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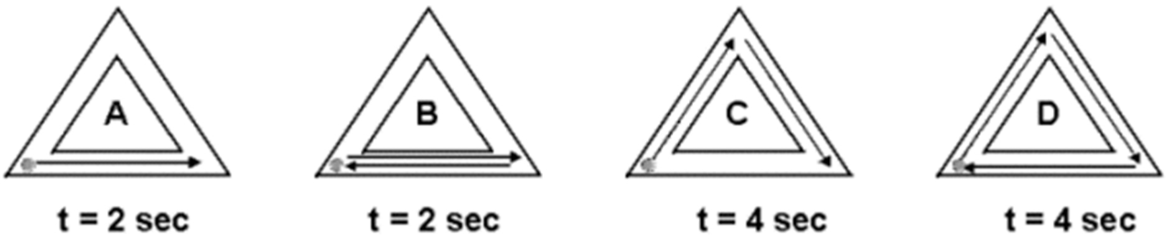
Assignment 03: Kinematics

(1) Four different mice (labelled **A**, **B**, **C**, and **D**) ran the equilateral triangular maze shown in the diagram below. They started in the lower left corner and followed the paths of the arrows. The times they took are also shown in the diagram.



State which mouse/mice fits/fit the following description.

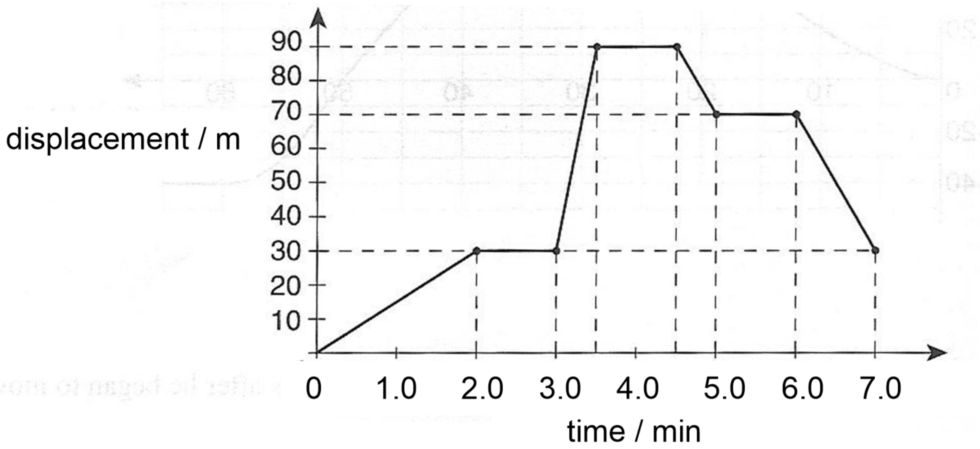
(a) This mouse had the greatest average speed. [1]

(b) These two mice had the same greatest change of displacement. [1]

(c) These two mice had an average velocity that points to the right. [1]

(d) This mouse had the greatest average velocity. [1]

(2) Randall was taking Lucky, his dog, for a walk early in the morning towards the rising Sun, when he decided to take note of their displacement with respect to time. He plotted the following graph as shown below.

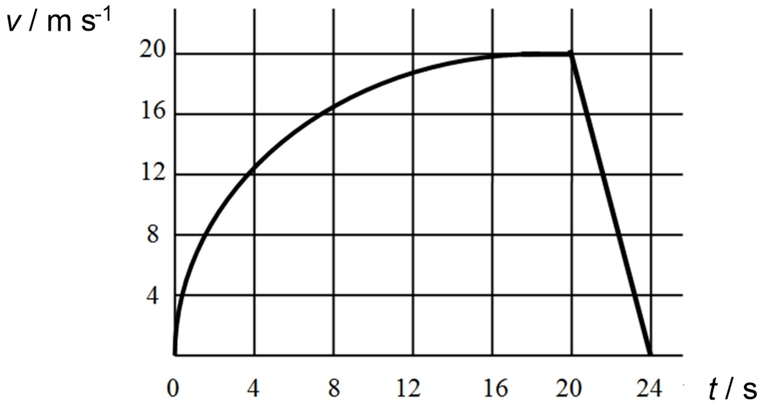


(a) Calculate the velocity of Randall and Lucky during the first 2.0 minutes, in m s^{-1}. [2]

