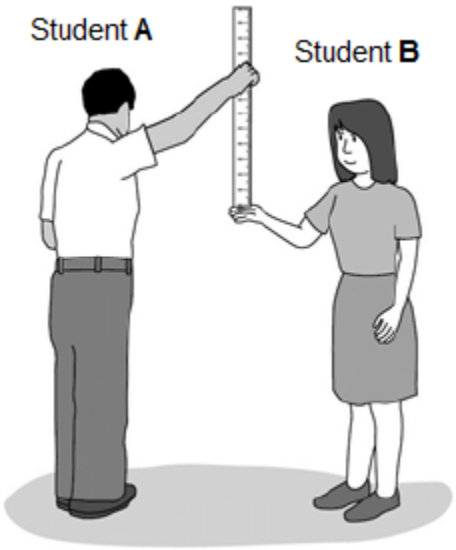
1 (a) The figure below shows two students investigating reaction time.



Student **A** lets the ruler go.

Student **B** closes her hand the moment she sees the ruler fall.

This investigation can be used to find out if listening to music changes the reaction times of a student.

Explain how.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(b) A second group of students used a stop clock and computer simulation test to measure their reaction times.

The table below shows their results.

Student	Reaction time in seconds		
	Test 1	**Test 2**	**Test 3**
X	0.44	0.40	0.34
Y	0.28	0.24	0.22
Z	0.36	0.33	0.47

Give **one** conclusion that can be made from the results for student **X** and student **Y**.

_____

_____

(1)

(c) Test **3** for student **Z** gave an anomalous result.

Suggest **two** possible reasons why this anomalous result occurred.

1. _____

_____

2. _____

_____

(2)

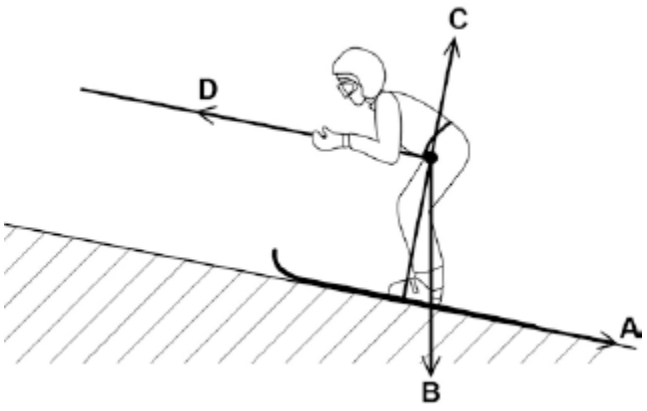
(Total 7 marks)

2 **Figure 1** shows a skier using a drag lift.

The drag lift pulls the skier from the bottom to the top of a ski slope.

The arrows, **A**, **B**, **C** and **D** represent the forces acting on the skier and her skis.

Figure 1



(a) Which arrow represents the force pulling the skier up the slope?

Tick **one** box.

A ☐

B ☐

C ☐

D ☐

(1)

(b) Which arrow represents the normal contact force?

Tick **one** box.

A ☐

B ☐

C ☐

D ☐

(1)

(c) The drag lift pulls the skier with a constant resultant force of 300N for a distance of 45 m.

Use the following equation to calculate the work done to pull the skier up the slope.

work done = force × distance

_____

_____

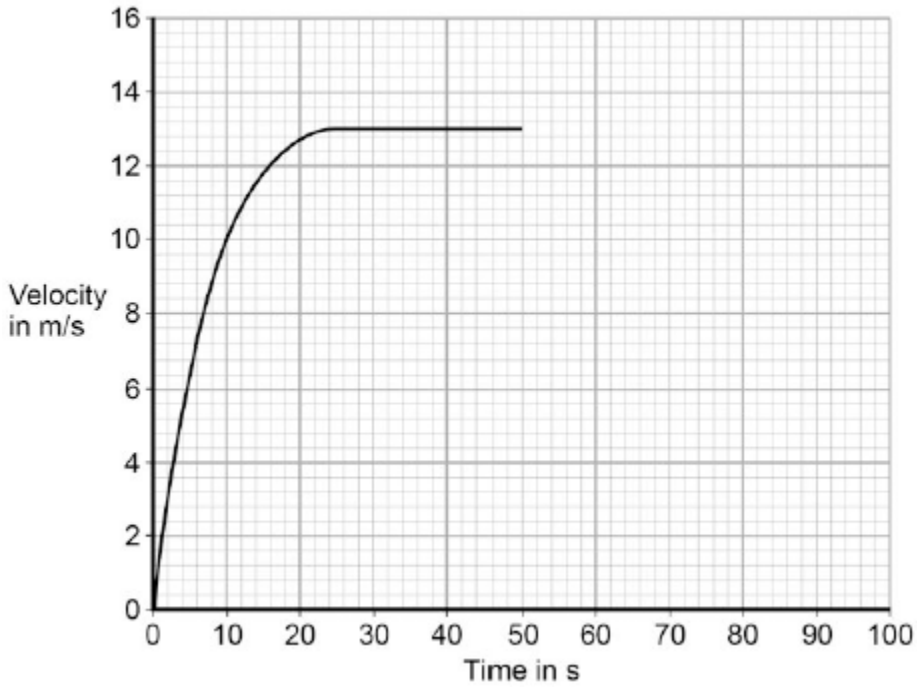
Work done = _____ J

(2)

(d) At the top of the slope the skier leaves the drag lift and skis back to the bottom of the slope.

Figure 2 shows how the velocity of the skier changes with time as the skier moves down the slope.

Figure 2



After 50 seconds the skier starts to slow down.

The skier decelerates at a constant rate coming to a stop in 15 seconds.

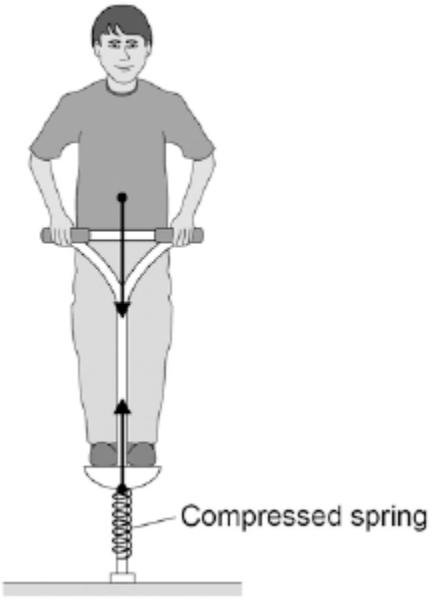
Draw a line on **Figure 2** to show the change in velocity of the skier as she slows down and comes to a stop.

(2)

(Total 6 marks)

3 The figure below shows the forces acting on a child who is balancing on a pogo stick.

The child and pogo stick are not moving.



(a) The downward force of the child on the spring is equal to the upward force of the spring on the child.

This is an example of which one of Newton's Laws of motion?

Tick **one** box.

First Law ☐

Second Law ☐

Third Law ☐

(1)

(b) Complete the sentence.

Use an answer from the box.

elastic potential	**gravitational potential**	**kinetic**

The compressed spring stores _____ energy.

(1)

(c) The child has a weight of 343 N.

Gravitational field strength = 9.8 N / kg

Write down the equation which links gravitational field strength, mass and weight.

_____

(1)

(d) Calculate the mass of the child.

_____

_____

_____

Mass = _____ kg

(3)

(e) The weight of the child causes the spring to compress elastically from a length of 30cm to a new length of 23cm.

Write down the equation which links compression, force and spring constant.

_____

(1)

(f) Calculate the spring constant of the spring.

Give your answer in newtons per metre.

_____

_____

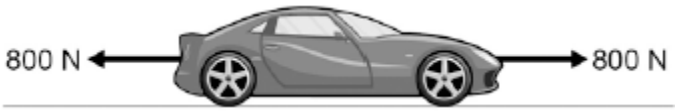
_____

Spring constant = _____ N / m

(4)

(Total 11 marks)

4 The figure below shows the horizontal forces acting on a car.



(a) Which **one** of the statements describes the motion of the car?

Tick **one** box.

It will be slowing down. ☐

It will be stationary. ☐

It will have a constant speed. ☐

It will be speeding up. ☐

(1)

(b) During part of the journey the car is driven at a constant speed for five minutes.

Which one of the equations links distance travelled, speed and time?

Tick **one** box.

distance travelled = speed + time ☐

distance travelled = speed × time ☐

distance travelled = speed − time ☐

distance travelled = speed ÷ time ☐

(1)

(c) During a different part of the journey the car accelerates from 9m / s to 18m / s in 6 s.

Use the following equation to calculate the acceleration of the car.

$$\text{acceleration} = \frac{\text{change in velociy}}{\text{time taken}}$$

_____

_____

acceleration = _____ m / s^2

(2)

(d) Which equation links acceleration, mass and resultant force?

Tick **one** box.

resultant force = mass + acceleration ☐

resultant force = mass × acceleration ☐

resultant force = mass − acceleration ☐

resultant force = mass ÷ acceleration ☐

(1)

(e) The mass of the car is 1120 kg. The mass of the driver is 80 kg.

Calculate the resultant force acting on the car and driver while accelerating.

_____

_____

Resultant force = _____ N

(2)

(f) Calculate the distance travelled while the car is accelerating.

Use the correct equation from the Physics Equation Sheet.

_____

_____

_____

Distance = _____ m

(3)

(g) A car driver sees a fallen tree lying across the road ahead and makes an emergency stop.

The braking distance of the car depends on the speed of the car.

For the same braking force, explain what happens to the braking distance if the speed doubles.

You should refer to kinetic energy in your answer.

(4)

(Total 14 marks)

5 In 2011, some of the scientists working at the CERN particle laboratory published the results of experiments they had conducted over the previous three years.

The scientists said that the results had shown that a particle, called a neutrino, was able to travel faster than the speed of light.

These unexpected results challenged the physics theory that nothing can travel faster than the speed of light.

(a) Suggest why most other scientists thought that the experimental results were unbelievable.

(1)

(b) The scientists at CERN believed their results were correct but could not explain them.

Suggest **two** reasons why the scientists decided to publish their results.

1.

2.

(2)

(c) The experiments conducted by the scientists involved measuring the time it took neutrinos to travel from CERN to another laboratory 730 000 m away.

Using the data, the speed of the neutrinos was calculated to be 300 007 400 m / s.

Calculate the time it would take the neutrinos to travel 730 000 m at a speed of 300 007 400 m / s.

Give your answer in standard form.

_____

_____

_____

_____

Time = _____ s

(3)

(d) In 2012, the scientists found that the unexpected results were caused by a timing error.

The error meant that the time recorded was always 60 nanoseconds less than the actual time.

Which **one** of the following is the same as 60 nanoseconds?

Tick **one** box.

60×10^{-3} s ☐

60×10^{-6} s ☐

60×10^{-9} s ☐

(1)

(e) What name is given to the type of error made by the scientists?

_____

(1)

(f) Suggest what the scientists should do to calculate an accurate value for the speed of a neutrino.

_____

_____

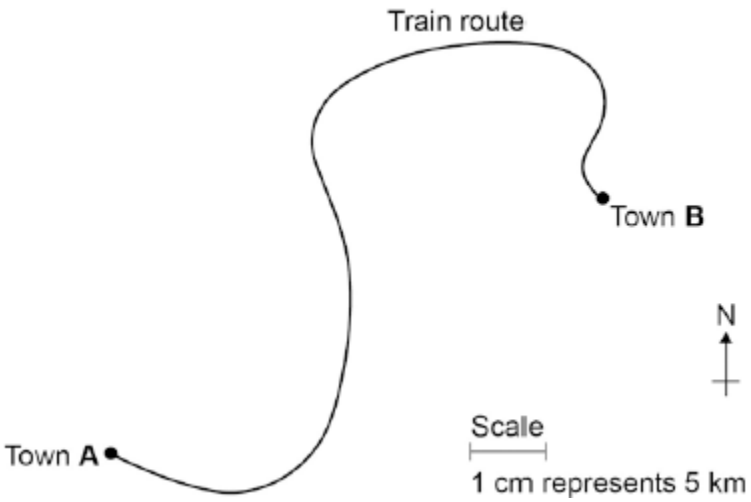
(1)

(Total 9 marks)

6 A train travels from town **A** to town **B**.

Figure 1 shows the route taken by the train.
Figure 1 has been drawn to scale.

Figure 1



(a) The distance the train travels between **A** and **B** is not the same as the displacement of the train.

What is the difference between distance and displacement?

_____

_____

_____

(1)

(b) Use **Figure 1** to determine the displacement of the train in travelling from **A** to **B**.

Show how you obtain your answer.

_____

_____

Displacement = _____ km

Direction = _____

(2)

(c) There are places on the journey where the train accelerates without changing speed.

Explain how this can happen.

_____

_____

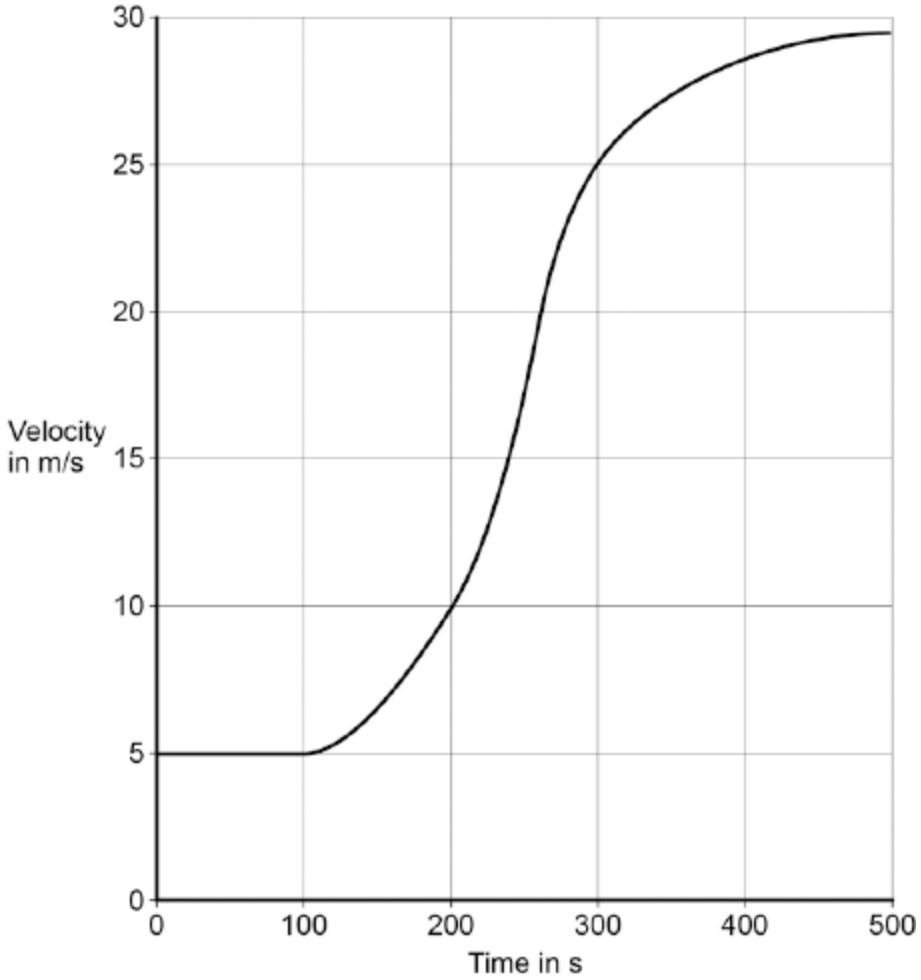
_____

_____

(2)

(d) **Figure 2** shows how the velocity of the train changes with time as the train travels along a straight section of the journey.

Figure 2



Estimate the distance travelled by the train along the section of the journey shown in **Figure 2**.

To gain full marks you must show how you worked out your answer.

Distance = _____ m

(3)

(Total 8 marks)

7 The stopping distance of a car is the sum of the thinking distance and the braking distance.

The table below shows how the thinking distance and braking distance vary with speed.

Speed in m / s	Thinking distance in m	Braking distance in m
10	6	6.0
15	9	13.5
20	12	24.0
25	15	37.5
30	18	54.0

(a) What is meant by the braking distance of a vehicle?

_____

_____

(1)

(b) The data in the table above refers to a car in good mechanical condition driven by an alert driver.

Explain why the stopping distance of the car increases if the driver is very tired.

_____

_____

_____

_____

(2)

(c) A student looks at the data in the table above and writes the following:

thinking distance ∝ speed

thinking distance ∝ speed

Explain whether the student is correct.

_____

_____

_____

_____

(2)

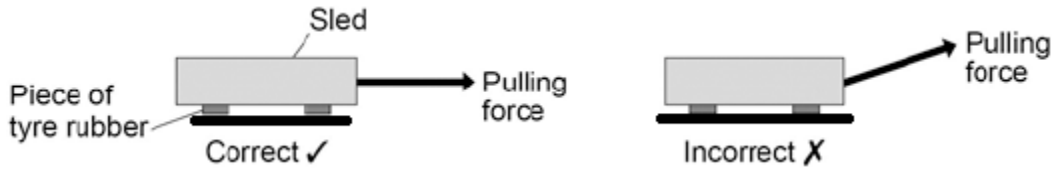
(d) Applying the brakes with too much force can cause a car to skid.

The distance a car skids before stopping depends on the friction between the road surface and the car tyres and also the speed of the car.

Friction can be investigated by pulling a device called a 'sled' across a surface at constant speed.

The figure below shows a sled being pulled correctly and incorrectly across a surface.

The constant of friction for the surface is calculated from the value of the force pulling the sled and the weight of the sled.



Why is it important that the sled is pulled at a constant speed?

Tick **one** box.

If the sled accelerates it will be difficult to control. ☐

If the sled accelerates the value for the constant of friction will be wrong. ☐

If the sled accelerates the normal contact force will change. ☐

(1)

(e) If the sled is pulled at an angle to the surface the value calculated for the constant of friction would not be appropriate.

Explain why.

_____

_____

_____

_____

(2)

(f) By measuring the length of the skid marks, an accident investigator determines that the distance a car travelled between the brakes being applied and stopping was 22 m.

The investigator used a sled to determine the friction. The investigator then calculated that the car decelerated at 7.2 m / s^2.

Calculate the speed of the car just before the brakes were applied.

Give your answer to two significant figures.

Use the correct equation from the Physics Equation Sheet.

_____

_____

_____

_____

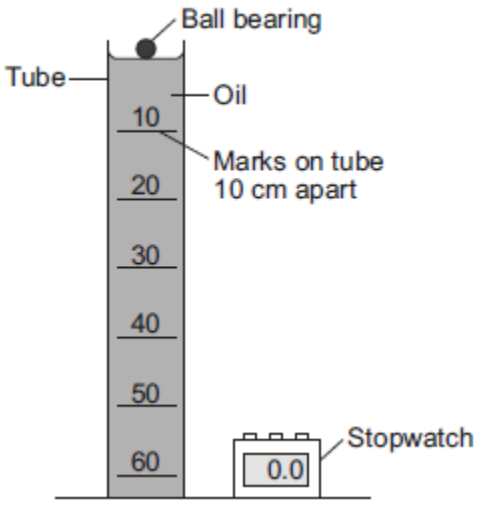
Speed = _____ m / s

(3)

(Total 11 marks)

8 A student investigated how the speed of a ball bearing changes as the ball bearing falls through a tube of oil.
Figure 1 shows the equipment the student used.

Figure 1



The student measured the time taken for the ball bearing to fall different distances.
Each distance was measured from the top of the oil.

(a) What is likely to have been the main source of error in this investigation?

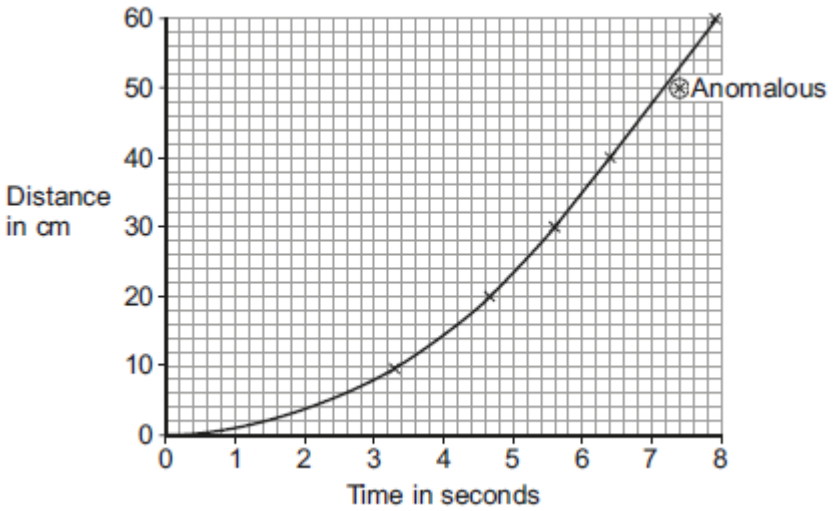
_____

_____

(1)

(b) **Figure 2** shows the student's results plotted as a graph.

Figure 2



(i) The student has identified one of the results as being anomalous.

Use the correct answer from the box to complete the sentence.

after	as	before

The anomalous result was caused by the stopwatch being started

_____ the ball bearing was released.

(1)

(ii) What can you conclude from the graph about the speed of the ball bearing during the first four seconds?

_____

_____

(1)

(iii) The graph shows that the ball bearing reached its terminal velocity.

Describe how the graph would be used to calculate the terminal velocity of the ball bearing.

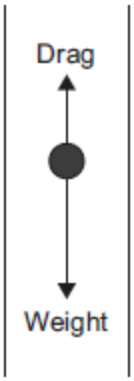
_____

_____

(1)

(iv) The directions of the two forces acting on the ball bearing as it falls through the oil are shown in **Figure 3**.

Figure 3



Explain, in terms of the forces shown in **Figure 3**, why the ball bearing reaches its terminal velocity.

_____

_____

_____

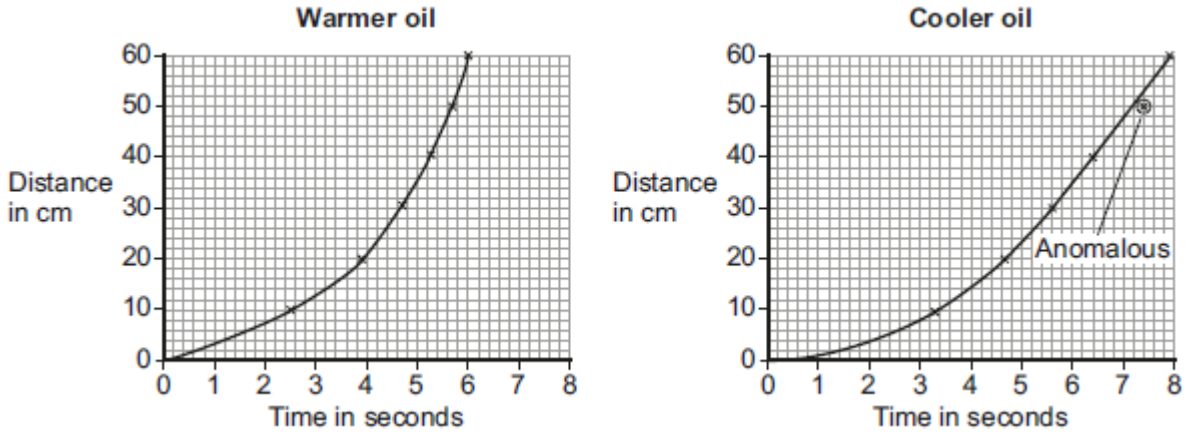
_____

(2)

(c) The student repeated the investigation using warmer oil.

Figure 4 shows the set of results using the warmer oil **and** the set of results using the cooler oil.

Figure 4



Compare the two graphs in **Figure 4**.

Use the correct answer from the box to complete the sentence.

less than	equal to	greater than

After falling 40 cm, the drag force on the ball bearing in the warmer oil is

_____ the drag force on the ball bearing in the cooler oil.

Explain the reason for your answer.

_____

_____

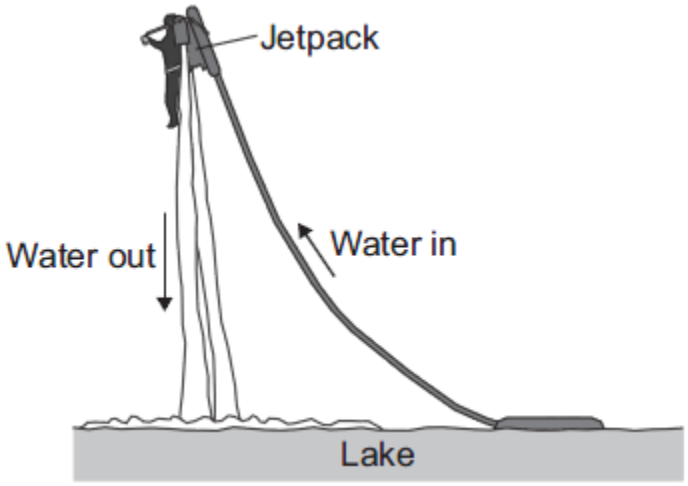
_____

_____

(3)

(Total 9 marks)

9 The diagram below shows a person using a device called a jetpack. Water is forced downwards from the jetpack and produces an upward force on the person.



(a) State the condition necessary for the person to be able to remain stationary in mid-air.

_____

_____

(1)

(b) The person weighs 700 N and the jetpack weighs 140 N.

(i) Calculate the combined mass of the person and the jetpack.

Gravitational field strength = 10 N/kg

_____

_____

_____

Combined mass = _____ kg

(2)

(ii) Increasing the upward force to 1850 N causes the person to accelerate upwards.

Calculate the acceleration of the person and the jetpack. Give the unit.

_____

_____

_____

_____

Acceleration = _____ Unit _____

(3)

(Total 6 marks)

10 A number of different forces act on a moving vehicle.

(a) A car moving at a steady speed has a driving force of 3000 N.

(i) What is the value of the resistive force acting on the car?

Tick (✓) **one** box.

	Tick (✓)
2000 N	
3000 N	
4000 N	

(1)

(ii) What causes most of the resistive force?

