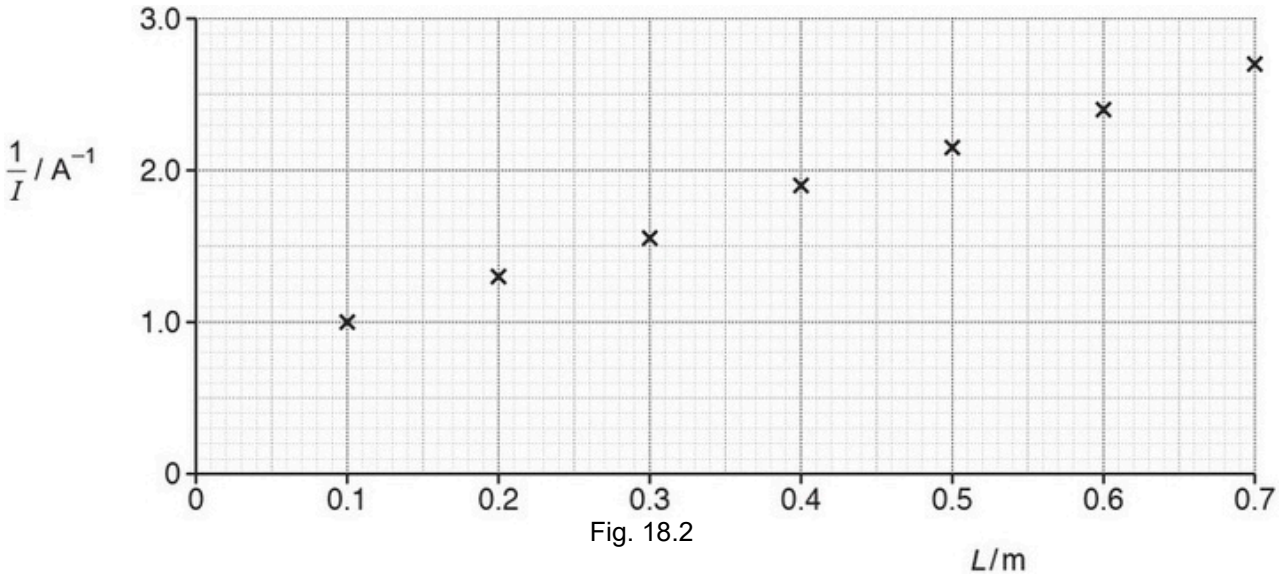


Fig. 18.2

(i)On Fig. 18.2 draw the straight line of best fit. Determine the gradient of this line.

gradient = ... A–1 m–1 [2]

(ii)Show that the gradient of the line is $\frac{\rho}{AE}$, where ρ is the resistivity of the material of the wire, A is the area of cross-section of the wire and E is the e.m.f. of the cell.

[2]

(iii)The e.m.f. E of the cell is 1.5 V. The diameter of the wire is 0.38 mm.

Use your answer to (i) and the equation given in (ii) to determine ρ.

ρ = ... Ωm [2]

(iv)Fig. 18.3 illustrates how the student had incorrectly measured all the lengths *L* of the wire.

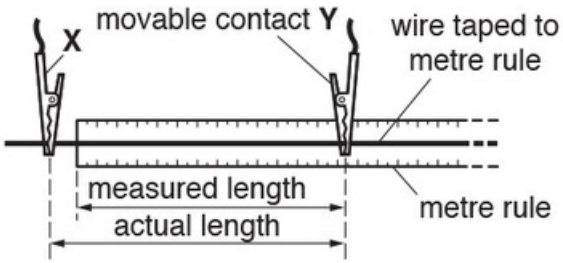


Fig. 18.3

According to the student, re-plotting the data points using the actual lengths of the wire will not affect the value of the resistivity obtained in (iii).

Explain why the student is correct.

[2]

63 An athlete is running at a speed of about 5 m s
What is a reasonable estimate for the kinetic energy of this athlete?

A 12 J 100
B J 900 J
C 800 000 J
D

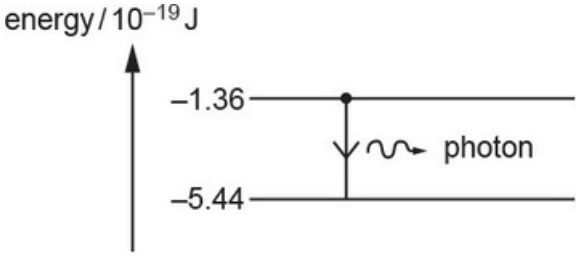
Your answer [1]

64 Which pair of quantities have the same S.I. base units?

A force, strain
B force, stress
C pressure, stress
D strain, upthrust

Your answer [1]

65 The diagram below shows two energy levels for the electron in the hydrogen atom.



The electron makes the transition shown by the arrow.