(b) Calculate the total distance covered by Randall in 7.0 minutes. [1]

(c) What is the change of displacement of Randall and his dog at the end of the 7.0 min walk? [1]

(3) The diagram shows a graph of the variation of the velocity v with time t for an object moving in a straight line.



(a) Describe the acceleration of the object from t = 4 s to t = 16 s. [1]

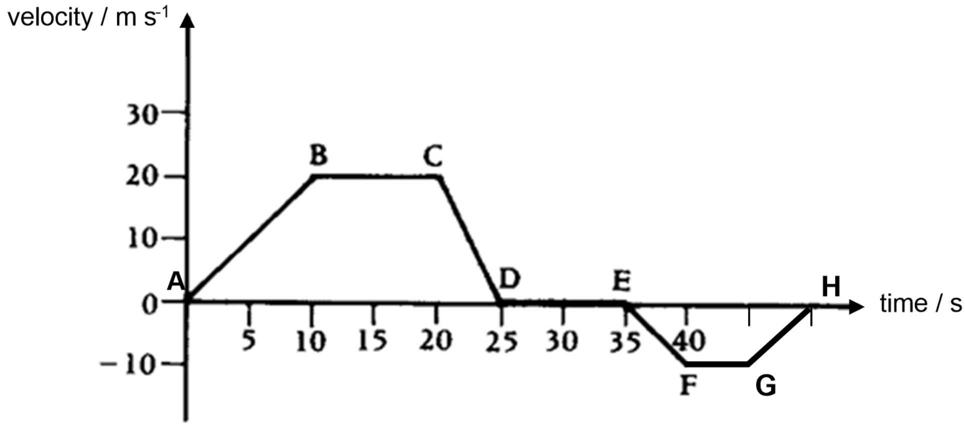
(b) State the velocity of the object when its acceleration is

(i) at its maximum value, velocity = ___________

(ii) zero. velocity = ___________ [2]

(c) Calculate the rate of change of velocity of the object during the last part of its motion. [1]

(4) The diagram shows how the velocity of a body moving in a straight line varies over a period of time. Take positive velocity to be the rightward direction.



(a) Identify and state the region(s) for each motion of the body below. [6]

(i) speed increases at a constant rate

(ii) non-zero constant velocity

(iii) speed decreases at a constant rate

(iv) zero velocity

(v) constant positive acceleration

(vi) constant negative acceleration

(b) Describe the acceleration of the body over the region marked **EF** on the graph. [1]

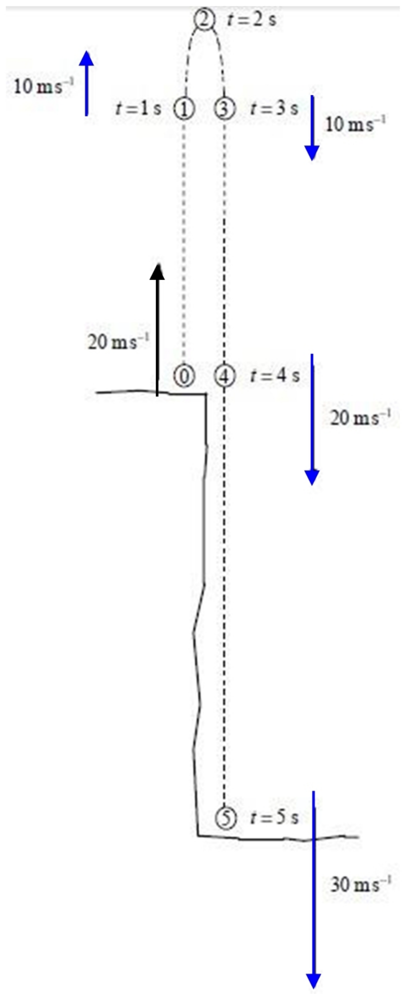
(c) Explain how the *distance travelled by the body* and the *change of displacement of the body* is determined from the graph over a duration of 50 s. [2]

