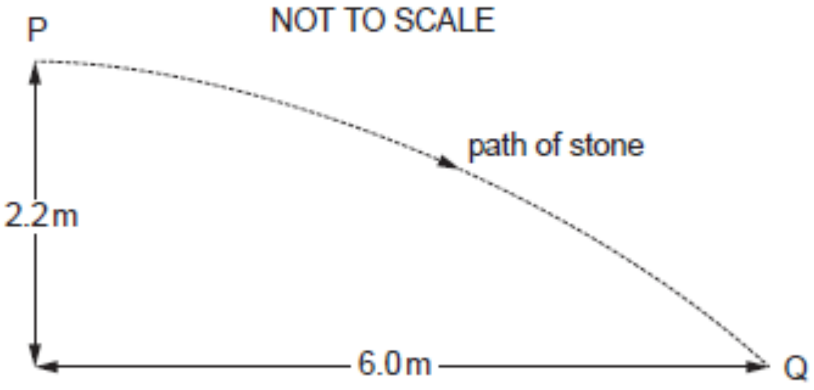
1.

**1.** *(a)* In an investigation of projectile motion, a student throws a stone. It is moving horizontally when it leaves his hand (at point P). It reaches the ground at point Q.




(i) By analysing a video of the stone's flight, its horizontal velocity component, $v_h$, is found to be almost constant. Discuss whether or not this is to be expected. [2]

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(ii) The approximate value of $v_h$ obtained from the video was $9.0\,\text{m}\,\text{s}^{-1}$. Determine whether this value is consistent with the measured distances recorded in the diagram. Show your reasoning clearly. [3]

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*(b)* Calculate the magnitude **and direction** of the stone's velocity just before it hits the ground. [4]

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2. **2.** *(a)* State the difference between a vector and a scalar and give one example of each. [2]

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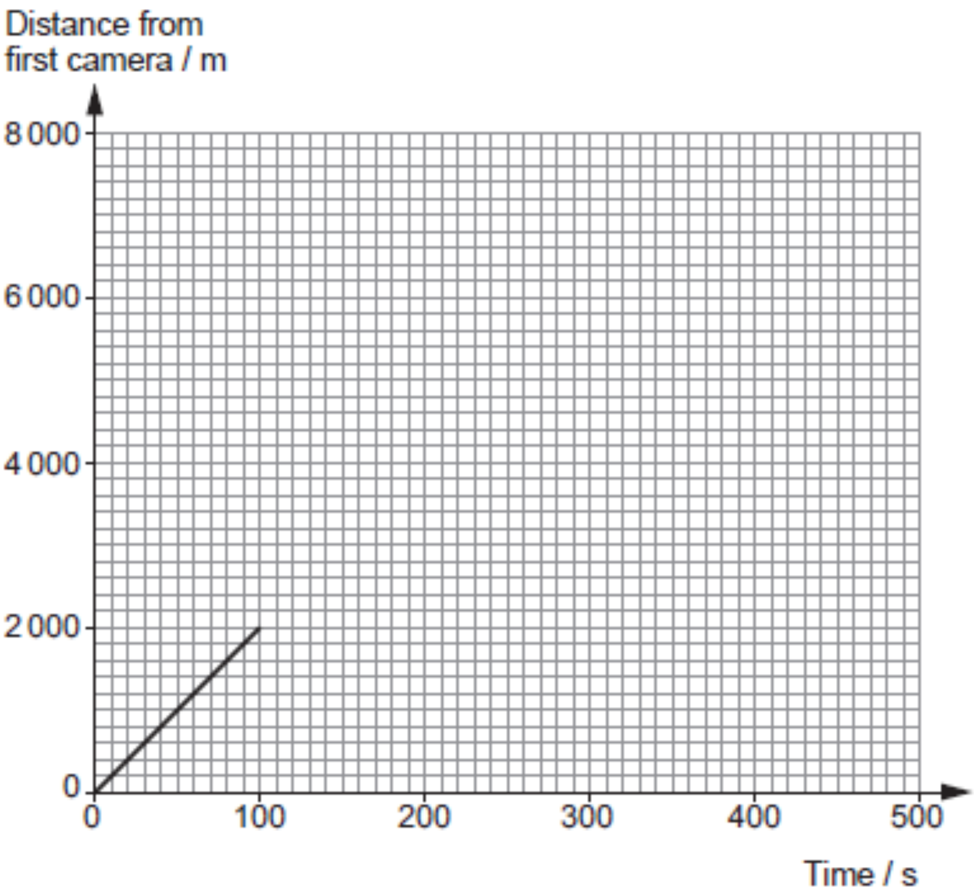
*(b)* Average (or mean) speed areas are now found on many motorways. A section of motorway has a mean speed of 60 km h$^{-1}$. The mean speed is monitored between two cameras placed 8 km apart. The graph shows the first 100 seconds of the motion of a car as it travels between the two cameras.

