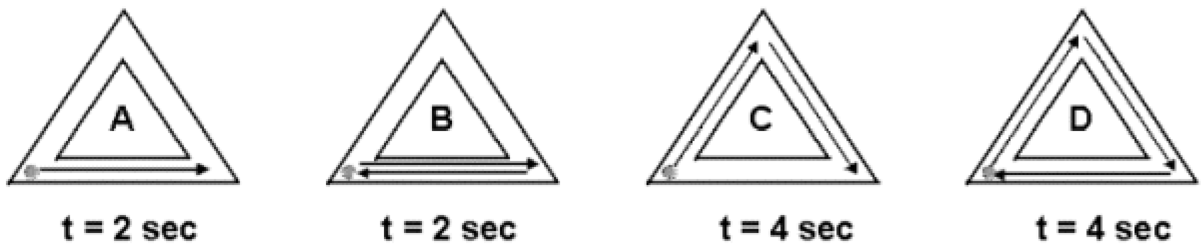
**Name:** **Index No:**

**Date:** **Class:**

## 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.** Total distance travelled per unit time is the greatest.

A: $s/2$
B: $2s / 2 = s$
C: $2s / 4 = s/2$
D: $3s / 4$

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

**A and C.** Both have the same change of displacement (i.e. their final positions are at lower right corner). B and D have zero change of displacement.

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

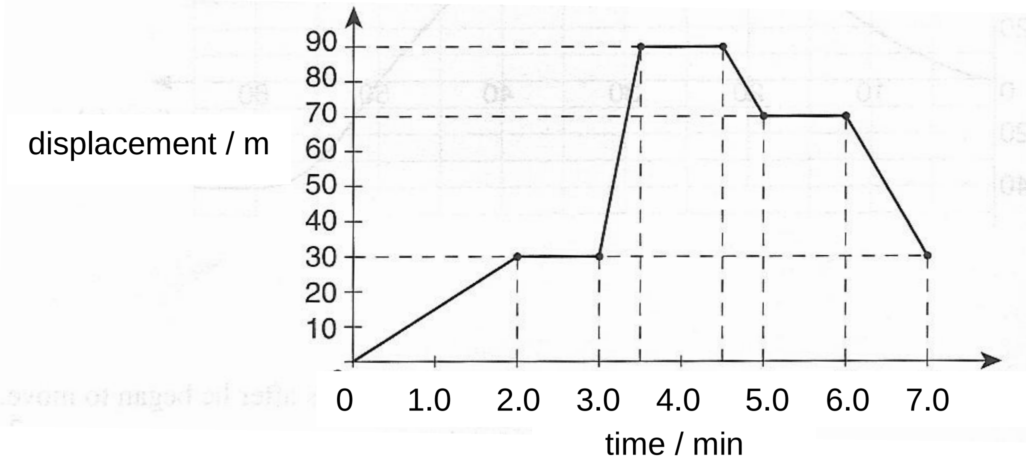
**A and C.** Both have the same change of displacement which points to the right.

[For C, use addition of vectors to get change of displacement.]

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

**A.** For the same change of displacement for A and C, A takes a shorter time.

(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]

velocity = (30 – 0) / [(2.0 – 0) x 60] [1]
= 0.25 m $s^{-1}$ [1] [only need magnitude]

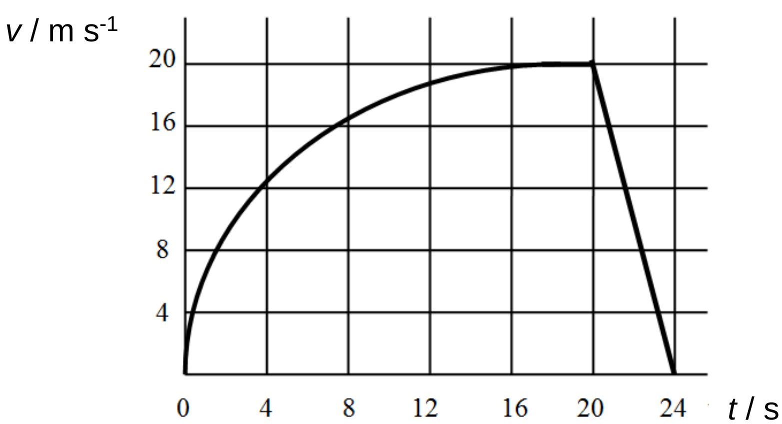
(b) Calculate the total distance covered by Randall in 7.0 minutes. [1]

total distance covered = 90 + 60
= 150 m [1]