Distance travelled is determined by finding ______________________________. [1]

Change of displacement is determined by finding ______________________________. [1]

(d) Determine the average velocity over the region **AF**. [2]

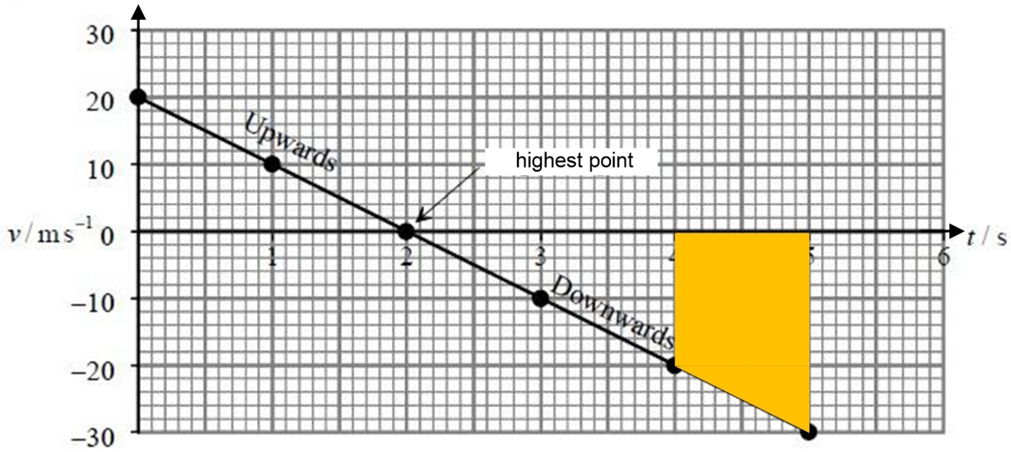
(5) A stone is projected almost vertically upwards at 20 m s^{-1} from the edge of a cliff. It finally lands on the ground at the base of the cliff. The sequence diagram below shows the position of the stone at one-second intervals. Position 0 is just after projection and position 5 is just before landing. Gravitational acceleration is taken as 10 m s^{-2} and air resistance is ignored.



(a) Draw in a vector **next to** positions 1, 3, 4 and 5 to represent the **instantaneous velocity** at that stage of the motion.

The vector at position 0 has been drawn for you. Pay attention to the direction and **relative lengths** of the vectors, and label them with their magnitudes, in m s^{-1}. [2]

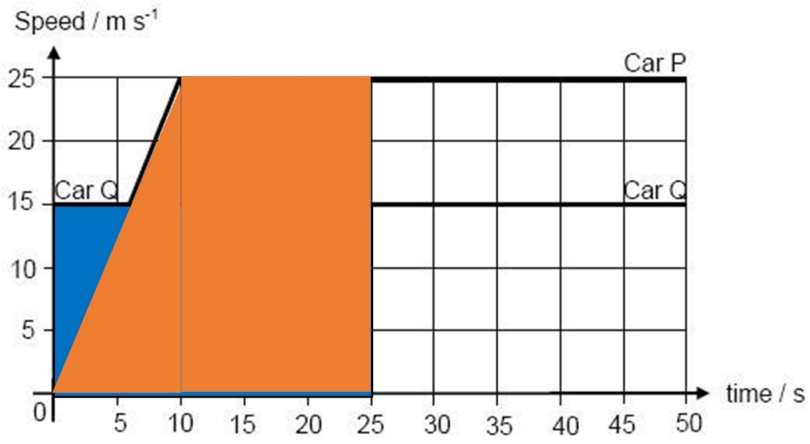
(b) On the diagram below, draw a velocity–time graph to represent the motion of the stone. Label the stages representing the **upwards motion** and the **downwards motion** and also label the **highest point** of the motion. Take positive velocity to be upward direction. [2]



