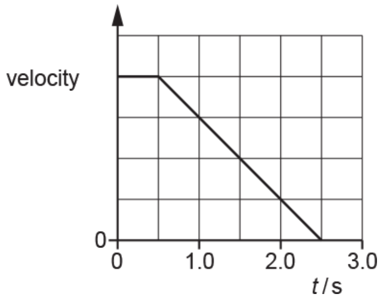
Motion

1. A car is driven at constant velocity until the driver sees an obstruction ahead at time t = 0. The velocity against time graph below shows the motion of the car as the driver brings it to a stop.



The thinking distance is 10 m.
What is the stopping distance for the car?

A 20 m
B 30 m
C 40 m
D 50 m

Your answer ☐ **[1]**

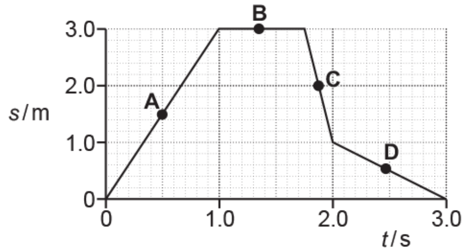
2. Which definition is correct and uses only quantities rather than units?

A Acceleration is the change in velocity per second.
B Resistance is potential difference per ampere.
C Intensity is energy per unit cross-sectional area.
D Electromotive force is energy transferred per unit charge.

Your answer ☐ **[1]**

3. An object is moving in a straight line.

The displacement s against time *t* graph for this object is shown below.

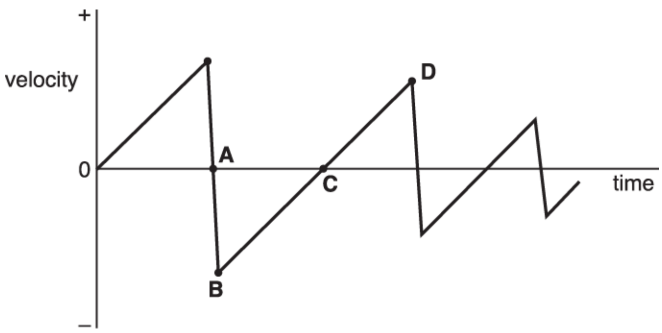


At which point **A, B, C** or **D**, does the object have the greatest speed?

Your answer ☐ **[1]**

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

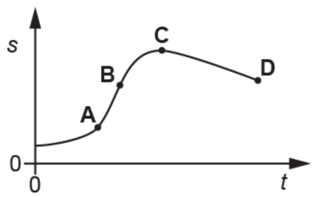
At which point does the ball reach its maximum height after the first bounce?



Your answer ☐

[1]

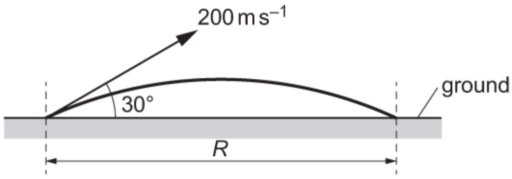
5. The graph below shows the variation of displacement *s* with time *t* for an object.



At which point, **A**, **B**, **C** or **D**, does the object have maximum velocity?

Your answer ☐ **[1]**

6. A bullet is fired at an angle of 30° to the horizontal ground at a velocity of 200 ms^{-1}.
The bullet is in flight for a time t.
Air resistance has negligible effect on the motion of the bullet.



What is the correct expression for the horizontal distance R travelled by the bullet?

A $R = 200 \times \cos 30° \times t$

B $R = 200 \times \sin 30° \times t$

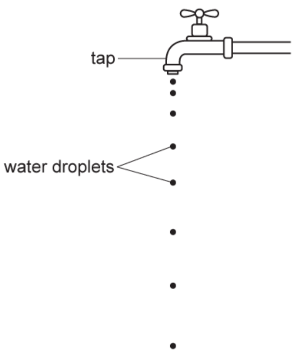
C $R = \frac{(200 \times \cos 30°)^2}{2 \times 9.81}$

D $R = \frac{(200 \times \sin 30°)^2}{2 \times 9.81}$

Your answer ☐ **[1]**

7. Droplets of water drip at a constant rate from a tap.

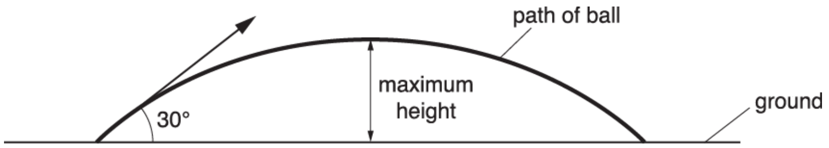
The diagram below shows this dripping tap.



Explain how you can deduce that the droplets are accelerating.

---[1]

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



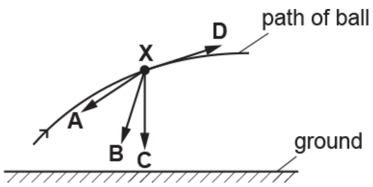
What is the kinetic energy of the ball at the maximum height?

A 0
B 0.25 *K*
C 0.75 *K*
D 0.87 *K*

Your answer

[1]

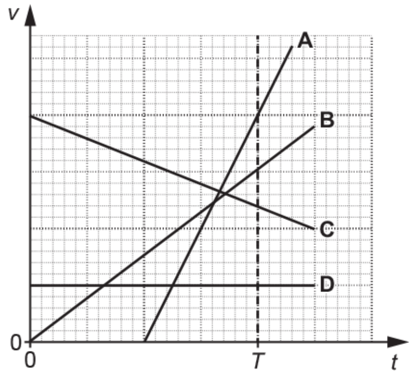
9. A ball is thrown through the air. The ball experiences a small amount of drag compared to its weight.
At a particular time the ball is at point **X**.
Which arrow best represents the direction of the resultant force on the ball when it is at **X**?



Your answer

[1]

10. The velocity *v* against time *t* graphs for four objects **A** , **B** , **C** and **D** are shown below.



Which object travels the greatest distance between $t = 0$ and $t = T$?

Your answer ☐ **[1]**

11 (a). The International Space Station (ISS) orbits the Earth at a height of 4.1×10^5 m **above** the Earth's surface.

The radius of the Earth is 6.37×10^6 m. The gravitational field strength g_0 at the Earth's surface is 9.81 N kg^{-1}.

Both the ISS and the astronauts inside it are in free fall.

Explain why this makes the astronauts feel **weightless**.

--- **[1]**

(b).

i. Calculate the value of the gravitational field strength *g* at the height of the ISS above the Earth.

g = ... N kg^{-1} **[3]**

ii. The speed of the ISS in its orbit is 7.7 km s^{-1}. Show that the period of the ISS in its orbit is about 90 minutes.

[2]

(c). Use the information in **(b)(ii)** and the data below to show that the root mean square (r.m.s.) speed of the air molecules inside the ISS is approximately 15 times smaller than the orbital speed of the ISS.

- molar mass of air = 2.9×10^{-2} kg mol^{-1}
  temperature of air inside the ISS = 20 °C
-

[3]

(d). The ISS has arrays of solar cells on its wings. These solar cells charge batteries which power the ISS. The wings always face the Sun.

Use the data below and your answer to **(b)(ii)** to calculate the **average** power delivered to the batteries.

- The total area of the cells facing the solar radiation is 2500 m^2.
- 7% of the energy of the sunlight incident on the cells is stored in the batteries.
- The intensity of solar radiation at the orbit of the ISS is 1.4 kW m^{-2} outside of the Earth's shadow and zero inside it.
- The ISS passes through the Earth's shadow for 35 minutes during each orbit.

average power = ... W **[4]**

12. A motorcyclist riding on a level track is told to stop via a radio microphone in his helmet. The distance *d* travelled from this instant and the initial speed *v* are measured from a video recording.

Fig. 2.1

A student is investigating how the stopping distance of a motorcycle with high-performance brakes varies with the initial speed.

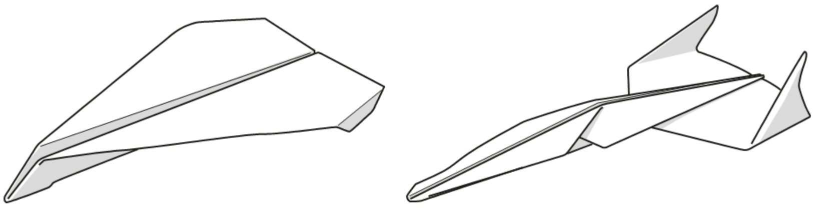
Explain why the student predicts that *v* and *d* are related by the equation

$$d = \frac{v^2}{2a} + vt$$

where *a* is the magnitude of the deceleration of the motorcycle and *t* is the thinking time of the rider.

[1]

13. Fig. 23.1 shows two designs for paper aeroplanes made from identical sheets of A4 paper. The condor is slow-moving with a long glide-time, whilst the piranha is designed for speed and accuracy but has a short glide-time.



condor piranha

Fig. 23.1

A student launches each plane horizontally with a velocity of 3.0 m s^{-1} using a catapult. The planes are launched from the same vertical height. This is repeated several times. The time *t* of flight in the air is recorded using a stopwatch. The results are shown in the table of Fig. 23.2.

condor: *t* / *s*	piranha: *t* / *s*
3.5	2.0
3.9	1.6
4.2	1.8
3.4	2.2
1.8	2.1

Fig. 23.2

Using Fig. 23.2, state the minimum and maximum flight times for the **piranha**.

minimum *t* = ... s

maximum *t* = ... s

[1]

14 (a). A student is carrying out an experiment in the laboratory to determine the acceleration of free fall *g*. The student drops a small steel ball from rest and records the time *t* taken for the ball to fall through a vertical distance *h*.

The results for different vertical distances are shown in the table below.

h **/ m**	***t*** **/ s**	t^2 **/ s²**
0.660	0.365	0.133
0.720	0.385	0.148
0.780	0.400	0.160
0.840	0.415	0.172
0.900	0.430	
0.960	0.445	0.198

[1]

Complete the table for the missing value of t^2.

(b). Fig. 3 shows the graph of t^2 (*y*-axis) against *h* (*x*-axis).

(i) Plot the missing data point and draw the straight line of best fit. **[2]**

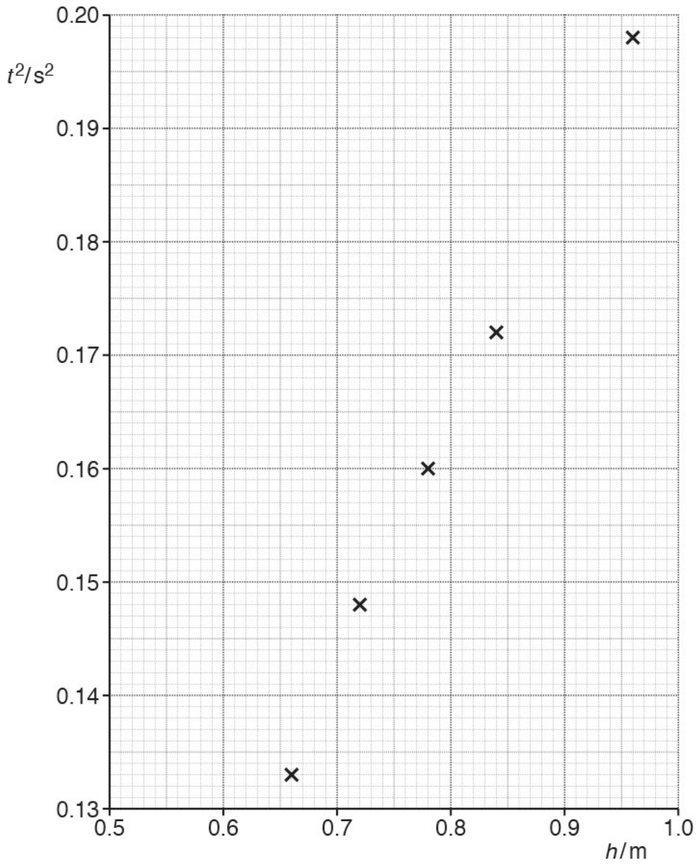


Fig. 3

(ii) Determine the gradient of the straight line of best fit.

gradient = -- $s^2\ m^{-1}$ **[1]**

(c).

i. Use the equations of motion for constant acceleration to show that the relationship between *t* and *h* is

$$t^2 = \left(\frac{2}{g}\right)h$$

where *g* is the acceleration of free fall.

[1]

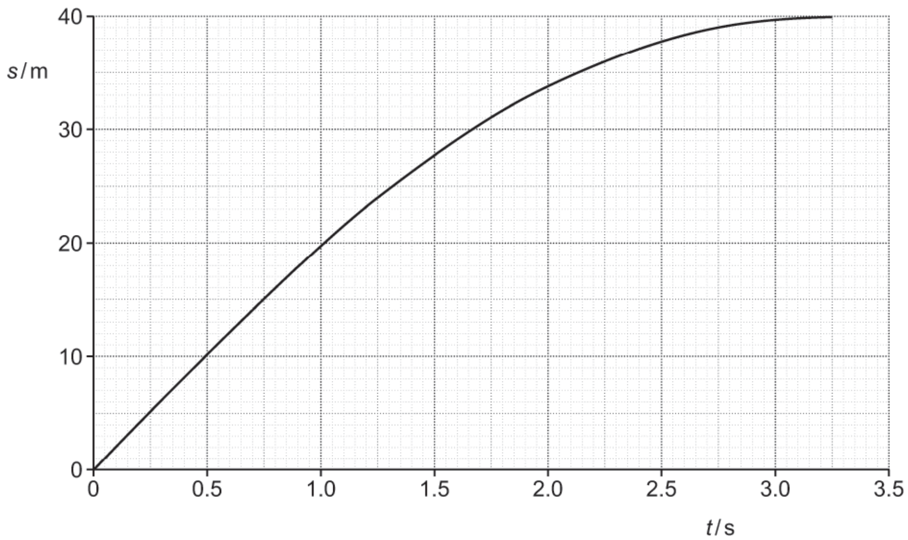
ii. Use your answer to **(c)(ii)** to determine the experimental value for *g*.

g = -- $m\ s^{-2}$ **[1]**

15. Define what is meant by the *stopping distance* of a vehicle.

--**[1]**

16. A car is travelling at a constant speed of 20 m s^{-1} along a straight road.
The driver sees a hazard ahead in the road, applies the brakes and brings the car to a stop.
The graph below shows the displacement *s* against time *t* for the car from the time that the driver sees the hazard to when the car stops.