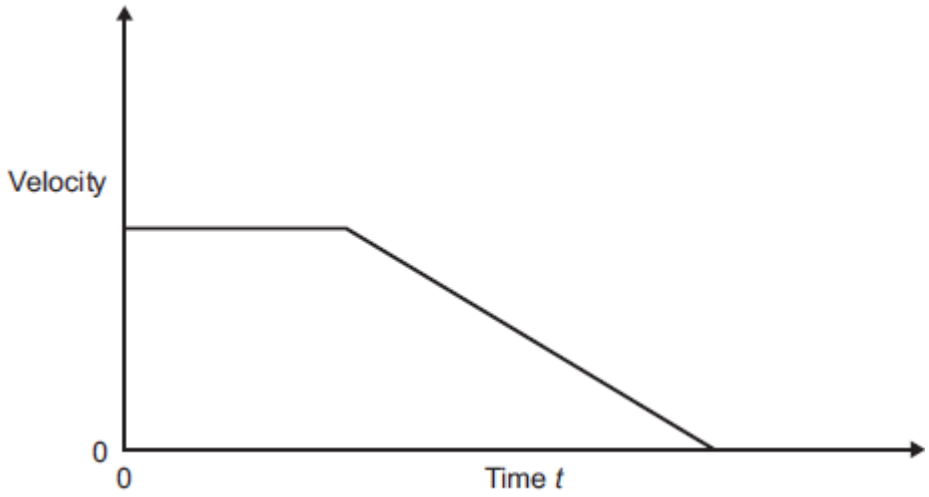
Tick (✓) **one** box.

	Tick (✓)
Air resistance	
Faulty brakes	
Poor condition of tyres	

(1)

(b) A car is moving along a road. The driver sees an obstacle in the road at time $t = 0$ and applies the brakes until the car stops.

The graph shows how the velocity of the car changes with time.



(i) Which feature of the graph represents the negative acceleration of the car?

Tick (✓) **one** box.

	Tick (✓)
The area under the graph	
The gradient of the sloping line	
The intercept on the y-axis	

(1)

(ii) Which feature of the graph represents the distance travelled by the car?

Tick (✓) **one** box.

	Tick (✓)
The area under the graph	
The gradient of the sloping line	
The intercept on the y-axis	

(1)

(iii) On a different journey, the car is moving at a **greater** steady speed.

The driver sees an obstacle in the road at time $t = 0$ and applies the brakes until the car stops.

The driver's reaction time and the braking distance are the same as shown the graph above.

On the graph above draw another graph to show the motion of the car.

(3)

(c) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

Thinking distance and braking distance affect stopping distance.

Explain how the factors that affect thinking distance and braking distance affect stopping distance.

(6)

(Total 13 marks)

11 (a) When a force is applied to a spring, the spring extends by 0.12 m.
The spring has a spring constant of 25 N / m.

Calculate the force applied to the spring.

_____

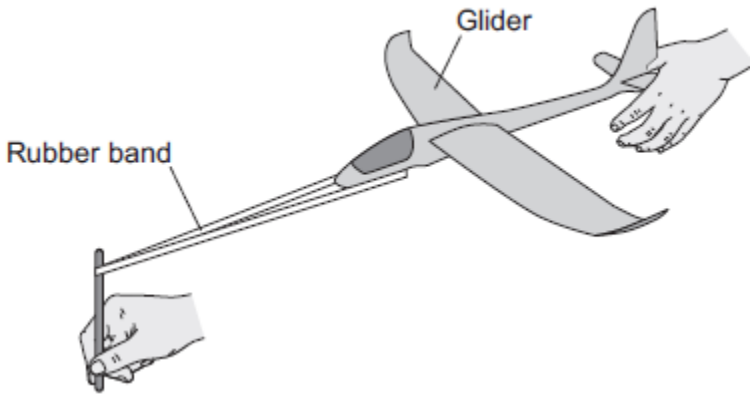
_____

Force = _____ N

(2)

(b) **Figure 1** shows a toy glider. To launch the glider into the air, the rubber band and glider are pulled back and then the glider is released.

Figure 1



(i) Use the correct answers from the box to complete the sentence.

chemical	**elastic potential**	**kinetic**	**thermal**

When the glider is released, the _____ energy

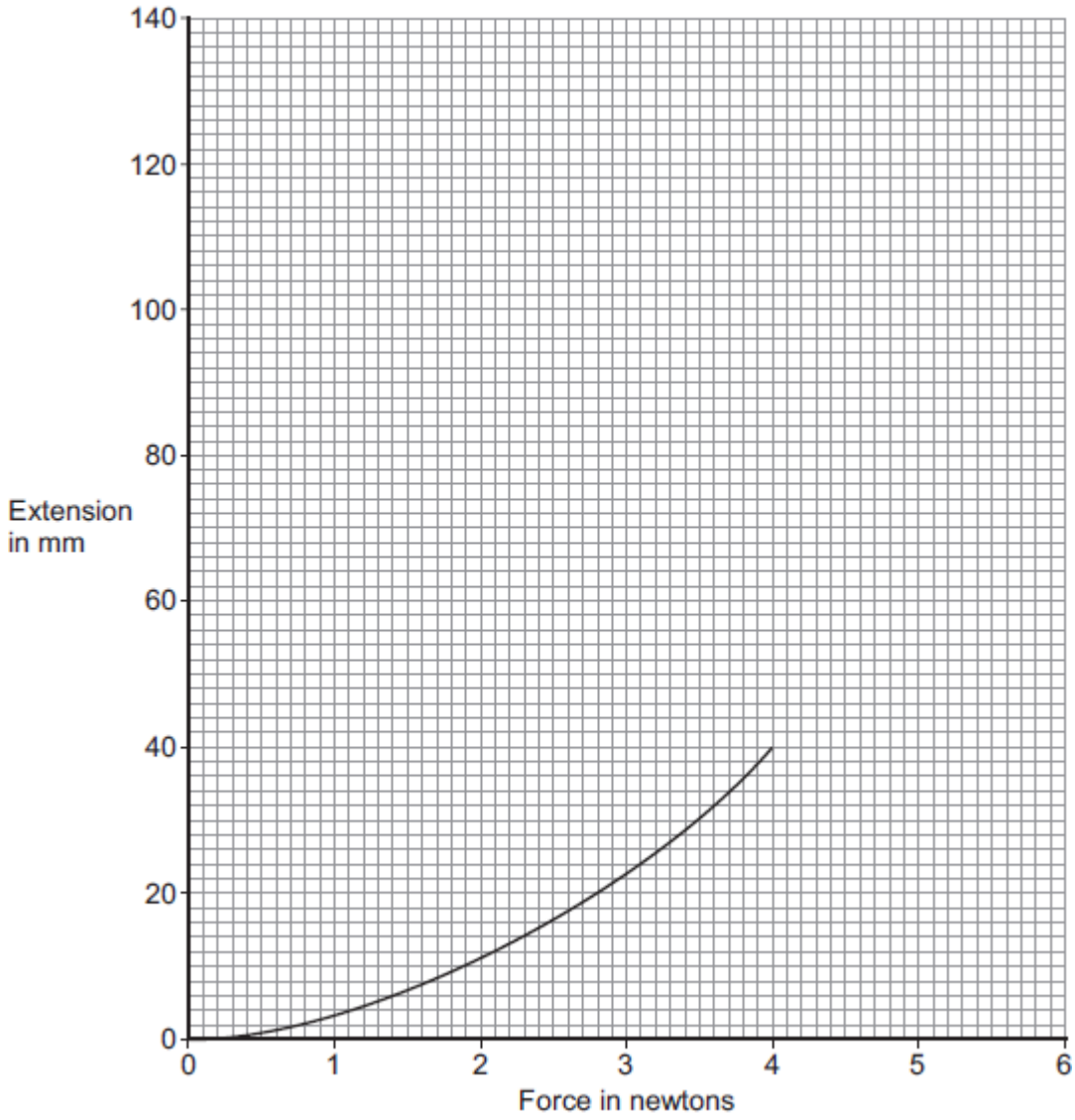
stored in the rubber band decreases and the glider gains

_____ energy.

(2)

(ii) **Figure 2** shows how the extension of the rubber band varies with the force applied to the rubber band.

Figure 2



What can you conclude, from **Figure 2**, would happen to the extension of the rubber band if the force applied to the rubber band was increased to 6 N?

The rubber band does **not** break.

_____

_____

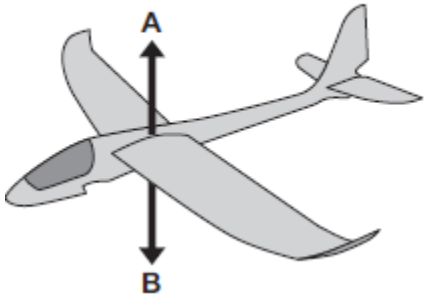
_____

_____

(2)

(c) **Figure 3** shows the vertical forces, **A** and **B**, acting on the glider when it is flying.

Figure 3



(i) What name is given to the force labelled **B**?

Draw a ring around the correct answer.

drag **friction** **weight**

(1)

(ii) Which **one** of the following describes the downward speed of the glider when force **B** is greater than force **A**?

Tick (✓) **one** box.

Downward speed increases ☐

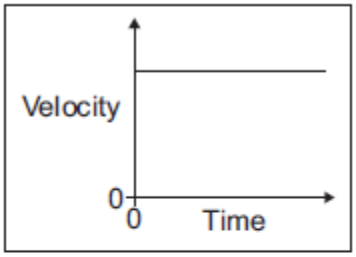
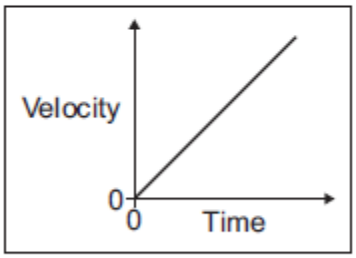
Downward speed is constant ☐

Downward speed decreases ☐

(1)

(Total 8 marks)

12 (a) Draw **one** line from each velocity–time graph to the statement describing the motion shown by the graph.

Velocity–time graph	Motion shown by graph
	Constant acceleration
	Not moving
	Constant deceleration
	Constant velocity

(2)

(b) Use the correct answer from the box to complete the sentence.

energy	**momentum**	**speed**

The velocity of an object includes both the _____ of the object and the direction the object is moving.

(1)

(c) At the start of a race, a horse accelerates from a velocity of 0 m / s to a velocity of 9 m / s in 4 seconds.

(i) Calculate the acceleration of the horse.

_____

_____

Acceleration = _____ m / s^2

(2)

(ii) When the horse accelerates, what, if anything, happens to the air resistance acting against the horse?

Tick (✓) **one** box.

The air resistance decreases ☐

The air resistance is constant ☐

The air resistance increases ☐

(1)

(d) A horse and a pony walk across a field at the same constant speed.

The horse has 4000 joules of kinetic energy.

The pony is **half** the mass of the horse.

What is the kinetic energy of the pony?

Draw a ring around the correct answer

2000 J **4000 J** **8000 J**

Give a reason for your answer.

_____

_____

(2)

(Total 8 marks)

13 (a) A car driver sees the traffic in front is not moving and brakes to stop his car.

The stopping distance of a car is the thinking distance plus the braking distance.

(i) What is meant by the 'braking distance'?

_____

_____

(1)

(ii) The braking distance of a car depends on the speed of the car and the braking force.

State **one** other factor that affects braking distance.

_____

_____

(1)

(iii) How does the braking force needed to stop a car in a particular distance depend on the speed of the car?

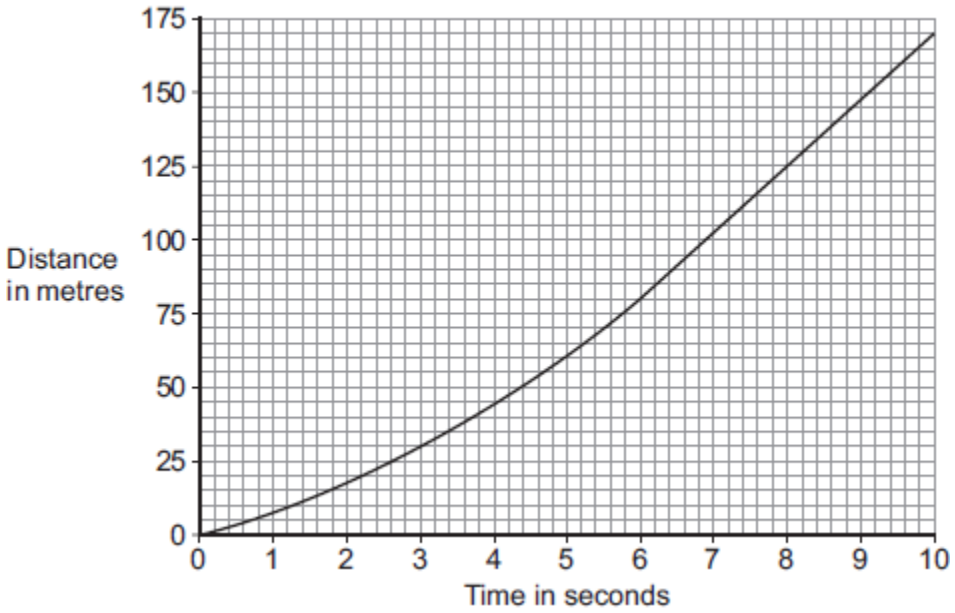
_____

_____

(1)

(b) **Figure 1** shows the distance−time graph for the car in the 10 seconds before the driver applied the brakes.

Figure 1



Use **Figure 1** to calculate the maximum speed the car was travelling at.
Show clearly how you work out your answer.

_____

_____

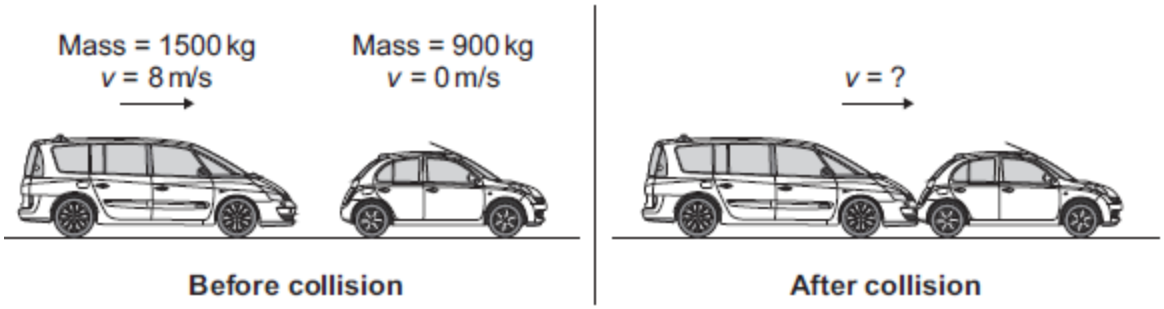
Maximum speed = _____ m / s

(2)

(c) The car did not stop in time. It collided with the stationary car in front, joining the two cars together.

Figure 2 shows both cars, just before and just after the collision.

Figure 2



(i) The momentum of the two cars was conserved.

What is meant by the statement 'momentum is conserved'?

_____

_____

(1)

(ii) Calculate the velocity of the two joined cars immediately after the collision.

_____

_____

_____

_____

_____

Velocity = _____ m / s

(3)

(d) Since 1965, all cars manufactured for use in the UK must have seat belts.

It is safer for a car driver to be wearing a seat belt, compared with not wearing a seat belt, if the car is involved in a collision.

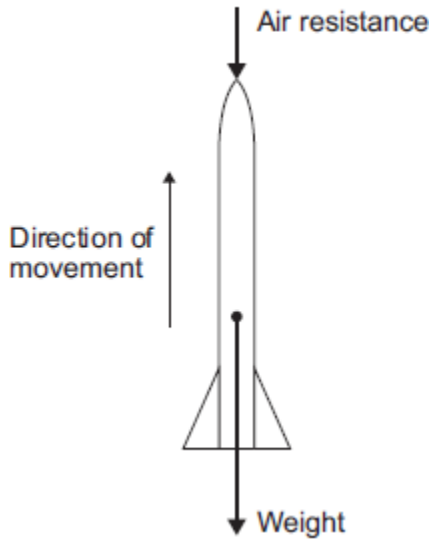
Explain why.

(4)

(Total 13 marks)

14 (a) **Figure 1** shows the forces acting on a model air-powered rocket just after it has been launched vertically upwards.

Figure 1



(i) How does the velocity of the rocket change as the rocket moves **upwards**?

_____

Give a reason for your answer.

_____

_____

(2)

(ii) The velocity of the rocket is not the same as the speed of the rocket.

What is the difference between the velocity of an object and the speed of an object?

_____

_____

_____

(1)

(b) The speed of the rocket just after being launched is 12 m / s.
The mass of the rocket is 0.05 kg.

(i) Calculate the kinetic energy of the rocket just after being launched.

_____

_____

_____

Kinetic energy = _____ J

(2)

(ii) As the rocket moves upwards, it gains gravitational potential energy.

State the maximum gravitational potential energy gained by the rocket.

Ignore the effect of air resistance.

Maximum gravitational potential energy = _____ J

(1)

(iii) Calculate the maximum height the rocket will reach.

Ignore the effect of air resistance.

Gravitational field strength = 10 N / kg.

_____

_____

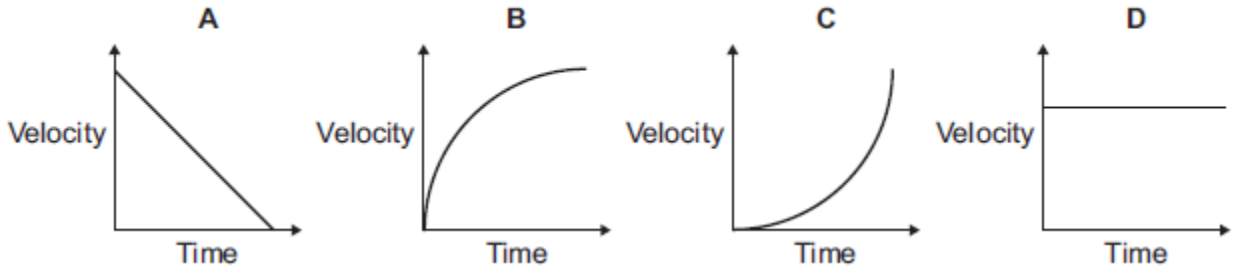
_____

Maximum height = _____ m

(2)

(iv) **Figure 2** shows four velocity−time graphs.

Figure 2



Taking air resistance into account, which graph, **A**, **B**, **C** or **D**, shows how the velocity of the rocket changes as it **falls** from the maximum height it reached until it just hits the ground?

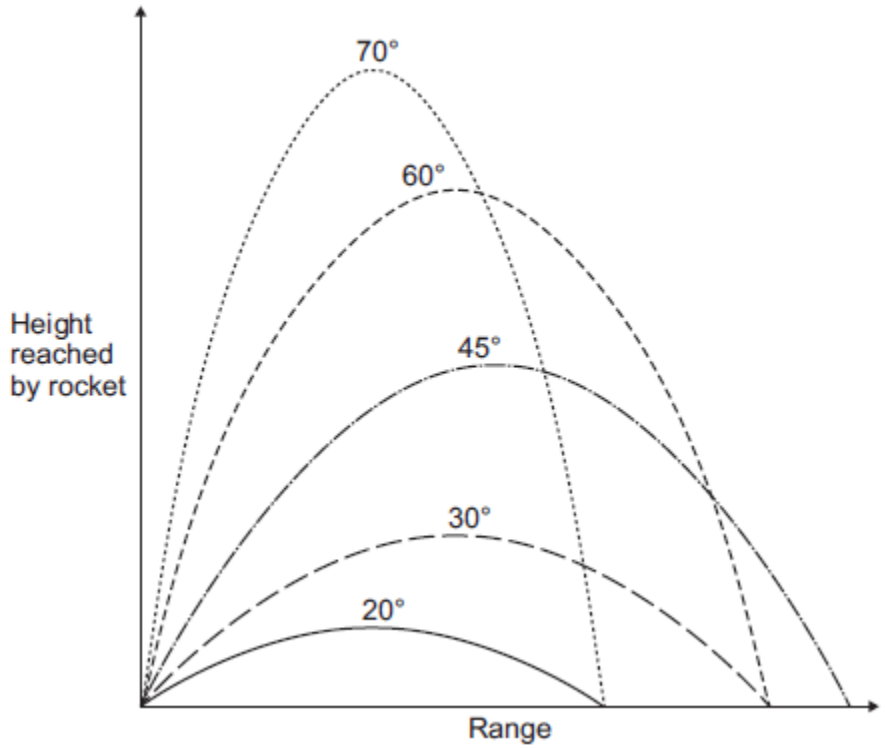
Write the correct answer in the box. ☐

(1)

(c) The rocket can be launched at different angles to the horizontal.
The horizontal distance the rocket travels is called the range.

Figure 3 shows the paths taken by the rocket when launched at different angles.
Air resistance has been ignored.

Figure 3



What pattern links the angle at which the rocket is launched and the range of the rocket?

_____

_____

_____

_____

(2)

(Total 11 marks)

15 When two objects interact, they exert forces on each other.

(a) Which statement about the forces is correct?

Tick (✓) **one** box.

	Tick (✓)
The forces are equal in size and act in the same direction.	
The forces are unequal in size and act in the same direction.	
The forces are equal in size and act in opposite directions.	
The forces are unequal in size and act in opposite directions.	

(1)

(b) A fisherman pulls a boat towards land.

The forces acting on the boat are shown in **Diagram 1**.

The fisherman exerts a force of 300 N on the boat.
The sea exerts a resistive force of 250 N on the boat.

Diagram 1

(i) Describe the motion of the boat.

_____

_____

_____

_____

(2)

(ii) When the boat reaches land, the resistive force increases to 300 N.
The fisherman continues to exert a force of 300 N.

Describe the motion of the boat.

Tick (✓) **one** box.

Accelerating to the right ☐

Constant velocity to the right ☐

Stationary ☐

(1)

(iii) Explain your answer to part **(b)(ii)**.

_____

_____

_____

_____

(2)

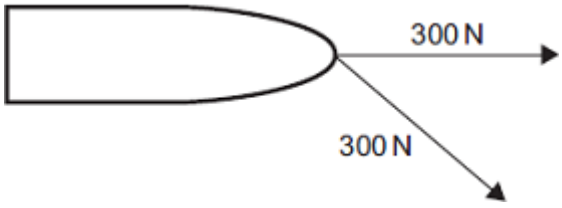
(iv) Another fisherman comes to help pull the boat. Each fisherman pulls with a force of 300 N, as shown in **Diagram 2**.

Diagram 2 is drawn to scale.

Add to **Diagram 2** to show the single force that has the same effect as the two 300 N forces.

Determine the value of this resultant force.

Diagram 2



Resultant force = _____ N

(4)

(Total 10 marks)

16 On 14 October 2012, a skydiver set a world record for the highest free fall from an aircraft.

After falling from the aircraft, he reached a maximum steady velocity of 373 m / s after 632 seconds.

(a) Draw a ring around the correct answer to complete the sentence.

This maximum steady velocity is called the | frictional / initial / terminal | velocity.

(1)

(b) The skydiver wore a chest pack containing monitoring and tracking equipment.
The weight of the chest pack was 54 N.

The gravitational field strength is 10 N / kg.

Calculate the mass of the chest pack.

_____

_____

Mass of chest pack = _____ kg

(2)

(c) During his fall, the skydiver's acceleration was not uniform.

Immediately after leaving the aircraft, the skydiver's acceleration was 10 m / s ^{2}.

(i) Without any calculation, estimate his acceleration a few seconds after leaving the aircraft.

Explain your value of acceleration in terms of forces.

Estimate _____

Explanation _____

_____

_____

_____

_____

_____

(3)

(ii) Without any calculation, estimate his acceleration 632 seconds after leaving the aircraft.

Explain your value of acceleration in terms of forces.

Estimate _____

Explanation _____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

17 An investigation was carried out to show how thinking distance, braking distance and stopping distance are affected by the speed of a car.

The results are shown in the table.

Speed in metres per second	Thinking distance in metres	Braking distance in metres	Stopping distance in metres
10	6	6	12
15	9	14	43
20	12	24	36
25	15	38	53
30	18	55	73

(a) Draw a ring around the correct answer to complete each sentence.

As speed increases, thinking distance

decreases.
increases.
stays the same.

As speed increases, braking distance

decreases.
increases.
stays the same.

(2)

(b) One of the values of stopping distance is incorrect.

Draw a ring around the incorrect value in the table.

Calculate the correct value of this stopping distance.

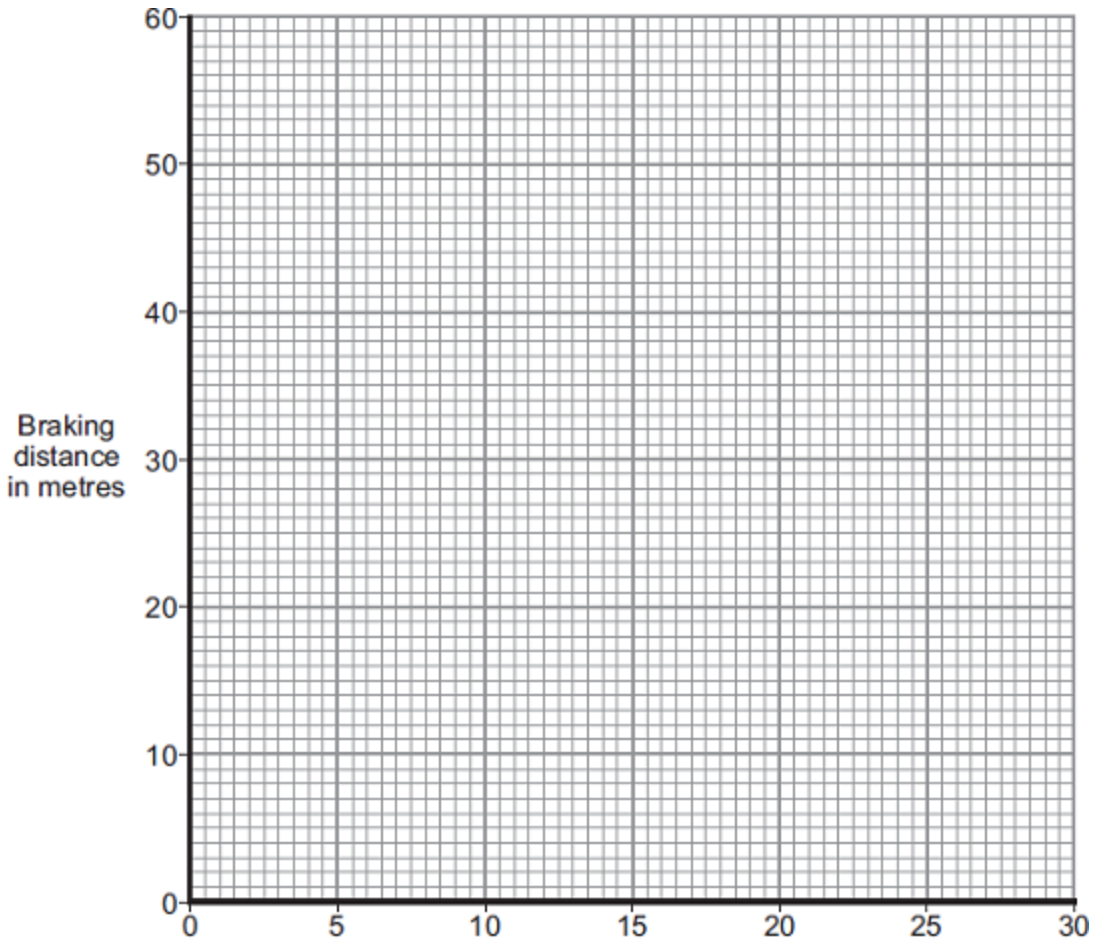
_____

Stopping distance = _____ m

(2)

(c) (i) Using the results from the table, plot a graph of braking distance against speed.