(c) What does the gradient of the graph represent? [1]

(d) Determine the height of the cliff, in m. [2]

(6) A straight road links point **A** to point **B**. Car **P** moves from point **A** to point **B** while car **Q** moves from point **B** to point **A** as shown in the diagram below. The diagram also shows the speed-time graph of the two cars.



(a) Describe the acceleration of car **P** from time = 0 s to time = 50 s. [2]

(b) The two cars met at time = 25 s.

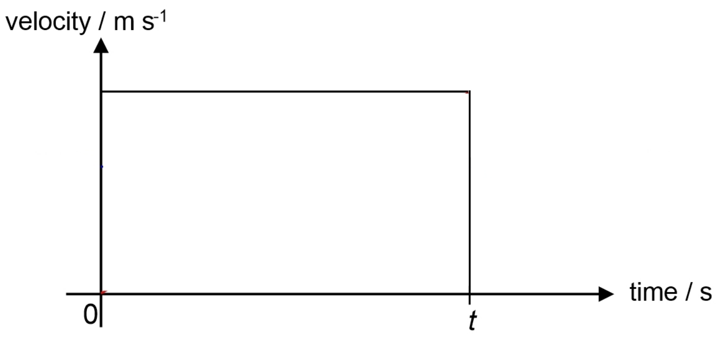
(i) What is the numerical difference in the speed between car **P** and car **Q** at the time when the cars met? [1]

(ii) What is the numerical difference in the velocity between car **P** and car **Q** at the time when the cars met? [1]

(c) Determine the distance between point **A** and point **B**. [2]

(7) A speeding car is travelling at a constant speed of 30.0 m s^{-1} when it passes a police car which is parked at the road shoulder. The police car then accelerates from rest at 7.0 m s^{-2}.

(a) On the diagram below, sketch the velocity-time graph for both cars for a period of t seconds. Assume the police car had a speed of v m s^{-1} at time = t seconds and v is greater than 30.0 m s^{-1}. [2]



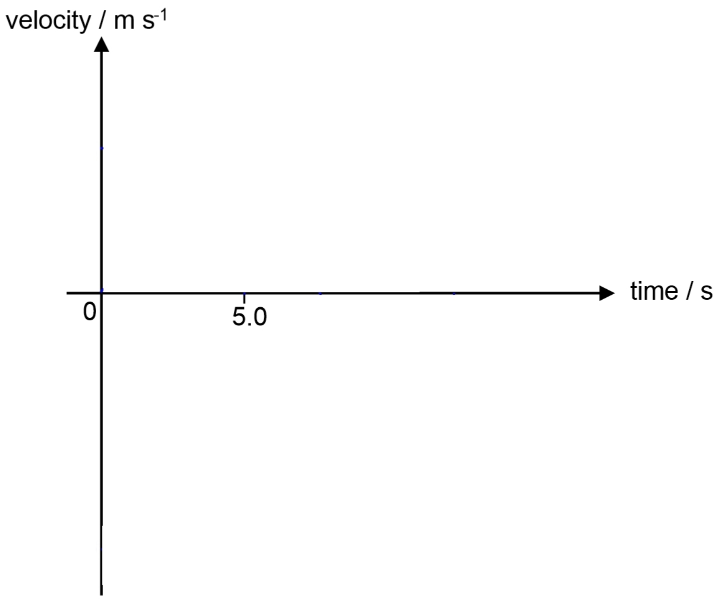
(b) Hence or otherwise, determine the velocity of the police car when it catches up with the speeding car. [2]

(8) A model rocket on the ground is launched vertically **from rest**. Its engine delivers a constant acceleration of 8.2 m s^{-2} for 5.0 s. Thereafter, the fuel is used up. Assume that air resistance is negligible. Take acceleration due to gravity = 10 m s^{-2}.