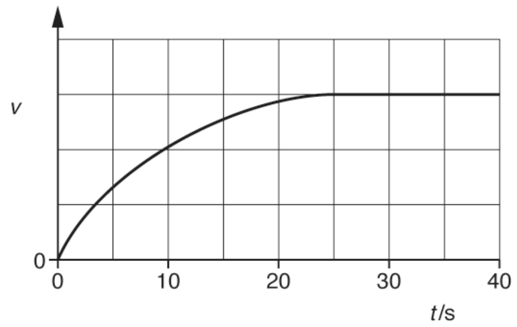


The braking force *F* acting on the car is constant.
The mass of the car is 950 kg.
The reaction time of the driver is 0.75 s.

State the gradient of the graph when *t* = 0.

gradient = ... m s^{-1} **[1]**

17. An object is dropped from rest at time t = 0. It falls vertically through the air.
The variation of the velocity v with time t is shown below.



Which statement is correct about this object?

A It has constant acceleration.
B It experiences zero drag at t = 30 s.
C It has an acceleration of 9.81 m s^{-2} at t = 0 s.
D It travels the same distance in every successive 10 s.

Your answer [1]

18. The table shows some data for a car travelling on a straight road with an initial speed of 13 m s^{-1}.

Thinking distance / m	**9.0**
Braking distance / m	14
Stopping distance / m	**23**

The car has a constant deceleration when the brakes are applied.
What is the magnitude of the deceleration of the car during braking?

A 0.46 m s^{-2}
B 3.7 m s^{-2}
C 6.0 m s^{-2}
D 9.4 m s^{-2}

Your answer [1]

19. A ball is launched horizontally at 5 m s^{-1} from the end of a table. The ball is in flight for 0.4 s before it lands on the floor. The ball is now launched from the end of the same table with a horizontal velocity 10 m s^{-1}.

What is the new time of flight of the ball?

A. 0.2 s
B. 0.4 s
C. 0.5 s
D. 0.8 s

Your answer

[1]

20. An object above the ground is released from rest at time t = 0.

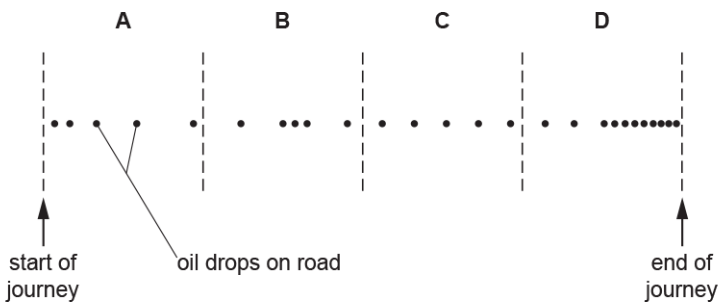
Air resistance is negligible.

What is the distance travelled by the object between t = 0.20 s and t = 0.30 s?

A 0.20 m
B 0.25 m
C 0.44 m
D 0.49 m

Your answer [1]

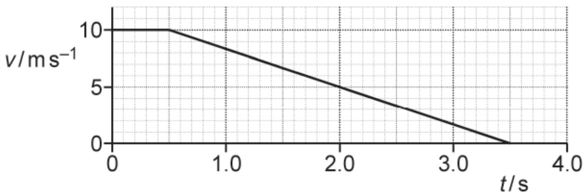
21. A car is dripping oil at a steady rate on a straight road.
The road is divided into four sections **A**, **B**, **C**, and **D**.



Which section of the road shows the car travelling at a constant speed?

Your answer ☐ **[1]**

22. A driver sees an obstacle ahead in the road at time $t = 0$ and then applies the brakes.
The velocity v against time t graph for the car is shown below.



Which row is correct?

	Reaction time of driver / s	Braking distance of car / m
A	0.5	15.0
B	0.5	17.5
C	3.5	15.0
D	3.5	17.5

Your answer ☐ **[1]**

23. A car accelerates uniformly from rest along a level road.
The effects of air resistance on the car are negligible.
The car travels 12 m in the second second of its journey.

How far does it travel in the fourth second?

A. 28 m
B. 35 m
C. 48 m
D. 64 m

Your answer ☐

[1]

24. A ball of diameter 2.50 cm is held above the ground. The bottom of the ball is 10.2 cm above the ground. The ball is released from rest.
Air resistance has negligible effect on the motion of the ball.

What is the time taken for the ball to reach the ground?

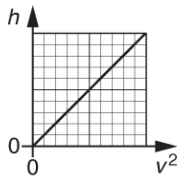
A 0.021 s
B 0.144 s
C 0.152 s
D 0.161 s

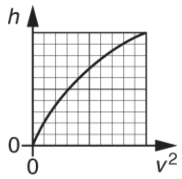
Your answer [1]

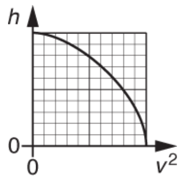
25. A ball is dropped from rest above the ground. Air resistance has negligible effect on the motion of the ball.

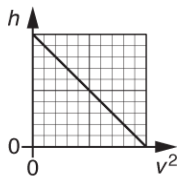
The speed of the ball is *v* after it has fallen a distance *h* from its point of release.

Which graph is correct for this falling ball?

A


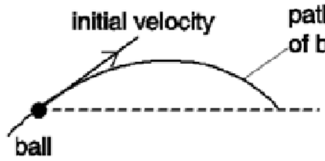
B


C


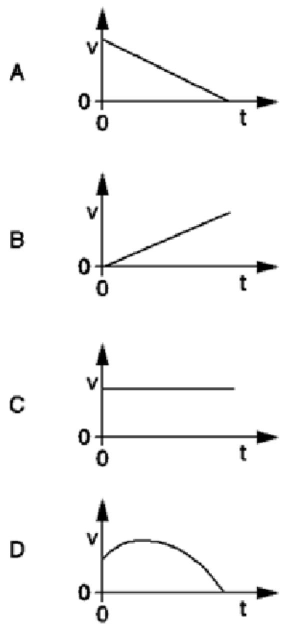
D


Your answer [1]

26. A ball is thrown with an initial velocity at an angle to the horizontal.



Air resistance has negligible effect on the motion of the ball.
While it is in flight, which graph shows the correct variation of the ball's horizontal velocity *v* with time *t?*



Your answer

[1]

27. A tennis ball is hit with a racket. The force applied by the racket on the ball is *F*. The ball has a vertical path through the air.

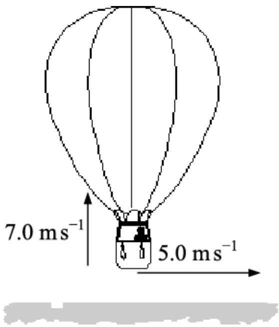
Which statement is correct when the ball is at its **maximum** height?

A The ball has a downward acceleration.
B The force acting on the ball is *F*.
C The ball experiences greatest drag.

D The weight of the ball is equal to the drag.

Your answer [1]

28. 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}

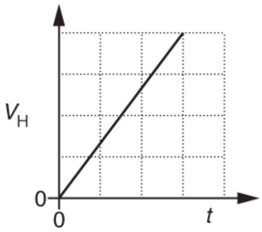
Your answer

[1]

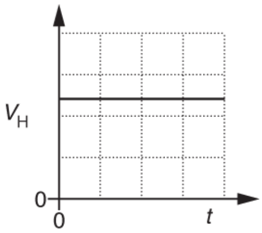
29. A projectile is fired in a horizontal direction at time $t = 0$.
Ignore air resistance.

Which graph correctly shows the horizontal component of the velocity V_H of the projectile against time t?

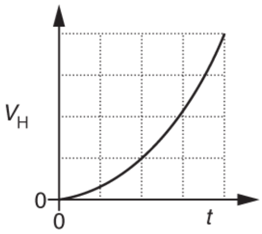
A



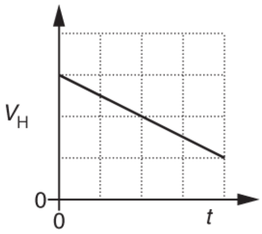
B



C



D



Your answer ☐ **[1]**

30. An object is initially at rest. A constant force is applied to the object and it moves in a straight line with constant acceleration. After a time t, the object has displacement s and velocity v.

Which of the following will **not** produce a straight line graph?

A. A graph of v against t.
B. A graph of s against v.
C. A graph of s against t^2.
D. A graph of v^2 against s.

Your answer

[1]

31. A ball is thrown vertically upwards with a speed of $5.0\ \text{m s}^{-1}$.
Ignore air resistance.

What is the maximum height reached by the ball?

A 0.3 m
B 0.8 m
C 1.3 m
D 2.5 m

Your answer

[1]

32. 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?

A. $32 \pm 1\ \text{m s}^{-1}$
B. $32.0 \pm 2.1\ \text{m s}^{-1}$
C. $32.0 \pm 0.2\ \text{m s}^{-1}$
D. $32 \pm 0.999\ \text{m s}^{-1}$

Your answer

[1]

33. The braking distance of a car is directly proportional to its initial kinetic energy.

The braking distance of a car is 18 m when its initial speed is 10 m s^{-1}.

What is the braking distance of the car, under the same conditions, when its initial speed is 25 ms^{-1}?

A 7.2 m

B 45 m

C 113 m

D 222 m

Your answer [1]

34 (a). An archer fires an arrow towards a target as shown below.

The diagram is **not** drawn to scale.

The centre of the target is at the same height as the initial position of the arrow.
The target is a distance of 90 m from the arrow.
The arrow has an initial velocity of 68 m s^{-1} and is fired at an angle of 11° to the horizontal.

Air resistance has negligible effect on the motion of the arrow.

Show that the time taken for the arrow to reach its maximum height is about 1.3 s.

[2]

(b). Describe how the kinetic energy of the arrow changes during its journey from when it is fired until it reaches its maximum height.

--- [2]

35. A motorcyclist riding on a level track is told to stop via a radio microphone in his helmet. The distance *d* travelled from this instant and the initial speed *v* are measured from a video recording.

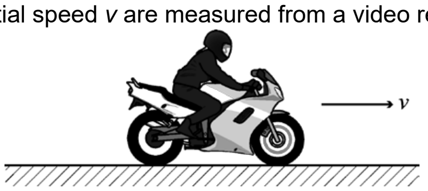


Fig. 2.1

A student is investigating how the stopping distance of a motorcycle with high-performance brakes varies with the initial speed.

The student decides to plot a graph of $\frac{d}{v}$ on the *y-axis* against *v* on the *x*-axis.

Explain why this is a sensible decision.

-- **[2]**

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

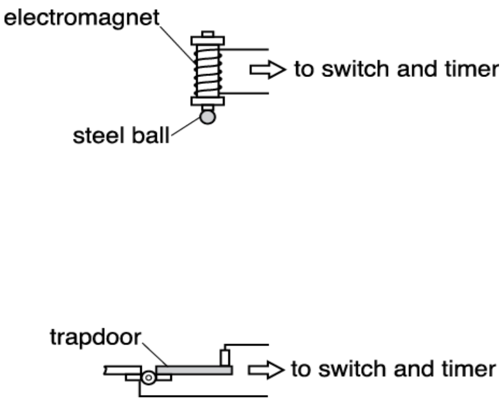


Fig. 16.1

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.

State **one** source of error when timing the drop of the steel ball and describe how the percentage uncertainty in the measurement of time can be minimised.

-- **[2]**

37. What are the correct base units for work done or energy?

A kg m
B kg m s^{-2}
C kg m^2s^{-2}
D kg m^2s^{-2}

Your answer [1]

38. A swimming pool designer investigates the depth *d* below a water surface reached by a diver when diving from
a height *h* above the water surface.
The designer models the diver as a uniform wooden cylinder.
The experimental arrangement is shown in Fig. 18.1.

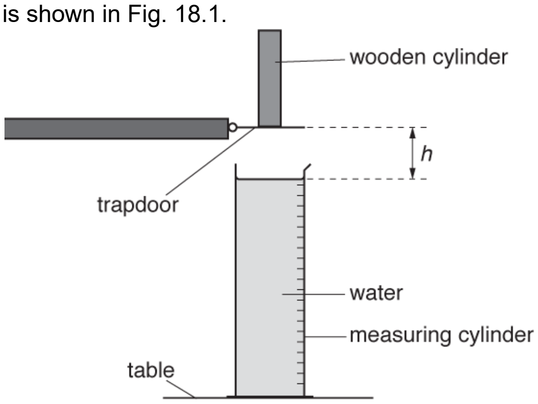


Fig. 18.1

The cylinder is released from **rest** from a trapdoor. The base of the cylinder is at a height *h* = 0.30 m above the water surface.
Calculate the speed of the cylinder just before the base hits the water. Ignore air resistance.

speed = ... m s^{-1} **[2]**

39. 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).

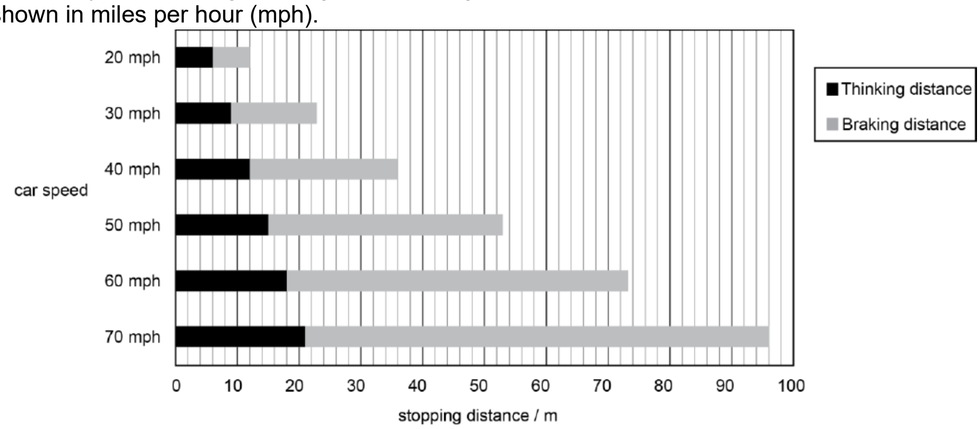


Fig. 16

State what is meant by *thinking distance* and state how it varies with initial speed of a car.

____

____

____ **[2]**

40 (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.