What is the wavelength of the photon emitted?

A 293 nm
B 366 nm
C 488 nm
D 1460 nm

Your answer [1]

66 In astronomy, distance can be measured in different units.

Which one of the following distances is the largest?

A 4.22 × 1016 m
B 1.91 pc
C 3.42 ly
D 593AU

Your answer [1]

67 The Young modulus E of a metal can be determined using the expression $E = \frac{4F}{\varepsilon\pi d^2}$, where F is the tension in the wire, d is the diameter of the wire and ε is the strain of the wire.

Here is some data.

Quantity	Percentage uncertainty
F	5.3 1.2 1.0
ε	
D	

What is the percentage uncertainty in the calculated value of E?

A 2.1 %
B 6.4 %
C 7.5 %
D 8.5 %

Your answer ☐ [1]

68 A student is doing an experiment on the magnetic force experienced by a current-carrying wire in a uniform magnetic field. The magnetic flux density B can be varied.

For a particular flux density, the current in the wire is 2.0A. The length of the wire in the field is 0.12 m. The angle between the current and the magnetic field is 30°. The force experienced by the wire is 7.7 × 10–2 N.

The student calculates B and records the results in a table.

Which row shows the correct table heading for B and the correct value for B?

	Table heading for B	Value for B
A	B / T B / T B / Wb	0.37
B	B / Wb	0.64
C		0.37
D		0.64

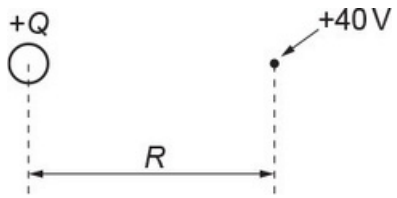
Your answer ☐ [1]

69 The total energy released in a single fusion reaction is 4.0 MeV.
What is the change in mass in this fusion reaction?

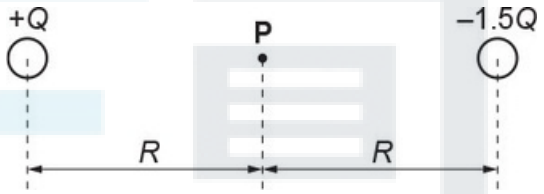
A 7.1×10^{-36} kg
B 7.1×10^{-30}kg
C 2.1×10^{-21}kg
D 4.4×10^{-17}kg

Your answer ☐ [1]

70 The electric potential at a distance *R* from the centre of a charge +*Q* is + 40 V.



What is the potential at the point P for the arrangement of the charges +*Q* and –1.5*Q* as shown below?



A – 20 V
B – 60 V
C + 80 V
D + 100 V

Your answer ☐ [1]

71(a) The Planck constant *h* is an important fundamental constant in quantum physics.
Determine the S.I. base units for *h*.

base units = ... [2]

(b)A researcher is investigating the de Broglie wavelength of charged particles.

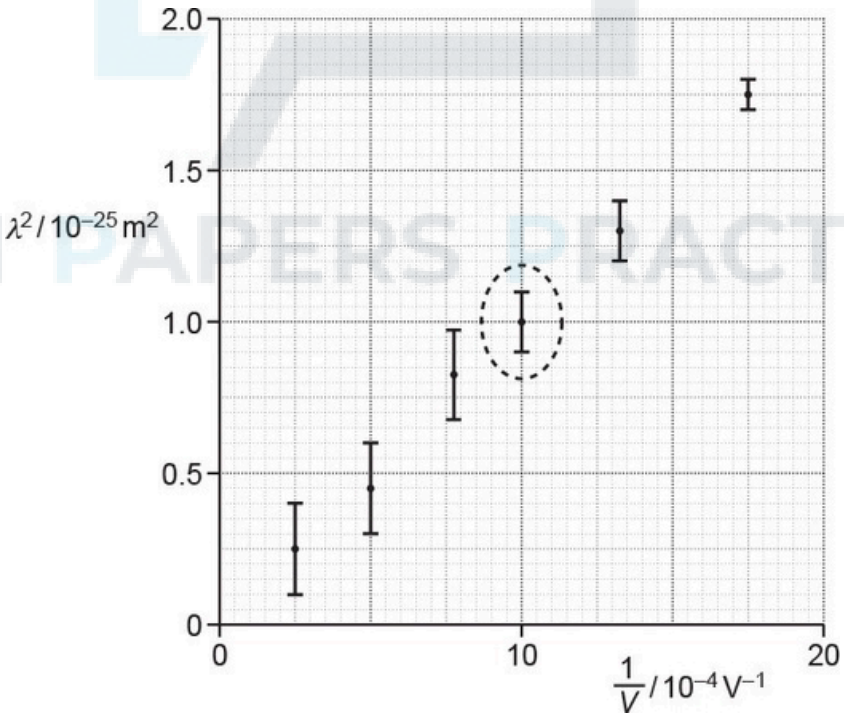
The charged particles are accelerated through a potential difference V. The de Broglie wavelength λ of these particles is then determined by the researcher.