(i) Show that the instantaneous speed of the car at $t$ = 50 s is approximately 70 km h$^{-1}$. [2]

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(ii) The car covers the 8 km between the two cameras at a mean speed of exactly 60 km h$^{-1}$. Complete the graph to show this motion. [3]
*Space is provided below for your calculations.*

*(c)* On another stretch of motorway, the speed limit is equivalent to 30 m s$^{-1}$. The maximum deceleration a normal car can achieve in dry conditions is assumed to be 8 m s$^{-2}$. Traffic police can estimate the speed of vehicles involved in accidents using the length of the marks made by skidding tyres on the road. In one accident, the skid marks were found to be 85 m long. Investigate whether or not the car that created the skid marks was travelling below the speed limit prior to the accident. [3]

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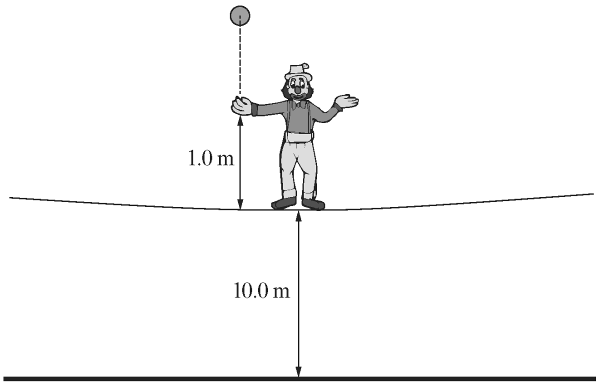
**3.**

*(a)* A circus performer standing on a tightrope 10.0 m above the ground throws a ball vertically upwards at a speed of 6.0 m s$^{-1}$. The ball leaves his hand 1.0 m above the tightrope as shown. *The diagram is not to scale.*




(i) Calculate the maximum height **above the ground** that the ball reaches. [3]

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(ii) The performer fails to catch the ball as it drops. Calculate:

(I) the speed with which the ball hits the ground; [2]

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(II) the **total** time the ball is in the air. [3]

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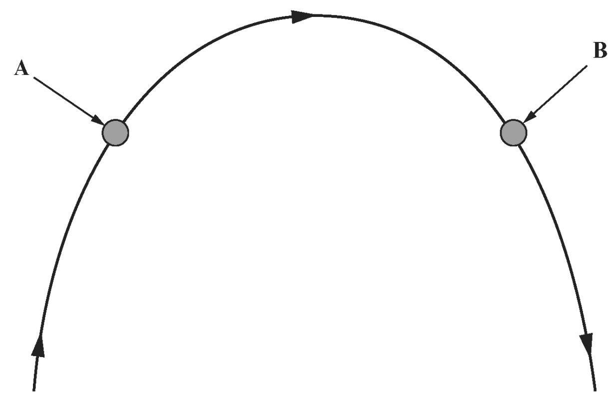
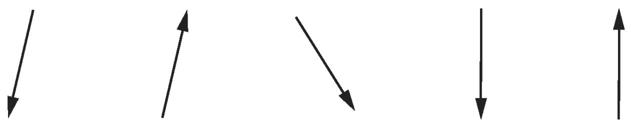
*(b)* Another ball is thrown into the air and follows the path shown. The ball is shown in two places, **A** and **B**.