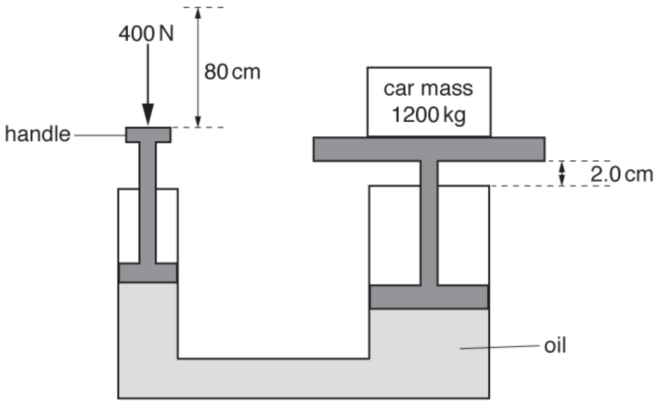


Fig. 16

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]**

41. A student uses a motion sensor to investigate the motion of a trolley crashing into a soft barrier. Fig. 21 shows the displacement *s* against time *t* graph for the trolley in one experiment.

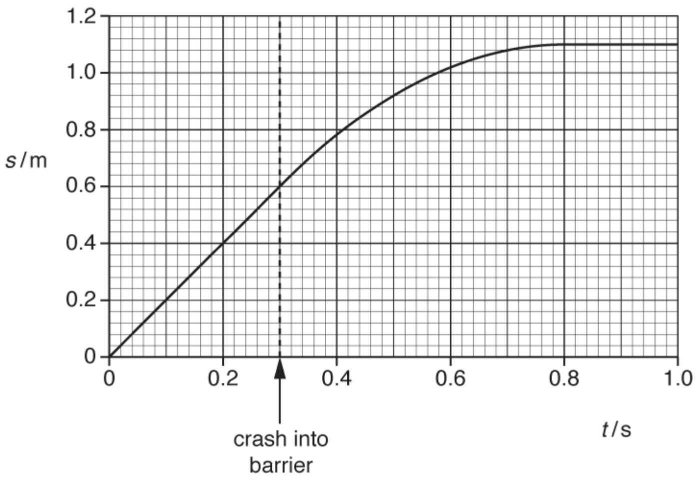


Fig. 21

The student assumes that the deceleration of the trolley is constant during the crash. Use Fig. 21 to determine the magnitude of the deceleration.

deceleration = ... m s^{-2} **[2]**

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

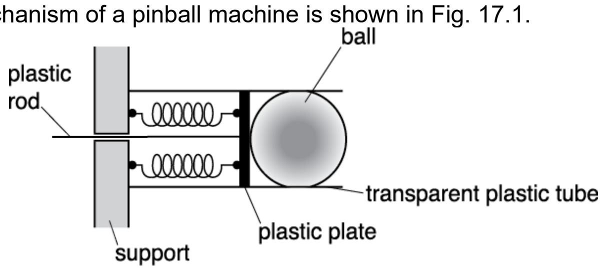


Fig. 17.1

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.

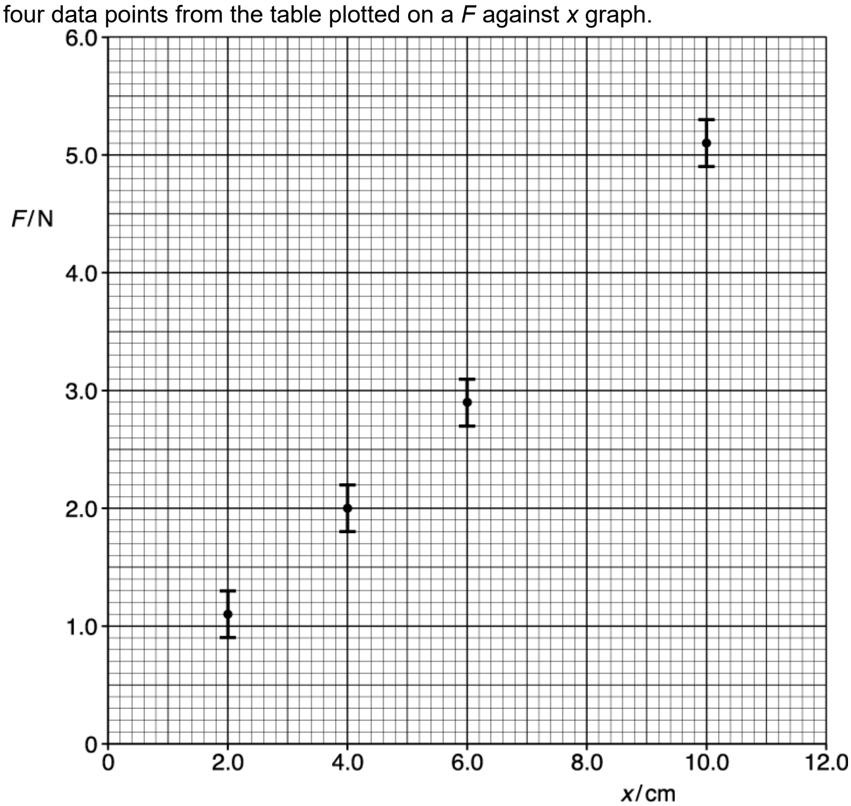


Fig. 17.2

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). A new arrangement for the ball-release mechanism using three identical springs is shown in Fig. 17.3.

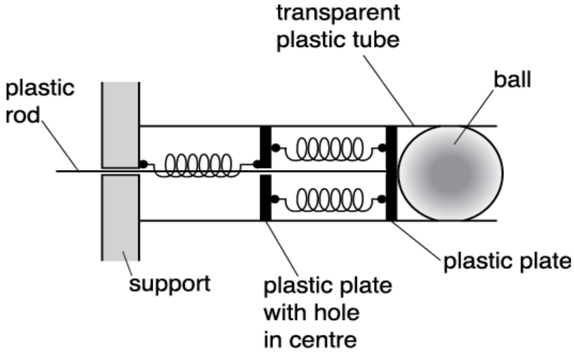


Fig. 17.3

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]

43 (a). A bicycle manufacturer carries out tests on the braking system of their new model.
A cyclist on this new bicycle travels at a constant initial speed U.
The cyclist applies the brakes at time $t = 0$ and the bicycle comes to a stop at time $t = 2.0$ s.

Fig. 20.1 shows the variation of the braking force F on the bicycle with time t.

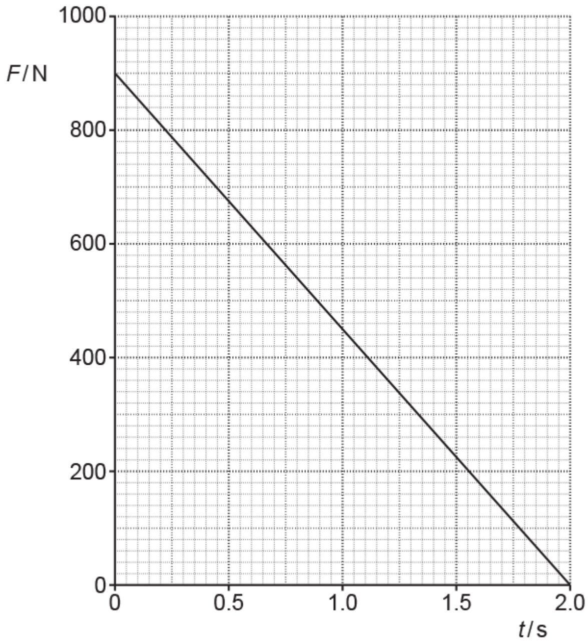


Fig. 20.1

The total mass of cyclist and bicycle is 71 kg.
Use Fig. 20.1 to calculate the initial speed U.

U = ... m s^{-1} **[2]**

(b). Complete Fig. 20.2 to show the variation of the speed of the bicycle from t = 0 to t = 2.0 s.

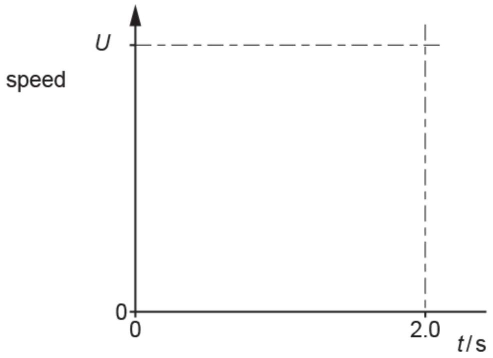


Fig. 20.2

[2]

44. Fig. 1 shows how the velocity v of a car varies with time t as the car approaches a road junction.

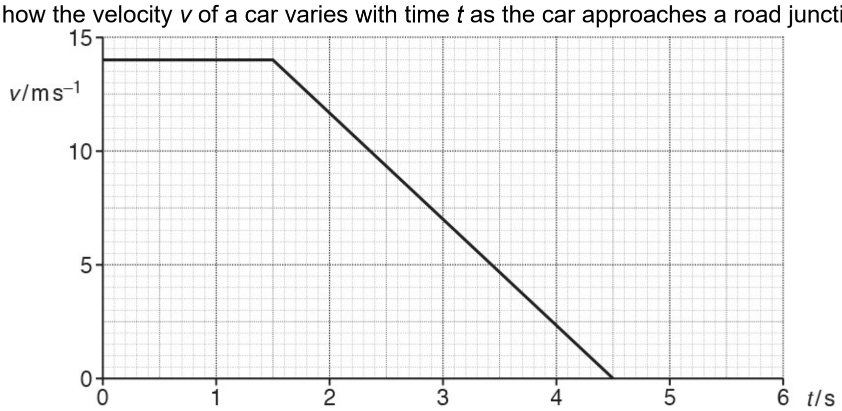


Fig. 1

Explain what feature of the graph shows the deceleration of the car and that the deceleration is constant after 1.5s.

____

____

____ **[2]**

45. Fig. 22.1 shows a graph of velocity *v* against time *t* for a skydiver falling vertically through the air.

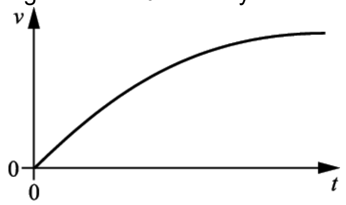


Fig. 22.1

State how you can use **Fig. 22.1** to determine the acceleration of the skydiver and describe how the acceleration varies with time.

____

____

____ **[2]**

46 (a). A student investigates the motion of a tennis ball of mass 57 g which falls vertically from rest, then bounces once on a soft horizontal surface.
Fig. 1 shows the variation with time *t* of the velocity *v* of the tennis ball falling from rest until it hits the soft surface.

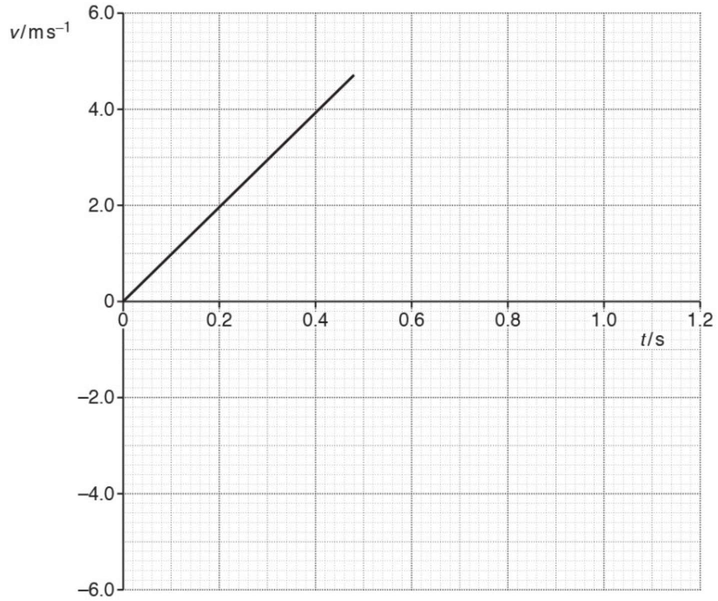


Fig. 1

Air resistance has a negligible effect on the motion of the tennis ball.

Use Fig. 1 to show that

i. the acceleration of the falling ball is about 10 m s^{-2}

[1]

ii. the kinetic energy of the ball just before impact with the surface is 0.63 J.

[2]

(b). The ball leaves the surface with 80% of the kinetic energy just before impact.

i. Calculate the magnitude of the velocity *v* of the ball as it leaves the surface.

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

ii. Complete Fig. 1 to show the variation of the velocity of the ball after it leaves the surface until it is at rest again.

[2]

iii. Determine the maximum height h reached by the ball after it bounces.

***h* = ... m [2]**

(c). The student repeats the experiment with a different ball that is affected by air resistance.

Explain how the graph in Fig. 1 now appears from the time the ball is released to the time it hits the surface.

____

____

____

____

____ **[2]**

47 (a). A metal ball is released from rest. It falls vertically towards the ground.
Fig. 22 shows the variation with time t of the displacement s of the ball.

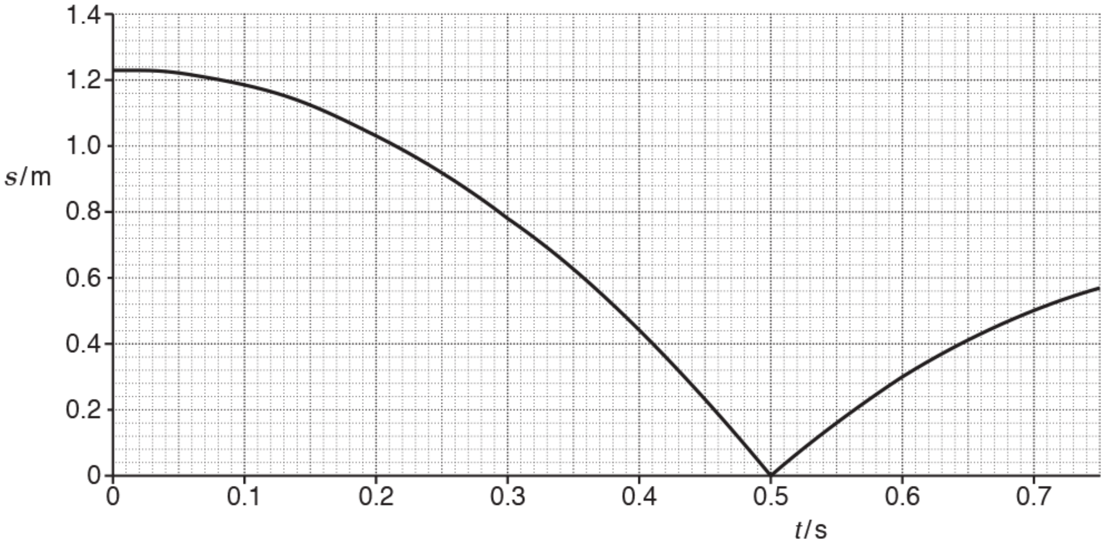


Fig. 22.