Each particle has mass m and charge q.

(i)Show that the de Broglie wavelength λ is given by the expression $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$

[2]

(ii)The researcher plots data points on a $\lambda 2$ against $\frac{1}{V}$ grid, as shown below.



1 Calculate the percentage uncertainty in λ for the data point circled on the grid.

percentage uncertainty = ... % [2]

2 Draw a straight line of best fit through the data points. [1]

3 The charge q on the particle is $2e$, where e is the elementary charge.

Use your best fit straight line to show that the mass m of the particle is about 10^{-26} kg.

[4]

72 A sound wave is incident at the ear.

The amplitude of the sound wave is 7.8 nm. The intensity of the sound at the earhole is 4.8 × 10–7 W m–2.

(i)Determine the power of the sound incident at the earhole by estimating the diameter of the earhole in mm.

diameter of earhole ≈ ..... mm

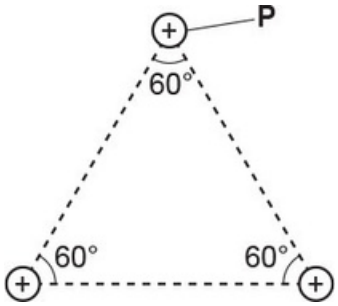
power = ... W [2]

(ii)A different sound wave is now incident at the ear.
The intensity of this wave is 9.6 × 10–7 W m–2.

Calculate the amplitude *A* in nm of this sound wave.

A = ... nm [2]

73 The diagram below shows the arrangement of the 3 protons inside the nucleus of lithium-6 $(^{6}_{3}Li)$



The separation between each proton is about 1.0×10^{-15} m.

(i)Calculate the magnitude of the repulsive electric force *F* experienced by the proton P.

F = ... N [4]

(ii)On the diagram above, draw an arrow to show the direction of the electric force *F* experienced by P.

[1]

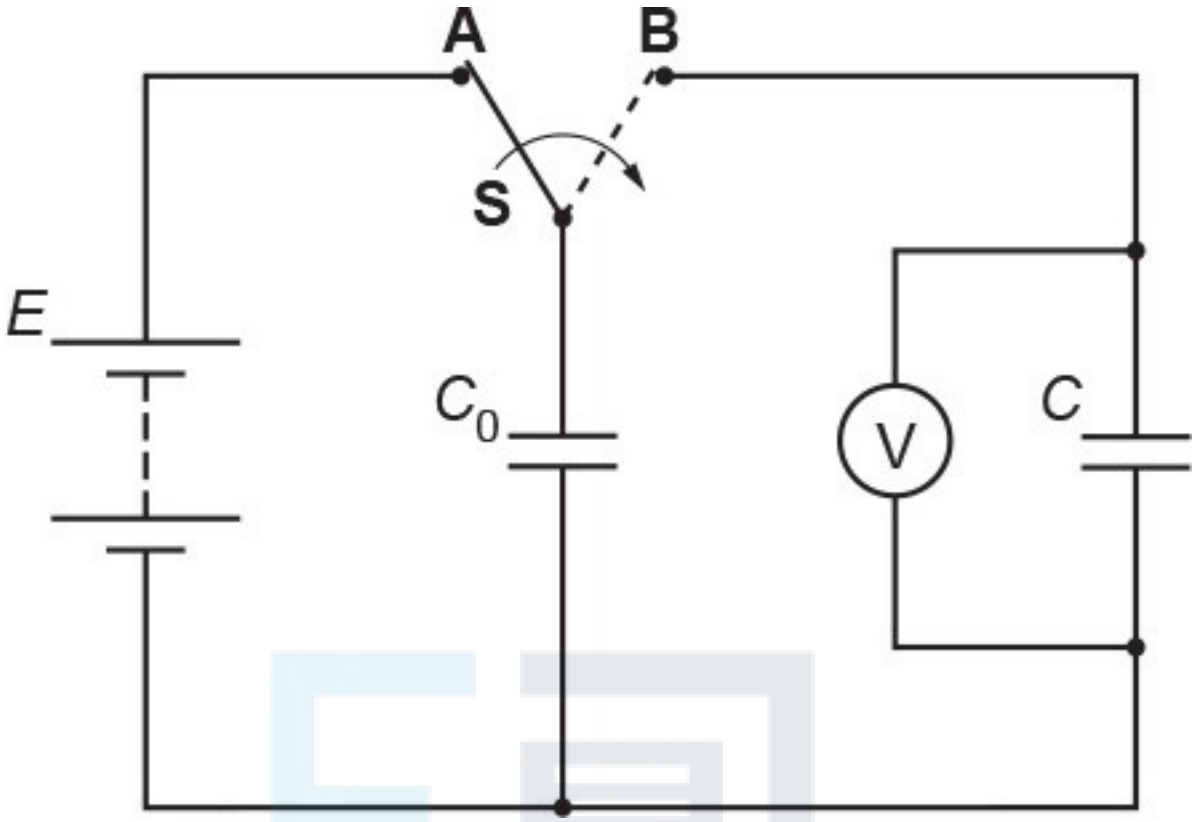
(iii)Explain how protons stay within the nucleus of lithium-6.

