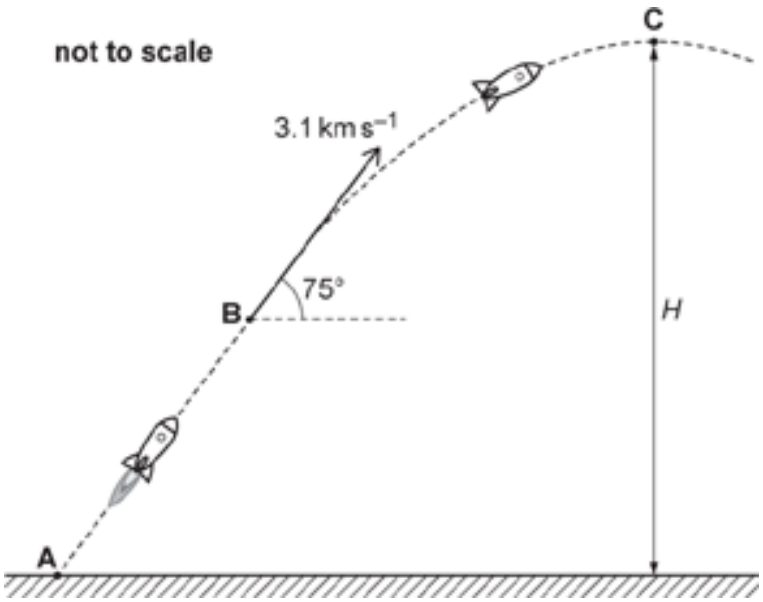
1. A scientist uses a rocket to study the Earth's atmosphere.

The scientist launches the rocket from rest at the point **A** at t = 0 seconds. The force produced by the rocket's engine causes it to accelerate.

At t = 50 seconds, the rocket's engine no longer produce an accelerating force as all of the fuel has been used. The rocket has reached point **B**. Its velocity is now 3.1 km s^{-1} at an angle of 75° to the horizontal.



The rocket reaches its maximum height at point **C**.

- Estimate the vertical displacement H between **A** and **C**. Assume that g = 9.81 m s^{-2} throughout.
- Clearly state any other assumptions required at each stage in your calculations.
- Evaluate the assumption that g = 9.81 m s^{-2} between **A** and **C**, supporting your discussion with a calculation. Assume that the radius of the Earth ≈ 6400 km.

[6]

2. 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]**

3. In 1929, the Nobel prize was awarded to Louis de Broglie for his discovery of the wave nature of electrons.

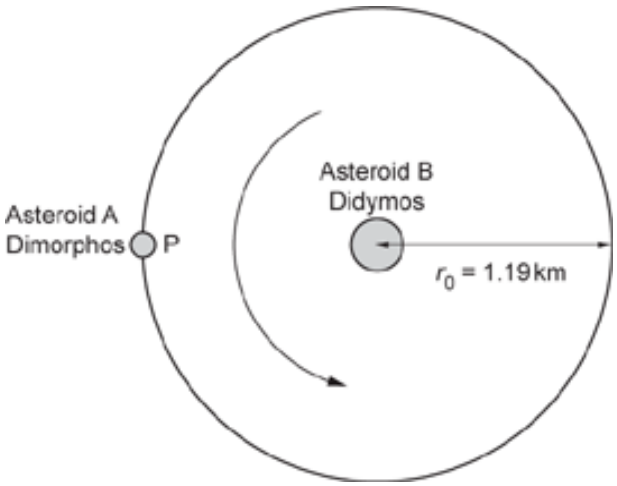
Describe, with the aid of a suitable diagram:

- how an experiment can be safely conducted to demonstrate the wave nature of electrons
- how the observations indicate the wave nature of electrons
- how an estimate of the de Broglie wavelength of the electrons compares with an estimate of the de Broglie wavelength for a car travelling at a speed of 110 Km / h on a motorway.

Diagram

[6]

4. 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 4.29×10^4 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 = ... km **[3]**

5. 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.