Air resistance has negligible effect on the motion of the ball.

The ball hits the ground at t = 0.50 s.
During the collision, the ball is in contact with the ground for a time of 1.8 ms.
The mass of the ball is 56 g.

Use an equation of motion to show that the speed of the ball is 4.9 ms^{-1} just before it hits the ground.

[2]

(b). Draw a suitable tangent to the curve in Fig. 22 and show that the **rebound** speed of the ball is about 3.5 ms^{-1}.

[3]

(c). Calculate the average resultant force acting on the ball during the collision.

force = ... N **[2]**

48. Fig. 2.1 shows the path of a golf ball which is struck at point **F** on the fairway landing at point **G** on the green. The effect of air resistance is negligible.

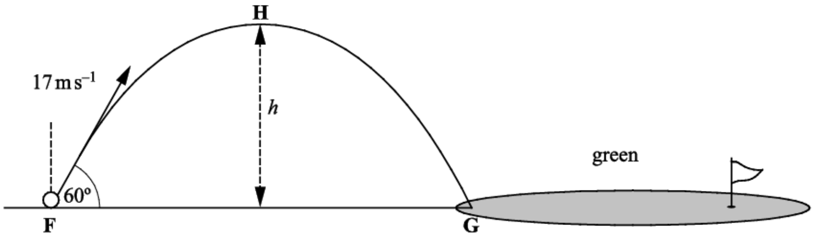


Fig. 2.1

The ball leaves the club at 17 m s^{-1} at an angle of 60° to the horizontal at time t = 0.

Show that the speed of the ball at the highest point **H** of the trajectory is between 8 and 9 m s^{-1}.

speed = ... m s^{-1} **[2]**

49. A trolley is placed on a long ramp and is released from rest from the top of the ramp. It travels to the bottom of the ramp with a constant acceleration.

A motion sensor is used to determine the velocity of the trolley at points **X** and **Y**, as shown in Fig. 21.

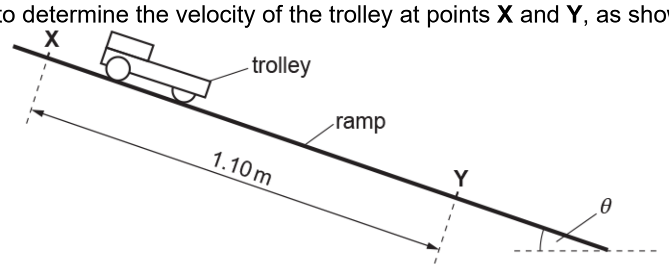


Fig. 21 (not to scale)

The distance between **X** and **Y** is 1.10 m. The trolley has velocity 1.3 ms^{-1} at **X** and velocity 2.5 ms^{-1} at **Y**.

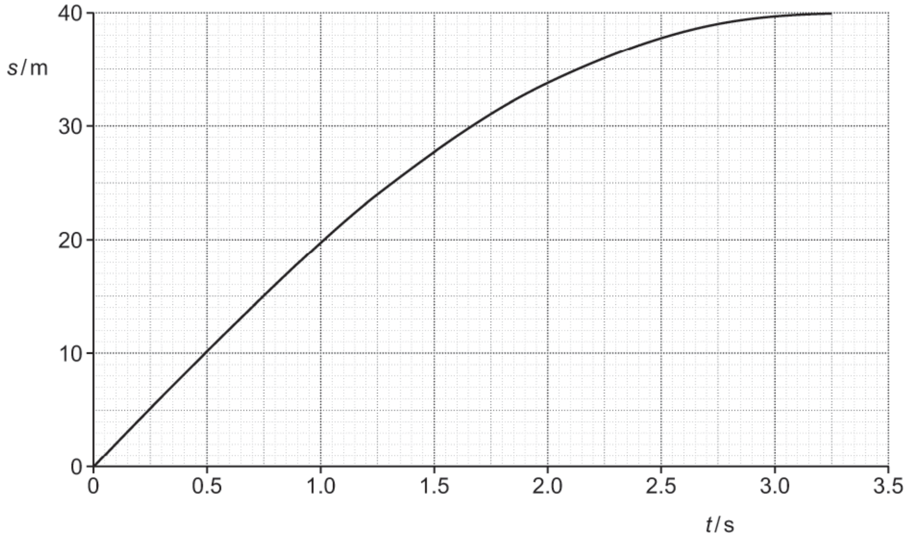
i. Calculate the acceleration a of the trolley.

a = ____________________ m s^{-2} **[2]**

ii. The frictional forces acting on the trolley are negligible.
The acceleration of the trolley down the ramp is equal to the component of the acceleration of free fall parallel to the ramp.
Use your answer to **(i)** to calculate the angle θ between the ramp and the horizontal.

θ = ____________________ ° **[2]**

50 (a). A car is travelling at a constant speed of 20 m s^{-1} along a straight road.
The driver sees a hazard ahead in the road, applies the brakes and brings the car to a stop.
The graph below shows the displacement *s* against time *t* for the car from the time that the driver sees the hazard to when the car stops.



The braking force *F* acting on the car is constant.
The mass of the car is 950 kg.
The reaction time of the driver is 0.75 s.

Draw a tangent to the graph at time *t* = 1.75 s.
Use this tangent to show that the speed of the car at *t* = 1.75 s is about 12 m s^{-1}.

[2]

(b). Explain how you can deduce from the graph that the brakes are applied at time *t* = 0.75s.

--- **[2]**

51. A police speed detector gun works by firing short pulses of electromagnetic radiation, a time t_0 apart, at the front of the vehicle which is moving directly towards the gun. The reflected pulses are received at a time t apart. A digital readout on the top of the gun displays the speed of the vehicle.

In the space below, by considering how far the vehicle moves in time t_0, show that the speed of the vehicle is given by the expression

$$v = \frac{c(t_0 - t)}{2t_0}$$

where c is the speed of light.

[3]

52. A student uses a motion-sensor connected to a laptop to investigate the motion of a hollow ball of mass 1.2×10^{-2} kg falling through air.

The ball is dropped from rest. It reaches terminal velocity before it reaches the ground.

The upthrust on the ball is negligible.

Fig. 17 shows the variation with time t of the velocity v of the ball as it falls towards the ground.

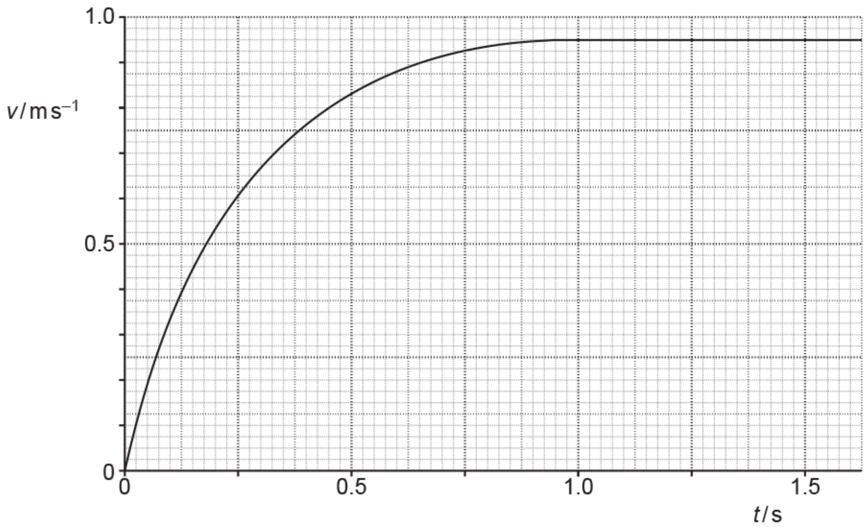
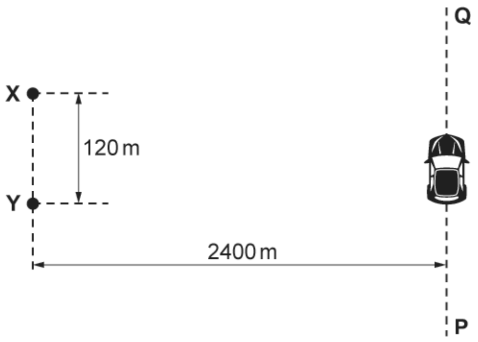


Fig. 17

Draw a tangent to the curve at t = 0.25 s and determine the acceleration of the ball.

acceleration = ... m s^{-2} **[3]**

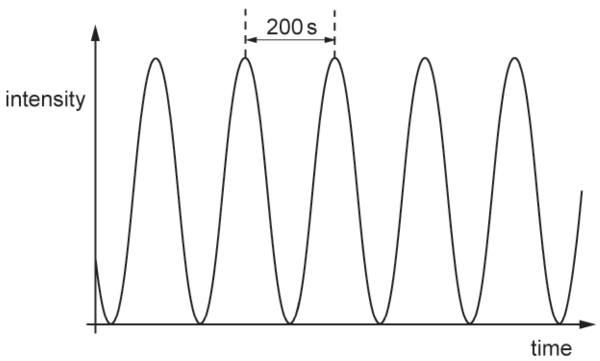
53. The diagram below shows two coherent sources of radio waves **X** and **Y**.



The diagram is **not** drawn to scale.

The radio waves are in phase at **X** and **Y**.
A car moves at a constant speed along the line **PQ**. The line **PQ** is parallel to line **XY**.
The separation between **X** and **Y** is 120 m.
The perpendicular distance between lines **PQ** and **XY** is 2400 m.

The intensity against time graph below shows the variation of the intensity of the radio waves at the position of the moving car.



The time between adjacent maxima is 200 s.
The speed of the car is 18 m s^{-1}.

Calculate the wavelength λ of the radio waves.

λ = ... m **[3]**

54 (a). A motorcyclist riding on a level track is told to stop via a radio microphone in his helmet. The distance *d* travelled from this instant and the initial speed *v* are measured from a video recording.

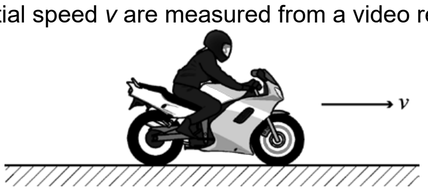


Fig. 2.1

A student is investigating how the stopping distance of a motorcycle with high-performance brakes varies with the initial speed.

The measured values of *v* and *d* are given in the table.

v / m s^{-1}	d / m	$\frac{d}{v}$ / s
10 ± 1	13.0 ± 0.5	
15 ± 1	24.5 ± 0.5	1.63 ± 0.14
20 ± 1	39.5 ± 0.5	1.98 ± 0.12
25 ± 1	57.5 ± 0.5	2.30 ± 0.11
30 ± 1	79.0 ± 0.5	2.63 ± 0.10
35 ± 1	103.0 ± 0.5	2.94 ± 0.09

i. Complete the missing value of $\frac{d}{v}$ in the table, including the absolute uncertainties. Use the data to complete the graph of **Fig. 2.2.** Four of the points have been plotted for you.

[2]

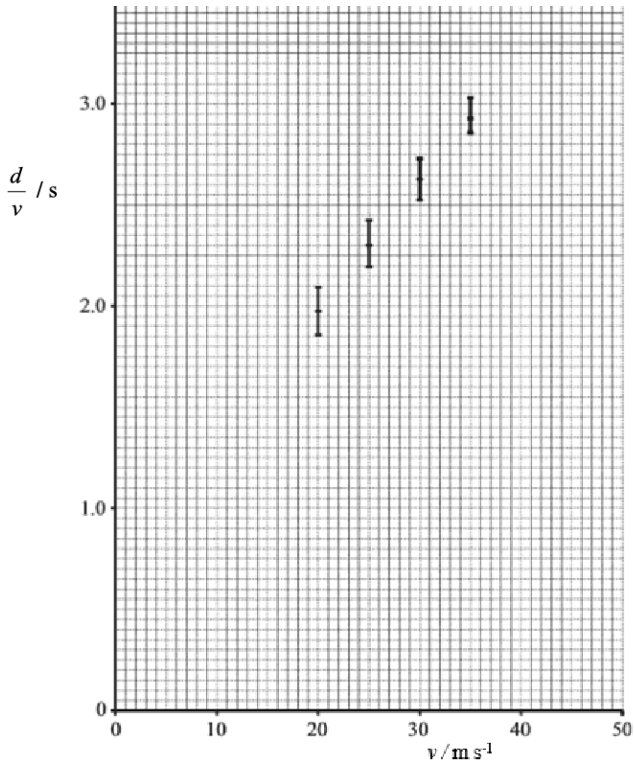


Fig. 2.2

ii. Use **Fig. 2.2** to determine the values of *a* and *t*, including their absolute uncertainties.

a = ... ± .... m s^{-2}

t = ... ± .... s

[4]

(b). It was suspected that the method used to determine the distance *d* included a zero error. The distance recorded by the student was **larger** than it should have been.

Discuss how this would affect the actual value of *t* obtained in **(c).**

____

____

____

____

____ **[3]**

55. A toy rocket is made from a 1.5 litre plastic bottle with fins attached for stability.

The bottle initially contains 0.30 litres of water, leaving 1.2 litres of trapped air at a temperature of 17 °C.
A pump is used to increase the pressure of the air within the plastic bottle to 2.4×10^5 Pa at the start of lift-off.

Fig. 1.1 shows the rocket at the start of lift-off.

1 litre = 10^{-3} m^3

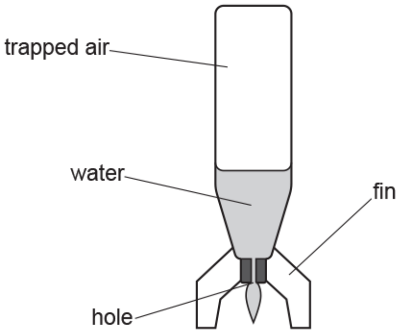
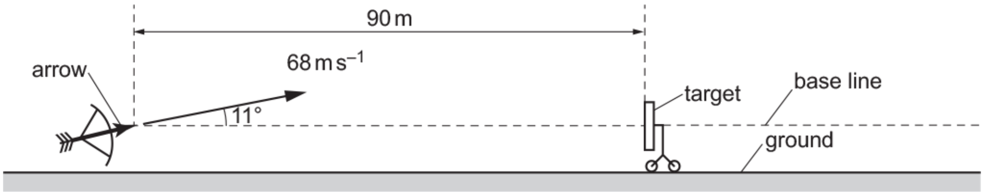


Fig. 2.1

Discuss whether adding more water initially would enable the rocket to reach a greater height.