After the fuel is used up, the rocket continues to coast upward, reaching a maximum height before falling back to the ground.

(a) Sketch a velocity-time graph to show the variation of the velocity with time of the rocket's motion from the launch until it reaches back to the ground. [3]

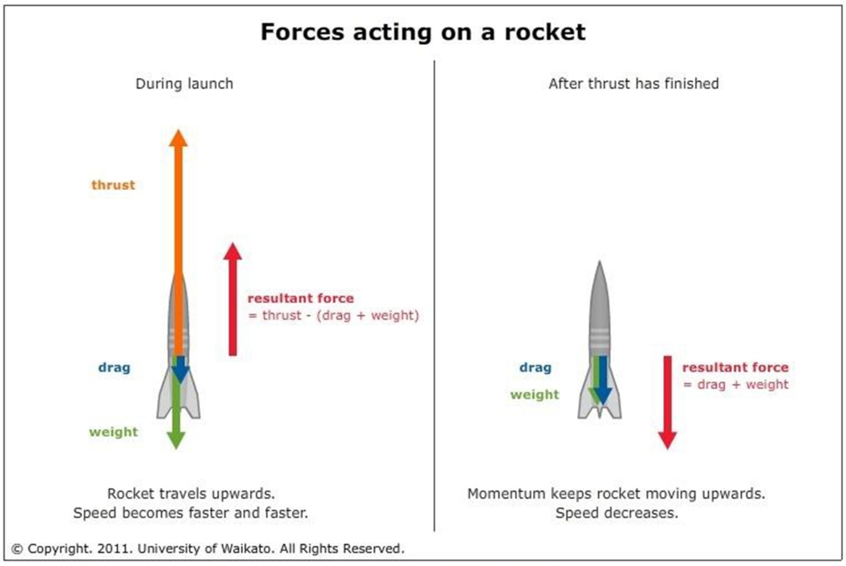
Let V_A be the velocity of the rocket at 5.0 s and V_B be the velocity of the rocket just before it hits the ground. Take positive velocity to be upward direction.



(b) Calculate the maximum height reached by the rocket. [4]

(c) Calculate the total time the rocket is in flight until it reaches the ground. [3]

In this question, we assumed air resistance to be negligible. In reality, air resistance (i.e. drag force) acts on the rocket when it moves up and falls down.



Source: https://www.sciencelearn.org.nz/images/399-rocket-forces

A rocket has three main forces acting on it during lift-off. The resultant force is the sum of these forces. The rocket will speed up (or slow down) in the direction of the resultant force.

Additional Practice

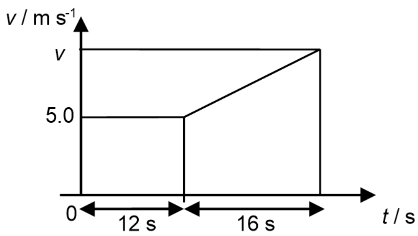
(9) A race car travels on a racetrack at 44 m s^{-1} and slows at a constant rate to a velocity of 22 m s^{-1} over 11 s. How far does it move during this time? [2]

(10) A truck travels with a uniform velocity of 18 km h^{-1} for 12 s. It then accelerates constantly at 1.5 m s^{-2} for 16 s.

Determine

(a) the total distance travelled by the truck, in m, [2]

(b) the final velocity of the truck, in m s^{-1}. [2]



(11) Tim drops a book from a vertical height of 10.0 m above the ground. Assume air resistance is negligible and the acceleration due to gravity is 10 m s^{-2}.

(a) Calculate the time the book takes to hit the ground. [2]

(b) Calculate the velocity of the book just before it hits the ground. [2]

$v^2 = u^2 + 2a(\Delta s)$