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

change of displacement = 30 m, towards the rising Sun or due East [state direction] [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]

Acceleration is decreasing and positive.

[DO NOT write "accelerate at a decreasing rate" because acceleration is already a rate. Instead, decreasing acceleration has the same meaning as **velocity** increasing at a decreasing rate.]

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

(i) at its maximum value, velocity = $0\ m\ s^{-1}$

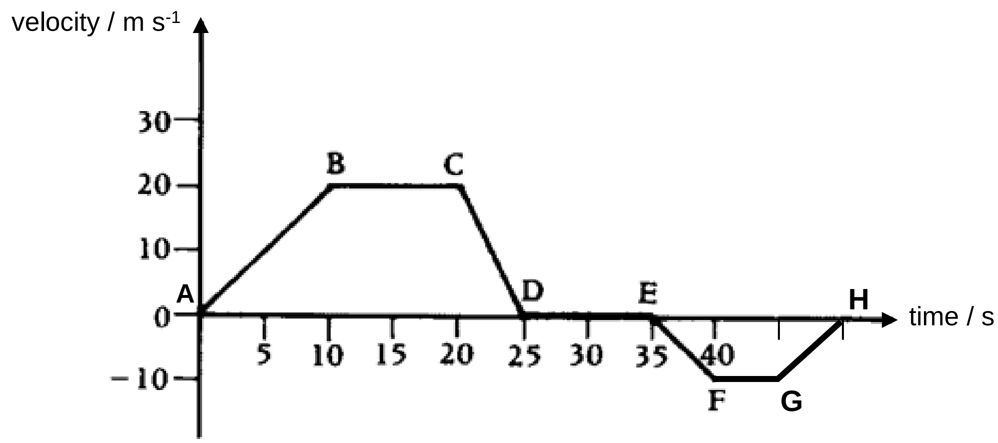
(ii) zero. velocity = $20\ m\ s^{-1}$ [2]

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

$a$ = (0 - 20) / (24 - 20)
= - 5 m $s^{-2}$

∴ Rate of change of velocity is - 5 m $s^{-2}$.

(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]

| | | Region(s) |
|---|---|---|
| (i) | speed increases at a constant rate | AB (const +ve acceleration in +ve velocity direction)<br>EF (const -ve acceleration in -ve velocity direction) |
| (ii) | non-zero constant velocity | BC (zero acceleration in +ve velocity direction)<br>FG (zero acceleration in -ve velocity direction) |
| (iii) | speed decreases at a constant rate | CD (const -ve acceleration in +ve velocity direction)<br>GH (const +ve acceleration in -ve velocity direction) |
| (iv) | zero velocity | DE (stationary) |
| (v) | constant positive acceleration | AB (v ↑ as it moves in +ve velocity direction)<br>GH (v ↓ as it moves in -ve velocity direction) |
| (vi) | constant negative acceleration | CD (v ↓ as it moves in +ve velocity direction)<br>EF (v ↑ as it moves in -ve velocity direction) |

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

Constant negative acceleration OR
Constant acceleration (of 2 m $s^{-2}$) to the left (in the leftward direction)
[acceleration = (-10 - 0) / (40 - 35) = - 2 m $s^{-2}$]
[Wrong: Constant deceleration. It is speeding up in the opposite direction, not slowing down.]