--- **[3]**

56 (a). An archer fires an arrow towards a target as shown below.



The diagram is **not** drawn to scale.

The centre of the target is at the same height as the initial position of the arrow.
The target is a distance of 90 m from the arrow.
The arrow has an initial velocity of 68 m s^{-1} and is fired at an angle of 11° to the horizontal.

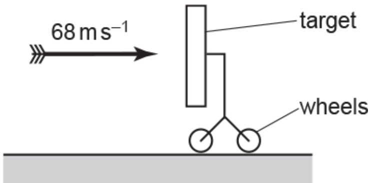
Air resistance has negligible effect on the motion of the arrow.

The arrow misses the target.

Calculate the horizontal distance, measured along the base line, by which the arrow misses the target.

horizontal distance = ... m **[3]**

(b). The arrow is now fired horizontally at 68 m s^{-1} into the target at very close range.



The arrow sticks into the target. The collision between the arrow and the target is inelastic.

i. Explain what is meant by an **inelastic collision** .

____

____ **[1]**

ii. The target is mounted on wheels. The target has a much larger mass than the mass of the arrow.

Using ideas of momentum, explain the velocity of the target immediately after the arrow sticks into the target.

____

____

____

____

[2]

57. A car is travelling along a straight road at 18 m s^{-1}.
The driver sees an obstacle and after 0.50 s applies the brakes.
The **stopping** distance of the car is 38 m.

Calculate the magnitude of the deceleration of the car when the brakes are applied.

deceleration = ... m s^{-2} **[3]**

58. Fig. 1 shows how the velocity v of a car varies with time t as the car approaches a road junction.

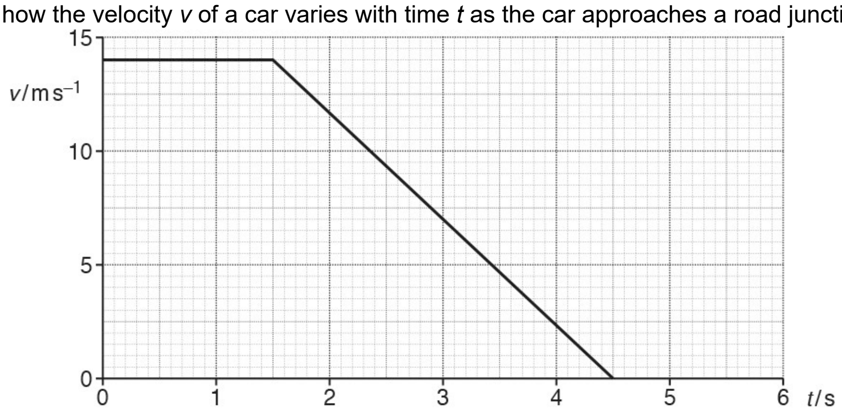


Fig. 1

The driver of the car applies the brakes at a distance of 20 m from the ‘stop line’ at the junction.

Calculate the distance s of the car relative to the stop line when the car comes to a stop.

s = ... m **[3]**

59. Fig. 22.2 shows an arrangement used to investigate how the kinetic energy of a toy car varies with its distance *d* from the top of the ramp.

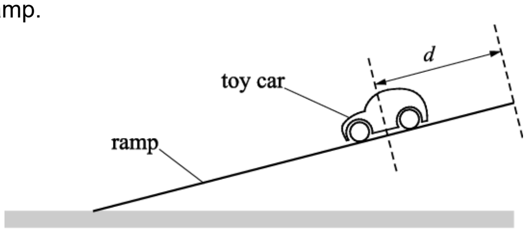


Fig. 22.2

Design a laboratory experiment to determine the kinetic energy of the car at one particular distance *d* from the top of the ramp.
In your description pay particular attention to

- how the apparatus is used
- what measurements are taken
- how the data is analysed.

-- **[3]**

60. Fig. 21 shows a stationary trolley on a smooth ramp.

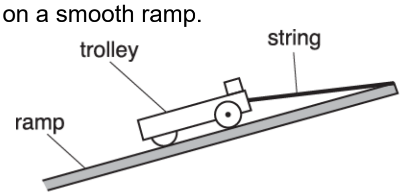


Fig. 21

A short length of string is attached between the end of the trolley and the top of the ramp. Assume that the frictional force acting on the trolley is negligible when it is stationary or when it is moving.

i. Other than the normal contact force, there are two other forces acting on the stationary trolley.
On **Fig. 21**, draw arrows to show these two forces. You do not need to name these forces.

[1]

ii. The string is cut at time t = 0. The trolley travels down the ramp with a constant acceleration of 3.0 m s^{-2}.
Calculate the time t taken by the trolley to travel a distance of 0.80 m down the ramp.

t = ... s **[2]**

61 (a). Fig. 2.1 shows the path of a golf ball which is struck at point **F** on the fairway landing at point **G** on the green. The effect of air resistance is negligible.

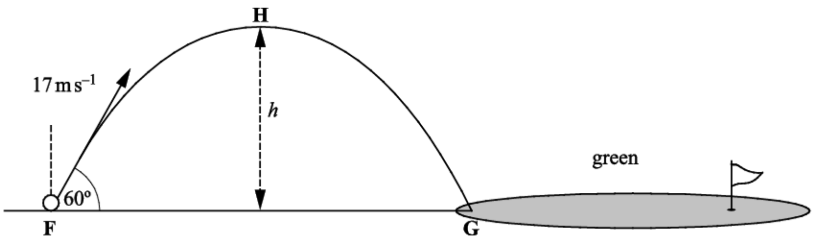


Fig. 2.1

The ball leaves the club at 17 m s^{-1} at an angle of 60° to the horizontal at time t = 0.

At t = 1.5 s the ball reaches point **H**. Calculate

i. the maximum height h of the ball

h = ... m **[3]**

ii. the distance between the points **F** and **G**.

distance **FG** = ... m **[2]**

(b). Suppose the same golfer standing at **F** had hit the ball with the same speed but at an angle of 30° to the horizontal. See **Fig. 2.2**.

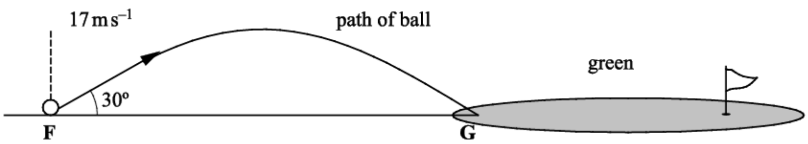


Fig. 2.2

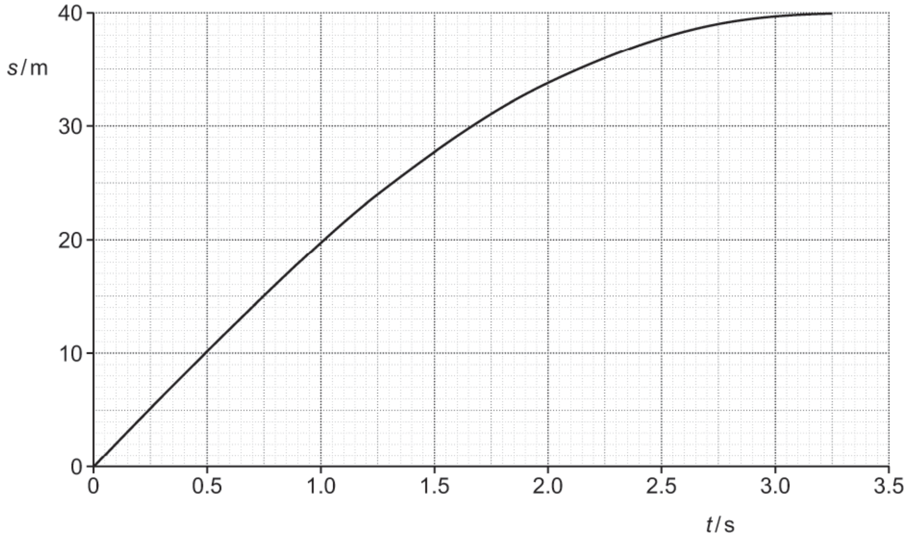
Show that the ball would still land at **G**.

[3]

(c). Compare the magnitude and direction of the two velocities as the ball lands at G and using this information suggest, with a reason, which trajectory you would choose to travel a longer distance after hitting the green at G.

--- **[2]**

62 (a). A car is travelling at a constant speed of 20 m s^{-1} along a straight road.
The driver sees a hazard ahead in the road, applies the brakes and brings the car to a stop.
The graph below shows the displacement *s* against time *t* for the car from the time that the driver sees the hazard to when the car stops.



The braking force *F* acting on the car is constant.
The mass of the car is 950 kg.
The reaction time of the driver is 0.75 s.

Describe and explain the variation of the displacement with time when the same driver applies the brakes in the same car when the initial speed of the car is 10 m s^{-1}.

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____

____ **[3]**

(b). Determine the braking force *F*.
You should use information from the graph.

F = ... N **[3]**

63. A student is determining the acceleration of free fall *g* using a metal sphere on a ramp. The sphere is released from the ramp at different heights. The speed *v* of the sphere at the bottom of the ramp is determined.

The acceleration of free fall *g* is given by the expression $g = \frac{v^2}{2d}$, where *d* is the initial height of the sphere and *v* is speed of the sphere at the bottom of the ramp.

The student records the following data.

- $d = 0.100 \pm 0.002$m
- $v = 1.4 \pm 0.1$ms^{-1}

Calculate the absolute uncertainty in *g*. Write your answer to **2** significant figures.

absolute uncertainty = ... ms^{-2} **[3]**

64. A trolley is placed on a long ramp and is released from rest from the top of the ramp. It travels to the bottom of the ramp with a constant acceleration.

Describe how a metre rule and a stopwatch can be used to determine the **final** velocity v of the trolley at the bottom of the ramp.

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____

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____ **[2]**

65 (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 $0.4v^2$, 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.

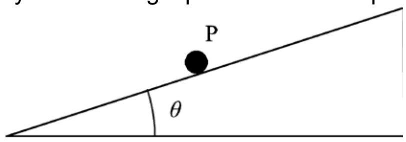

Fig. 17.1

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**.

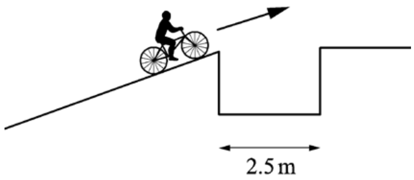

Fig. 17.2

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]**

66. Fig. 21.1 shows a toy locomotive on a circular track of radius 0.60 m.

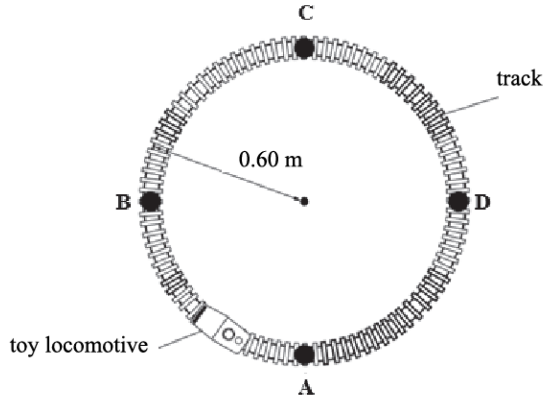

Fig. 21.1

At time t = 0, the locomotive is at point **A**. The locomotive travels at a constant speed round the track. It takes 20 s to travel completely round the track.

i. Calculate the speed of the locomotive.

speed = ... m s^{-1} **[2]**

ii. **Fig. 21.2** shows the variation of the magnitude of the displacement s of the locomotive from **A** with time t.

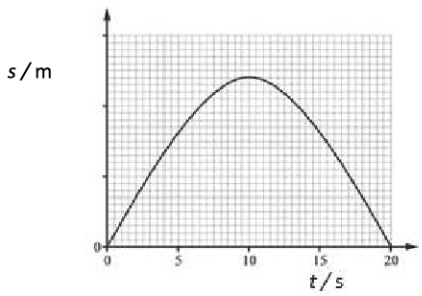

Fig. 21.2

Explain the graph shown in **Fig. 21.2**

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____ **[2]**

67. Two cars, **A** and **B**, are travelling clockwise at constant speeds around the track shown in **Fig. 16.1**.
The track consists of two straight parallel sections each of length 200 m, the ends being joined by semi-circular sections of diameter 80 m.
The speed of **A** is 20 ms^{-1} and that of **B** is 23 ms^{-1}.

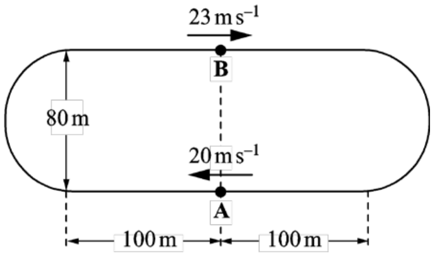

Fig. 16.1

i. Calculate the time for **A** to complete one lap of the track.

time for one lap = ...s **[2]**

ii. Starting from the positions shown in **Fig. 16.1** determine the shorter of the two distances along the track between **A** and **B**, immediately after **A** has completed one lap.

distance = ...m **[2]**

68. A student is carrying out an experiment in the laboratory to determine the acceleration of free fall *g*. The student drops a small steel ball from rest and records the time *t* taken for the ball to fall through a vertical distance *h*.

The results for different vertical distances are shown in the table below.

h / m	***t* / s**	***t*² / s²**
0.660	0.365	0.133
0.720	0.385	0.148
0.780	0.400	0.160
0.840	0.415	0.172
0.900	0.430	
0.960	0.445	0.198

Describe and explain how the student could use standard laboratory equipment to make accurate measurements of *h* and *t*.