Draw a line of best fit through your points.



(3)

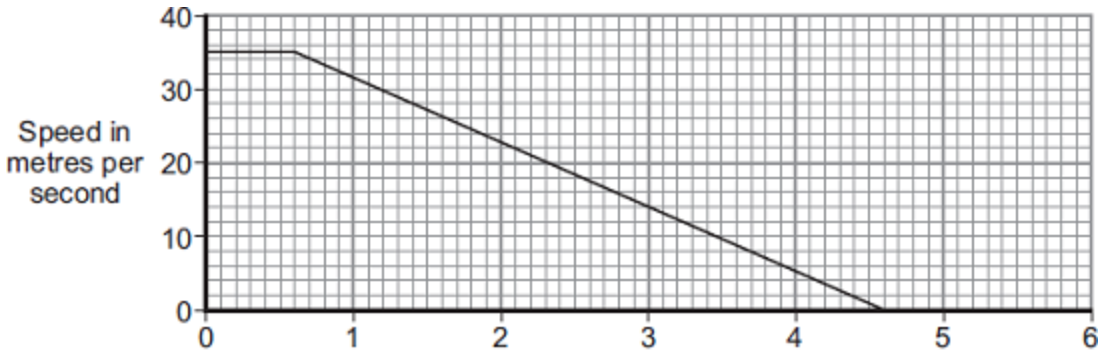
(ii) Use your graph to determine the braking distance, in metres, at a speed of 22 m / s.

Braking distance = _____ m

(1)

(d) The speed–time graph for a car is shown below.

While travelling at a speed of 35 m / s, the driver sees an obstacle in the road at time $t = 0$. The driver reacts and brakes to a stop.



(i) Determine the braking distance.

_____

_____

_____

_____

Braking distance = _____ m

(3)

(ii) If the driver was driving at 35 m / s on an icy road, the speed–time graph would be different.

Add another line to the speed–time graph above to show the effect of travelling at 35 m / s on an icy road and reacting to an obstacle in the road at time $t = 0$.

(3)

(e) A car of mass 1200 kg is travelling with a velocity of 35 m / s.

(i) Calculate the momentum of the car.

Give the unit.

_____

_____

_____

Momentum = _____

(3)

(ii) The car stops in 4 seconds.

Calculate the average braking force acting on the car during the 4 seconds.

_____

_____

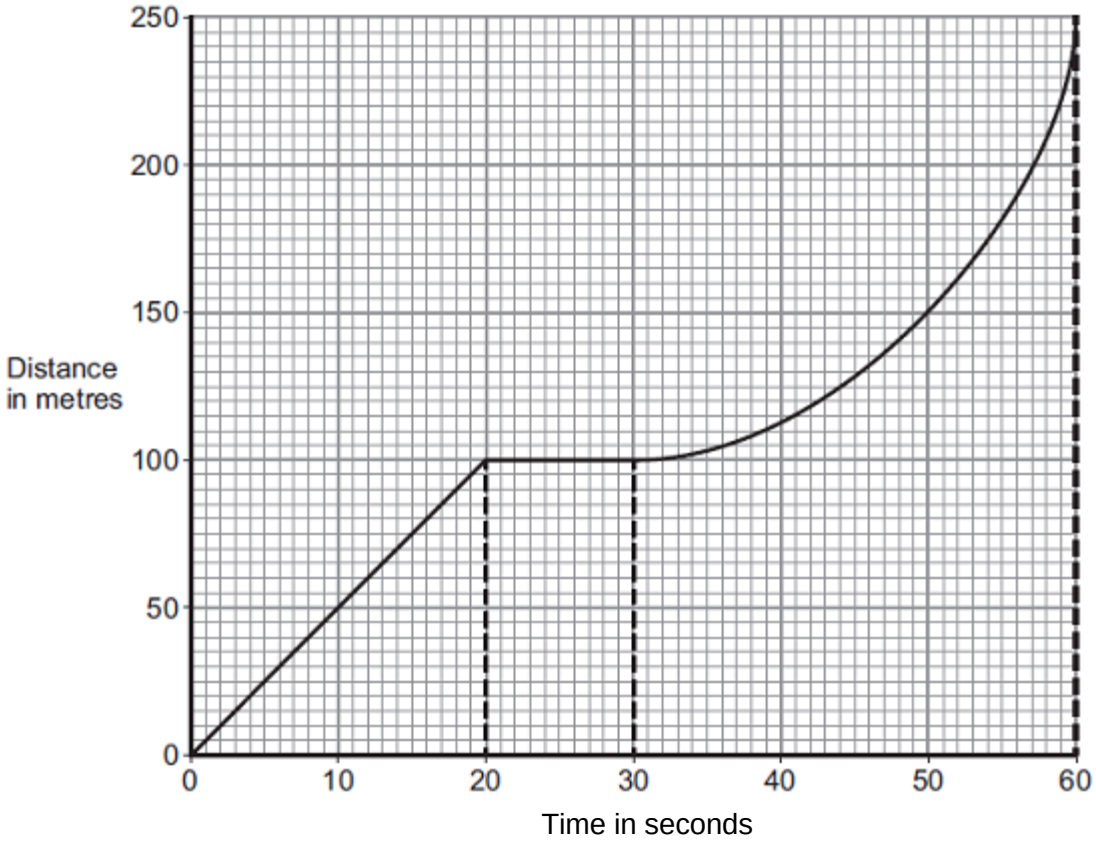
Force = _____ N

(2)

(Total 19 marks)

18 A bus is taking some children to school.

(a) The bus has to stop a few times. The figure below shows the distance–time graph for part of the journey.



(i) How far has the bus travelled in the first 20 seconds?

Distance travelled = _____ m

(1)

(ii) Describe the motion of the bus between 20 seconds and 30 seconds.

_____

_____

(1)

(iii) Describe the motion of the bus between 30 seconds and 60 seconds.

Tick (✓) **one** box.

	Tick (✓)
Accelerating	
Reversing	
Travelling at constant speed	

(1)

(iv) What is the speed of the bus at 45 seconds?

Show clearly on the figure above how you obtained your answer.

_____

_____

_____

Speed = _____ m / s

(3)

(b) Later in the journey, the bus is moving and has 500 000 J of kinetic energy.

The brakes are applied and the bus stops.

(i) How much work is needed to stop the bus?

_____

Work = _____ J

(1)

(ii) The bus stopped in a distance of 25 m.

Calculate the force that was needed to stop the bus.

_____

_____

Force = _____ N

(2)

(iii) What happens to the kinetic energy of the bus as it is braking?

_____

_____

_____

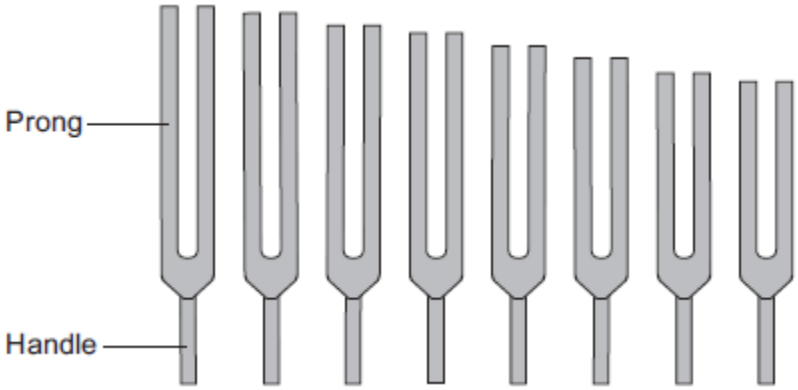
_____

(2)

(Total 11 marks)

19 **Figure 1** shows a set of tuning forks.

Figure 1



A tuning fork has a handle and two prongs. It is made from metal.

When the prongs are struck on a hard object, the tuning fork makes a sound wave with a single frequency. The frequency depends on the length of the prongs.

(a) Use the correct answer from the box to complete each sentence.

direction	loudness	pitch	speed

The frequency of a sound wave determines its _____ .

The amplitude of a sound wave determines its _____ .

(2)

(b) Each tuning fork has its frequency engraved on it. A student measured the length of the prongs for each tuning fork.

Some of her data is shown in the table.

Frequency in hertz	Length of prongs in cm
320	9.5
384	8.7
480	7.8
512	7.5

(i) Describe the pattern shown in the table.

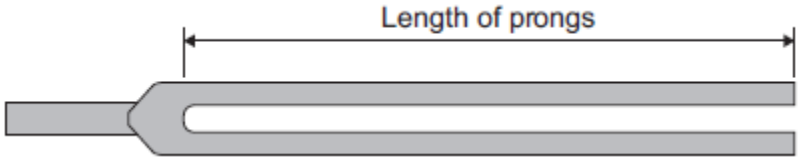
_____

_____

(1)

(ii) **Figure 2** shows a full-size drawing of a tuning fork.

Figure 2



Measure and record the length of the prongs.

Length of prongs = _____ cm

(1)

Use the data in the table above to estimate the frequency of the tuning fork in **Figure 2**.

Explain your answer.

_____

_____

_____

_____

_____

Estimated frequency = _____ Hz

(3)

(c) Ultrasound waves are used in hospitals.

(i) Use the correct answer from the box to complete the sentence.

electronic	**hydraulic**	**radioactive**

Ultrasound waves can be produced by _____ systems.

(1)

(ii) The frequency of an ultrasound wave used in a hospital is 2×10^6 Hz.

It is **not** possible to produce ultrasound waves of this frequency using a tuning fork.

Explain why.

_____

_____

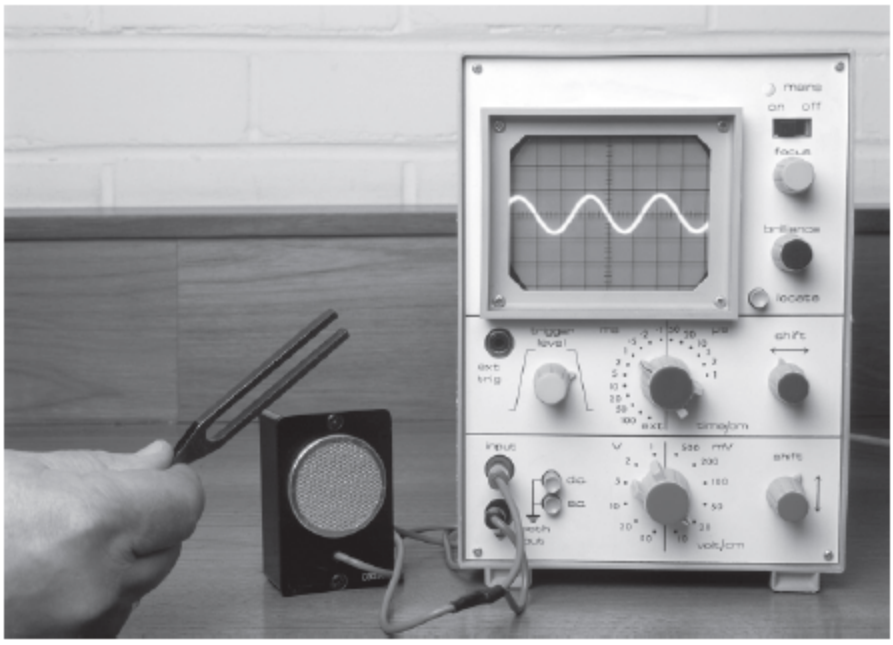
_____

_____

(2)

(d) **Figure 3** shows a tuning fork and a microphone. The microphone is connected to an oscilloscope.

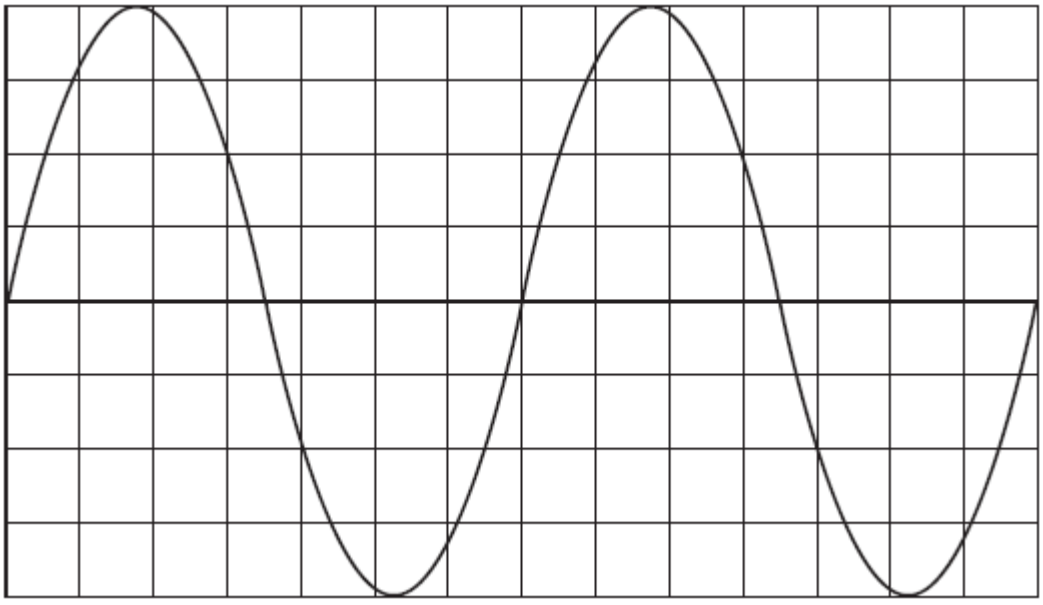
Figure 3



When the tuning fork is struck and then placed in front of the microphone, a trace appears on the oscilloscope screen.

Figure 4 shows part of the trace on the screen.

Figure 4



Each horizontal division in **Figure 4** represents a time of 0.0005 s.

What is the frequency of the tuning fork?

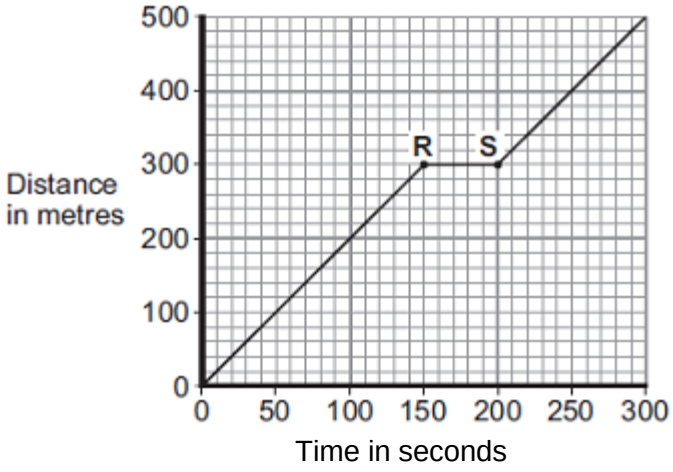
Frequency = _____ Hz

(3)

(Total 13 marks)

20 (a) **Figure 1** shows the distance–time graph for a person walking to a bus stop.

Figure 1



(i) Which **one** of the following statements describes the motion of the person between points **R** and **S** on the graph?

Tick (✓) **one** box.

Not moving ☐

Moving at constant speed ☐

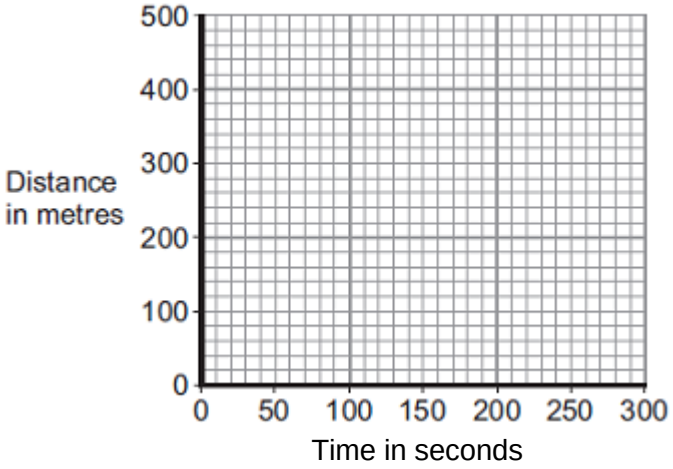
Moving with increasing speed ☐

(1)

(ii) Another person, walking at constant speed, travels the same distance to the bus stop in 200 seconds.

Complete **Figure 2** to show a distance–time graph for this person.

Figure 2



(1)

(b) A bus accelerates away from the bus stop at 2.5 m/s^2.

The total mass of the bus and passengers is 14 000 kg.

Calculate the resultant force needed to accelerate the bus and passengers.

_____

_____

_____

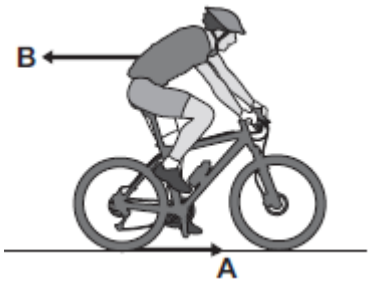
Resultant force = _____ N

(2)

(Total 4 marks)

21 (a) **Figure 1** shows the horizontal forces acting on a moving bicycle and cyclist.

Figure 1



(i) What causes force **A**?

Draw a ring around the correct answer.

friction **gravity** **weight**

(1)

(ii) What causes force **B**?

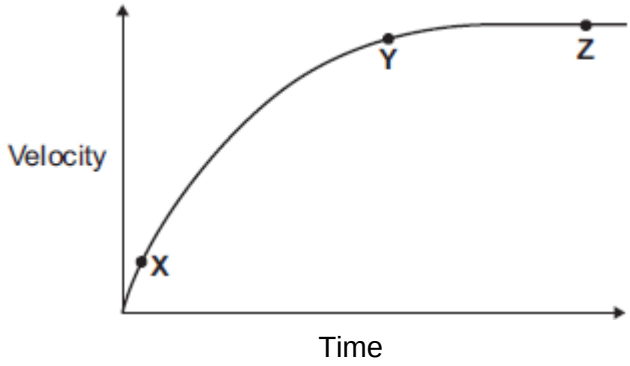
_____

(1)

(iii) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

Figure 2 shows how the velocity of the cyclist changes during the first part of a journey along a straight and level road. During this part of the journey the force applied by the cyclist to the bicycle pedals is constant.

Figure 2



Describe how **and** explain, in terms of the forces **A** and **B**, why the velocity of the cyclist changes:

- between the points **X** and **Y**
- and between the points **Y** and **Z**, marked on the graph in **Figure 2**.

Extra space

(6)

(b) (i) The cyclist used the brakes to slow down and stop the bicycle.

A constant braking force of 140 N stopped the bicycle in a distance of 24 m.

Calculate the work done by the braking force to stop the bicycle. Give the unit.

_____

_____

_____

Work done = _____

(3)

(ii) Complete the following sentences.

When the brakes are used, the bicycle slows down. The kinetic energy of the bicycle _____ .

At the same time, the _____ of the brakes increases.

(2)

(Total 13 marks)

22 (a) What is ultrasound?

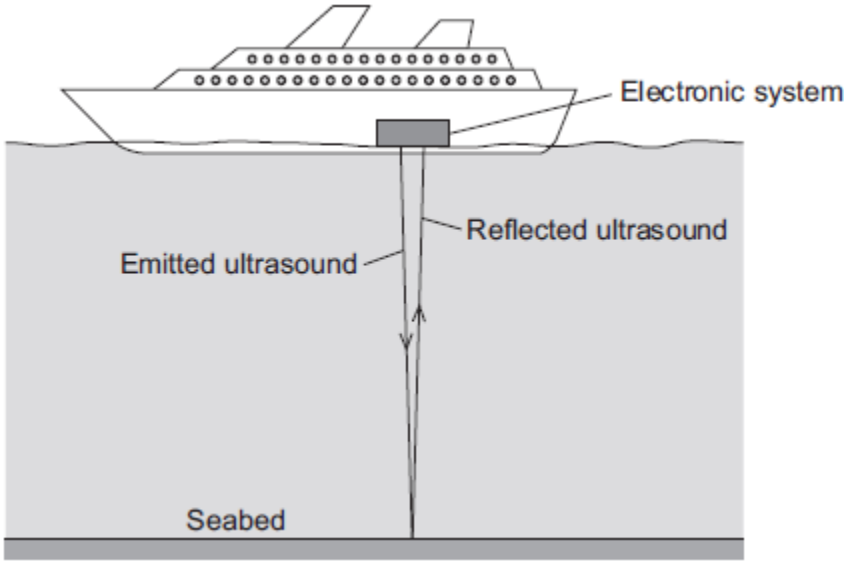
_____

_____

(1)

(b) **Figure 1** shows how ultrasound is used to measure the depth of water below a ship.

Figure 1



A pulse of ultrasound is sent out from an electronic system on-board the ship.

It takes 0.80 seconds for the emitted ultrasound to be received back at the ship.

Calculate the depth of the water.

Speed of ultrasound in water = 1600 m / s

_____

_____

_____

_____

Depth of water = _____ metres

(3)

(c) Ultrasound can be used in medicine for scanning.

State **one** medical use of ultrasound scanning.

_____

(1)

(d) Images of the inside of the human body can be made using a Computerised Tomography (CT) scanner. The CT scanner in **Figure 2** uses X-rays to produce these images.

Figure 2

monkeybusinessimages/iStock/Thinkstock

State **one** advantage and **one** disadvantage of using a CT scanner, compared with ultrasound scanning, for forming images of the inside of the human body.

Advantage of CT scanning _____

_____

_____

Disadvantage of CT scanning _____

_____

_____

(2)

(Total 7 marks)

23 (a) Human ears can detect a range of sound frequencies.

(i) Use the correct answers from the box to complete the sentence.

2	**20**	**200**	**2000**	**20 000**

The range of human hearing is from about _____ Hz to _____ Hz.

(2)

(ii) What is ultrasound?

_____

_____

(1)

(iii) Ultrasound can be used to find the speed of blood flow in an artery.

State **one** other medical use of ultrasound.

_____

(1)

(b) The speed of an ultrasound wave in soft tissue in the human body is 1.5×10^3 m / s and the frequency of the wave is 2.0×10^6 Hz.

Calculate the wavelength of the ultrasound wave.

_____

_____

Wavelength = _____ m

(2)

(c) When ultrasound is used to find the speed of blood flow in an artery:

- an ultrasound transducer is placed on a person's arm
- ultrasound is emitted by the transducer
- the ultrasound is reflected from blood cells moving **away** from the transducer
- the reflected ultrasound is detected at the transducer.

Describe the differences between the ultrasound waves emitted by the transducer and the reflected waves detected at the transducer.

_____

_____

_____

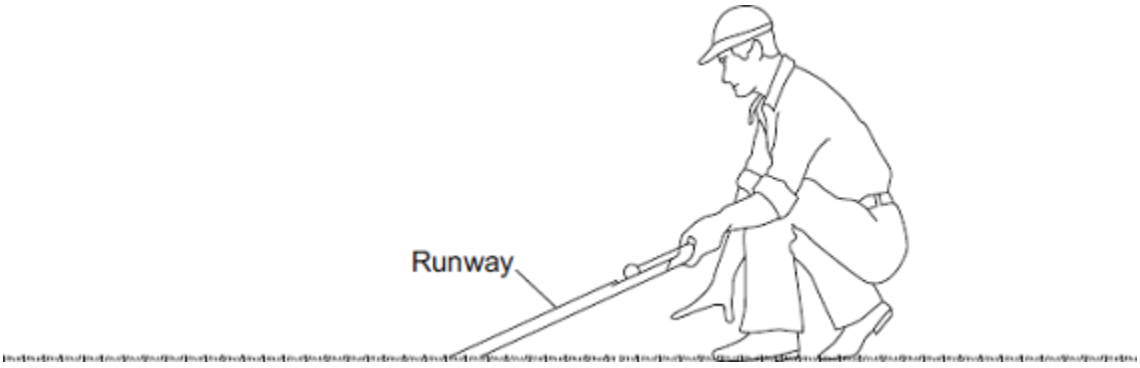
_____

(2)

(Total 8 marks)

24 **Figure 1** shows a golfer using a runway for testing how far a golf ball travels on grass.
One end of the runway is placed on the grass surface.
The other end of the runway is lifted up and a golf ball is put at the top.
The golf ball goes down the runway and along the grass surface.

Figure 1



(a) A test was done three times with the same golf ball.

The results are shown in **Figure 2**.

Figure 2

(i) Make measurements on **Figure 2** to complete **Table 1**.

Table 1

Test	Distance measured in centimetres
1	8.5
2	
3	

(2)

(ii) Calculate the mean distance, in centimetres, between the ball and the edge of the runway in **Figure 2**.

Mean distance = _____ cm

(1)

(iii) **Figure 2** is drawn to scale.
Scale: 1 cm = 20 cm on the grass.

Calculate the mean distance, in centimetres, the golf ball travels on the grass surface.

_____

Mean distance on the grass surface = _____ cm

(1)

(iv) The distance the ball travels along the grass surface is used to estimate the 'speed' of the grass surface.

The words used to describe the 'speed' of a grass surface are given in **Table 2**.

Table 2

'Speed' of grass surface	**Mean distance the golf ball travels in centimetres**
Fast	250
Medium fast	220
Medium	190
Medium Slow	160
Slow	130

Use **Table 2** and your answer in part **(iii)** to describe the 'speed' of the grass surface.

_____

(1)

(b) The shorter the grass, the greater the distance the golf ball will travel.
A student uses the runway on the grass in her local park to measure the distance the golf ball travels.

(i) Suggest **two** variables the student should control.

_____

_____

_____

(2)

(ii) She carried out the test five times.
Her measurements, in centimetres, are shown below.

75 **95** **84** **74** **79**

What can she conclude about the length of the grass in the park?

_____

_____

(1)

(c) Another student suggests that the ‘speed’ of a grass surface depends on factors other than grass length.

She wants to test the hypothesis that ‘speed’ depends on relative humidity.

Relative humidity is the percentage of water in the air compared to the maximum amount of water the air can hold. Relative humidity can have values between 1% and 100%.

The student obtains the data in **Table 3** from the Internet.

Table 3

Relative humidity expressed as a percentage	Mean distance the golf ball travels in centimetres
71	180
79	162
87	147

(i) Describe the pattern shown in **Table 3**.

_____

_____

(1)

(ii) The student writes the following hypothesis:
'The mean distance the golf ball travels is inversely proportional to relative humidity.'

Use calculations to test this hypothesis and state your conclusion.