(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 the sum of area ABCD and area EFGH. [1]

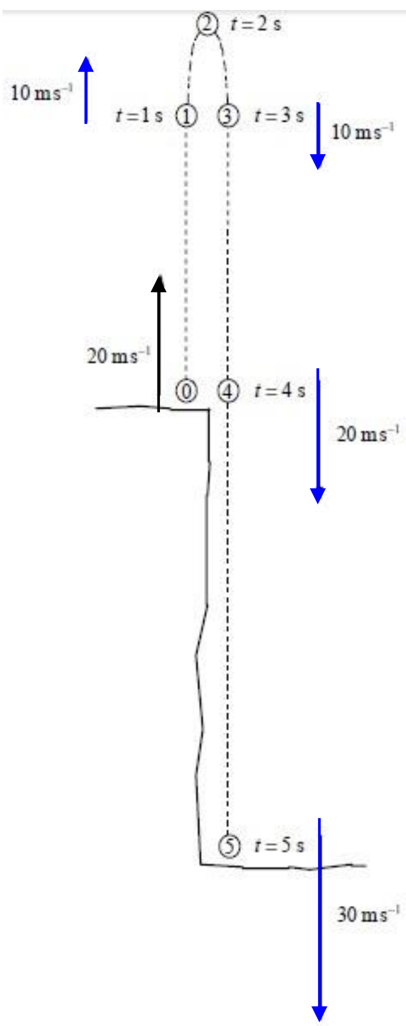
Change of displacement is determined by finding the difference of area ABCD and area EFGH. [1]

Since the graph shows the body changing its direction of motion (from E to H, object is moving to the left), this means the distance travelled by the body is greater than its change of displacement.

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

average velocity over AF = change of displacement / total time
= [½ (20)(10 + 25) – ½ (5)(10)]/40 [1]
= [350 – 25] / 40
= 8.1 m/s (to 2 s.f.), to the right [Give magnitude and direction.] [1]

(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.

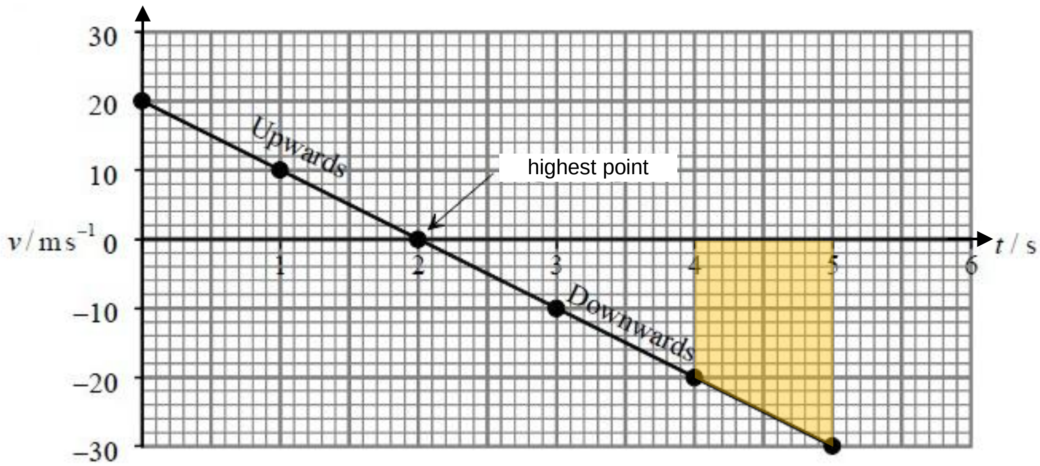
The vector at position 0 has been drawn for you. Pay attention to the direction and **relative lengths** of the vectors, and label them with their magnitudes, in m $s^{-1}$. [2]

Any 2 correct vectors (direction and relative vector length): [1]

All 4 correct vectors (direction and relative vector length): [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]

Correct graph: [1] Correct labels: [1]