[4]

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

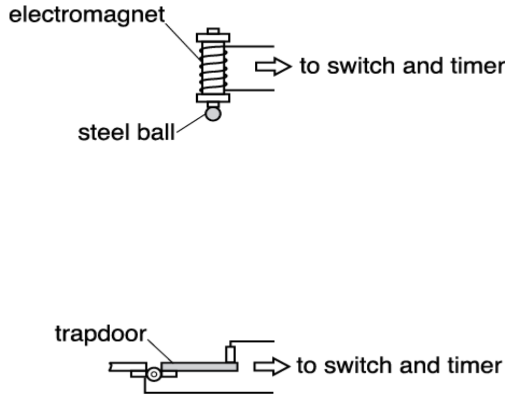

Fig. 16.1

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]**

70. A student uses a motion sensor to investigate the motion of a trolley crashing into a soft barrier. Fig. 21 shows the displacement *s* against time *t* graph for the trolley in one experiment.

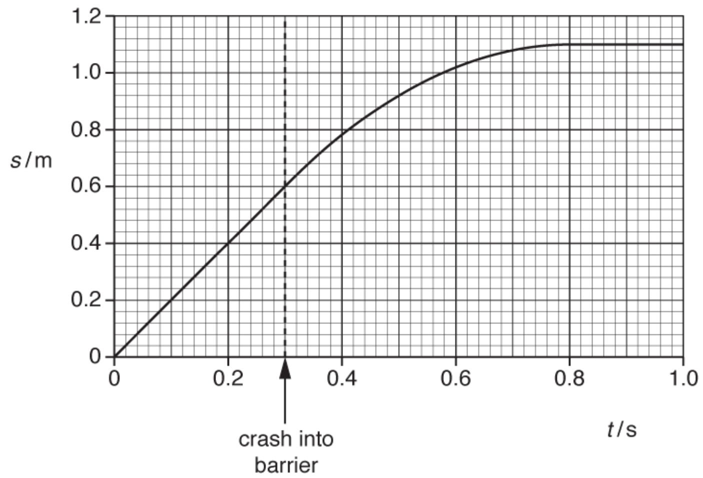

Fig. 21

Use Fig. 21 to describe and explain the variation of the velocity of the trolley from t = 0 to t = 1.0 s.

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____ **[4]**

71. A metal ball is released from rest. It falls vertically towards the ground.
Fig. 22 shows the variation with time t of the displacement s of the ball.

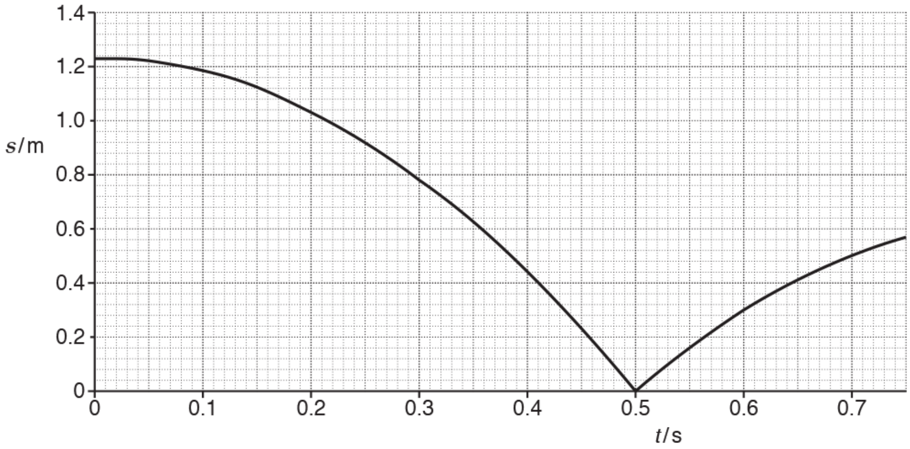

Fig. 22

Air resistance has negligible effect on the motion of the ball.

The ball hits the ground at *t* = 0.50 s.
During the collision, the ball is in contact with the ground for a time of 1.8 ms.
The mass of the ball is 56 g.

Describe and explain the variation of the velocity of the ball from t = 0.20 s to t = 0.70 s.

No calculations are required.

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72. A **proton** travels from point **P** to point **Q** in a uniform electric field as shown in Fig. 21.2.

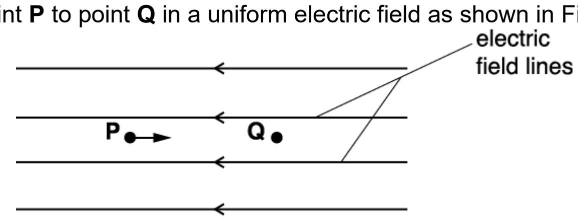

Fig. 21.2

The velocity of the proton at **P** is 7.2×10^6 m s^{-1} and the velocity at **Q** is 2.4×10^6 m s^{-1}. The distance between **P** and **Q** is 1.2 cm.

Calculate

i. the magnitude of the deceleration of the proton

deceleration = ... m s^{-2} **[2]**

ii. the electric field strength E.

E = ... N C^{-1} **[2]**

73. In a hockey match a hockey ball is hit 18.0 m from the front of the goal. The ball leaves the hockey stick with initial velocity v at an angle θ to the horizontal ground. The ball passes over the goal at a maximum height of 2.0 m as shown in Fig. 3.

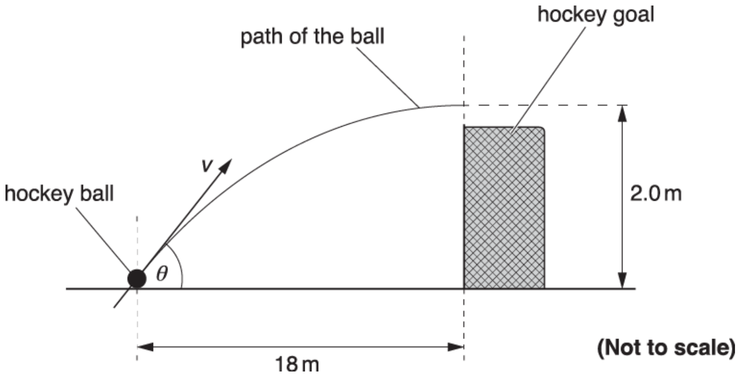

Fig. 3

The initial vertical component of the velocity of the ball is 6.3 m s^{-1}. Air resistance has negligible effect on the motion of the ball.

i. Show that the time t taken for the ball to reach the maximum height is about 0.6 s.

[1]

ii. Use the answer to **(i)** and **Fig. 3** to show that the horizontal component of the velocity of the ball as it leaves the hockey stick is about 30 m s^{-1}.

[1]

iii. Calculate the magnitude of the initial velocity v of the ball.

v = ... m s^{-1} **[2]**

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

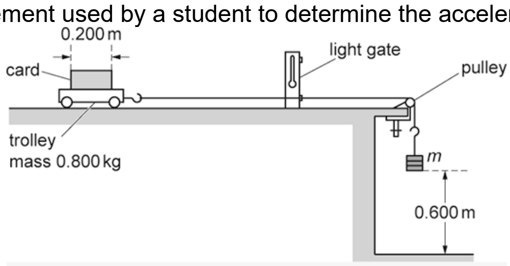

Fig. 4.1

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 v^2 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]

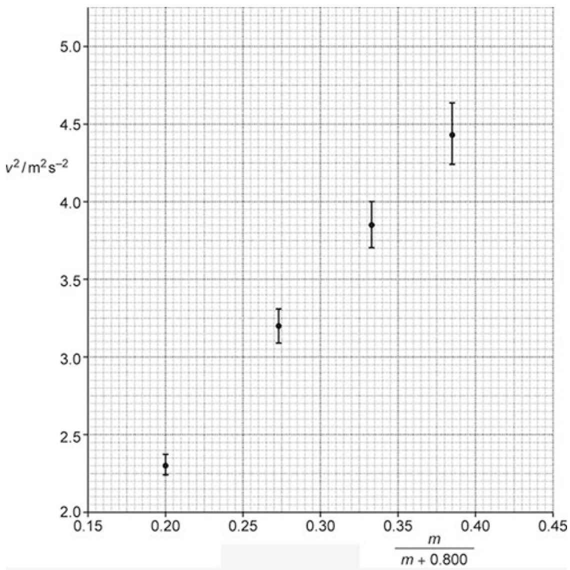

Fig. 4.2

(c).

i. Use the equation given in **(a)** to show that the gradient of the graph of v^2 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.

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-- [4]

75 (a). A student carries out an experiment to measure *g*, the acceleration due to gravity, by measuring the time *t* for a steel ball to fall a distance *s*.
The method is shown in **Fig. 2.1**

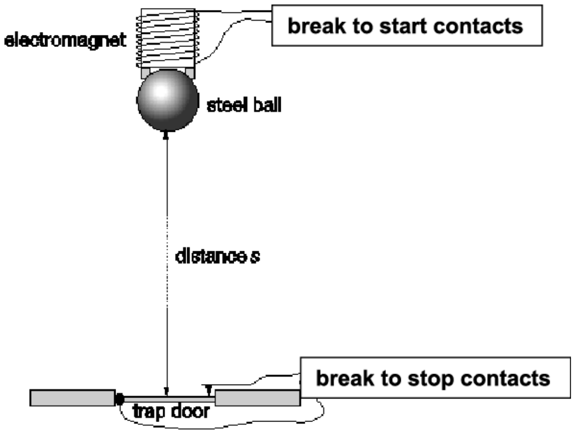

Fig 2.1

The break-to-start and break-to-stop contacts are connected to an electronic timer. As the steel ball is released from the electromagnet, the electronic timer starts. The ball falls a distance *s* before it hits a hinged metal 'trap door'. The trap door opens, breaks the circuit and stops the timer.

The student records the following data for a range of distances *s*, averaging the time *t* at each distance over several drops. He intends to plot a graph of *s* against t^2 so adds a third column to his table of results.

s/m	mean t/s	t^2/s^2
0.40	0.31	0.10
0.60	0.38	0.14
0.80	0.42	0.18
1.00	0.47	
1.20	0.51	
1.40	0.55	0.30

i. Complete the table. Add the final two points to the graph of **Fig. 2.2**. Draw a straight line of best fit on **Fig. 2.2**.

[3]

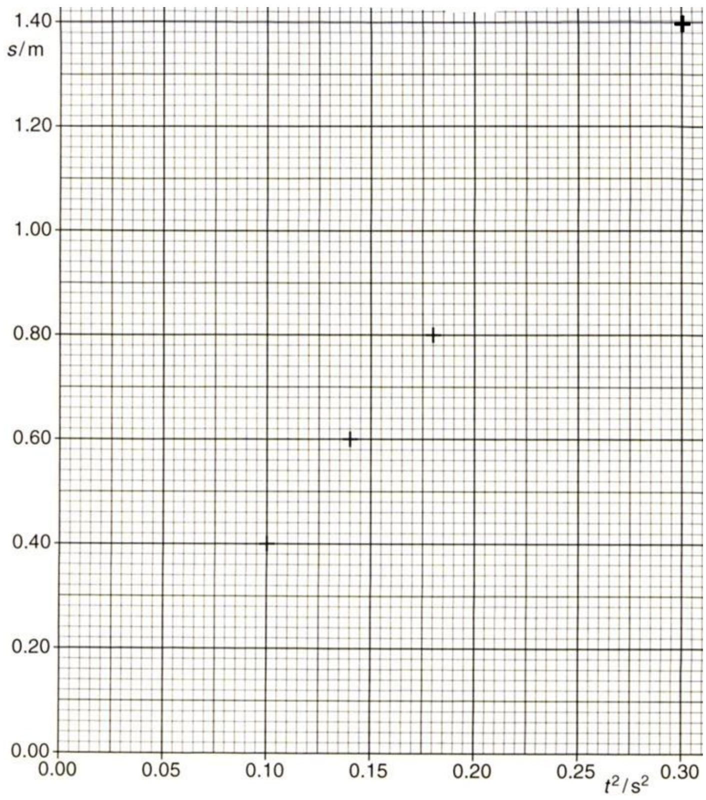

Fig 2.2

ii. Determine the gradient of the line. Show clearly your working.

gradient = ... m s^{-2} **[2]**

(b). The student expected the line to go through the origin and have a gradient of *g*/2. The timing device he used measures to within 0.01 s and the distance *s* was measured to within 0.01 m.

i. The fact that the line of best fit does not pass through the origin is unlikely to have been caused by random errors in his measurements. Justify this statement.

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[2]

ii. Explain how a systematic error in each of the measured quantities could contribute to the line not passing through the origin and what effect, if any, each would have on the gradient of the line.

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____ **[4]**

iii. Suggest one source of possible systematic error in the experiment.

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____ **[1]**

76. Cars **A** and **B** are on a straight road with car **A** moving at 22 ms^{-1} and car **B** at rest. As car **A** passes car **B**, car **B** accelerates from rest in the same direction at 1.5 ms^{-2} for 16 s. It then moves with constant velocity.

Fig. 16.2 shows the graph of velocity against time for car **A**. The time t = 0 is taken when the cars are alongside.

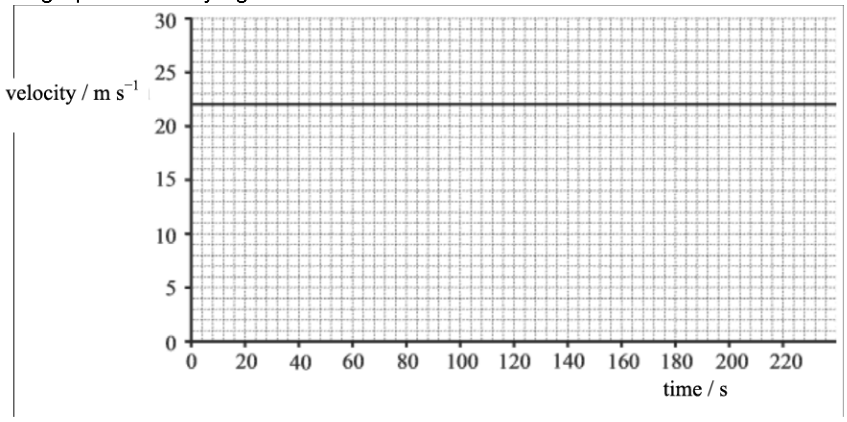

Fig. 16.2

i. Sketch the graph of velocity against time for car **B** on **Fig. 16.2.**

[2]

ii. Determine the time taken for car **B** to be alongside car **A**.

time = ...s **[3]**

77. Electrons in a beam are accelerated from rest by a potential difference V between two vertical plates before entering a uniform electric field of electric field strength E between two horizontal parallel plates, a distance 2d apart.