(3)

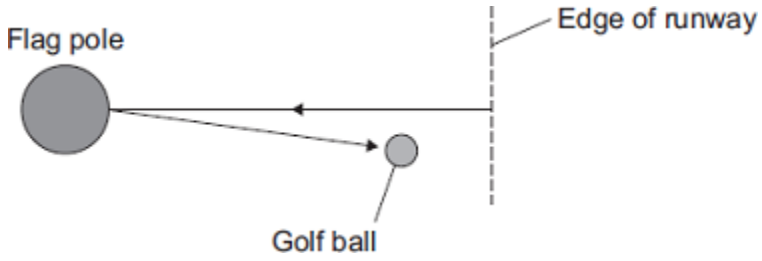
(iii) The data in **Table 3** does **not** allow a conclusion to be made with confidence.

Give a reason why.

(1)

(d) In a test, a golf ball hits a flag pole on the golf course and travels back towards the edge of the runway as shown in **Figure 3**.

Figure 3



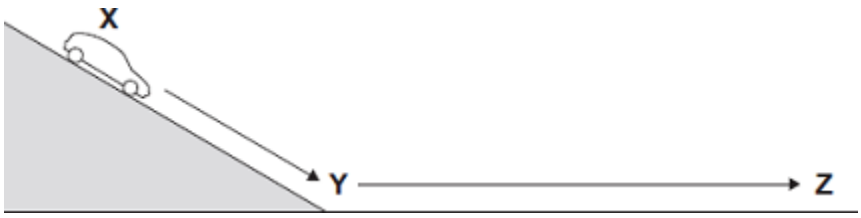
The distance the ball travels and the displacement of the ball are **not** the same.

What is the difference between distance and displacement?

(2)

(Total 15 marks)

25 (a) The diagram shows a car at position **X**.



The handbrake is released and the car rolls down the slope to **Y**.
The car continues to roll along a horizontal surface before stopping at **Z**.
The brakes have **not** been used during this time.

(i) What type of energy does the car have at **X**?

_____

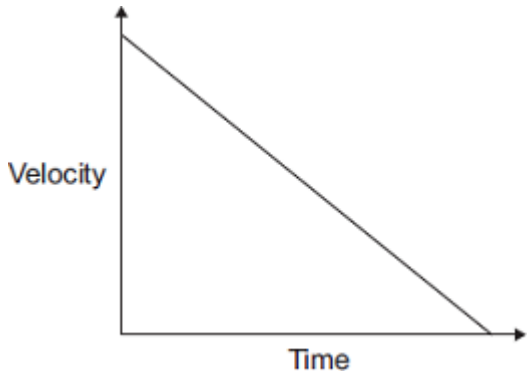
(1)

(ii) What type of energy does the car have at **Y**?

_____

(1)

(b) The graph shows how the velocity of the car changes with time between **Y** and **Z**.



(i) Which feature of the graph represents the negative acceleration between **Y** and **Z**?

_____

(1)

(ii) Which feature of the graph represents the distance travelled between **Y** and **Z**?

_____

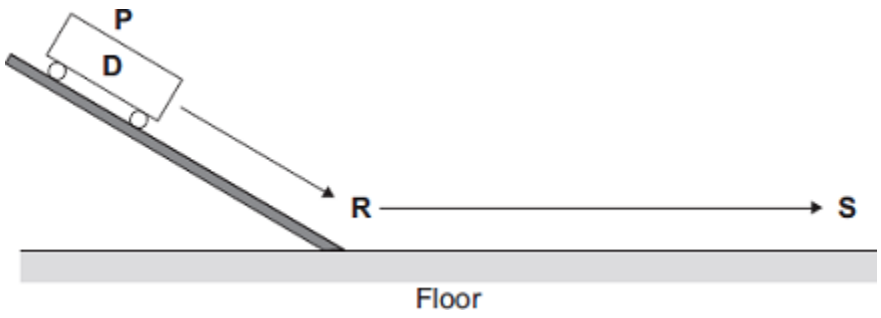
(1)

(iii) The car starts again at position **X** and rolls down the slope as before. This time the brakes are applied lightly at **Y** until the car stops.

Draw on the graph another straight line to show the motion of the car between **Y** and **Z**.

(2)

(c) Three students carry out an investigation. The students put trolley **D** at position **P** on a slope. They release the trolley. The trolley rolls down the slope and along the floor as shown in the diagram.



The students measure the distance from **R** at the bottom of the slope to **S** where the trolley stops. They also measure the time taken for the trolley to travel the distance **RS**.
They repeat the investigation with another trolley, **E**.

Their results are shown in the table.

Trolley	Distance RS in centimetres	Time taken in seconds	Average velocity in centimetres per second
D	65	2.1	
E	80	2.6	

(i) Calculate the average velocity, in centimetres per second, between **R** and **S** for trolleys **D** and **E**. Write your answers in the table.

_____

_____

_____

(3)

(ii) Before the investigation, each student made a prediction.

- Student **1** predicted that the two trolleys would travel the same distance.
- Student **2** predicted that the average velocity of the two trolleys would be the same.
- Student **3** predicted that the negative acceleration of the two trolleys would be the same.

Is each prediction correct?

Justify your answers.

_____

_____

_____

_____

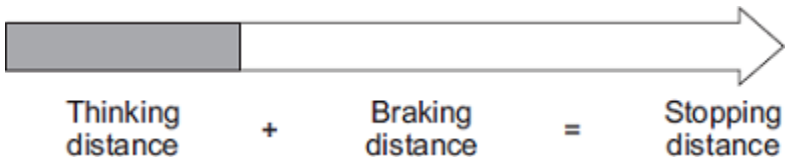
_____

_____

(3)

(Total 12 marks)

26 The diagram shows how the thinking distance and braking distance of a car add together to give the stopping distance of the car.



(a) Use words from the box to complete the sentence.

distance	**energy**	**force**	**time**

The stopping distance is found by adding the distance the car travels during the driver's reaction _____ and the distance the car travels under the braking _____ .

(2)

(b) Which **one** of the following would **not** increase the thinking distance?

Tick (✓) **one** box.

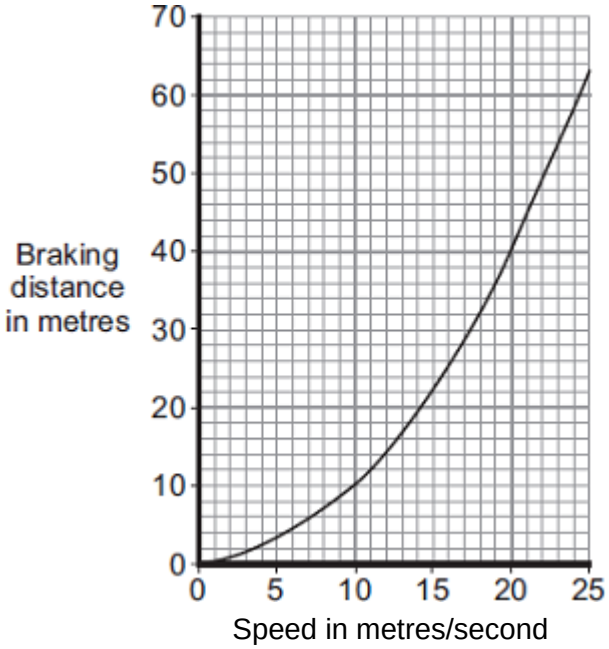
The car driver being tired. ☐

The car tyres being badly worn. ☐

The car being driven faster. ☐

(1)

(c) The graph shows how the braking distance of a car changes with the speed of the car. The force applied to the car brakes does not change.



(i) What conclusion about braking distance can be made from the graph?

_____

_____

_____

_____

(2)

(ii) The graph is for a car driven on a dry road.

Draw a line on the graph to show what is likely to happen to the braking distance at different speeds if the same car was driven on an icy road.

(1)

(d) A local council has reduced the speed limit from 30 miles per hour to 20 miles per hour on a few roads. The reason for reducing the speed limit was to reduce the number of accidents.

(i) A local newspaper reported that a councillor said:

"It will be much safer because drivers can react much faster when driving at 20 miles per hour than when driving at 30 miles per hour."

This statement is wrong. Why?

_____

_____

(1)

(ii) The local council must decide whether to introduce the lower speed limit on a lot more roads.

What evidence should the local council collect to help make this decision?

_____

_____

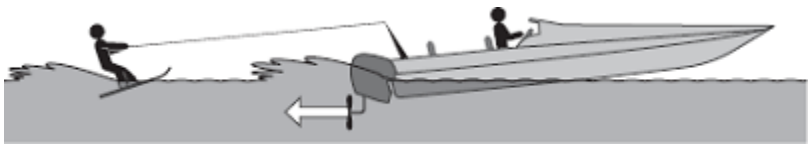
_____

_____

(2)

(Total 9 marks)

27 The diagram shows a boat pulling a water skier.



(a) The arrow represents the force on the water produced by the engine propeller. This force causes the boat to move.

Explain why.

_____

_____

_____

_____

(2)

(b) The boat accelerates at a constant rate in a straight line. This causes the velocity of the water skier to increase from 4.0 m/s to 16.0 m/s in 8.0 seconds.

(i) Calculate the acceleration of the water skier and give the unit.

Acceleration = _____

(3)

(ii) The water skier has a mass of 68 kg.

Calculate the resultant force acting on the water skier while accelerating.

Resultant force = _____ N

(2)

(iii) Draw a ring around the correct answer to complete the sentence.

The force from the boat pulling the water skier forwards

will be

less than
the same as
greater than

the answer to part **(b)(ii)**.

Give the reason for your answer.

(2)

(Total 9 marks)

28 (a) The stopping distance of a vehicle is made up of two parts, the thinking distance and the braking distance.

(i) What is meant by *thinking distance*?

(1)

(ii) State **two** factors that affect thinking distance.

1. _____

_____

2. _____

_____

(2)

(b) A car is travelling at a speed of 20 m/s when the driver applies the brakes. The car decelerates at a constant rate and stops.

(i) The mass of the car and driver is 1600 kg.

Calculate the kinetic energy of the car and driver before the brakes are applied.

_____

_____

_____

Kinetic energy = _____ J

(2)

(ii) How much work is done by the braking force to stop the car and driver?

Work done = _____ J

(1)

(iii) The braking force used to stop the car and driver was 8000 N.

Calculate the braking distance of the car.

_____

_____

_____

_____

Braking distance = _____ m

(2)

(iv) The braking distance of a car depends on the speed of the car and the braking force applied.

State **one** other factor that affects braking distance.

_____

_____

(1)

(v) Applying the brakes of the car causes the temperature of the brakes to increase.

Explain why.

_____

_____

_____

_____

(2)

(c) Hybrid cars have an electric engine and a petrol engine. This type of car is often fitted with a regenerative braking system. A regenerative braking system not only slows a car down but at the same time causes a generator to charge the car's battery.

State and explain the benefit of a hybrid car being fitted with a regenerative braking system.

_____

_____

_____

_____

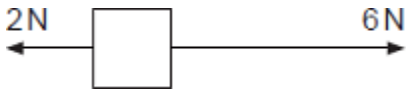
_____

_____

(3)

(Total 14 marks)

29 (a) The diagram shows two forces acting on an object.



What is the resultant force acting on the object?

Tick (✓) **one** box.

8 N to the right ☐

8 N to the left ☐

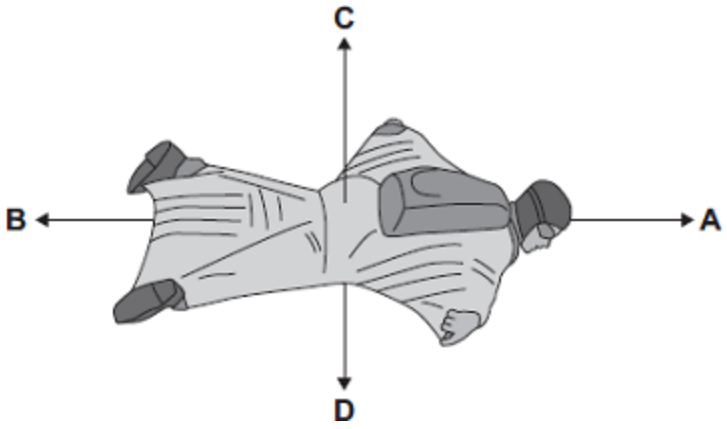
4 N to the right ☐

4 N to the left ☐

(1)

(b) BASE jumpers jump from very high buildings and mountains for sport.

The diagram shows the forces acting on a BASE jumper in flight.
The BASE jumper is wearing a wingsuit.



(i) Draw a ring around the correct answer in the box to complete each sentence.

The BASE jumper accelerates forwards when force **A**

is

smaller than
equal to
bigger than

force **B**.

The BASE jumper falls with a constant speed when force **C**

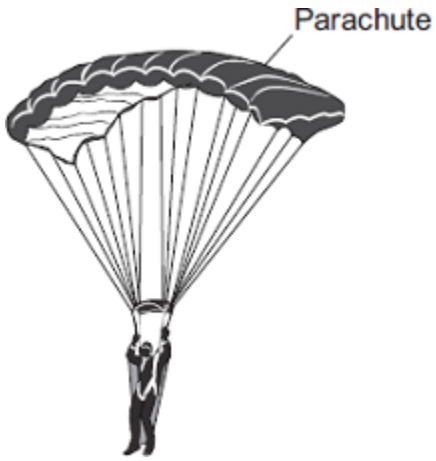
is

smaller than
equal to
bigger than

force **D**.

(2)

(ii) To land safely the BASE jumper opens a parachute.



What effect does opening the parachute have on the speed of the falling BASE jumper?

_____

Give a reason for your answer.

_____

_____

(2)

(Total 5 marks)

30 Some students designed and built an electric-powered go-kart.
The go-kart is shown below.

(a) Suggest **two** changes that could be made to the design of the go-kart to increase its top speed.

1. _____

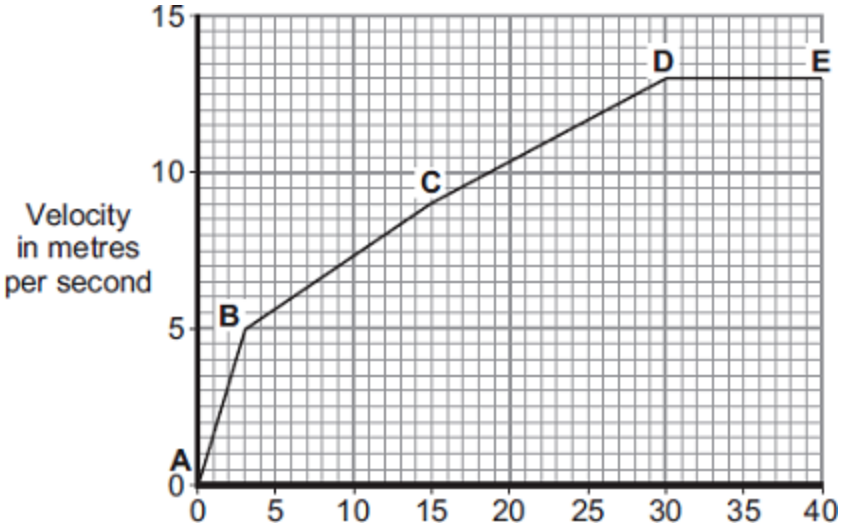
_____

2. _____

_____

(2)

(b) A go-kart with a new design is entered into a race.
The velocity-time graph for the go-kart, during the first 40 seconds of the race, is shown below.



(i) Between which **two** points did the go-kart have the greatest acceleration?

Tick (✓) **one** box.

A–B ☐

B–C ☐

C–D ☐

Give a reason for your answer.

_____

_____

(2)

(ii) The go-kart travels at a speed of 13 m/s between points **D** and **E**.
The total mass of the go-kart and driver is 140 kg.

Calculate the momentum of the go-kart and driver between points **D** and **E**.

_____

_____

Momentum = _____ kg m/s

(2)

(Total 6 marks)

31 A car has an oil leak. Every 5 seconds an oil drop falls from the bottom of the car onto the road.

(a) What force causes the oil drop to fall towards the road?

_____

(1)

(b) The diagram shows the spacing of the oil drops left on the road during part of a journey

Describe the motion of the car as it moves from **A** to **B**.

_____

Explain the reason for your answer.

_____

_____

_____

_____

(3)

(c) When the brakes are applied, a braking force slows down and stops the car.

(i) The size of the braking force affects the braking distance of the car.

State **one** other factor that affects the braking distance of the car.

_____

(1)

(ii) A braking force of 3 kN is used to slow down and stop the car in a distance of 25 m.

Calculate the work done by the brakes to stop the car and give the unit.

_____

_____

_____

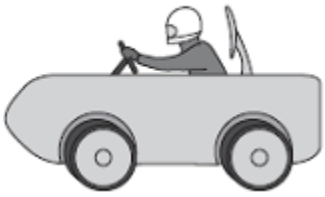
Work done = _____

(3)

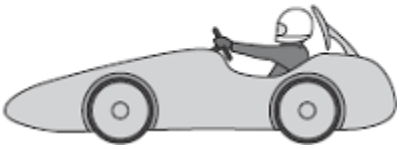
(Total 8 marks)

32 (a) Some students have designed and built an electric-powered go-kart. After testing, the students decided to make changes to the design of their go-kart.

First design **X**



Final design **Y**



The go-kart always had the same mass and used the same motor.

The change in shape from the first design (**X**) to the final design (**Y**) will affect the top speed of the go-kart.

Explain why.

_____

_____

_____

_____

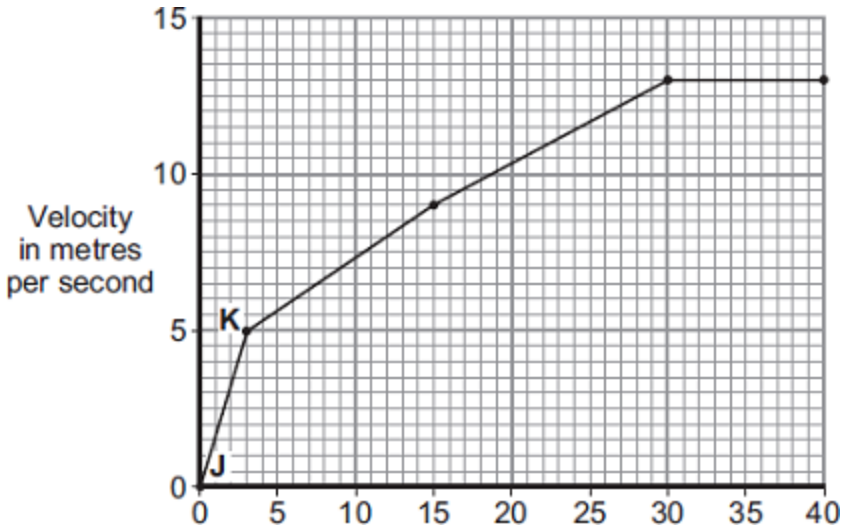
_____

_____

(3)

(b) The final design go-kart, **Y**, is entered into a race.

The graph shows how the velocity of the go-kart changes during the first 40 seconds of the race.



(i) Use the graph to calculate the acceleration of the go-kart between points **J** and **K**.

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

_____

_____

_____

Acceleration = _____ m/s^2

(2)

(ii) Use the graph to calculate the distance the go-kart travels between points **J** and **K**.

_____

_____

_____

Distance = _____ m

(2)

(iii) What causes most of the resistive forces acting on the go-kart?

_____

(1)

(Total 8 marks)

33 (a) A car driver makes an emergency stop.

The chart shows the 'thinking distance' and the 'braking distance' needed to stop the car.

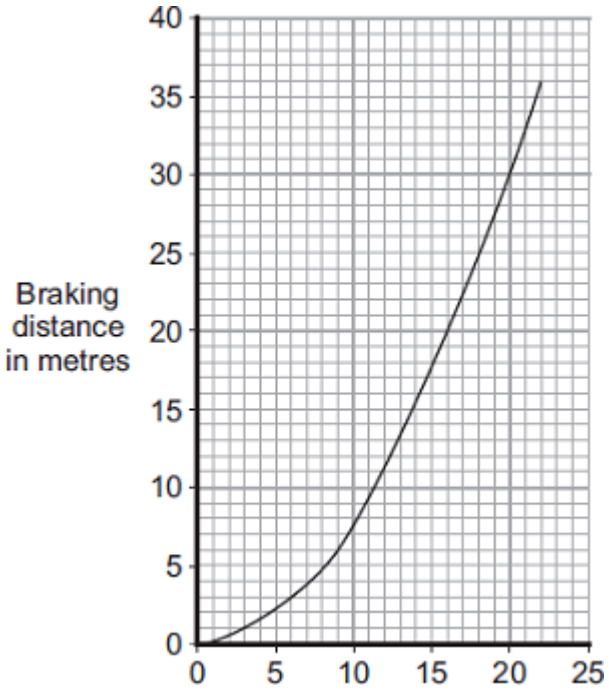
Calculate the total stopping distance of the car.

_____

Stopping distance = _____ m

(1)

(b) The graph shows how the braking distance of a car driven on a dry road changes with the car's speed.



The braking distance of the car on an icy road is longer than the braking distance of the car on a dry road.

(i) Draw a new line on the graph to show how the braking distance of the car on an icy road changes with speed.

(2)

(ii) Which **one** of the following would also increase the braking distance of the car?

Put a tick (✓) in the box next to your answer.

Rain on the road ☐

The driver having drunk alcohol ☐

The driver having taken drugs ☐

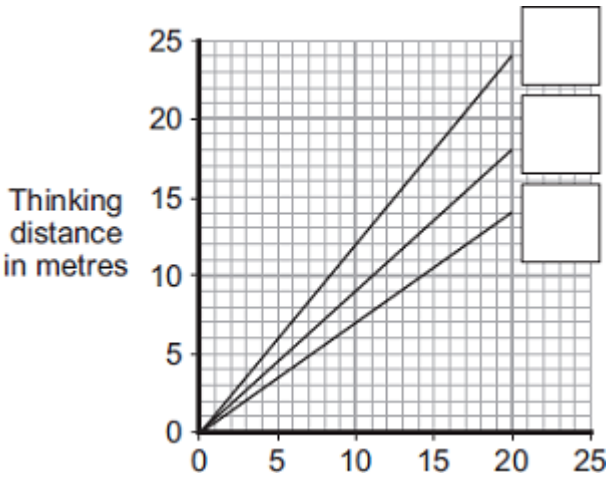
(1)

(c) The thinking distance depends on the driver's reaction time.

The table shows the reaction times of three people driving under different conditions.

Car driver	Condition	Reaction time in second
A	Wide awake with no distractions	0.7
B	Using a hands-free mobile phone	0.9
C	Very tired and listening to music	1.2

The graph lines show how the thinking distance for the three drivers, **A**, **B**, and **C**, depends on how fast they are driving the car.



(i) Match each graph line to the correct driver by writing **A**, **B**, or **C** in the box next to the correct line.

(2)

(ii) The information in the table cannot be used to tell if driver **C**'s reaction time is increased by being tired **or** by listening to music.
Explain why.

_____

_____

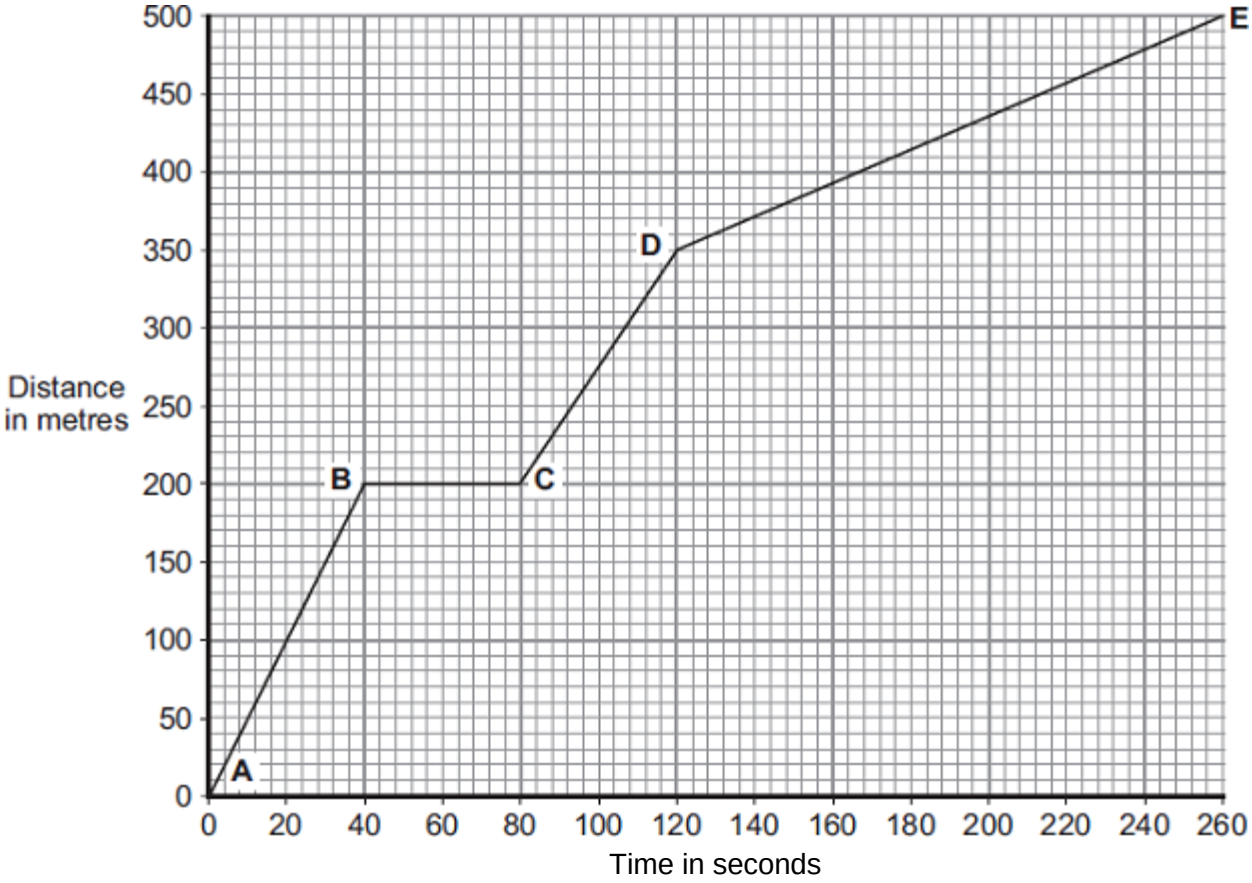
_____

_____

(2)

(Total 8 marks)

34 Part of a bus route is along a high street.
The distance-time graph shows how far the bus travelled along the high street and how long it took.



(a) Between which two points was the bus travelling the slowest?

Put a tick (✓) in the box next to your answer.

Points	Tick (✓)
A – B	
C – D	
D – E	

Give a reason for your answer.

_____

_____

(2)

(b) The bus travels at 5 m/s between points **A** and **B**.
The bus and passengers have a total mass of 16 000 kg.

Use the equation in the box to calculate the momentum of the bus and passengers between points **A** and **B**.

momentum = mass x velocity

Show clearly how you work out your answer.