(i) Assuming the force of air resistance is negligible, circle **one** of the following drawings that shows the direction of the resultant force on the ball when it is at **A**. Explain your answer. [2]



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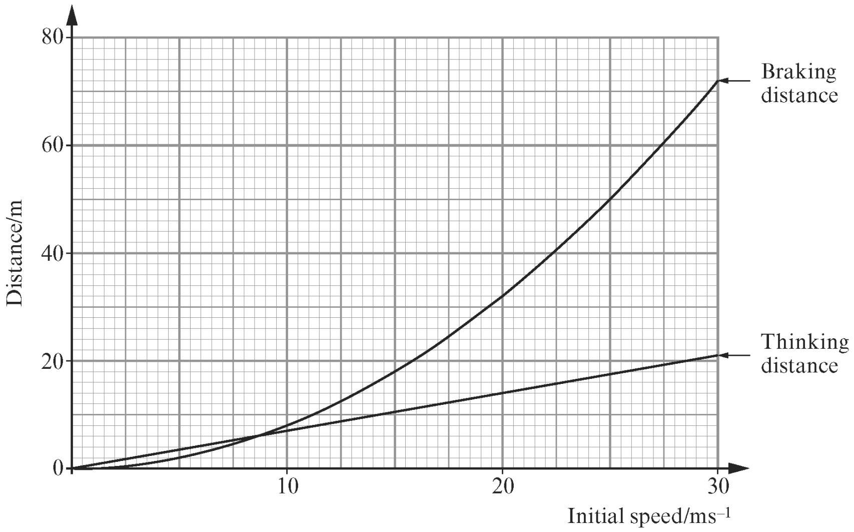
(ii) Assuming the force of air resistance **cannot** be neglected, sketch a diagram below to show the forces acting on the ball as it falls towards the ground in position **B** as shown in the above diagram. [2]

4.

The following graph gives data taken from the 'Highway Code' for 'Thinking' and 'Braking' distances for a car when stopping. Thinking distance is the distance a car travels between the driver seeing an incident and beginning to apply the brakes. Braking distance is the distance a car travels while it is decelerating.




*(a)* The graph of braking distance against speed is curved. Use information from the graph to test whether braking distance is proportional to (initial speed)$^2$. [3]

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*(b)* (i) Calculate the mean deceleration of a car as it slows down from $15\,m\,s^{-1}$ to rest. [3]

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(ii) Hence calculate the mean braking force acting on the car given that it has a mass of 800 kg. [1]

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*(c)* Suggest why the graph of thinking distance against speed is a straight line. [2]

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*(d)* (i) What is the **total** stopping distance for a car initially travelling at $30\,\mathrm{m\,s^{-1}}$? [1]

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(ii) Ineffective brakes would increase the total stopping distance. Explain, in terms of thinking distance and braking distance why this would be the case. [2]

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*(e)* 'Average speed areas' are now found on many motorways. One such stretch of motorway has a speed limit of 50 km/hour. The average speed is monitored between two cameras placed 10 km apart. The driver of a car notes that he has travelled 6.0 km from the first camera at a speed of 80 km/hour. Determine the speed with which he has to travel the remaining 4.0 km in order that his average speed for the whole 10 km is 50 km/hour. [4]

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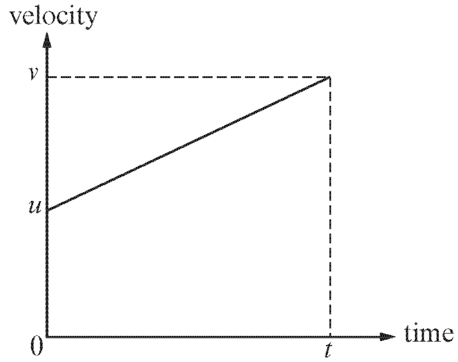
5.