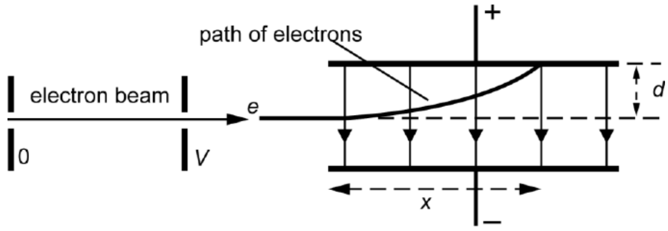

Fig. 2.1

The path of the electrons is shown in Fig. 2.1. The electron beam travels a horizontal distance x parallel to the plates before hitting the top plate. The beam has been deflected through a vertical distance d.

Show that x is related to V by the equation

$$x^2 = \frac{4dV}{E}.$$

[5]

78(a). This question is about the motion of a ball suspended by an elastic string above a bench. The mass of the string is negligible compared to that of the ball. Ignore air resistance.

Fig. 6.1

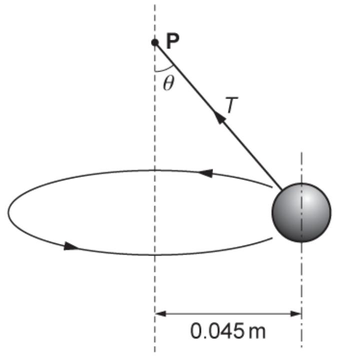

Fig. 6.2 (not to scale)

In Fig. 6.1 the ball of weight 1.2 N hangs vertically at rest from a point **P**. The extension of the string is 0.050 m. The string obeys Hooke's law.

In Fig. 6.2 the ball is moving in a horizontal circle of radius 0.045 m around a vertical axis through **P** with a period of 0.67 s. The string is at an angle θ to the vertical. The tension in the string is T.

On Fig. 6.2 draw and label one other force acting on the ball. **[1]**

(b).

i. Resolve the tension T horizontally and vertically and show that the angle θ is 22°.

ii. Calculate the extension x of the string shown in Fig. 6.2.

x = ... m **[3]**

(c). Whilst rotating in the horizontal plane the ball suddenly becomes detached from the string. The bottom of the ball is 0.18 m above the bench at this instant. The ball falls as a projectile towards the bench beneath. Fig. 6.3 shows the view from above.

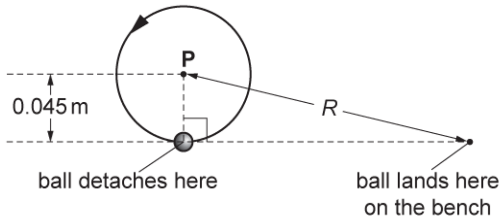

Fig. 6.3

Calculate the horizontal distance *R* from the point on the bench vertically below the point **P** to the point where the ball lands on the bench.

R = ... m **[4]**

(d). Returning to the situation shown in Fig. 6.2, state and explain what happens when the rate of rotation of the ball is increased.

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____ **[2]**

79. 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

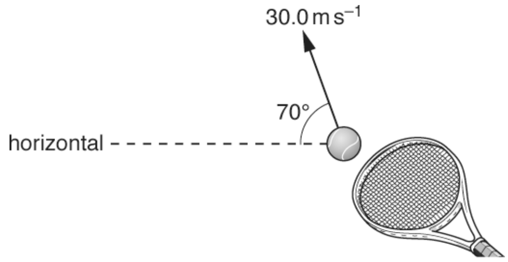

Fig. 16

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 E_k of the ball when it is at its maximum height.

E_k = ____ J **[2]**

80. *A group of students decide to determine the acceleration of free fall using the arrangement shown in Fig. 16.2.

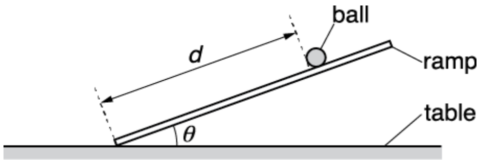

Fig. 16.2

The experiment uses a metal ball and a ramp.
The ball is at a distance *d* from the bottom of the ramp. The ramp makes an angle θ to the horizontal table. The ball is released from rest at time *t* = 0. The ball takes time *t* to travel the distance *d*.
The relationship between *d* and *t* is given by the equation

$$d = \frac{1}{2}(g\sin\theta)t^2.$$

Describe how you can conduct an experiment, and how the data can be analysed to determine the acceleration of free fall *g*.

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____ **[6]**

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

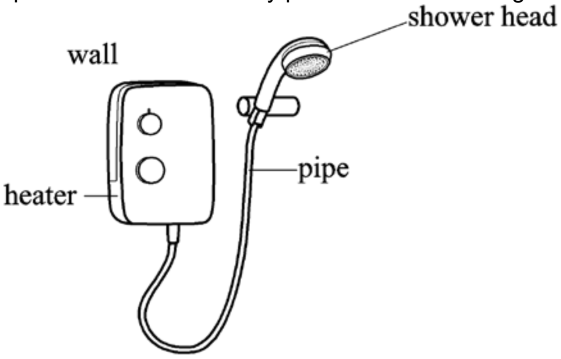

Fig.1.1

Water moves at constant speed through a pipe of cross-sectional area 7.5×10^{-5} m^2 to a shower head shown in **Fig. 1.1.** The maximum mass of water which flows per second is 0.070 kg s^{-1}.

i. Show that the maximum speed of the water in the pipe is about 0.9 m s^{-1}.

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

[2]

ii. The total cross-sectional area of the holes in the shower head is one quarter that of the pipe. Calculate the maximum speed of the water as it leaves the shower head.

maximum speed = ... m s^{-1} **[1]**

iii. Calculate the magnitude of the force caused by the accelerating water on the shower head.

force = ... N **[2]**

iv. Draw on to **Fig. 1.1** the direction of the force in **(iii)**.

[1]

82. This question is about a photoelectric cell, which is an electronic device that detects photons.
Fig. 6 shows a cross-section through a simple photocell.

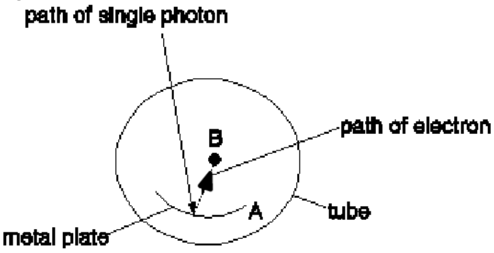

Fig. 6

A metal plate **A** is coated with potassium in an evacuated transparent tube. A photon of high enough energy, incident on the plate, can cause an electron to be released from the surface towards the collector rod **B**.

There is a potential difference of 12 V between plate **A** and rod **B** so that released electrons are accelerated towards and collected by rod **B**. **B** is 5.0 mm from **A.**
Light of wavelength 570 nm is incident on plate **A**.

i. Calculate the speed *v* of electrons arriving at rod **B**.

v = ... ms^{-1} **[4]**

ii. Estimate the response time of the photocell, that is the time it takes for electrons to travel from **A** to **B**.

response time = ... s **[2]**

83 (a). Fig. 3 shows a swimmer of mass 65 kg, weight 640 N, being lifted vertically upwards from the sea by a cable of negligible mass compared to the swimmer.

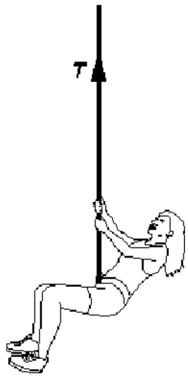

Fig. 3

The tension **T** in the cable from the time that she leaves the water at t = 0 until t = 1.5 s is 670 N. At t = 1.5 s **T** reduces to and remains constant at 640 N.

i. Use Newton's laws to describe qualitatively the motion of the swimmer for the first 4.0 s of her ascent.

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____

____ **[2]**

ii. Show that at t = 4.0 s her height h above the water is more than 2 m and that she is rising at about 0.7 m s^{-1}.

speed = ... m s^{-1}

h = ... m **[4]**

(b). The cable is attached to a winch rotated by an electric motor in a rescue helicopter. The electric supply to the motor has an e.m.f. of 28 V. The circuit has a total resistance of 0.11 Ω. When the swimmer is rising at 0.70 m s^{-1} the motor draws a current of 30 A from the supply.

Under these conditions calculate:

i. the power lost in the electrical circuit

power lost = ... W **[2]**

ii. the efficiency of the motor

efficiency = ... **[4]**

84. * A student rolls a marble at different speeds on a carpet to model the braking of a car.

The student wishes to investigate how the total distance x travelled before the marble stops (braking distance) depends on its initial speed *v*.

The speed *v* and distance *x* are related by the equation $\frac{1}{2}mv^2 = Fx$ where m is the mass of the marble and *F* is the constant frictional force acting on the marble.

- Describe how an experiment can be conducted in the laboratory to investigate the relationship between *v* and *x*.
- Explain how the data can be analysed to determine *F*.

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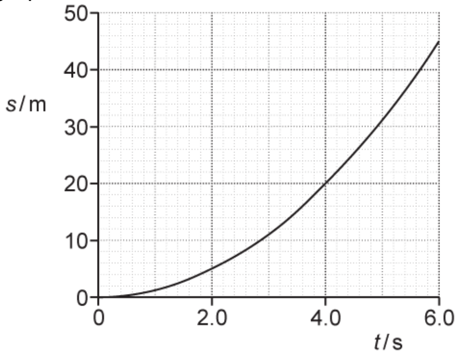
[6]

85. A car starts from rest at time $t = 0$.

The car travels in a straight line with a **constant** acceleration.

The displacement s against time t graph for this car is shown below.



i. Use the graph to show that the speed of the car at t = 4.0s is $10 ms^{-1}$.

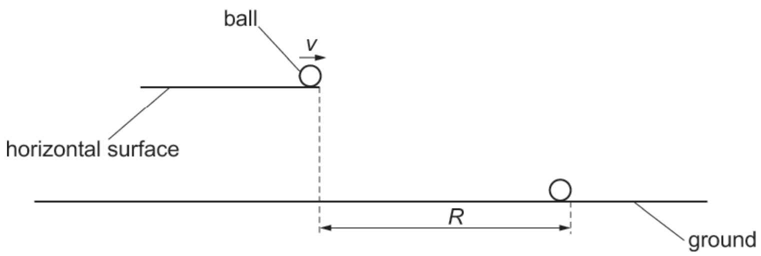
[3]

ii. The mass of the car is 1200kg.

Calculate the rate of change of momentum of the car from $t = 0$ to $t = 4.0$ s. Include an appropriate unit for your answer.

rate of change of momentum = ... unit .... **[3]**

86. * A metal ball leaves a horizontal surface with velocity *v*.
A student investigates the horizontal distance *R* that the ball travels before it hits the ground.



It is suggested that the relationship between *R* and *v* is given by

$$R = v\sqrt{\frac{Q}{g}}$$

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

Describe with the aid of a suitable diagram how an experiment can be safely conducted, and how the data can be analysed, to determine *Q*.

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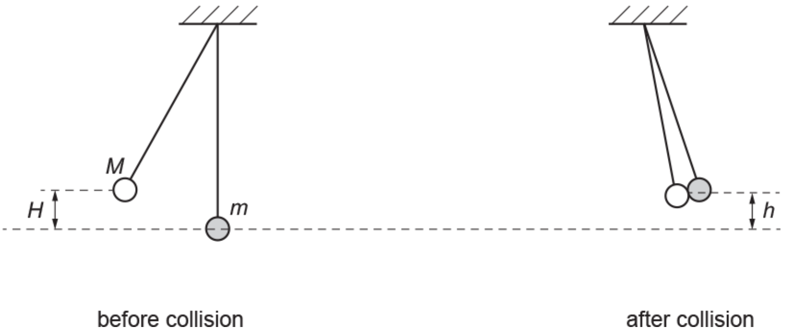
[6]

87. * A student makes a pendulum using a length of string with a ball of adhesive putty which acts as a bob. The mass of this bob is *M*.
A similar second pendulum is constructed with the same length of string but with a bob of a smaller mass. The mass of this bob is *m*.

The arrangement of the pendulums is shown below.



The bob of mass *M* is pulled back to a vertical height of *H* from its rest position. It is released and collides with the bob of mass *m*. The two bobs then stick together and reach a maximum vertical height *h* from the rest position.

The height *h* is given by the equation $h = \left(\frac{M}{M+m}\right)^2 H$.

Describe how to perform an experiment to test the validity of this equation and how the data can be analysed.

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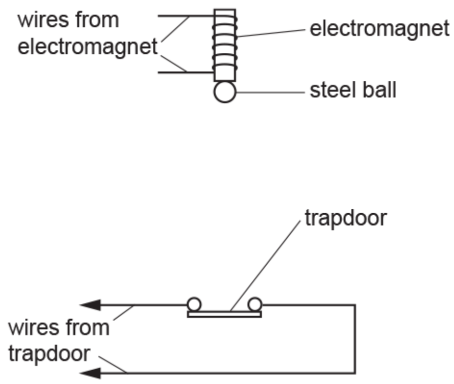
[6]

88. A student wants to determine the value of the acceleration of freefall *g*.

The diagram below shows part of the arrangement which the student used.



A steel ball is dropped from an electromagnet. The ball falls vertically. The ball hits a trapdoor and opens the trapdoor.
The ball travels a distance s from the bottom of the electromagnet to the trapdoor in a time *t*.

The student uses the equation $s = \frac{1}{2} gt^2$ to determine *g*.

i. Show that the equation $s = \frac{1}{2} gt^2$ is homogeneous, with both sides of the equation having the same base units.

[2]

ii. Describe how the student could use standard laboratory equipment to take accurate measurements of the distance s and the time *t*.

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____ **[4]**

89. Fig. 24 shows two horizontal metal plates in a vacuum.

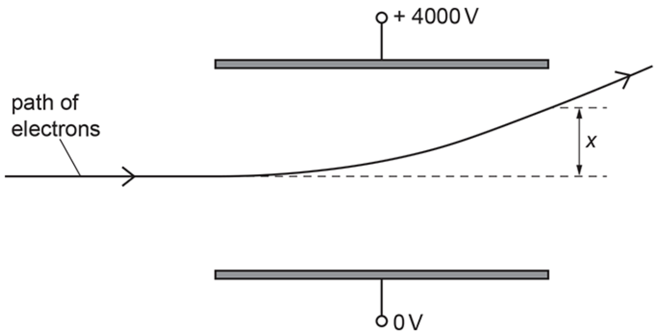


Fig. 24

The diagram is **not** drawn to scale.
Electrons travelling horizontally enter the space between the charged plates and are deflected vertically.