_____

_____

Momentum = _____ kg m/s

(2)

(c) A cyclist made the same journey along the high street.
The cyclist started at the same time as the bus and completed the journey in 220 seconds.
The cyclist travelled the whole distance at a constant speed.

(i) Draw a line on the graph to show the cyclist's journey.

(2)

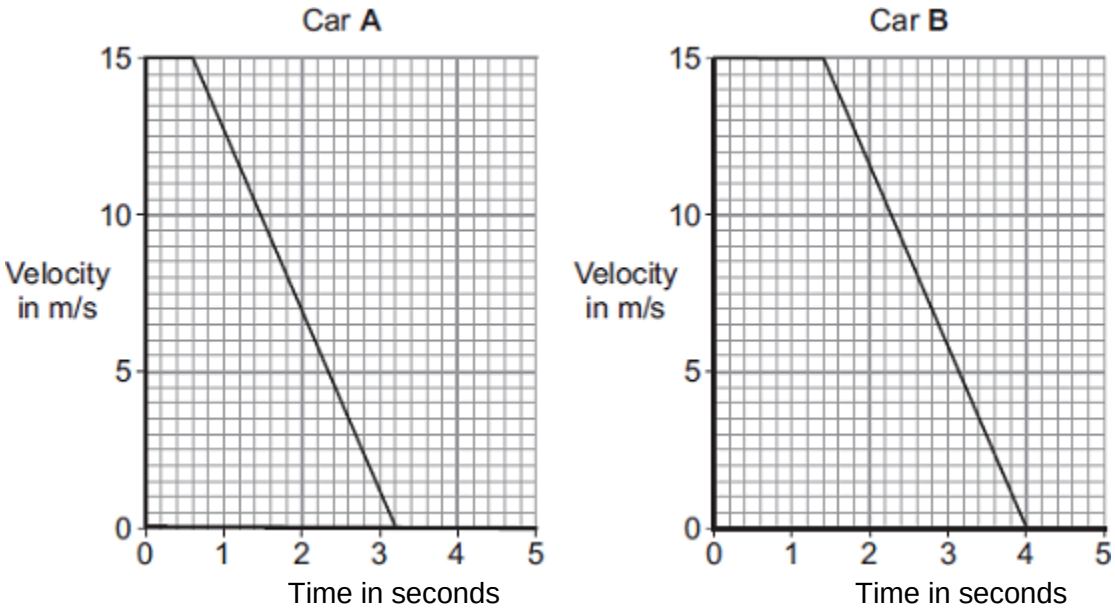
(ii) After how many seconds did the cyclist overtake the bus?

The cyclist overtook the bus after _____ seconds.

(1)

(Total 7 marks)

35 (a) The graphs show how the velocity of two cars, **A** and **B**, change from the moment the car drivers see an obstacle blocking the road.



One of the car drivers has been drinking alcohol. The other driver is wide awake and alert.

(i) How does a comparison of the two graphs suggest that the driver of car **B** is the one who has been drinking alcohol?

_____

_____

(1)

(ii) How do the graphs show that the two cars have the same deceleration?

_____

_____

(1)

(iii) Use the graphs to calculate how much further car **B** travels before stopping compared to car **A**.

Show clearly how you work out your answer.

_____

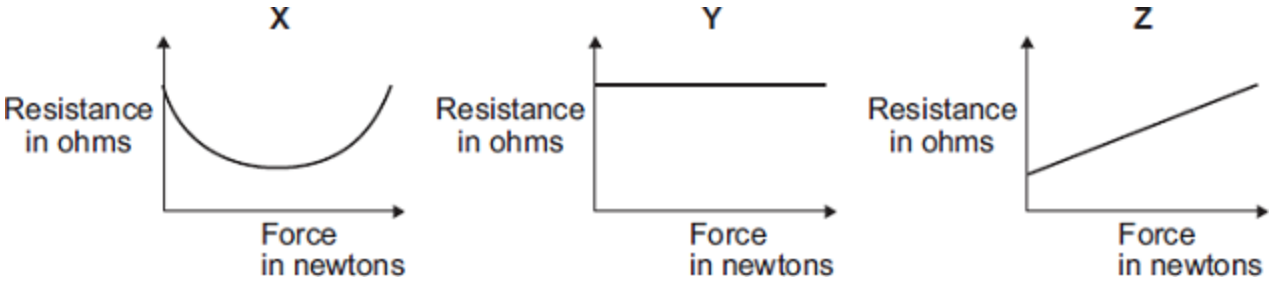
_____

_____

Additional stopping distance = _____ m

(3)

(b) In a crash-test laboratory, scientists use sensors to measure the forces exerted in collisions. The graphs show how the electrical resistance of 3 experimental types of sensor, **X**, **Y**, and **Z**, change with the force applied to the sensor.



Which of the sensors, **X**, **Y** or **Z**, would be the best one to use as a force sensor?

_____

Give a reason for your answer.

_____

_____

_____

_____

(2)

(Total 7 marks)

36 The London Eye is one of the largest observation wheels in the world.

© Angelo Ferraris/Shutterstock

The passengers ride in capsules. Each capsule moves in a circular path and accelerates.

(a) Explain how the wheel can move at a steady speed and the capsules accelerate at the same time.

_____

_____

_____

(2)

(b) In which direction is the resultant force on each capsule?

_____

(1)

(c) The designers of the London Eye had to consider **three** factors which affect the resultant force described in part (b).

Two factors that increase the resultant force are:

- an increase in the speed of rotation
- an increase in the total mass of the wheel, the capsules and the passengers.

Name the other factor that affects the resultant force and state what effect it has on the resultant force.

_____

_____

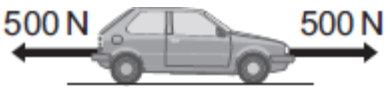
(1)

(Total 4 marks)

37 (a) The diagrams, **A**, **B** and **C**, show the horizontal forces acting on a **moving** car.

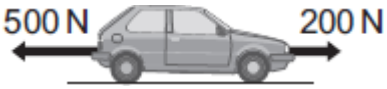
Draw a line to link each diagram to the description of the car's motion at the moment when the forces act.

Draw only **three** lines.



A

B

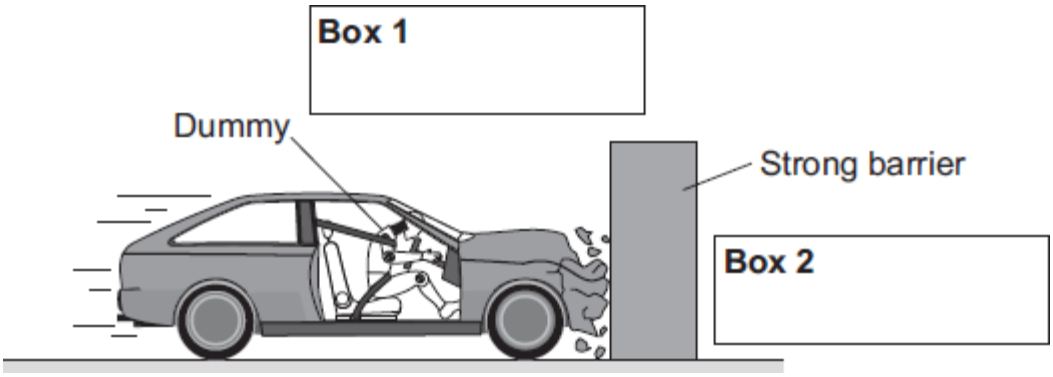


C

stationary
constant speed
slowing down
accelerating forwards

(3)

(b) The front crumple zone of a car is tested at a road traffic laboratory. This is done by using a remote control device to drive the car into a strong barrier. Electronic sensors are attached to a dummy inside the car.



(i) Draw an arrow in **Box 1** to show the direction of the force that the car exerts on the barrier.

(1)

(ii) Draw an arrow in **Box 2** to show the direction of the force that the barrier exerts on the car.

(1)

(iii) Complete the following by drawing a ring around the correct line in the box.

The car exerts a force of 5000 N on the barrier. The barrier does not move. The force

exerted by the barrier on the car will be

more than
equal to
less than

5000 N.

(1)

(iv) Which **one** of the following gives the most likely reason for attaching electronic sensors to the dummy?

Put a tick (✓) in the box next to your answer.

To measure the speed of the car just before the impact. ☐

To measure the forces exerted on the dummy during the impact. ☐

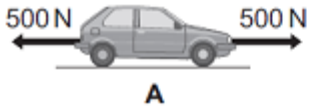
To measure the distance the car travels during the impact. ☐

(1)

(Total 7 marks)

38 (a) A car is being driven along a straight road. The diagrams, **A**, **B** and **C**, show the horizontal forces acting on the moving car at three different points along the road.

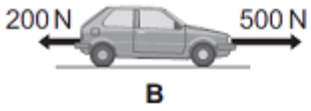
Describe the motion of the car at each of the points, **A**, **B** and **C**.



A

_____

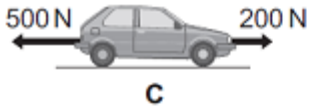
_____



B

_____

_____



C

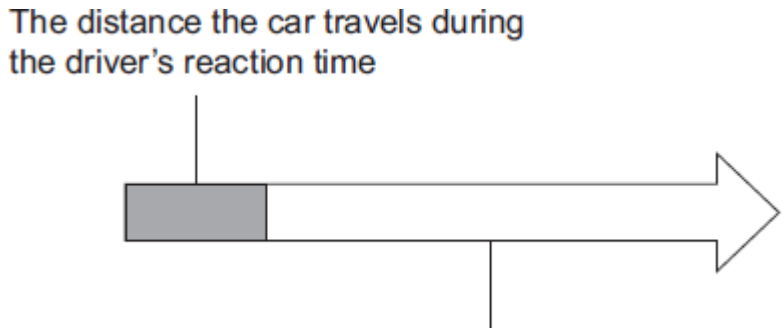
_____

_____

(3)

(b) The diagram below shows the stopping distance for a family car, in good condition, driven at 22 m/s on a dry road. The stopping distance has two parts.

(i) Complete the diagram below by adding an appropriate label to the second part of the stopping distance.



_____

_____

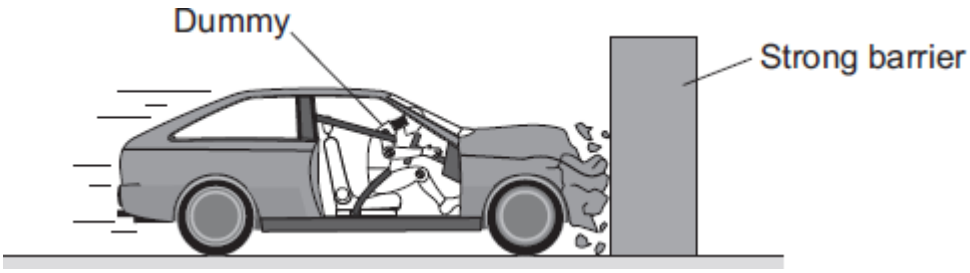
(1)

(ii) State **one** factor that changes both the first part **and** the second part of the stopping distance.

_____

(1)

(c) The front crumple zone of a car is tested at a road traffic laboratory. This is done by using a remote control device to drive the car into a strong barrier. Electronic sensors are attached to the dummy inside the car.



(i) At the point of collision, the car exerts a force of 5000 N on the barrier.

State the size and direction of the force exerted by the barrier on the car.

_____

_____

(1)

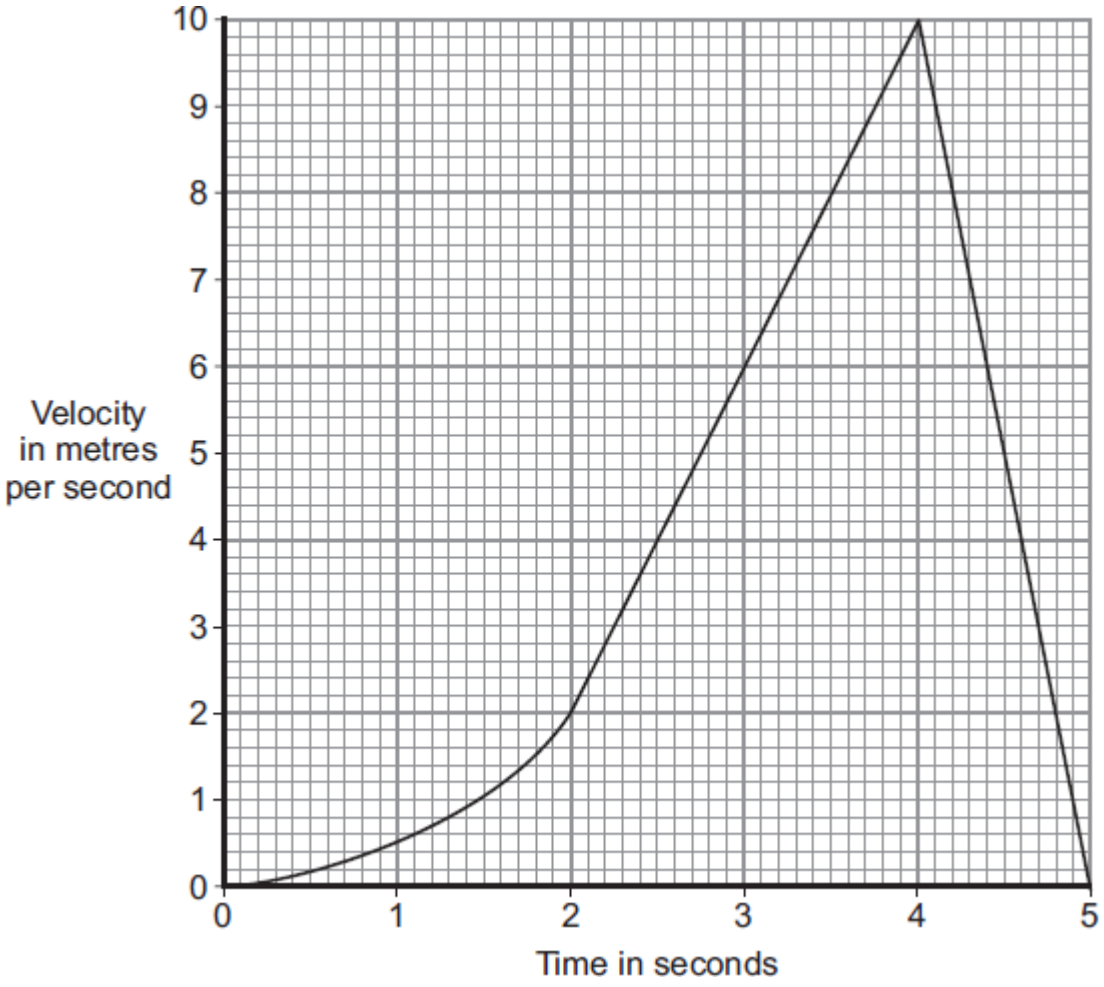
(ii) Suggest why the dummy is fitted with electronic sensors.

_____

_____

(1)

(iii) The graph shows how the velocity of the car changes during the test.



Use the graph to calculate the acceleration of the car just before the collision with the barrier.

Show clearly how you work out your answer, including how you use the graph, and give the unit.

_____

_____

_____

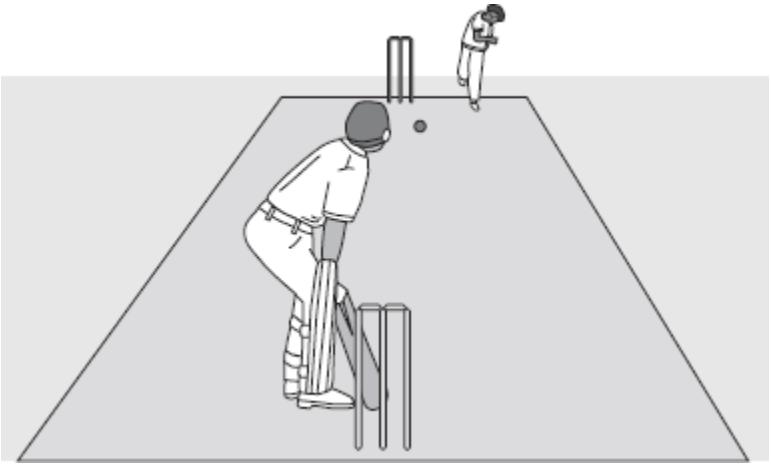
_____

Acceleration = _____

(3)

(Total 10 marks)

39 The picture shows players in a cricket match.



(a) A fast bowler bowls the ball at 35 m/s. The ball has a mass of 0.16 kg.

Use the equation in the box to calculate the kinetic energy of the cricket ball as it leaves the bowler's hand.

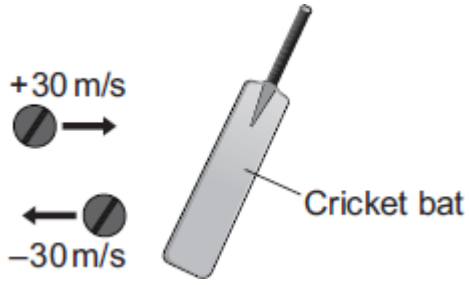
$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{speed}^2$$

Show clearly how you work out your answer.

Kinetic energy = _____ J

(2)

(b) When the ball reaches the batsman it is travelling at 30 m/s. The batsman strikes the ball which moves off at 30 m/s in the opposite direction.



(i) Use the equation in the box to calculate the change in momentum of the ball.

momentum = mass × velocity

Show clearly how you work out your answer.

Change in momentum = _____ kg m/s

(2)

(ii) The ball is in contact with the bat for 0.001 s.

Use the equation in the box to calculate the force exerted by the bat on the ball.

$$\text{force} = \frac{\text{change in momentum}}{\text{time taken for the change}}$$

Show clearly how you work out your answer.

Force = _____ N

(1)

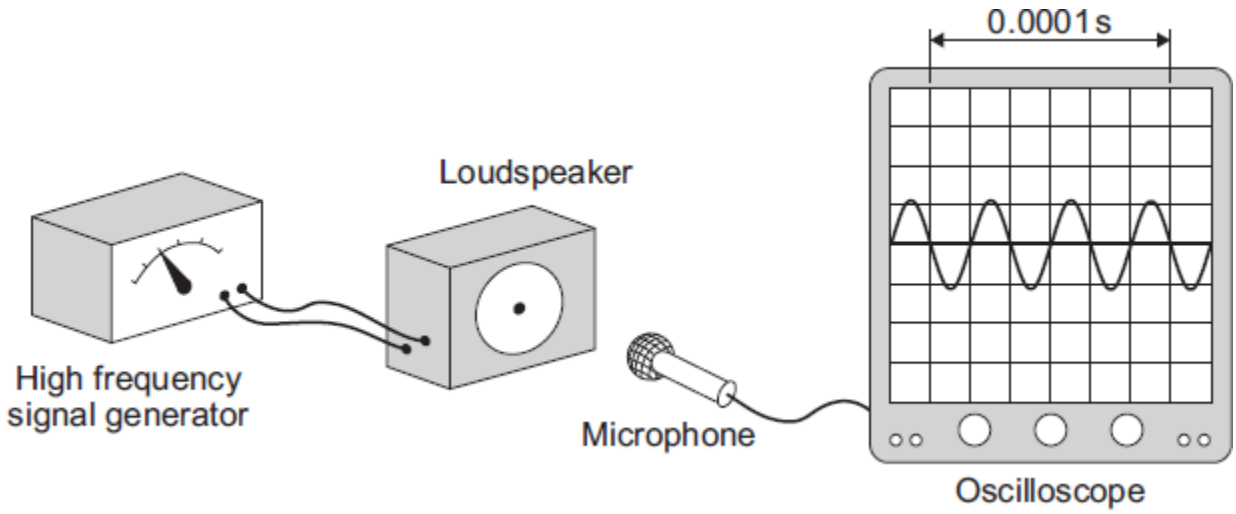
(c) A fielder, as he catches a cricket ball, pulls his hands backwards.

Explain why this action reduces the force on his hands.

(2)

(Total 7 marks)

40 (a) The diagram shows a microphone being used to detect the output from a loudspeaker.
The oscilloscope trace shows the wave pattern produced by the loudspeaker.



(i) How many waves are produced by the loudspeaker in 0.0001 seconds?

_____

(1)

(ii) How many waves are produced by the loudspeaker every second?
Assume the input to the loudspeaker does not change.

_____

_____

(1)

(iii) A person with normal hearing cannot hear the sound produced by the loudspeaker.

Explain why.

_____

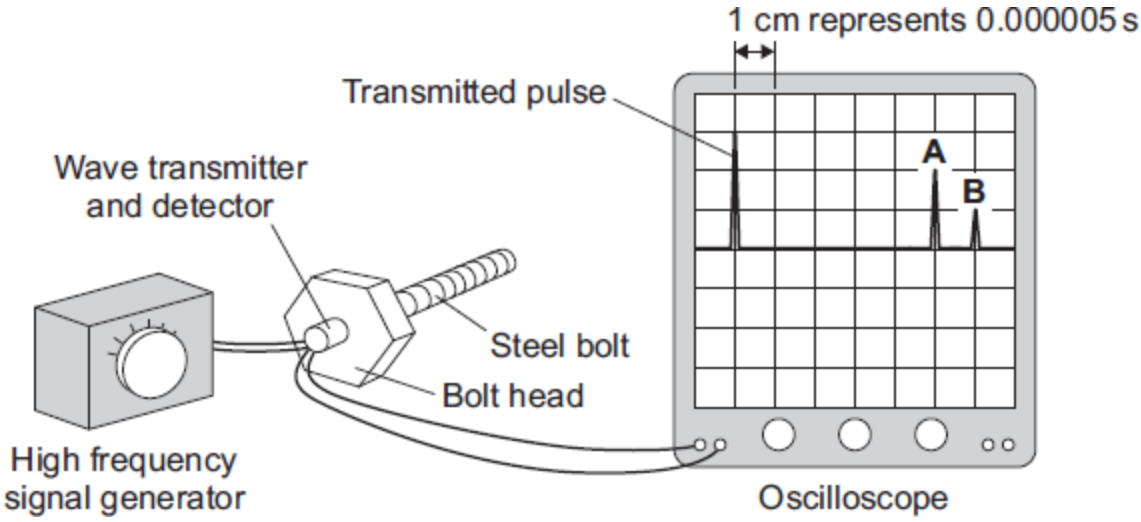
_____

_____

_____

(2)

(b) The diagram shows how a very high frequency sound wave can be used to check for internal cracks in a large steel bolt. The oscilloscope trace shows that the bolt does have an internal crack.



(i) Explain what happens to produce pulse **A** and pulse **B**.

_____

_____

_____

_____

(2)

(ii) Use the information in the diagram and the equation in the box to calculate the distance from the head of the bolt to the internal crack.

distance = speed × time

Speed of sound through steel = 6000 m/s

Show clearly how you work out your answer.

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

41 (a) The diagram shows the forces acting on a parachutist in free fall.

The parachutist has a mass of 75 kg.

Calculate the weight of the parachutist.

gravitational field strength = 10 N/kg

Show clearly how you work out your answer and give the unit.

_____

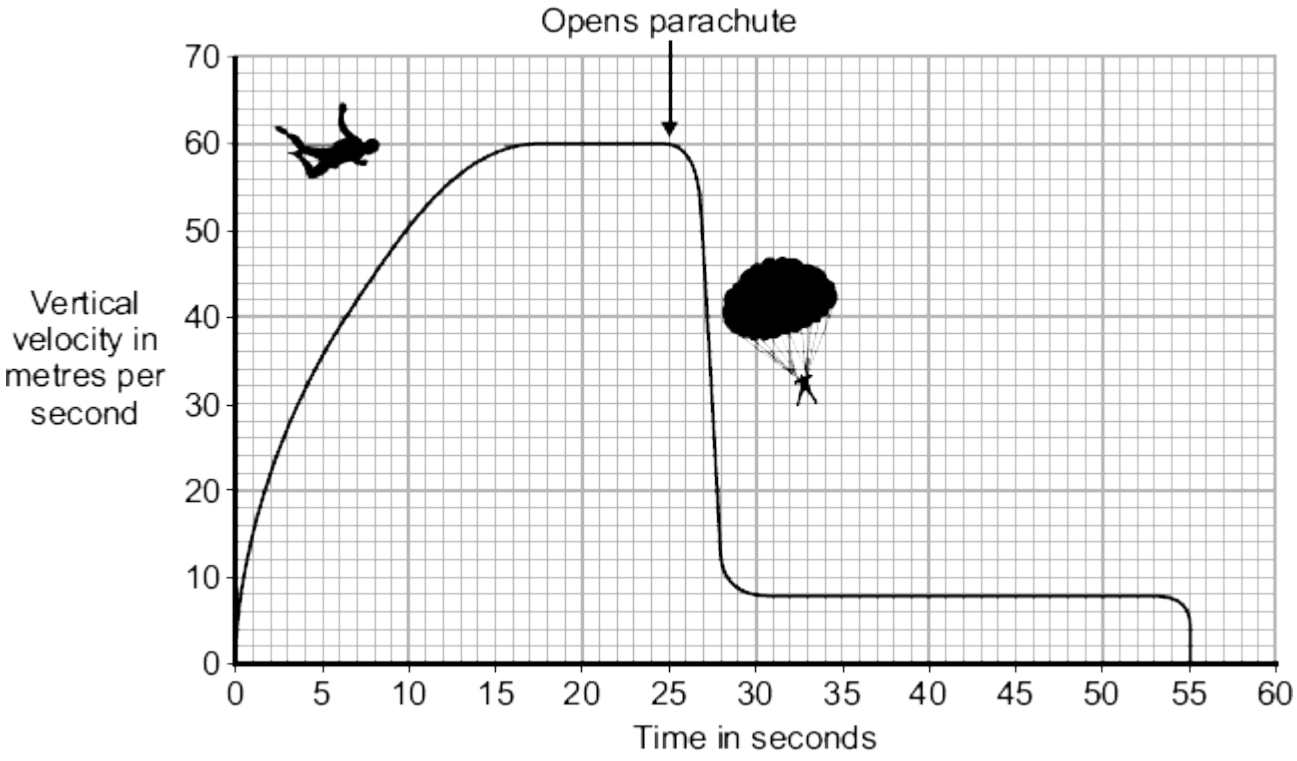
_____

Weight = _____

(3)

(b) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

The graph shows how the vertical velocity of a parachutist changes from the moment the parachutist jumps from the aircraft until landing on the ground.