---

[2]

74(a) The diagram below shows a circuit containing two capacitors which are both initially uncharged. The battery has e.m.f. E and negligible internal resistance.

The switch S is first moved to position A until the capacitor of capacitance $C0$ is fully charged.



The switch S is then moved to position B. The initial charge stored by the capacitor of capacitance $C0$ is shared between the two capacitors.

The final reading on the voltmeter is V.

Show that $V = \frac{C_0}{C + C_0} E$.

[2]

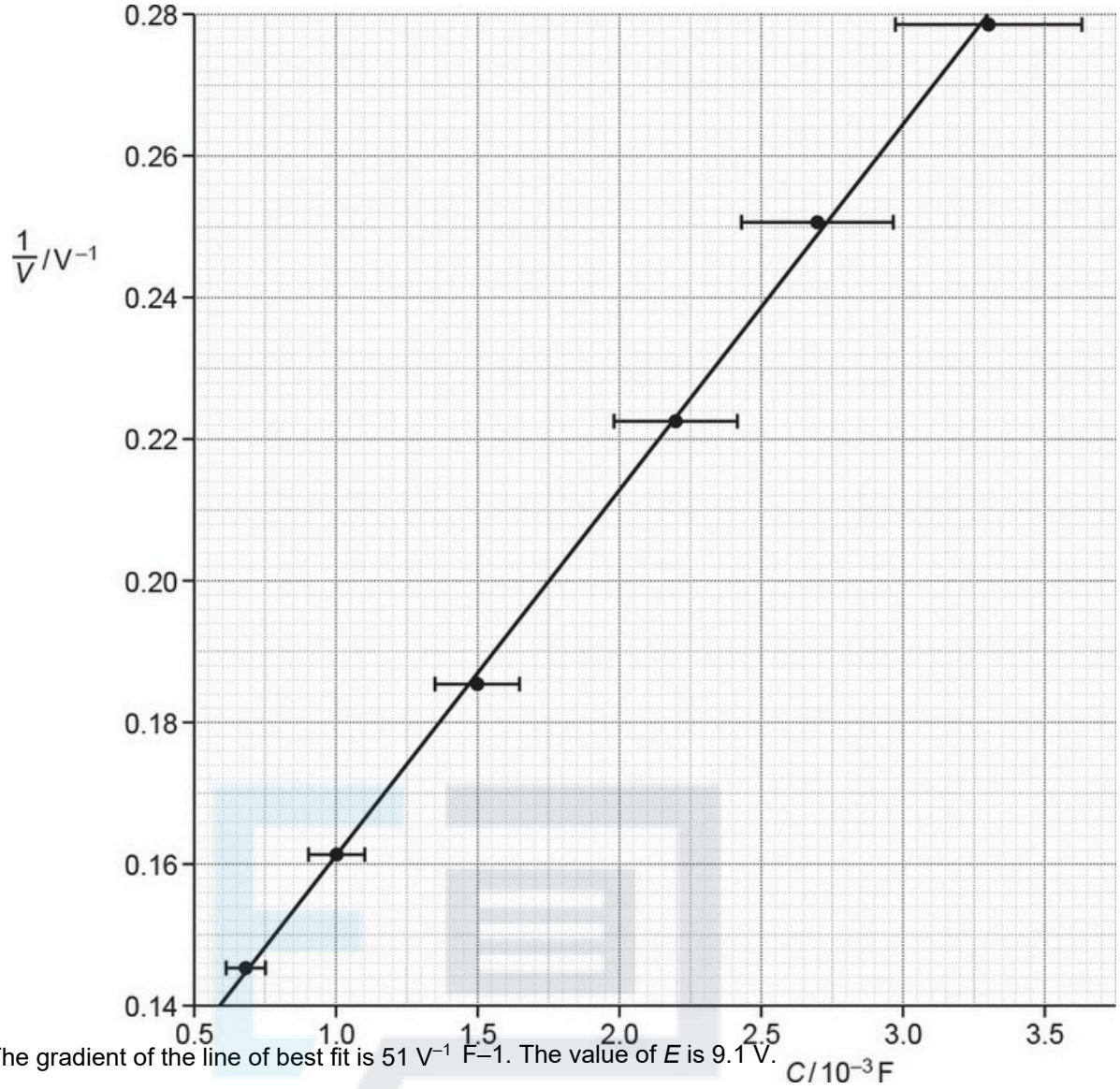
(b)A student wants to determine the values of E and C 0 by repeating the experiment above and measuring the potential difference (p.d.) V for a selection of capacitors of capacitance C.