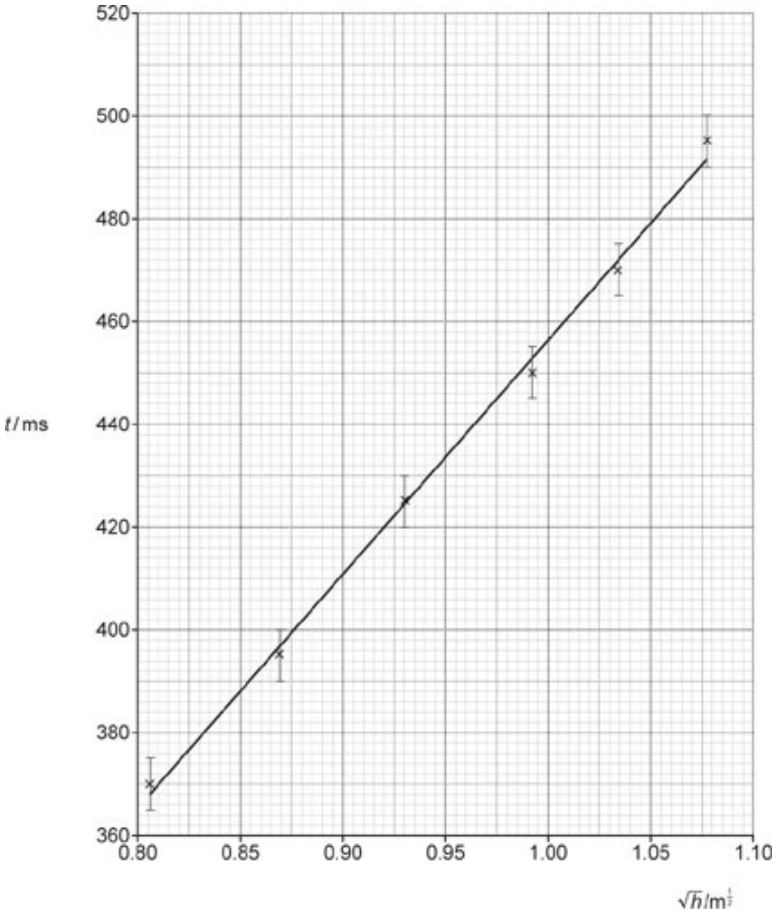
The table shows the results. Values of $\sqrt{h}$ have been included.

***h*/m**	$\sqrt{h}$ / 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 $\sqrt{h}$ / m$^{\frac{1}{2}}$ on the x-axis is plotted.



- Describe how to measure *h* and *t*.
- Use the graph to determine *g*, including the percentage uncertainty.

[6]

6. Which row contains **only** scalar quantities?

A Absolute temperature, displacement, moment
B Acceleration, force, momentum
C Gravitational potential, kinetic energy, mass
D Kinetic energy, mass, momentum

Your answer ☐ **[1]**

7(a). A tent is secured by 3 ropes along each of its long sides, as shown in **Fig. 18. 1**.

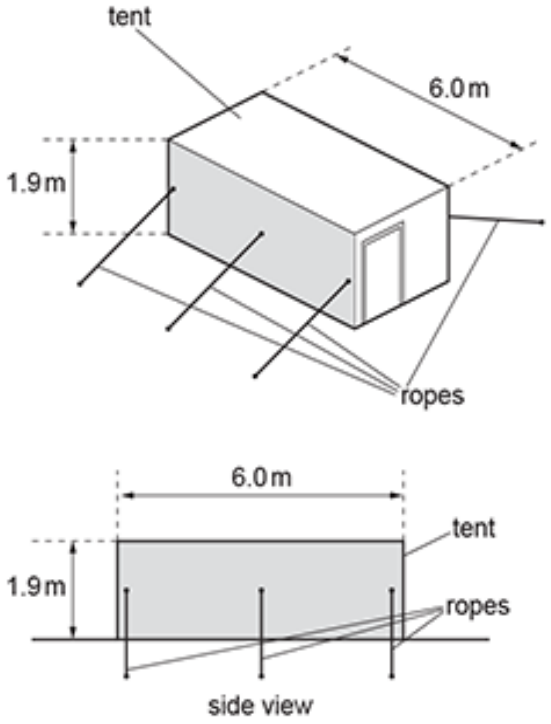


Fig. 18.1

Wind of speed 12 ms^{-1} blows at right angles to the **shaded** side of the tent for 3.0 s. The density of air is 1.2 kg m^{-3}.

i. Show that the mass of air which hits the tent in this time is about 490 kg.

[3]

ii. All of the air incident on the shaded side of the tent is deflected at 90° to the original direction as shown in **Fig. 18. 2**.

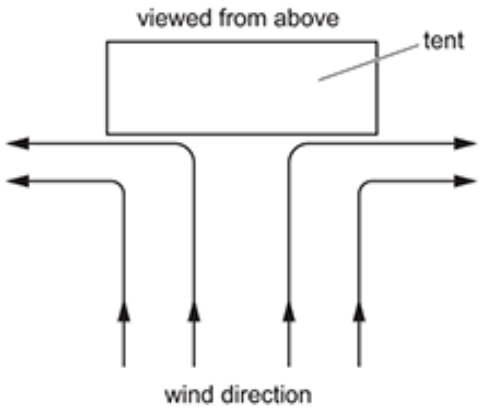


Fig. 18.2

Use the information given in **(a)(i)** to calculate the magnitude of the force *F* exerted by the wind on the shaded side of the tent.

F = ... N **[2]**

(b). *When the wind speed exceeds 20 ms^{-1} the ropes securing the tent break.

Describe, and explain in terms of forces, how the ropes and the shape of the tent could be modified to withstand wind speed exceeding 40 ms^{-1}.

[6]

8.

For a simple harmonic oscillator, the acceleration a is given by the equation $a = -\omega^2 x$, where ω is the angular frequency and x is the displacement.

Show that this equation is homogeneous by reducing both sides to S.I. base units.

[2]

END OF QUESTION PAPER