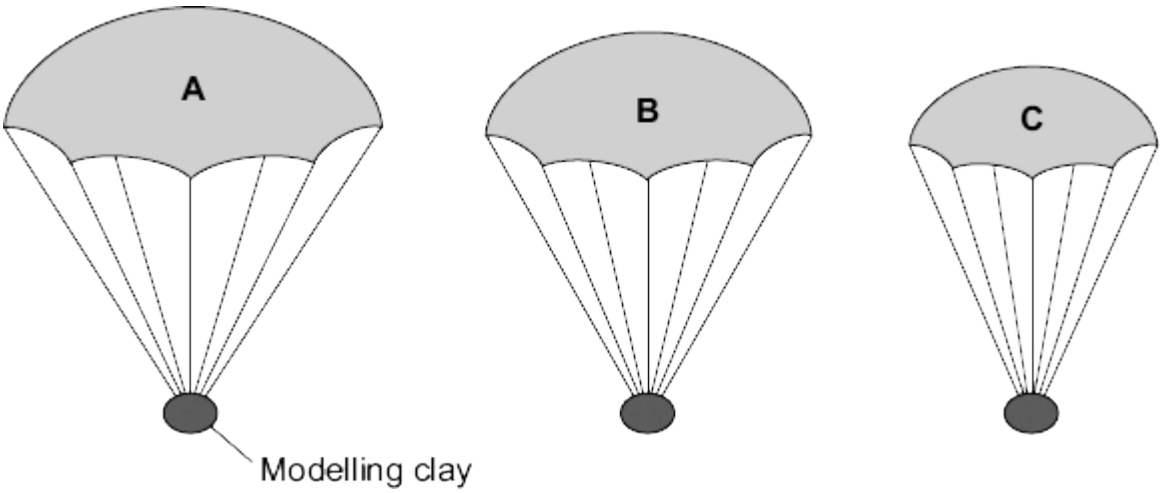
Using the idea of forces, explain why the parachutist reaches a terminal velocity and why opening the parachute reduces the terminal velocity.

(6)

(c) A student wrote the following hypothesis.

'*The larger the area of a parachute, the slower a parachutist falls.'*

To test this hypothesis the student made three model parachutes, **A**, **B** and **C**, from one large plastic bag. The student dropped each parachute from the same height and timed how long each parachute took to fall to the ground.



(i) The height that the student dropped the parachute from was a control variable.

Name **one** other control variable in this experiment.

_____

(1)

(ii) Use the student's hypothesis to predict which parachute, **A**, **B** or **C**, will hit the ground first.

Write your answer in the box. ☐

Give a reason for your answer.

_____

_____

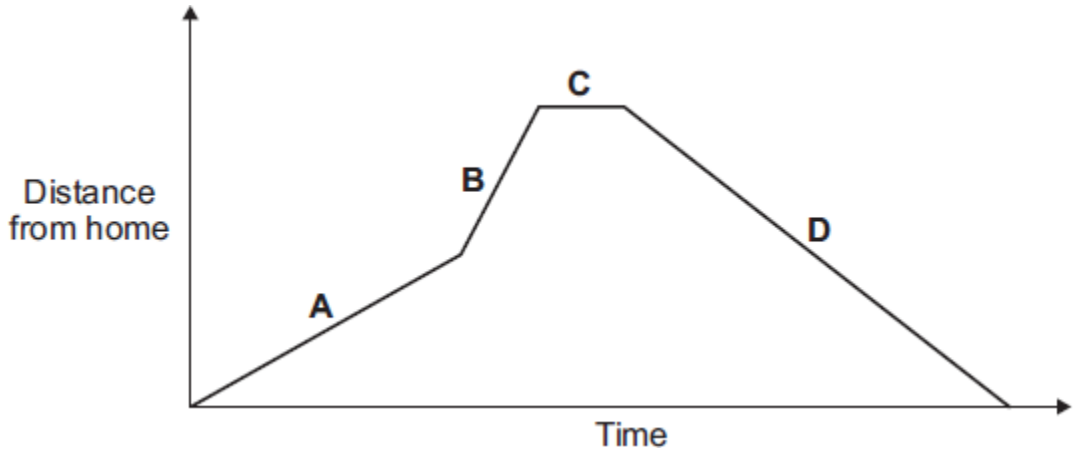
_____

(2)

(Total 12 marks)

42 (a) A person takes their dog for a walk.

The graph shows how the distance from their home changes with time.



Which part of the graph, **A**, **B**, **C** or **D**, shows them walking the fastest?

Write your answer in the box. ☐

Give the reason for your answer.

_____

_____

(2)

(b) During the walk, both the speed and the velocity of the person and the dog change.

How is *velocity* different from *speed*?

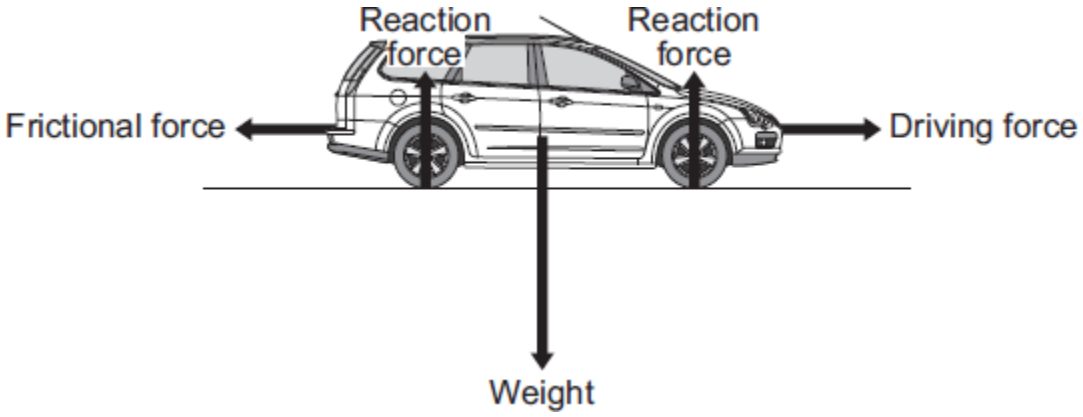
_____

_____

(1)

(Total 3 marks)

43 The diagram shows the forces acting on a car. The car is being driven along a straight, level road at a constant speed of 12 m/s.



(a) The driver then accelerates the car to 23 m/s in 4 seconds.

Use the equation in the box to calculate the acceleration of the car.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken for change}}$$

Show clearly how you work out your answer and give the unit.

Acceleration = _____

(3)

(b) Describe how the horizontal forces acting on the car change during the first **two** seconds of the acceleration.

(3)

(Total 6 marks)

44 A high-speed train accelerates at a constant rate in a straight line.

The velocity of the train increases from 30 m/s to 42 m/s in 60 seconds.

(a) (i) Calculate the change in the velocity of the train.

_____

Change in velocity = _____ m/s

(1)

(ii) Use the equation in the box to calculate the acceleration of the train.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken for change}}$$

Show clearly how you work out your answer and give the unit.
Choose the unit from the list below.

m/s **m/s^2** **N/kg** **Nm**

_____

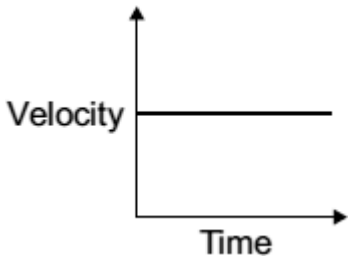
_____

Acceleration = _____

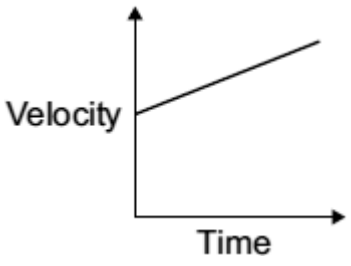
(2)

(b) Which **one** of the graphs, **A**, **B** or **C**, shows how the velocity of the train changes as it accelerates?

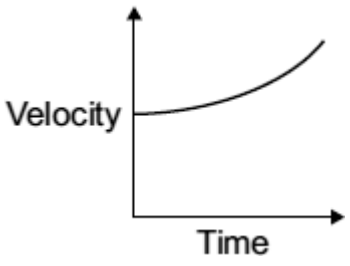
Write your answer, **A**, **B** or **C**, in the box.



A



B



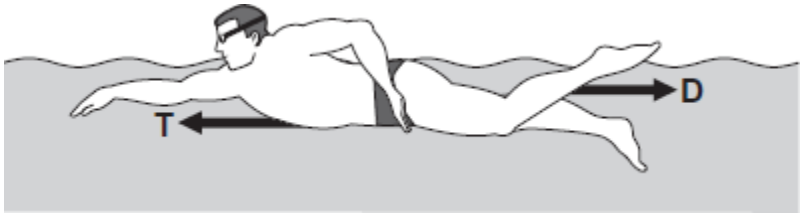
C

Graph ☐

(1)

(Total 4 marks)

45 (a) The diagram shows the horizontal forces acting on a swimmer.



(i) The swimmer is moving at constant speed.
Force **T** is 120 N.

What is the size of force **D**?

_____ N

(1)

(ii) By increasing force **T** to 140 N, the swimmer accelerates to a higher speed.

Calculate the size of the initial resultant force acting on the swimmer.

_____

_____

Initial resultant force = _____ N

(1)

(iii) Even though the swimmer keeps the force **T** constant at 140 N, the resultant force on the swimmer decreases to zero.

Explain why.

_____

_____

_____

_____

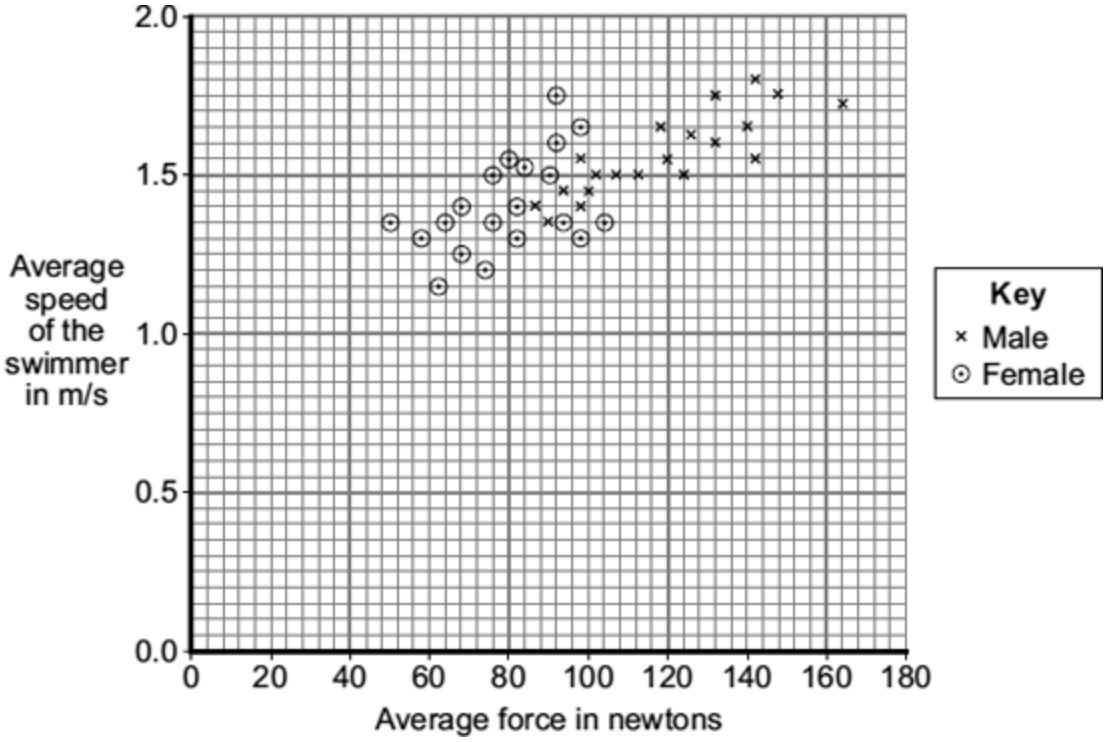
_____

_____

(3)

(b) A sports scientist investigated how the force exerted by a swimmer's hands against the water affects the swimmer's speed.
The investigation involved 20 males and 20 females swimming a fixed distance.
Sensors placed on each swimmer's hands measured the force 85 times every second over the last 10 metres of the swim.
The measurements were used to calculate an average force.
The average speed of each swimmer over the last 10 metres of the swim was also measured.

The data from the investigation is displayed in the graph.



(i) What was the dependent variable in this investigation?

_____

(1)

(ii) Explain **one** advantage of measuring the force 85 times every second rather than just once or twice every second.

_____

_____

_____

_____

(2)

(iii) Give **one** way in which the data for the male swimmers is different from the data for the female swimmers.

_____

_____

(1)

(iv) Considering only the data from this investigation, what advice should a swimming coach give to swimmers who want to increase their average speed?

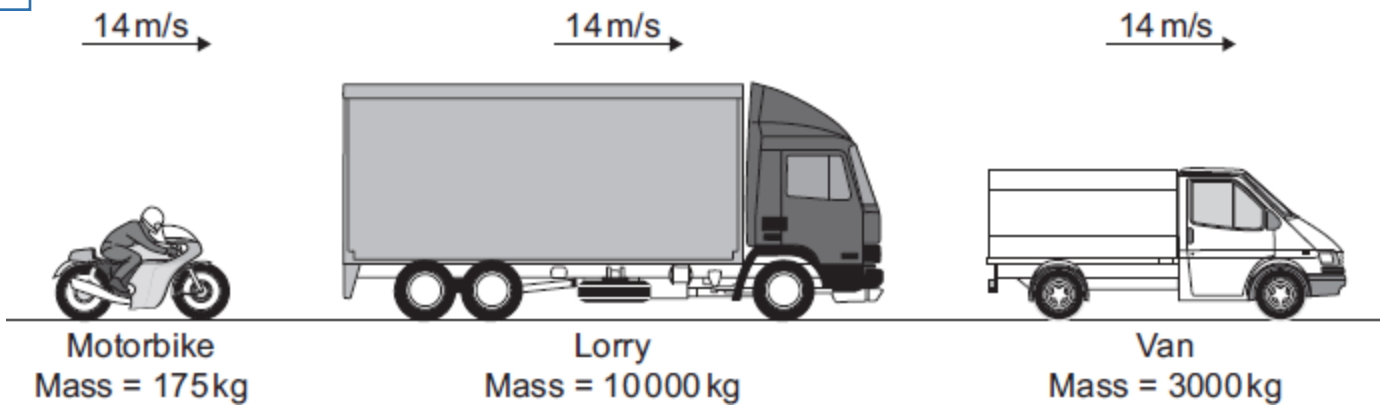
_____

_____

(1)

(Total 10 marks)

46 (a) (i) The diagram shows three vehicles travelling along a straight road at 14 m/s.



Which vehicle has the greatest momentum?

_____

Give the reason for your answer.

_____

_____

_____

(2)

(ii) Use the equation in the box to calculate the momentum of the motorbike when it travels at 14 m/s.

momentum = mass × velocity

Show clearly how you work out your answer.

_____

_____

Momentum = _____ kg m/s

(2)

(b) The motorbike follows the lorry for a short time, and then accelerates to overtake both the lorry and van.

(i) Complete the following sentence by drawing a ring around the correct line in the box.

When the motorbike starts to overtake, the kinetic energy

of the motorbike

decreases.
stays the same.
increases.

(1)

(ii) Give a reason for your answer to part (b)(i).

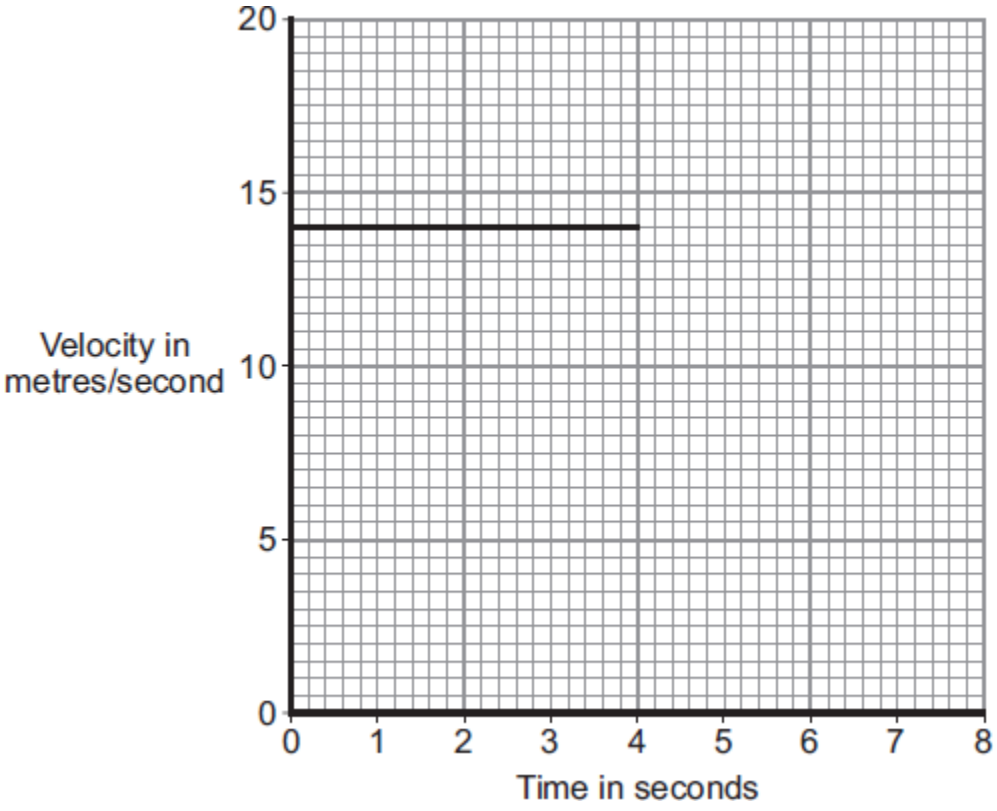
_____

_____

(1)

(iii) The graph shows the velocity of the motorbike up to the time when it starts to accelerate. The motorbike accelerates constantly, going from a speed of 14 m/s to a speed of 20 m/s in a time of 2 seconds. The motorbike then stays at 20 m/s.

Complete the graph to show the motion of the motorbike over the next 4 seconds.



(3)

(Total 9 marks)

47 Motorway accidents have many causes.

(a) Which **one** of the following is most likely to increase the chance of a car being in an accident?

Tick (✓) the box next to your answer.

The car has just had new tyres fitted. ☐

The driver has been drinking alcohol. ☐

A road surface in dry conditions ☐

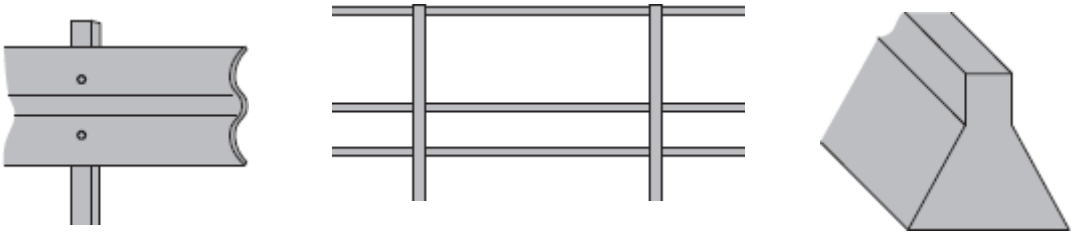
Give a reason for your answer.

_____

_____

(2)

(b) The diagram shows three designs of motorway crash barriers.



Steel sheets | Steel 'ropes' | Solid concrete

Before a new design of barrier is used, it must be tested.
A car of mass 1500 kg is driven at 30 m/s to hit the barrier at an angle of 20 degrees.
This barrier must slow the car down and must not break.

Explain why the mass of the car, the speed of the car and the angle at which the car hits the barrier must be the same in every test.

_____

_____

_____

_____

_____

(2)

(c) A group of scientists has suggested that new designs of crash barriers should be first tested using computer simulations.

Which **two** statements give sensible reasons for testing new barrier designs using a computer simulation?

Put a tick (✓) in the box next to each of your answers.

The design of the barrier can be changed easily. ☐

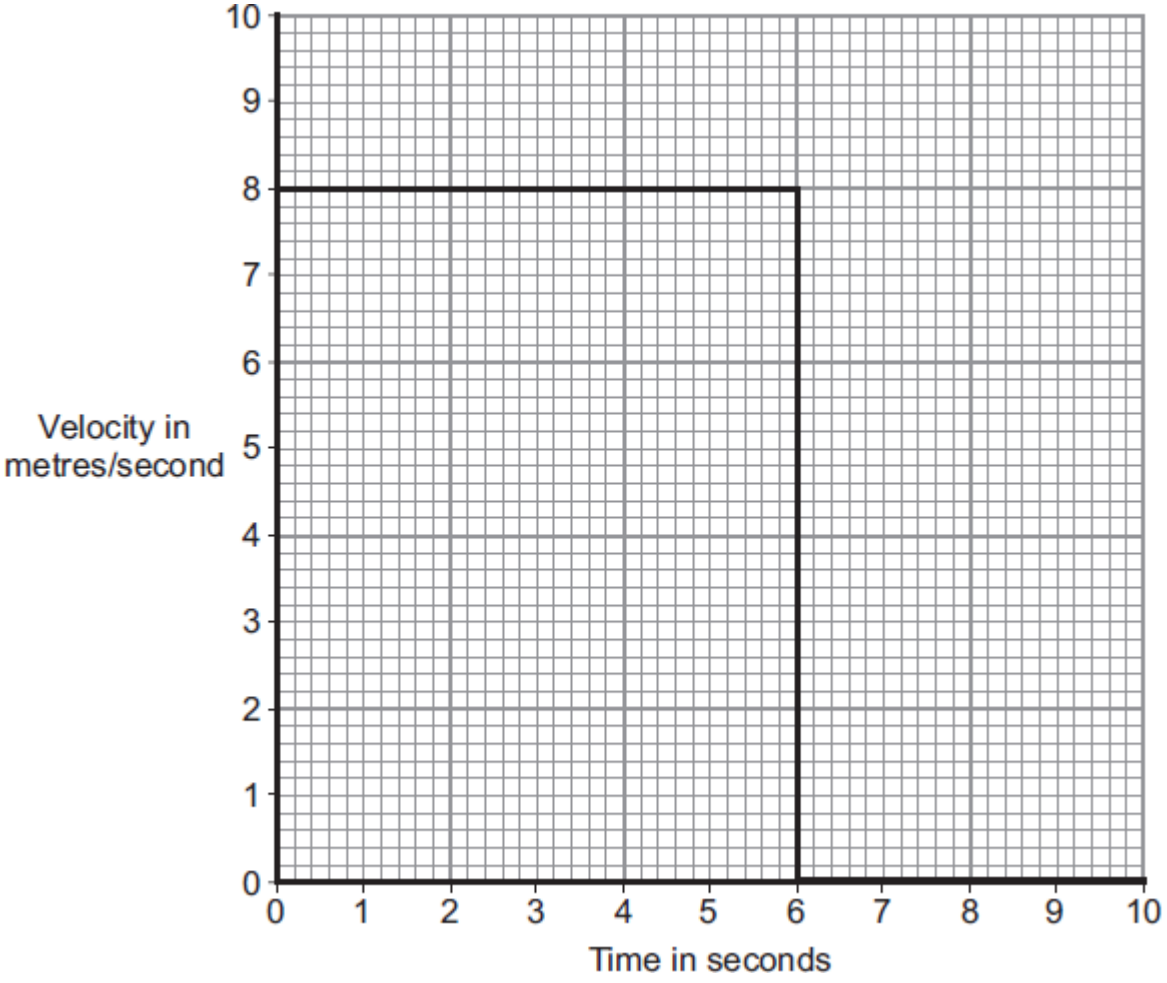
Data for different conditions can be obtained quickly. ☐

Simulations are more realistic than using cars and barriers. ☐

(1)

(Total 5 marks)

48 The diagram shows the velocity-time graph for an object over a 10 second period.



(a) Use the graph to calculate the distance travelled by the object in 10 seconds.

Show clearly how you work out your answer.

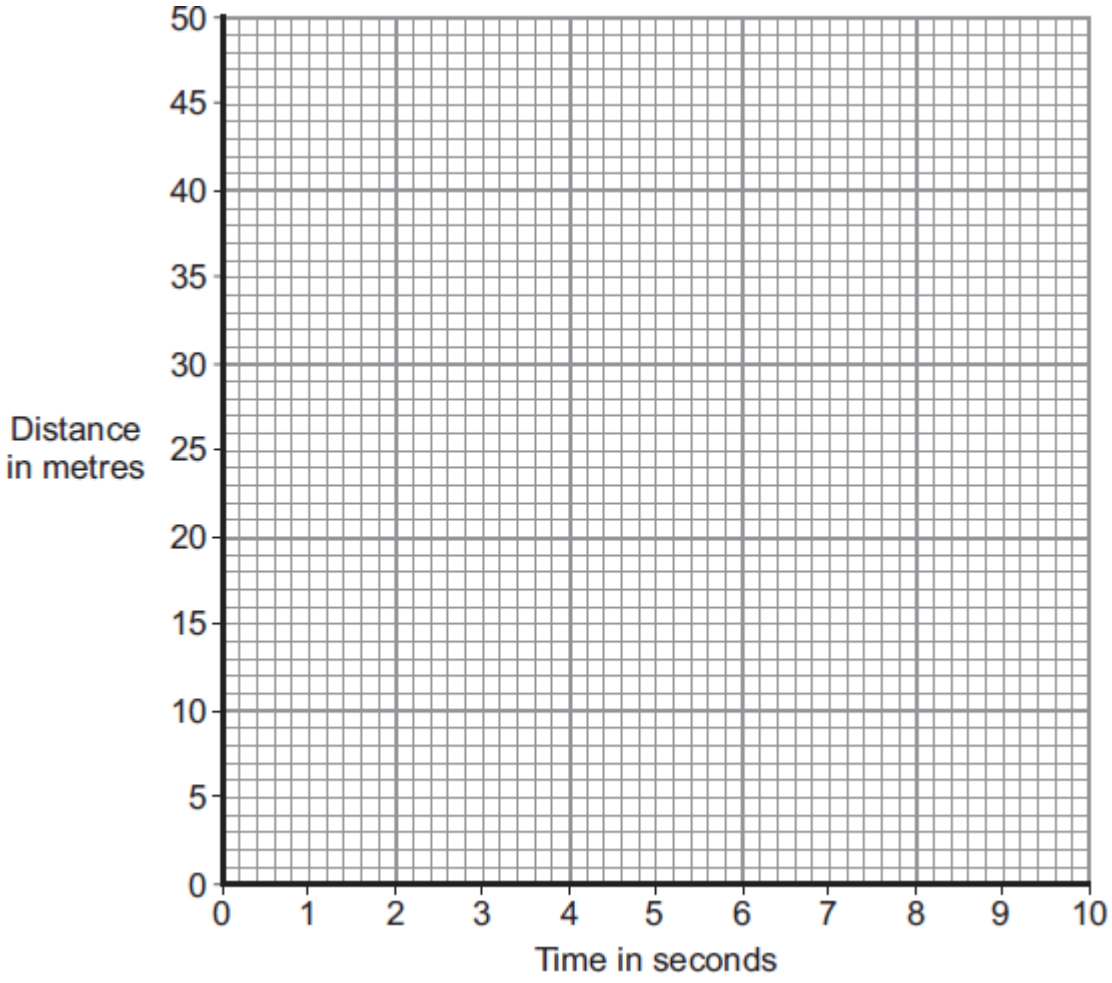
_____

_____

Distance = _____ m

(2)

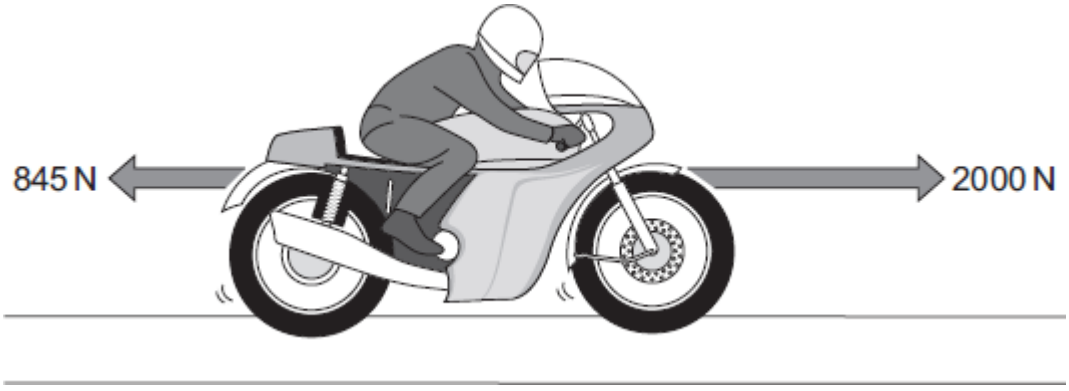
(b) Complete the distance-time graph for the object over the same 10 seconds.