*(a)* A velocity-time graph is given for a body which is accelerating in a straight line.




(i) Using the symbols given on the graph, write down an expression for the gradient and state what it represents. [2]

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(ii) Using the symbols given on the graph, write down an expression for the area under the graph and state what it represents. [2]

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(iii) Hence or otherwise show clearly that, using the usual symbols,

$$x = ut + \tfrac{1}{2}at^2$$ [2]

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*(b)* A cyclist accelerates **from rest** with a constant acceleration of $0.50\,\mathrm{m\,s^{-2}}$ for 12.0 s. Calculate

(i) the distance travelled in this time; [2]

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(ii) the maximum velocity attained. [2]

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*(c)* After 12.0 s, the cyclist stops pedalling and 'freewheels' to a standstill with constant deceleration over a distance of 120 m.

(i) Calculate the time taken for the cyclist to decelerate to a stand-still. [2]

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(ii) Calculate the magnitude of the cyclist's deceleration. [2]

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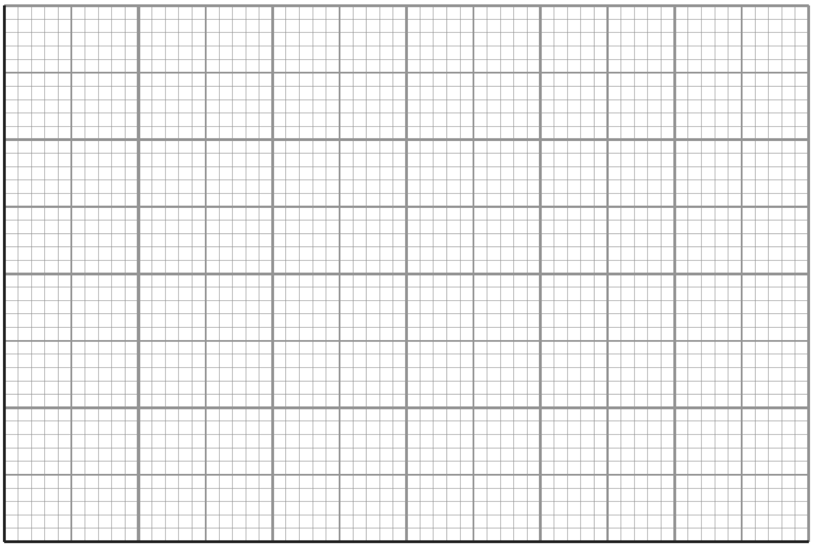
*(d)* Draw an acceleration-time graph on the grid below for the **whole of the cyclist's journey**. [4]



*(e)* In reality the cyclist would not slow down with constant deceleration. This is because the total resistive force acting on the cyclist consists of a constant frictional force of 8.0 N **and** an air resistance force which is proportional to the square of the cyclist's velocity.

(i) When the cyclist was travelling with maximum velocity, the total resistive force acting was 165 N. Calculate the force of air resistance at this velocity. [1]

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(ii) Hence calculate the total resistive force acting when the cyclist is moving at half the maximum velocity. [2]

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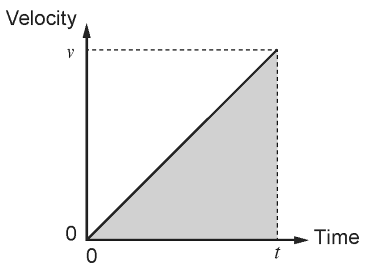
**6.**

*(a)* A velocity-time graph is given for a body which is accelerating from rest in a straight line.