The potential difference between the plates is 4000 V.
The distance between the plates is 0.08 m.
The initial speed of the electrons is 6.0×10^7 m s^{-1}.
The vertical deflection of the electrons at the far end of the plates is x.

i. Show that the vertical acceleration a of an electron between the plates is 8.8×10^{15} m s^{-2}.

[3]

ii. The length of each plate is 0.12 m.

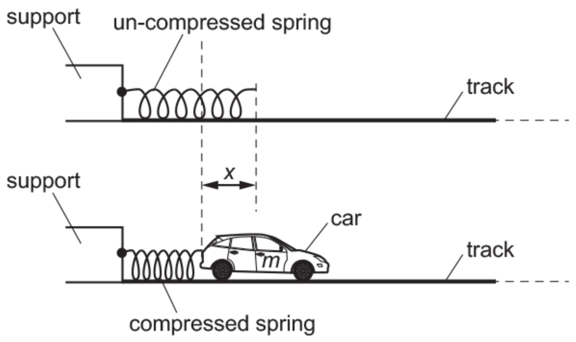
Show that the time *t* taken by the electron to travel this length is 2.0×10^{-9} s.

[1]

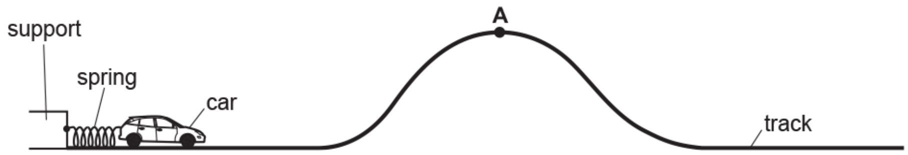
iii. Calculate the vertical deflection x of the electron.

x = ... m **[2]**

90. One end of a spring is fixed to a support.
A toy car, which is on a smooth horizontal track, is pushed against the free end of the spring.
The spring compresses. The car is then released. The car accelerates to the right until the spring returns back to its original length.



The arrangement is used to propel the toy car along a smooth track.



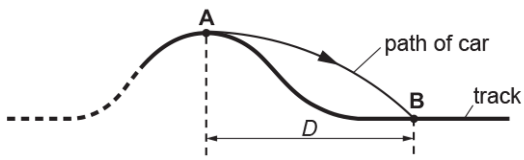
i. Point **A** is at the top of the track.
The launch speed of the car is now adjusted until the car just reaches **A** with zero speed.
The height of **A** is 0.20 m above the horizontal section of the track.

All the elastic potential energy of the spring is transferred to gravitational potential energy of the car.

Calculate the initial compression *x* of the spring.

x = ... m **[3]**

ii. At a specific speed, the car leaves point **A** horizontally and lands on the track at point **B**.
The horizontal distance between **A** and **B** is D.



Air resistance has negligible effect on the motion of the car between **A** and **B**.

1 Explain how the time of flight between **A** and **B** depends on the speed of the car at **A**.

[2]

2 Explain how the distance *D* depends on the speed of the car at **A**.

[2]

91. Electrons in a beam are accelerated from rest by a potential difference *V* between two vertical plates before entering a uniform electric field of electric field strength *E* between two horizontal parallel plates, a distance 2*d* apart.

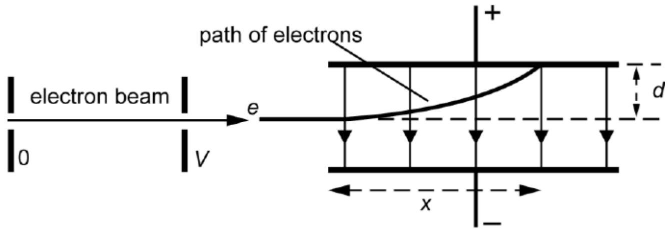


Fig. 2.1

The path of the electrons is shown in Fig. 2.1. The electron beam travels a horizontal distance *x* parallel to the plates before hitting the top plate. The beam has been deflected through a vertical distance *d*.

For different values of the accelerating p.d. *V*, the horizontal distance *x* is recorded. A table of results is shown with a third column giving values of x^2 including the absolute uncertainties.

***V* / V**	***x* / cm**	**x^2 / cm^2**
500	3.3 ± 0.1	10.9 ± 0.7
600	3.6 ± 0.1	13.0 ± 0.7
700	3.9 ± 0.1	15.2 ± 0.8
800	4.2 ± 0.1	17.6 ± 0.8
900	4.5 ± 0.1	20.3 ± 0.9
1000	4.7 ± 0.1	

i. Complete the missing value in the table, including the absolute uncertainty.

[1]

ii. Fig. 2.2 shows the axes for a graph of x^2 on the *y*-axis against *V* on the *x*-axis. The first four points have been plotted including error bars for x^2. Use data from the table to complete the graph.

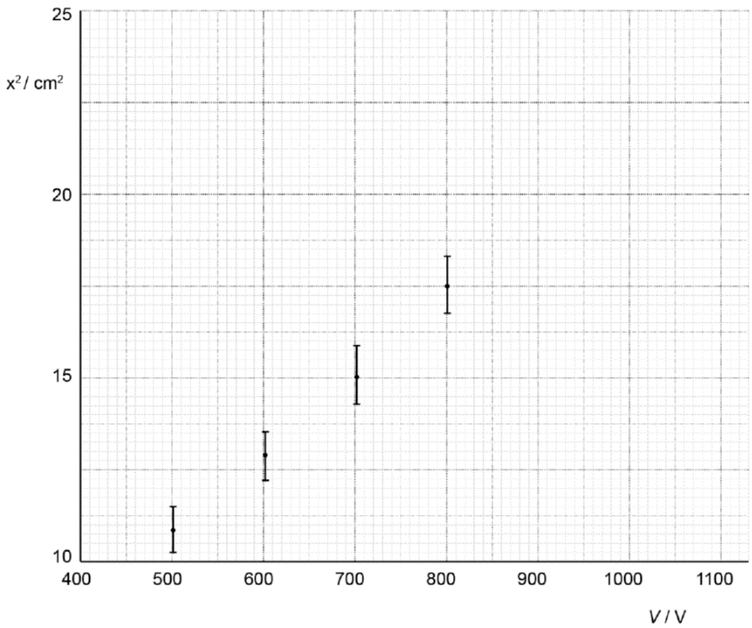


Fig. 2.2

[2]

iii. The separation of the horizontal plates is 4.0 ± 0.1 cm.
Use the graph to determine a value for E. Include the absolute uncertainty and an appropriate unit in your answer

E = **............................**±**.......................**unit**.......................** **[4]**

92. Fig. 1 shows a high-speed electric train.

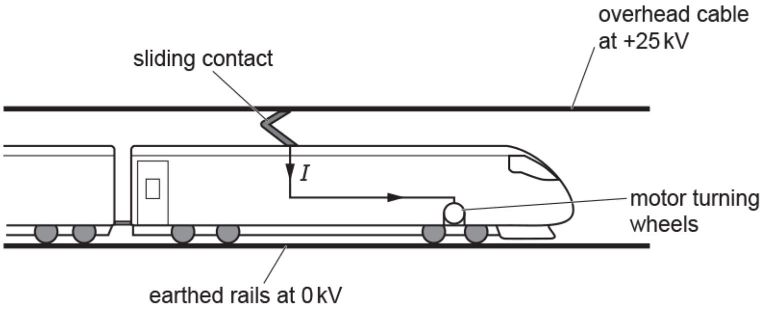


Fig. 1

The potential difference between the overhead cable and the rails on the ground is 25 kV.
The sliding contact on the top of the train constantly touches the overhead cable.
The overhead cable supplies a current I to the electric motor of the train.
The motor turns the wheels. The train experiences a **resultant** forward force *F*.

The total mass of the train is 2.1×10^5 kg.

The train accelerates from rest. The value of F is 190 kN for speeds less than 6.0 m s^{-1}.

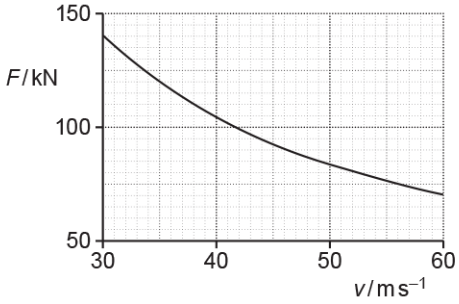
i. Show that the train's acceleration is about 1 m s^{-2}.

[1]

ii. Calculate the distance s that the train travels to reach a speed of 6.0 m s^{-1}.

s = ... m**[2]**

iii. The speed of the train is v.
During one period of its journey, the train accelerates from v = 30 m s^{-1} to v = 60 m s^{-1}.
The graph of *F* against v for this period is shown below.



1. Use the graph to show that output power of the electric motor during this period is constant at about 4 MW.

2. Calculate the current *I* in the electric motor when the train is travelling at 50 m s^{-1}. **[3]**

I = ... A**[2]**

93. Fig. 20.1 shows an electric motor used to lift and lower a load.

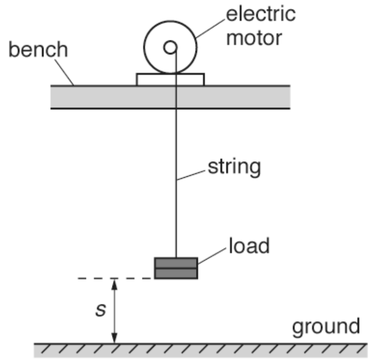


Fig. 20.1

At time t = 0 the load is on the ground with displacement s = 0.
Fig. 20.2 shows the variation of the displacement s of the load with time t.

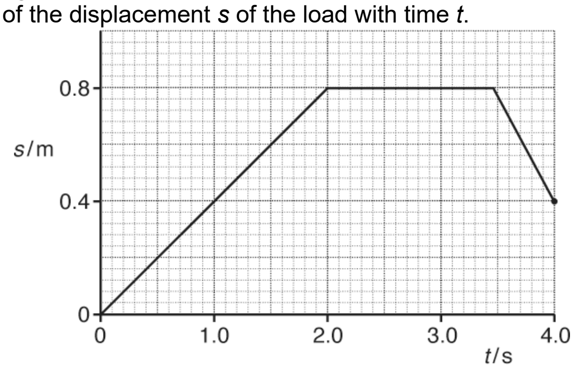


Fig. 20.2

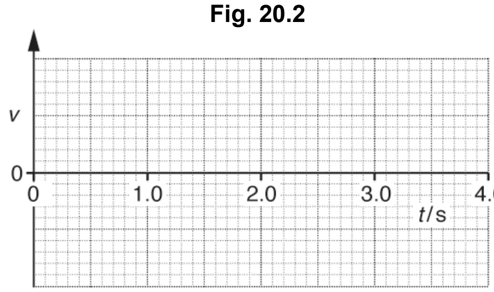


Fig. 20.3

i. On Fig. 20.3, sketch a graph to show the variation of the velocity v of the load with time t.
You do not need to insert a scale on the v axis.

[3]

ii. Describe how the kinetic energy and the gravitational potential energy of the load varies from t = 0 to t = 2.0 s.

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____ **[2]**

iii. During the **downward** journey of the load, the string breaks at t = 4.0 s. It then falls vertically towards the ground. The mass of the load is 120 g. Air resistance is negligible.

1 Calculate the velocity V of the load just before it hits the ground.

V = ms^{-1} **[2]**

The load hits the ground and comes to **rest** in a time interval of 25 ms.

2 Calculate the average force F exerted by the ground on the load.

F = N **[2]**

94. 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).

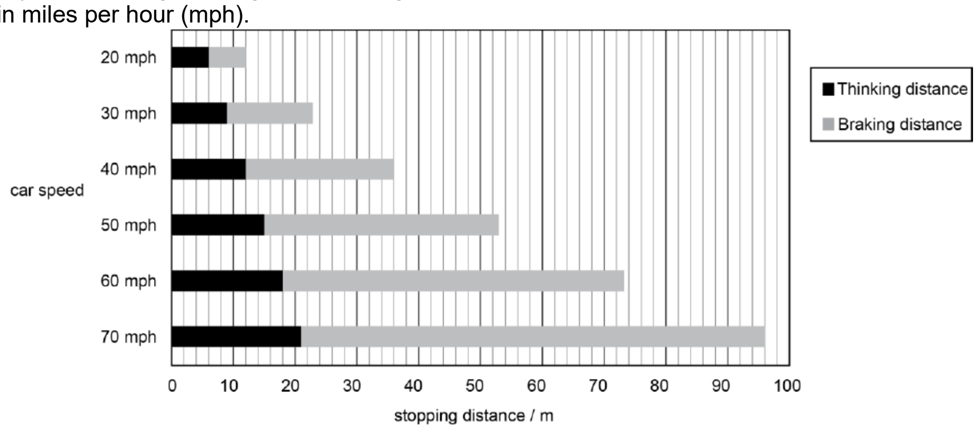

Fig. 16

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.

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____

____ **[4]**

95. Fig. 1.1 shows a train of mass 1.9×10^5 kg travelling at 61 kmh^{-1} along a level track.

Fig. 1.1

i. Show that the train is travelling at about 17 ms^{-1}.

[1]

ii. The brakes of the train are applied and the train is brought to rest in a distance of 310 m. Calculate

1. the initial kinetic energy E_k of the train

E_k = ... J **[2]**

2. the average deceleration *a* of the train

a = ... ms^{-2} **[3]**

3. the average braking force *F* on the train.

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

iii. Fig. 1.2 shows a similar train travelling at 61 $km h^{-1}$ up an incline.

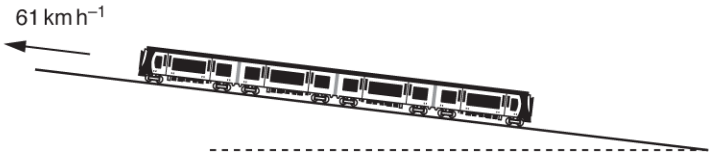

Fig. 1.2

The brakes of the train are applied with the **same** average braking force. State and explain how the distance that the train travels, from when the brakes are applied until the train stops, compares with when the train is travelling on level track.

____

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____ **[2]**

END OF QUESTION PAPER