(2)

(Total 4 marks)

49 The arrows in the diagram represent the horizontal forces acting on a motorbike at one moment in time.



(a) The mass of the motorbike and rider is 275 kg.

Calculate the acceleration of the motorbike at this moment in time.

Show clearly how you work out your answer.

Acceleration = _____ m/s^2

(3)

(b) A road safety organisation has investigated the causes of motorbike accidents.

The main aim of the investigation was to find out whether there was any evidence that young, inexperienced riders were more likely to be involved in an accident than older, experienced riders.

Data obtained by the organisation from a sample of 1800 police files involving motorbike accidents, is summarised in the table.

Size of motorbike engine	Percentage of all motorbikes sold	Total number in the sample of 1800 accident files
up to 125 cc	36	774
126 to 350 cc	7	126
351 to 500 cc	7	162
over 500 cc	50	738

Most of the motorbikes with engines up to 125 cc were ridden by young people.
The motorbikes with engines over 500 cc were ridden by older, more experienced riders.

(i) In terms of the main aim of the investigation, is this data valid?

Draw a ring around your answer. **NO** **YES**

Explain the reason for your answer.

_____

_____

_____

_____

(2)

(ii) The organisation concluded that:

"Young, inexperienced riders are more likely to be involved in a motorbike accident than older, experienced riders".

Explain how the data supports this conclusion.

_____

_____

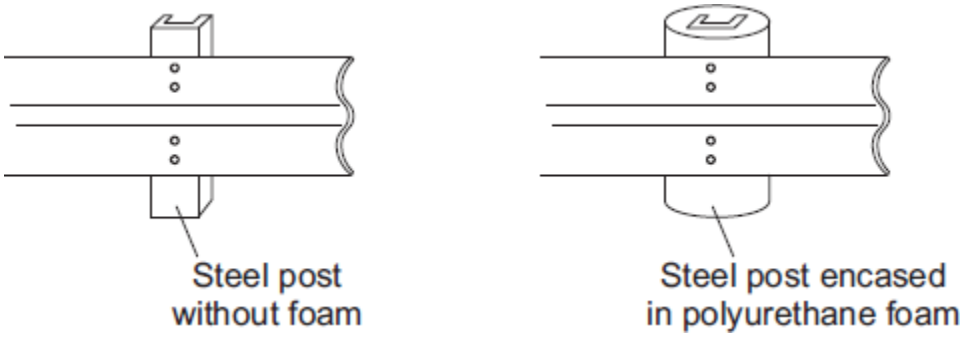
_____

_____

(2)

(c) Of particular concern to motorbike riders is the design of steel crash barriers. Riders falling off and sliding at high speed into a steel support post are often seriously injured.

One way to reduce the risk of serious injury is to cover the post in a thick layer of high impact polyurethane foam.



(i) Use the ideas of momentum to explain how the layer of foam reduces the risk of serious injury to a motorbike rider sliding at high speed into the support post.

_____

_____

_____

_____

_____

(3)

(ii) Crash barrier tests use dummies that collide at 17 m/s with the barrier. Each test costs about £12 000. New safety devices for crash barriers are tested many times to make sure that they will improve safety.

Do you think that the cost of developing the new safety devices is justified?

Draw a ring around your answer. **NO** **YES**

Give a reason for your answer.

_____

_____

(1)

(Total 11 marks)

50 A cyclist travelling along a straight level road accelerates at 1.2 m/s^2 for 5 seconds. The mass of the cyclist and the bicycle is 80 kg.

(a) Calculate the resultant force needed to produce this acceleration.

Show clearly how you work out your answer and give the unit.

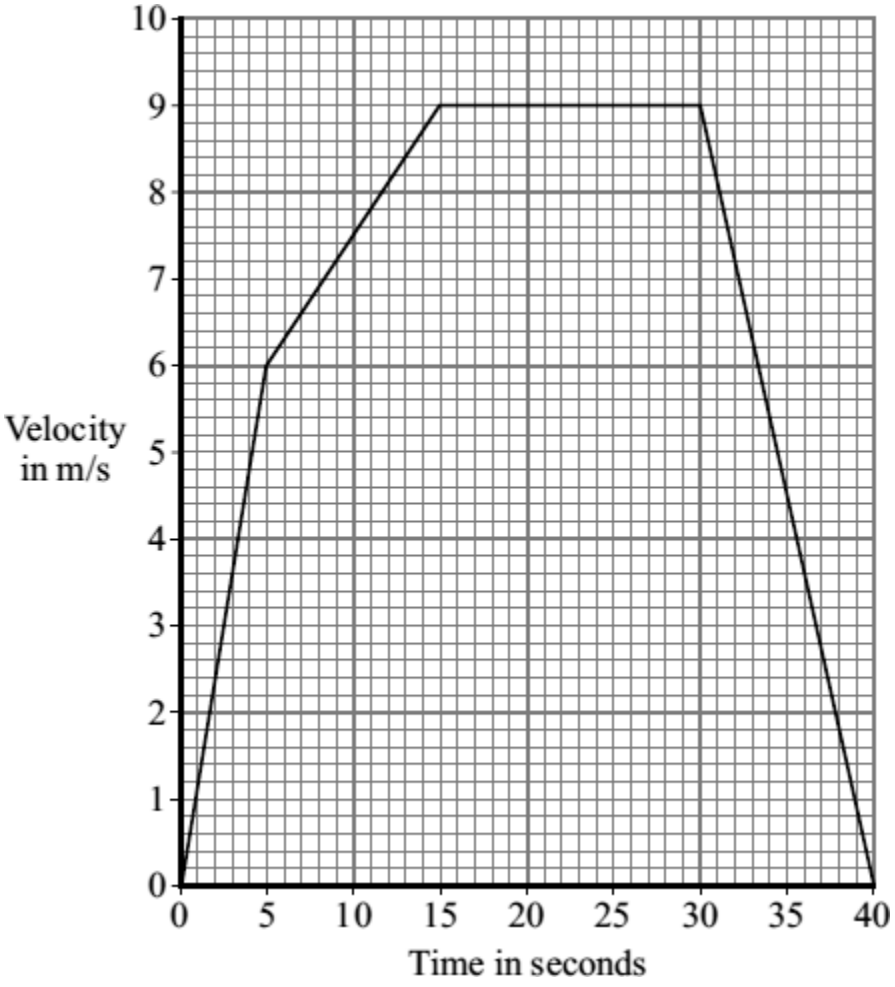
_____

_____

Resultant force = _____

(3)

(b) The graph shows how the velocity of the cyclist changes with time.



(i) Complete the following sentence.

The velocity includes both the speed and the _____ of the cyclist.

(1)

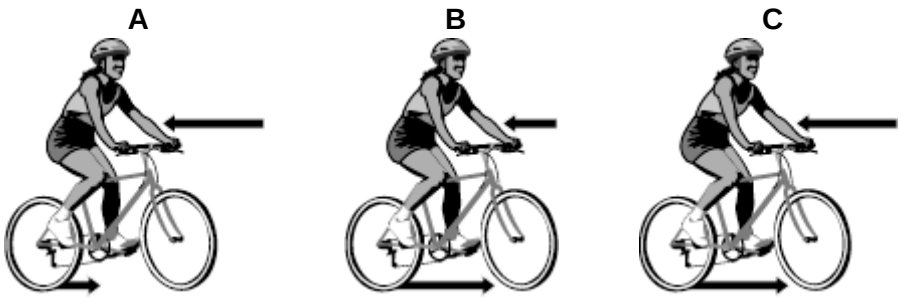
(ii) Why has the data for the cyclist been shown as a line graph instead of a bar chart?

_____

_____

(1)

(iii) The diagrams show the horizontal forces acting on the cyclist at three different speeds. The length of an arrow represents the size of the force.



Which **one** of the diagrams, **A**, **B** or **C**, represents the forces acting when the cyclist is travelling at a constant 9 m/s?

_____

Explain the reason for your choice.

_____

_____

_____

_____

_____

_____

(3)

(Total 8 marks)

51 (a) The total stopping distance of a car has two parts. One part is the distance the car travels during the driver's reaction time. This distance is often called the 'thinking distance'.

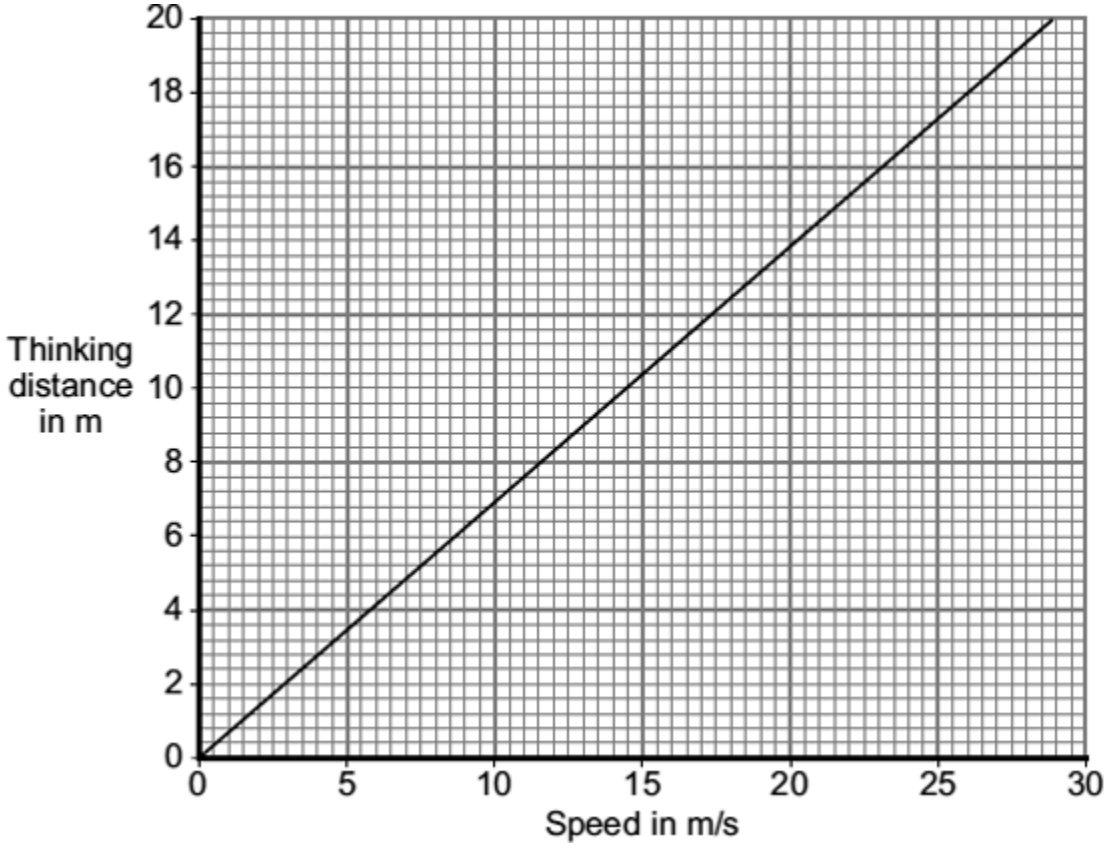
What distance is added to the 'thinking distance' to give the total stopping distance?

_____

_____

(1)

(b) The graph shows the relationship between the speed of a car and the thinking distance.



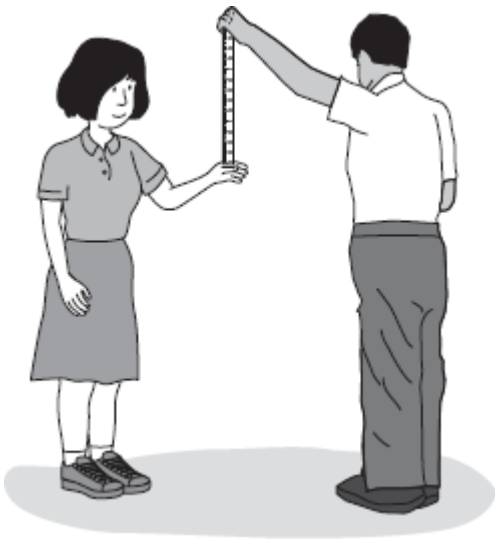
Describe the relationship between speed and thinking distance.

_____

_____

(2)

(c) The diagram shows two students investigating reaction time.



One student holds a 30 cm ruler, then lets go. As soon as the second student sees the ruler fall, she closes her hand, stopping the ruler. The further the ruler falls before being stopped, the slower her reaction time.

(i) One student always holds the ruler the same distance above the other student's hand.
In this experiment, what type of variable is this?

Put a tick (✓) in the box next to your answer.

independent variable ☐

dependent variable ☐

control variable ☐

(1)

(ii) Describe how this experiment could be used to find out whether listening to music affects reaction time.

_____

_____

_____

_____

(2)

(d) The following information is written on the label of some cough medicine.

> **WARNING**: Causes drowsiness.
> Do not drive or operate machinery.

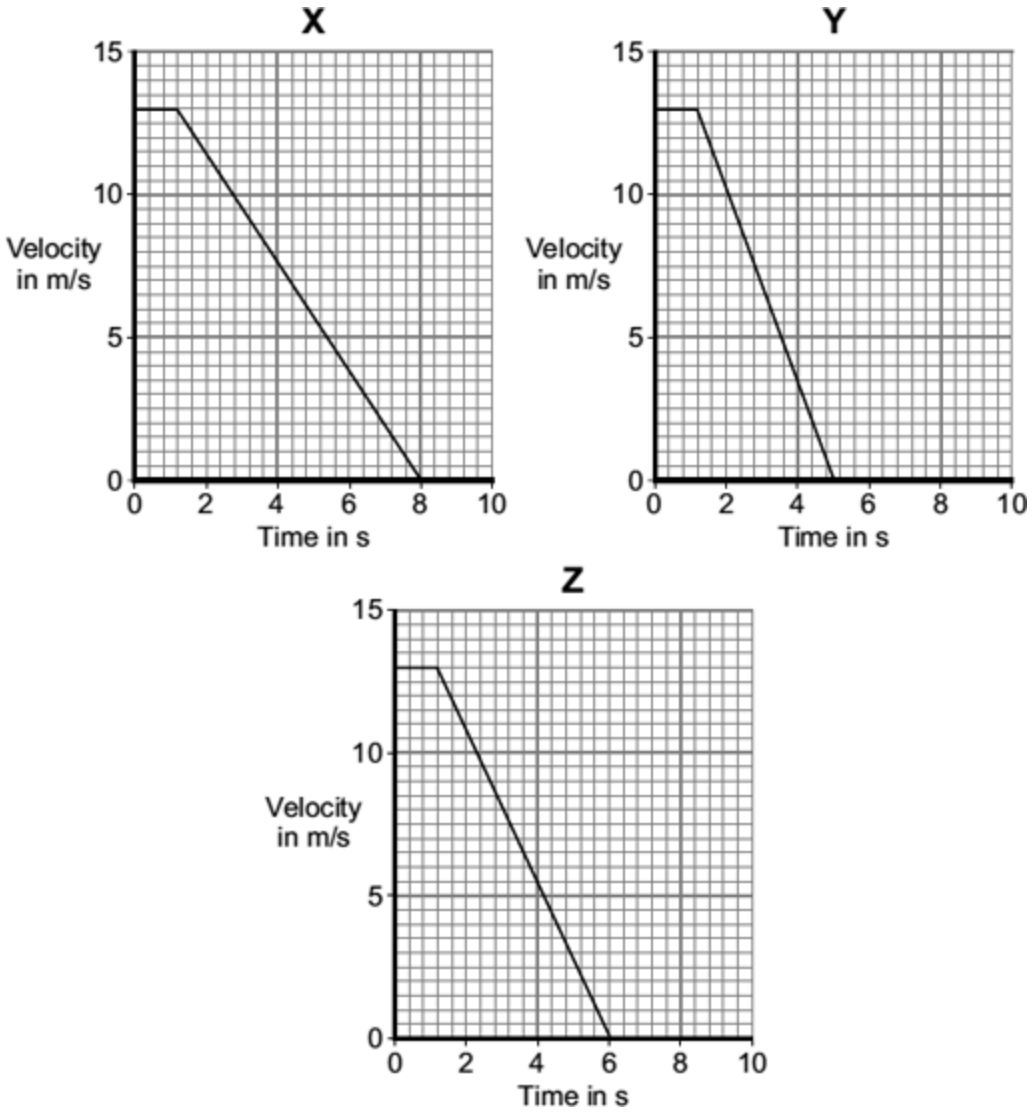
How is feeling drowsy (sleepy) likely to affect a driver's reaction time?

_____

_____

(1)

(e) Three cars, **X**, **Y** and **Z** , are being driven along a straight road towards a set of traffic lights. The graphs show how the velocity of each car changes once the driver sees that the traffic light has turned to red.



Which one of the cars, **X**, **Y** or **Z** , stops in the shortest distance?

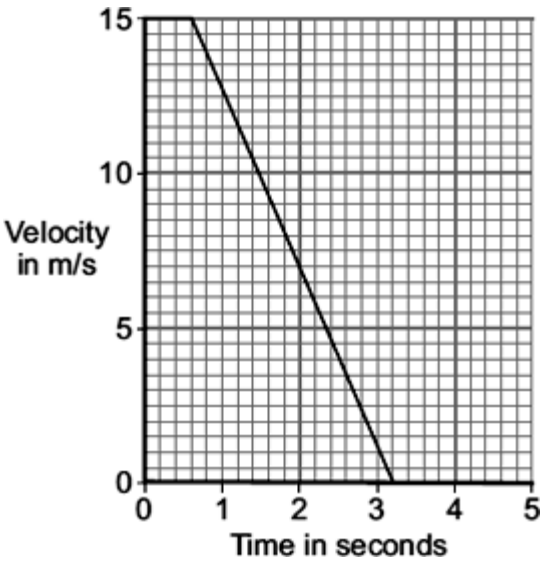
_____

(1)

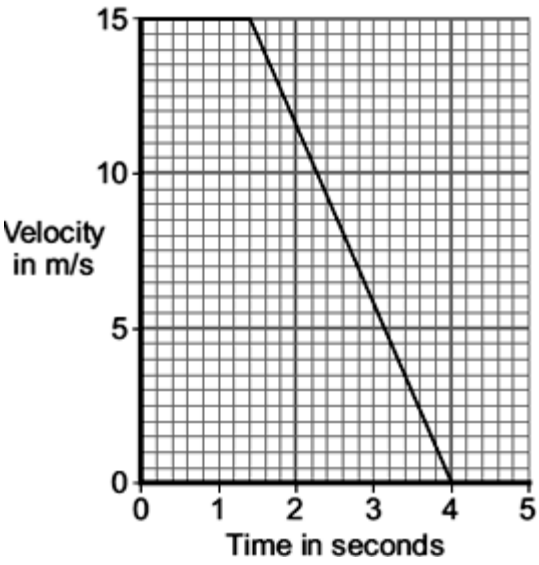
(Total 8 marks)

52 (a) The graphs show how the velocity of two cars, **A** and **B**, change from the moment the car drivers see an obstacle blocking the road.

Car A



Car B



One of the car drivers has been drinking alcohol. The other driver is wide awake and alert.

(i) How does a comparison of the two graphs suggest that the driver of car **B** is the one who has been drinking alcohol?

_____

_____

(1)

(ii) How do the graphs show that the two cars have the same deceleration?

_____

_____

(1)

(iii) Use the graphs to calculate how much further car **B** travels before stopping compared to car **A**.

Show clearly how you work out your answer.

_____

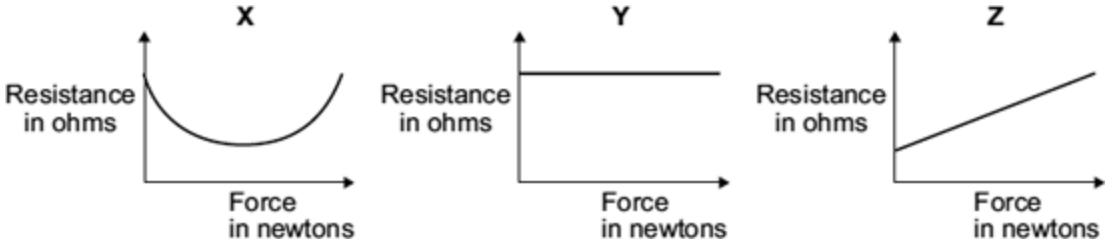
_____

_____

Additional stopping distance = _____ m

(3)

(b) In a crash test laboratory, scientists use sensors to measure the forces exerted in collisions. The graphs show how the electrical resistance of 3 experimental types of sensor, **X**, **Y** and **Z**, change with the force applied to the sensor.



Which of the sensors, **X**, **Y** or **Z**, would be the best one to use as a force sensor?

_____

Give a reason for your answer.

_____

_____

_____

_____

(2)

(Total 7 marks)

53 (a) The diagram shows an athlete at the start of a race. The race is along a straight track.

In the first 2 seconds, the athlete accelerates constantly and reaches a speed of 9 m/s.

(i) Calculate the acceleration of the athlete.

Show clearly how you work out your answer.

_____

_____

_____

Acceleration = _____

(2)

(ii) Which **one** of the following is the unit for acceleration?

Draw a ring around your answer.

J/s **m/s** **m/s^2** **Nm**

(1)

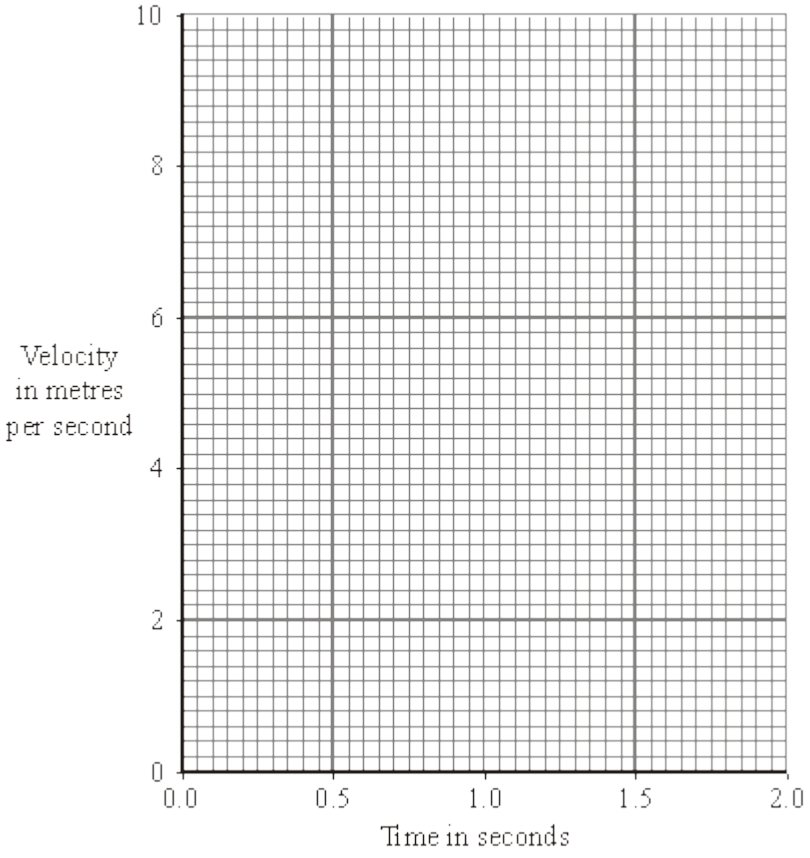
(iii) Complete the following sentence.

The velocity of the athlete is the _____ of

the athlete in a given direction.

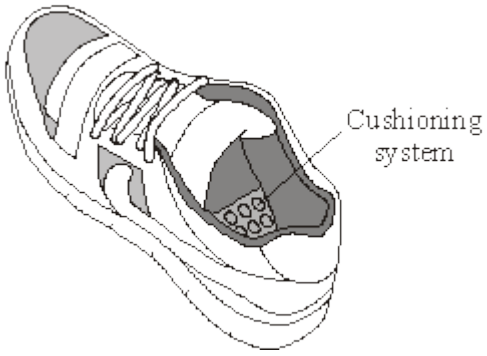
(1)

(iv) Complete the graph to show how the velocity of the athlete changes during the first 2 seconds of the race.

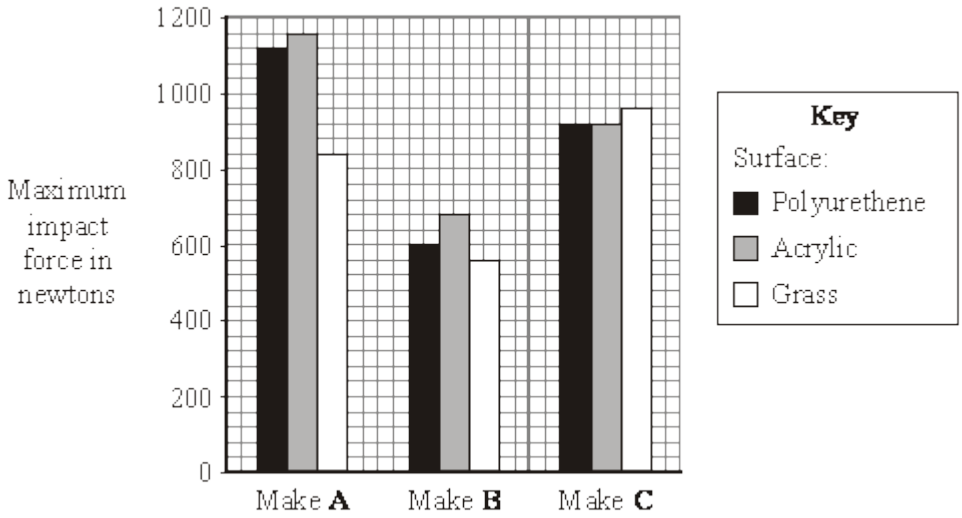


(2)

(b) Many running shoes have a cushioning system. This reduces the impact force on the athlete as the heel of the running shoe hits the ground.