(i) What does the shaded area under the graph represent? [1]

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(ii) Use the graph to show that, using the usual symbols:

$$x = \frac{1}{2}at^2$$

[3]

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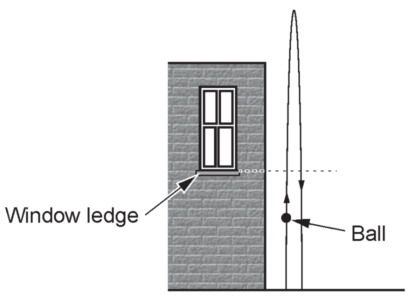
*(b)* A ball is thrown vertically upwards and passes a window ledge 0.3 s after being released. It passes the window ledge on its way back down, 1.6 s **later**. Ignore air resistance.




(i) Determine the time of flight of the ball. [1]

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(ii) Calculate the initial velocity of the ball when it is released. [3]

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(iii) Calculate the height of the window ledge above the ground. [2]

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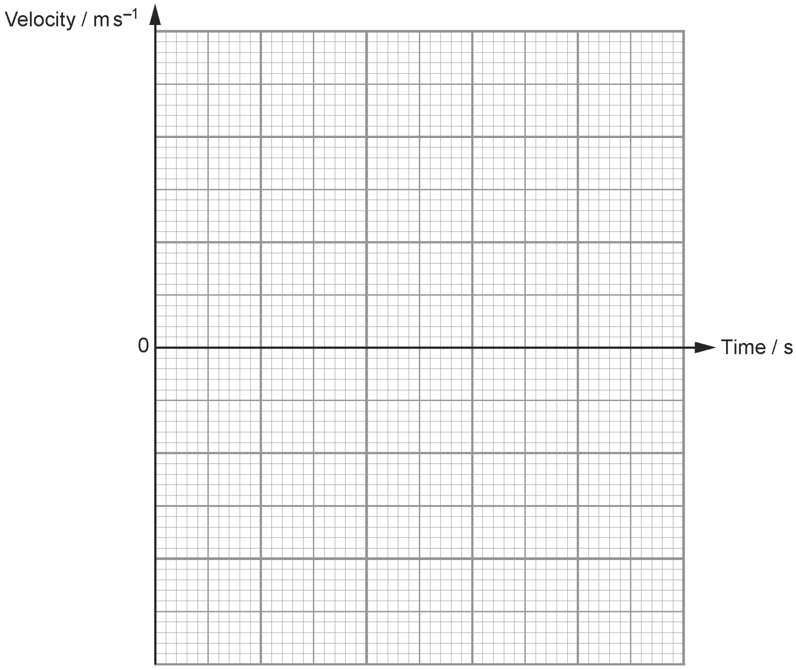
*(c)* Draw, on the grid below, a velocity-time graph for the whole of the ball's flight. Include suitable scales on both axes. [3]




*(d)* In reality, air resistance also acts on the ball. In the spaces provided draw **three** free body diagrams showing the forces acting on the ball at the positions indicated. **Label** these forces. [4]

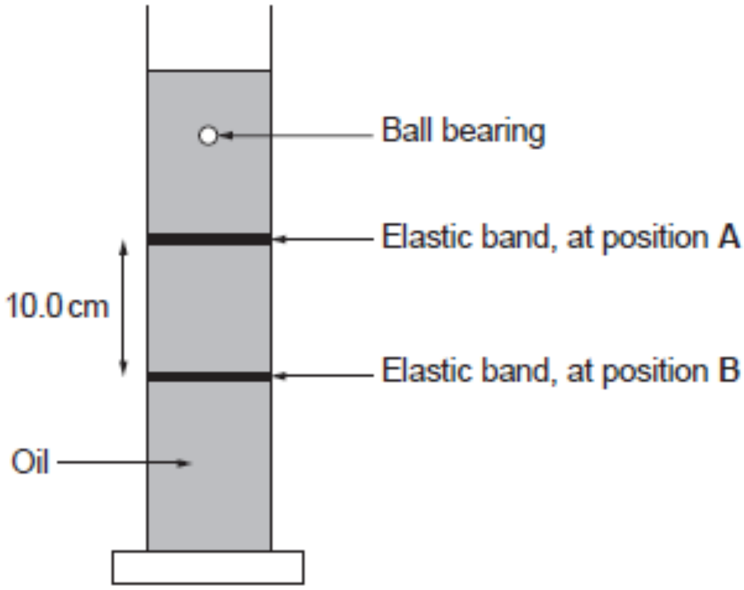
As the ball passes the window ledge **travelling upwards**