The student decides to plot a graph of $\frac{1}{V}$ against C.

(i)Use the expression in (a) to show that the graph should be a straight line of gradient $\frac{1}{C_0 E}$ and y-intercept $\frac{1}{E}$.

[1]

(ii)The data points, error bars and the line of best fit drawn by the student are shown in the graph below.



The gradient of the line of best fit is 51 V^{-1} F^{-1}. The value of E is 9.1 V.

Determine the value of $C0$ in millifarads (mF). Write your answer to 2 significant figures.

C 0 = ... mF [2]

(iii)Draw on the graph a straight line of worst fit.

Use this line to determine the absolute uncertainty in your value of C 0. Write your answer to an appropriate number of significant figures.

absolute uncertainty = ... mF [4]

(c) The experiment is repeated with a resistor of resistance 10 kΩ placed in series between S and the capacitor of capacitance *C* 0.

State with a reason what effect, if any, this would have on the experiment.

---

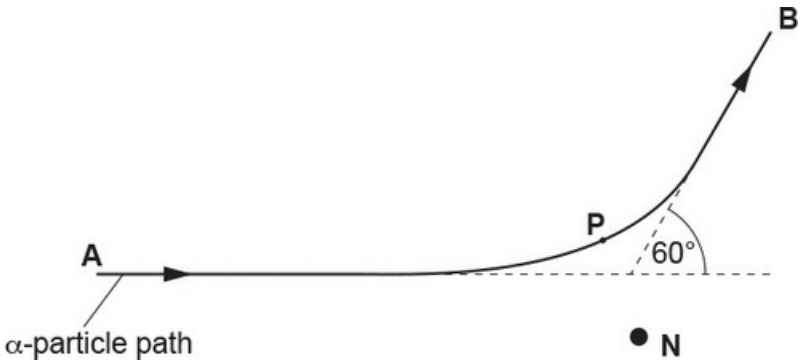
[1]

---

75 A beam of α-particles is incident on a thin gold foil. Most α-particles pass straight through the foil. A few are deflected by gold nuclei.

The diagram shows the path of one α-particle which passes close to a gold nucleus N in the foil. The α-particle is deflected through an angle of 60° as it travels from A to B.

P marks its position of closest approach to the gold nucleus.



The magnitude of the final momentum of the α-particle at B is equal to its initial value at A.

The gold nucleus N is initially at rest. During the passage of the α-particle from A to B, no other forces act on the two particles.

In the following questions label any relevant angles.

(i) Draw two vectors in the spaces below to represent the initial momentum and the final momentum of the α-particle.

initial momentum at A

final momentum at B

[2]

(ii) Draw a vector in the space below to represent the momentum of the nucleus N when the α-particle reaches B.

Explain how you determined this momentum.

---

[2]

END OF QUESTION PAPER