The bar chart shows the maximum impact force for three different makes of running shoe used on three different types of surface.



(i) Which **one** of the three makes of running shoe, **A**, **B** or **C**, has the best cushioning system?

_____

Explain the reason for your answer.

_____

_____

_____

_____

(3)

(ii) The data needed to draw the bar chart was obtained using a robotic athlete fitted with electronic sensors.

Why is this data likely to be more reliable than data obtained using human athletes?

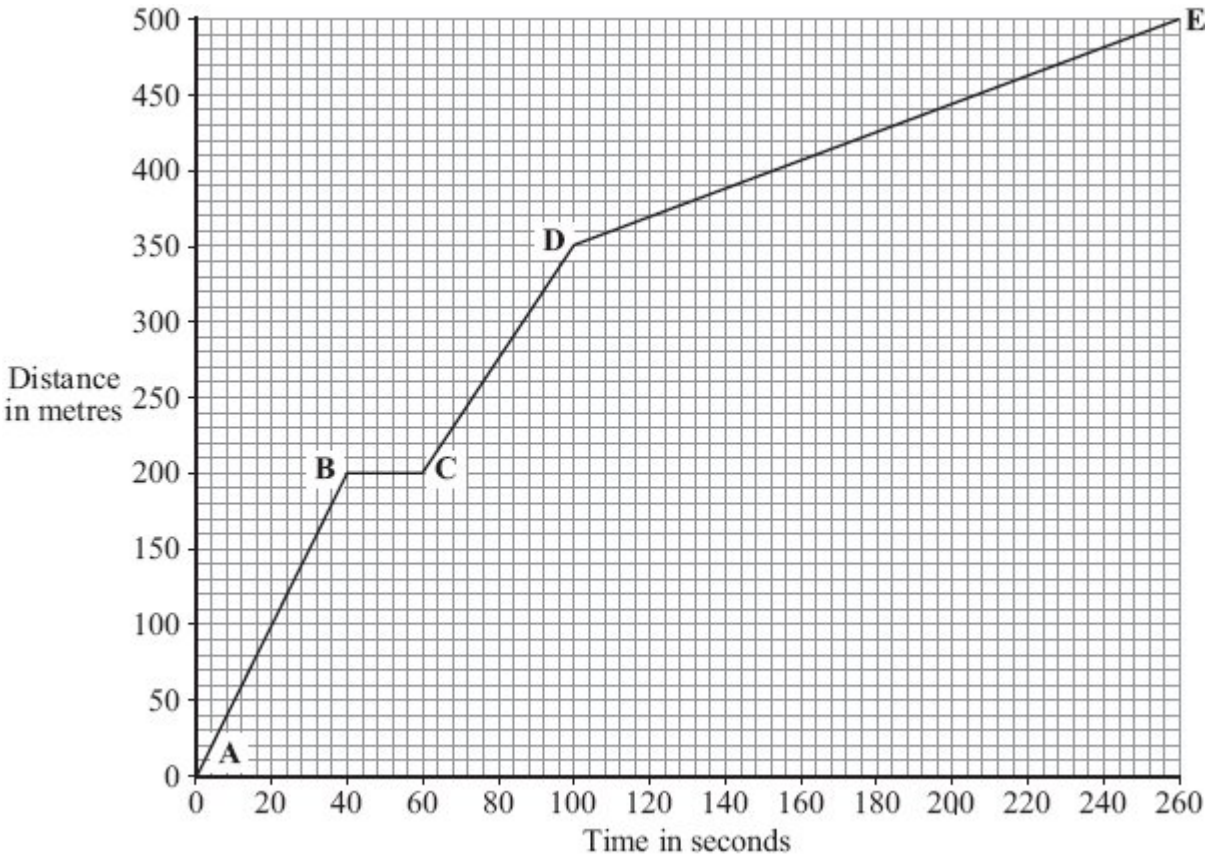
_____

_____

(1)

(Total 10 marks)

54 Part of a bus route is along a high street.
The distance – time graph shows how far the bus travelled along the high street and how long it took.



(a) The bus travels the **slowest** between points **D** and **E**.

How can you tell this from the graph?

_____

_____

(1)

(b) Between which two points was the bus travelling the **fastest**?

Put a tick (✓) in the box next to your answer.

Points	
A – B	
B – C	
C – D	

(1)

(c) There is a bus stop in the high street.
This is marked as point **B** on the graph.

(i) What is the distance between point **A** on the graph and the bus stop?

Distance _____ metres

(1)

(ii) How long did the bus stop at the bus stop?
Show clearly how you work out your answer.

_____

Time = _____ seconds

(2)

(d) A cyclist made the same journey along the high street.
The cyclist started at the same time as the bus and completed the journey in 200 seconds.
The cyclist travelled the whole distance at a constant speed.

(i) Draw a line on the graph to show the cyclist's journey.

(2)

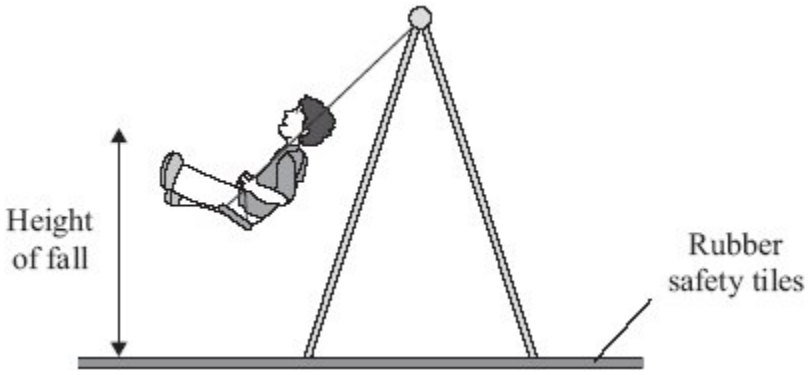
(ii) After how many seconds did the cyclist overtake the bus?

The cyclist overtook the bus after _____ seconds.

(1)

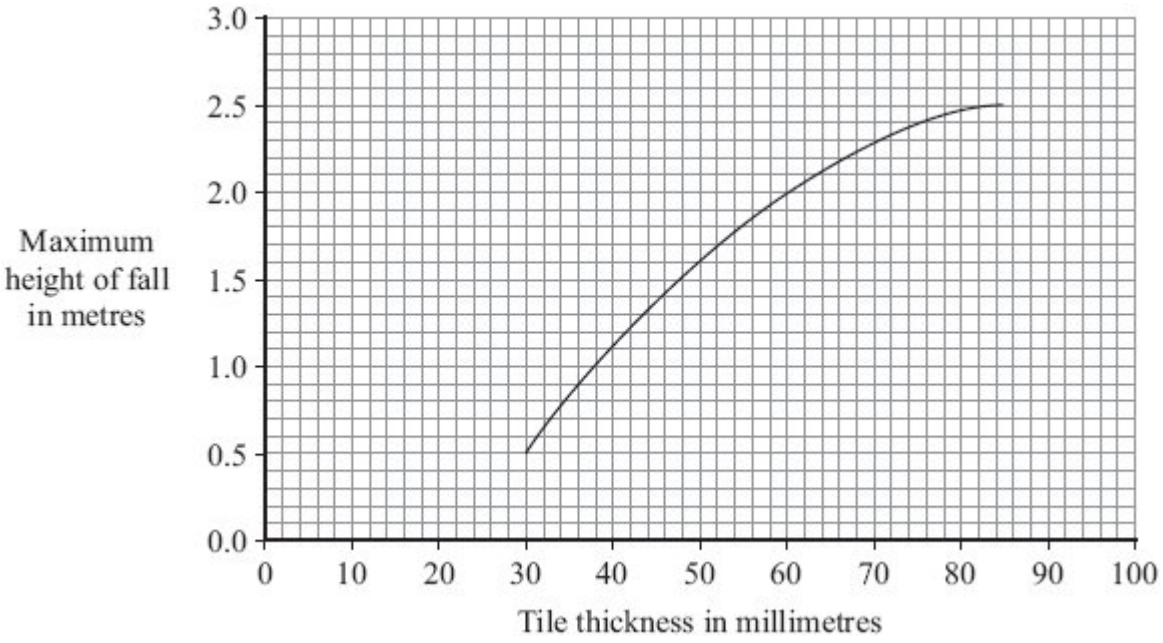
(Total 8 marks)

55 The diagram shows a child on a playground swing.



The playground surface is covered in rubber safety tiles. The tiles reduce the risk of serious injury to children who fall off the swing.

The graph gives the maximum height that a child can fall onto rubber safety tiles of different thicknesses and be unlikely to get a serious head injury.



(i) Describe how the maximum height of fall relates to the thickness of the rubber safety tile.

_____

_____

(1)

(ii) The maximum height of any of the playground rides is 2 metres.

What tile thickness should be used in the playground?

_____

Give a reason for your answer.

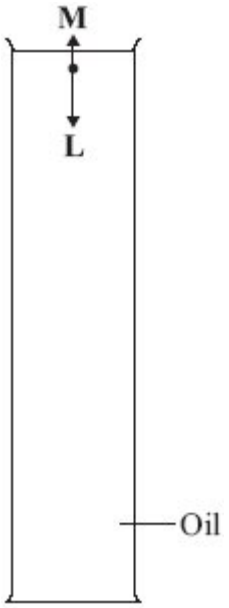
_____

_____

(2)

(Total 3 marks)

56 (a) The diagram shows a steel ball-bearing falling through a tube of oil.
The forces, **L** and **M**, act on the ball-bearing.

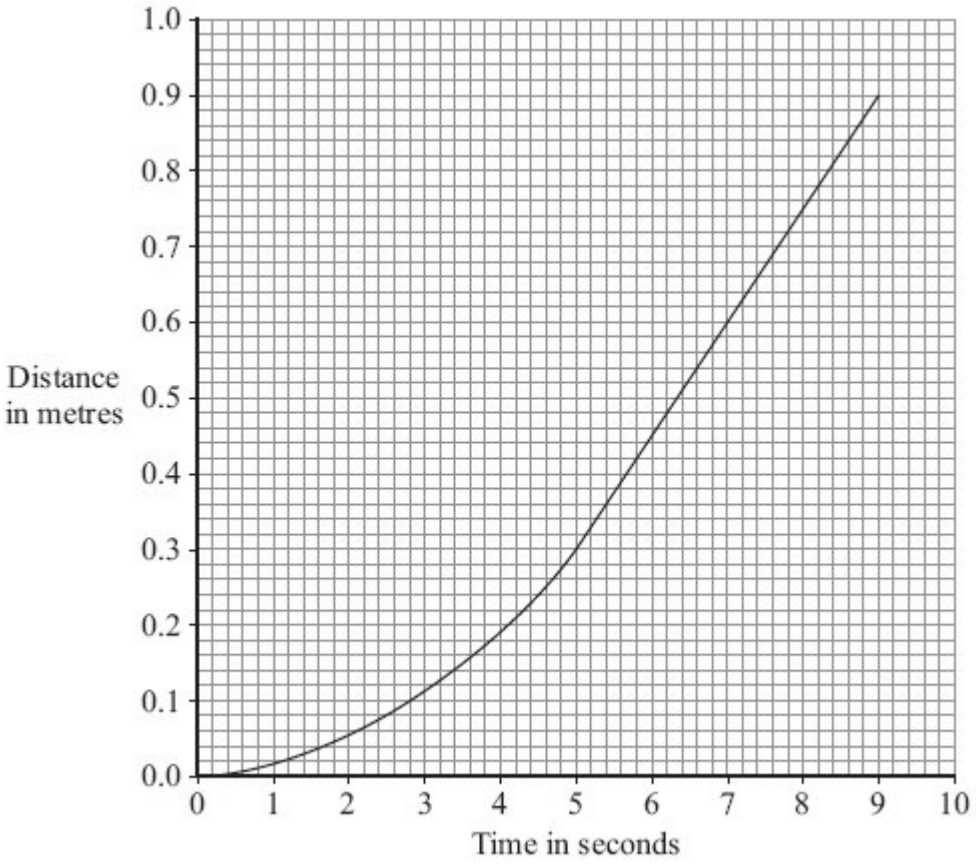


What causes force **L**?

_____

(1)

(b) The distance – time graph represents the motion of the ball-bearing as it falls through the oil.



(i) Explain, in terms of the forces, **L** and **M**, why the ball-bearing accelerates at first but then falls at constant speed.

_____

_____

_____

_____

_____

_____

(3)

(ii) What name is given to the constant speed reached by the falling ball-bearing?

_____

(1)

(iii) Calculate the constant speed reached by the ball-bearing.

Show clearly how you use the graph to work out your answer.

_____

_____

_____

Speed = _____ m/s

(2)

(Total 7 marks)

57 (a) The diagrams show oscilloscope traces for the same musical note played on two different instruments. The oscilloscope settings are not changed.

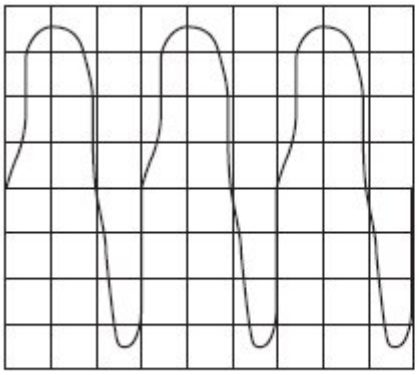


Diagram X

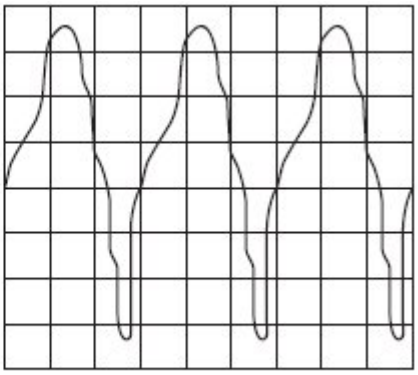


Diagram Y

(i) How can you tell, from the diagrams, that it is the same musical note?

_____

_____

(1)

(ii) How can you tell, from the diagrams, that the musical note has been played on different instruments?

_____

_____

(1)

(b) This passage is from an electronics magazine.

> *Electronic systems can be used to produce ultrasound waves. These waves have a higher frequency than the upper limit for hearing in humans.*
> *Ultrasound waves are partially reflected when they meet a boundary between two different media.*

(i) Approximately what is the highest frequency that humans can hear?

State the number and the unit.

_____

(1)

(ii) What does the word *media* mean when it is used in this passage?

_____

_____

(1)

(iii) What happens to the ultrasound which reaches the boundary between two different media and is **not** reflected?

_____

_____

_____

_____

(2)

(Total 6 marks)

58 The diagram shows the horizontal forces acting on a car travelling along a straight road.

(a) Complete the following sentences by drawing a ring around the correct word in each box.

(i) When the driving force equals the drag force, the speed ofthe car is

decreasing
constant
increasing

(1)

(ii) Putting the brakes on transforms the car's kinetic energy mainly into

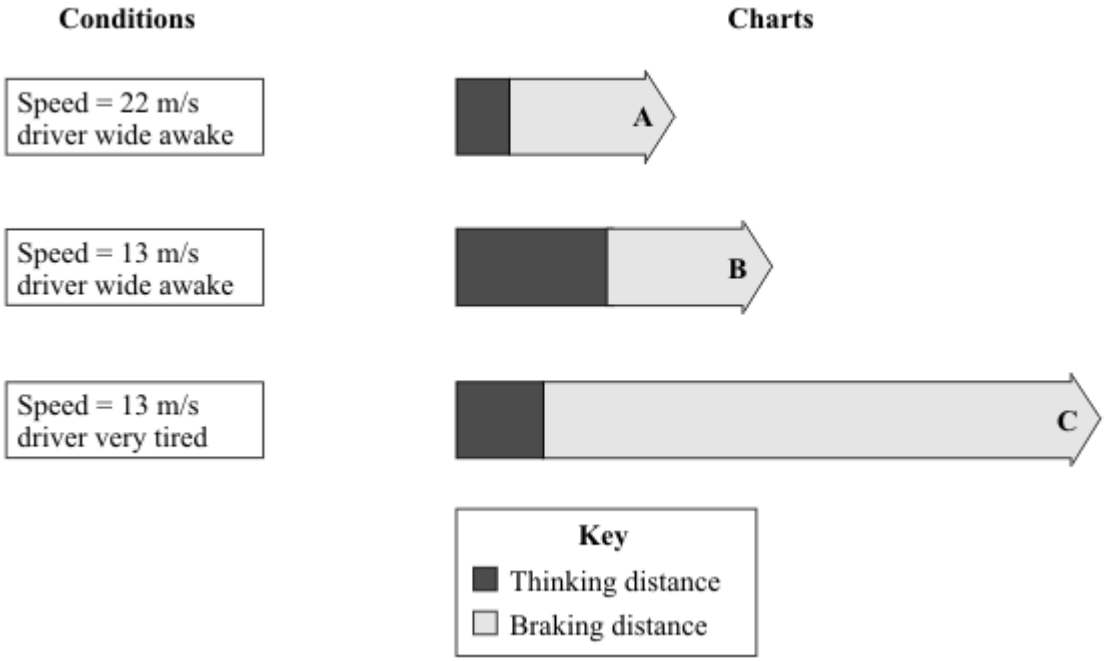
heat
light
sound

(1)

(b) The charts, **A**, **B** and **C** give the thinking distance and the braking distance for a car driven under different conditions.

(i) Draw straight lines to match each chart to the correct conditions.

Draw only **three** lines.



(2)

(ii) The three charts above all apply to dry road conditions.

How would the braking distances be different if the road were wet?

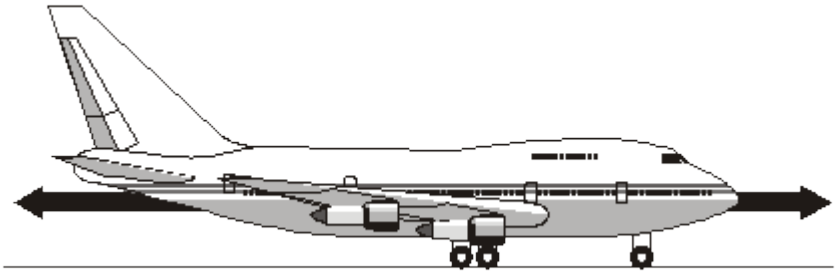
_____

_____

(1)

(Total 5 marks)

59 (a) The diagram shows an aircraft and the horizontal forces acting on it as it moves along a runway. The *resultant force* on the aircraft is zero.



(i) What is meant by the term *resultant force*?

_____

_____

(1)

(ii) Describe the movement of the aircraft when the resultant force is zero.

_____

_____

(1)

(b) The aircraft has a take-off mass of 320 000 kg. Each of the 4 engines can produce a maximum force of 240 kN.

Calculate the maximum acceleration of the aircraft.

Show clearly how you work out your answer and give the unit.

_____

_____

_____

Acceleration = _____

(3)

(c) As the aircraft moves along the runway to take off, its acceleration decreases even though the force from the engines is constant.

Explain why.

_____

_____

_____

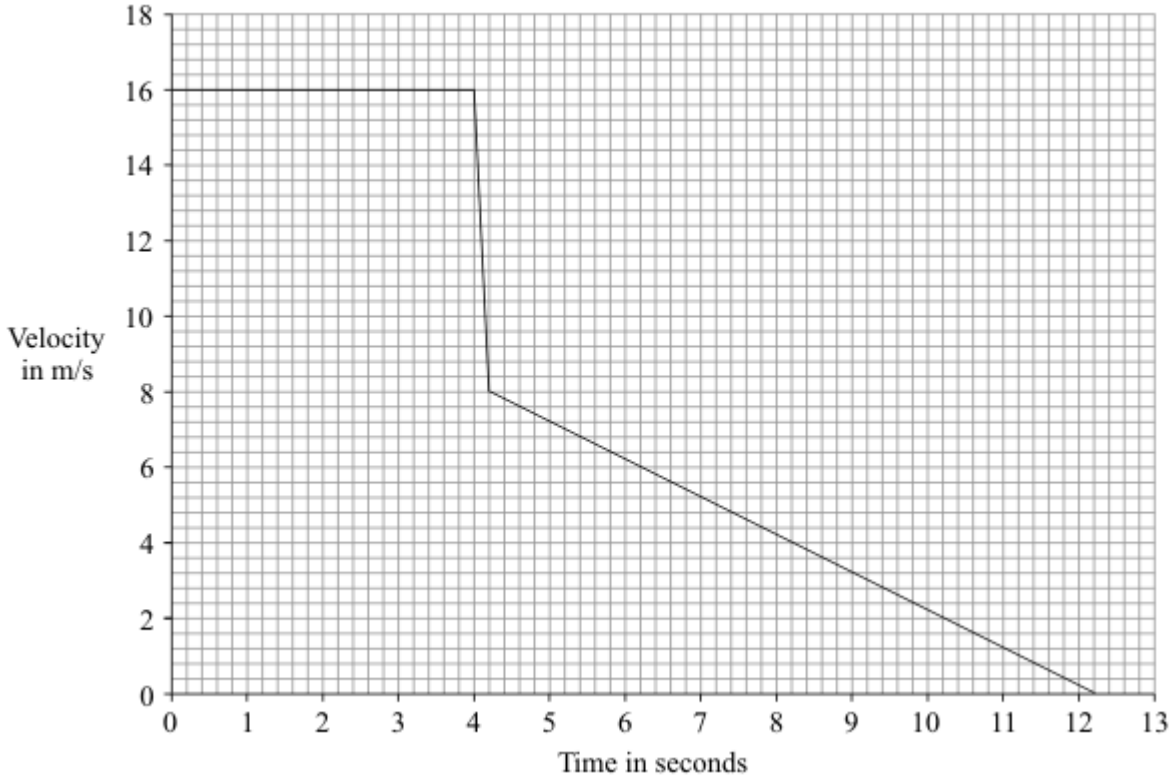
_____

(2)

(Total 7 marks)

60 In an experiment at an accident research laboratory, a car driven by remote control was crashed into the back of an identical stationary car. On impact the two cars joined together and moved in a straight line.

(a) The graph shows how the velocity of the remote-controlled car changed during the experiment.



(i) How is the *velocity* of a car different from the speed of a car?

_____

(1)

(ii) Use the graph to calculate the distance travelled by the remote-controlled car before the collision.

Show clearly how you work out your answer.

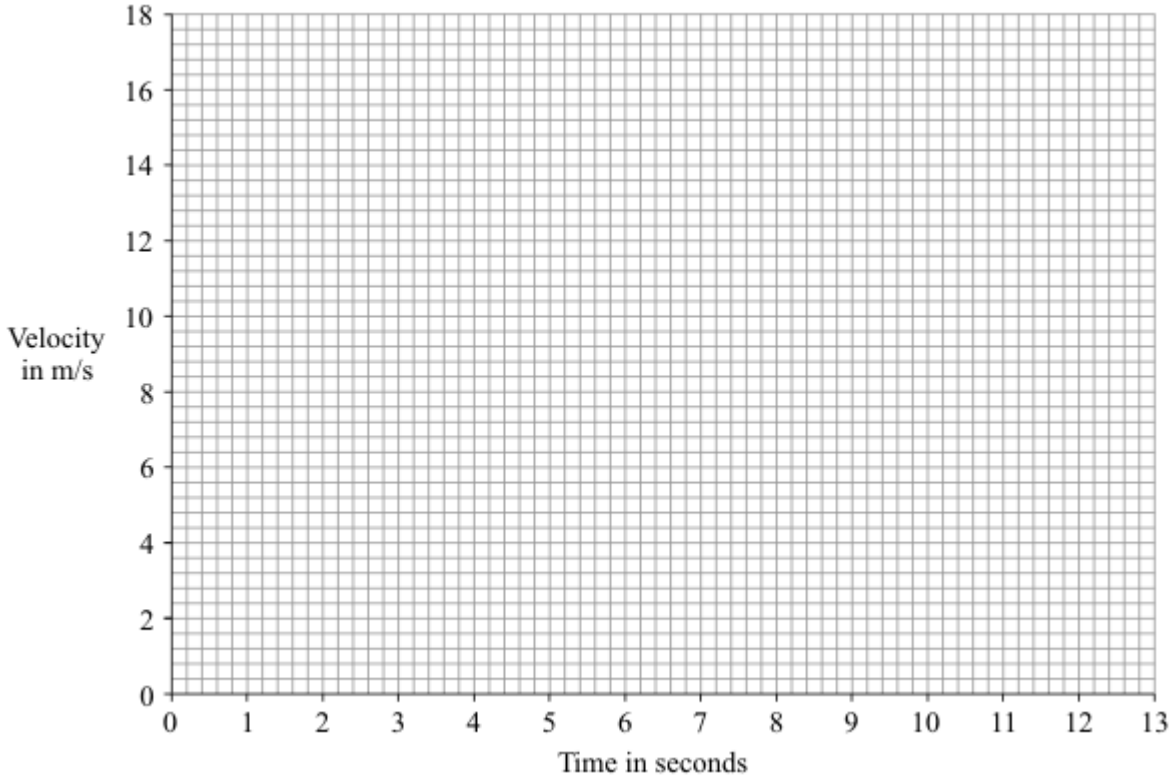
_____

_____

Distance = _____ m

(2)

(iii) Draw, on the grid below, a graph to show how the velocity of the second car changed during the experiment.



(2)

(iv) The total momentum of the two cars was not conserved.

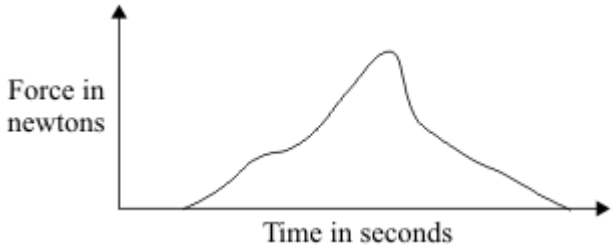
What does this statement mean?

_____

_____

(1)

(b) The graph line shows how the force from a seat belt on a car driver changes during a collision.



Scientists at the accident research laboratory want to develop a seat belt that produces a constant force throughout a collision.

Use the idea of momentum to explain why this type of seat belt would be better for a car driver.

_____

_____

_____

_____

(2)

(Total 8 marks)