At maximum height above the ground

As the ball passes the window ledge **travelling downwards**

7.

6. Emma investigates the viscosity of oil by measuring the terminal velocities of a number of different sized ball bearings as they move through it. She uses the following apparatus.




*(a)* (i) Once released, a ball bearing attains terminal velocity before it reaches the elastic band at position **A**. Explain what is meant by terminal velocity. [1]

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(ii) At terminal velocity the two main forces acting on the ball bearing are its weight and the drag of the oil. According to Newton's third law, for each of these forces there is a corresponding equal and opposite force. Identify each of these forces and the body upon which it acts. [2]

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*(b)* Emma measures the time it takes the ball bearings to fall from the elastic band at position **A** to the elastic band at position **B**. She carries out each measurement twice, and obtains the following results. The distance between the two elastic bands is 10.0 cm. The uncertainty in this distance can be considered negligible when calculating the uncertainty in the terminal velocity.

| Ball bearing | | Time to fall | | | Terminal velocity | |
|---|---|---|---|---|---|---|
| Diameter, $d$ / cm | (Diameter)$^2$, $d^2$ / cm$^2$ | Reading 1 / s | Reading 2 / s | Mean / s | Velocity, $v$ / cm s$^{-1}$ | Uncertainty, $\Delta v$ / cm s$^{-1}$ |
| 0.24 | 0.058 | 14.0 | 14.6 | 14.3 | | ± 0.01 |
| 0.32 | 0.10 | 8.0 | 8.6 | 8.3 | | ± 0.05 |
| 0.40 | 0.16 | 5.3 | 5.9 | | 1.8 | ± |
| 0.48 | 0.23 | 3.6 | 4.1 | | 2.6 | ± |
| 0.64 | 0.41 | 2.2 | 1.9 | 2.1 | 4.8 | ± 0.3 |

Complete the table. *Space has been left for any calculations if needed.* [4]

*(c)* (i) Emma's friend, Fiona, thinks that the terminal velocity, $v$, is directly proportional to the square of the diameter, $d$, of the ball bearing,

$$v \propto d^2.$$

Plot a suitable graph to check whether Fiona is correct. [4]

(ii) Evaluate whether or not Fiona is correct. [2]

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8.

**7.** (a) Ignoring the effects of air resistance, describe how, if at all, the vertical and horizontal components of a projectile's velocity change during flight on Earth. [2]

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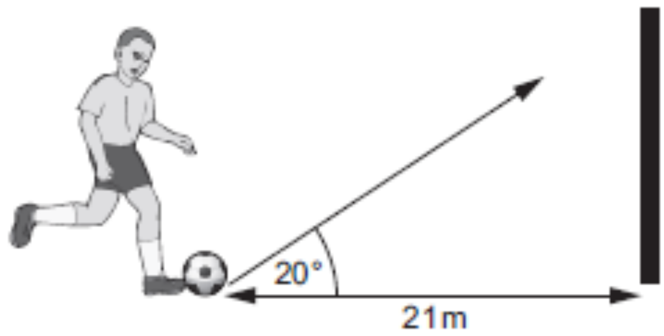
(b) (i) A football player takes a free kick 21 m away from the goal. The ball leaves the ground at an angle of 20°. Show that the velocity he must strike the ball at is approximately 25 m $s^{-1}$ if it is to reach its maximum height at the moment it reaches the goal. *Ignore the effects of air resistance.* [4]

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(ii) The height of the cross bar is 2.44 m above the ground. Justify numerically whether the ball crosses the goal line above or below the bar. [3]

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(iii) Discuss how air resistance might affect the height at which the ball reaches the goal. [2]

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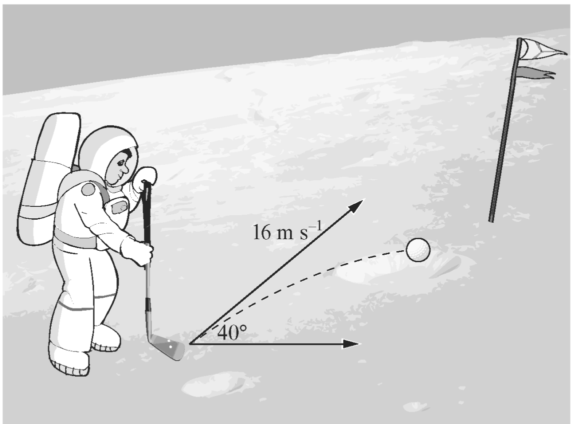
**9.**

The astronauts of Apollo 14 played golf on the Moon. They struck a number of shots such as the one shown below.




*(a)* (i) Calculate the horizontal and vertical components of velocity of the golf ball at the instant it was struck. [2]

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(ii) Describe the essential difference between the horizontal and vertical components of velocity during the flight of the ball. [1]

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*(b)* The acceleration due to gravity on the Moon is $1.6\,m\,s^{-2}$. Assuming the shot is played on horizontal ground, calculate

(i) the total time of flight, [3]

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(ii) the horizontal distance the ball travels, [1]

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(iii) the maximum height reached. [2]

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*(c)* A similar golf shot is played on Earth. Give two reasons why your answer to *(b)*(iii) would be different. [2]

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2. ..........................................................................................................................................

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**10.** (a) (i) Show that v = u + at is consistent with the definition of acceleration.

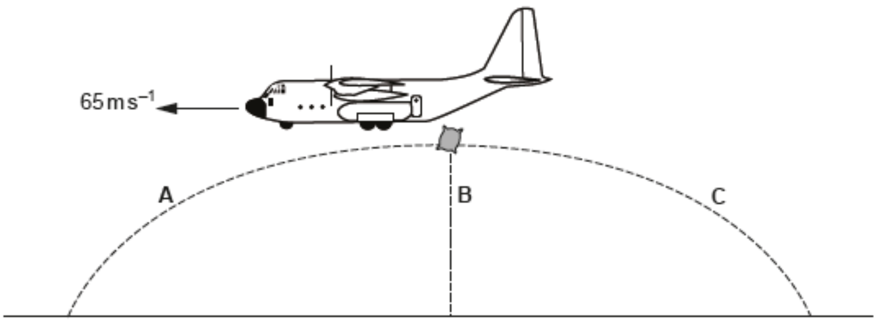
[2]

(ii) x = (u + v)t is another equation of uniformly accelerated motion. Use this equation and v = u + at to show clearly that:

[2]

$$x = ut + \frac{1}{2}at^2$$

(b) The aeroplane shown below is travelling horizontally at 65 m s-1. It is used to drop sacks of flour as emergency supplies. A sack is shown at the instant it is released from the low flying aeroplane. Ignore air resistance for this question. The diagram is not to scale.




(i) A villager standing to the side observes the flight path of the sack. Which path, A, B or C shows the path of the sack? Explain your answer.

[3]

ii) (I) To avoid damaging the sack, the maximum vertical component of the sack's velocity must not exceed 30 m s-1. Show that the maximum height from which the sack can be dropped is about 46 m.

[2]

(II) Calculate the time taken for the sack to reach the ground if it is dropped from a height of 46 m.

[2]

(iii) Calculate the resultant velocity of the sack on impact with the ground when it is dropped from 46 m.

[3]