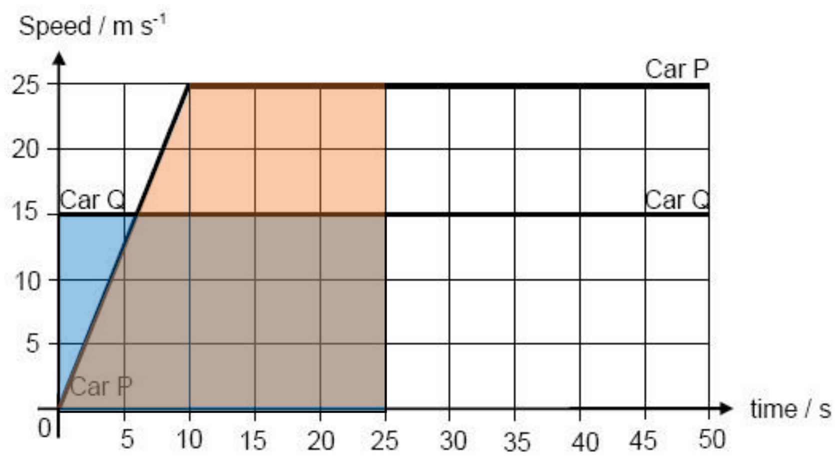

(c) What does the gradient of the graph represent? [1]

Stone's acceleration / Acceleration due to gravity / Acceleration of free fall
[Apply to context instead of just writing acceleration.]

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

Height of cliff = change of displacement from $t$ = 4 s to $t$ = 5 s
= area of trapezium
= ½ (5 - 4)(20 + 30) [1]
= 25 m [1]

(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]

From time = 0 s to time = 10 s, car P undergoes <u>constant positive acceleration</u> (or constant acceleration of 2.5 m $s^{-2}$). [1]

From time = 10 s to time = 50 s, its <u>acceleration</u> is <u>zero</u>. [1]
[X: 0 acceleration. Write out the term.]

(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]

25 – 15 = <u>10 m $s^{-1}$</u> [Necessary to write the units.]

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

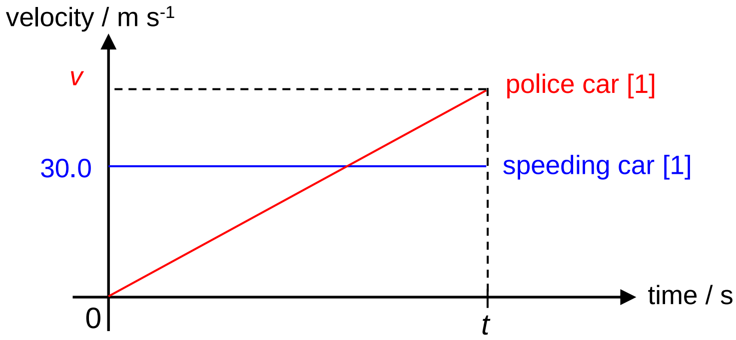
25 – (- 15) = <u>40 m $s^{-1}$</u>

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

distance between A and B = distance travelled by car Q + distance travelled by car P
= <u>(15 x 25)</u> + [(½ x 25 x (15 + 25)] [1]
(gives 380 to 2 s.f.)
= 375 + 500
= <u>880 m</u> (correct to 2 s.f.) [1] [Accept 875 m]

(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]

When the police car catches up with the speeding car, both had the <u>same change of displacement</u>, $\Delta s$ <u>for</u> the <u>same time interval</u>, $\Delta t$.

$[v_1(\Delta t)] = \frac{1}{2}(\Delta t)(u_2 + v_2)$
$(30.0)(\Delta t) = \frac{1}{2}(\Delta t)(0 + v_2)$ [1]
$v_2 = \underline{60.0 \text{ m s}^{-1}}$ [1]

<u>Alternatively,</u>
$\Delta s_c = (30.0)(\Delta t)$
$\Delta s_p = \frac{1}{2}(7.0)(\Delta t)^2$ [initial velocity, $u = 0$]

Equate both change of displacements,
$(30.0)(\Delta t) = \frac{1}{2}(7.0)(\Delta t)^2$
$3.5(\Delta t)^2 - 30.0(\Delta t) = 0$
$[3.5(\Delta t) - 30.0](\Delta t) = 0$

$\Delta t = 0$ s or 8.571 s

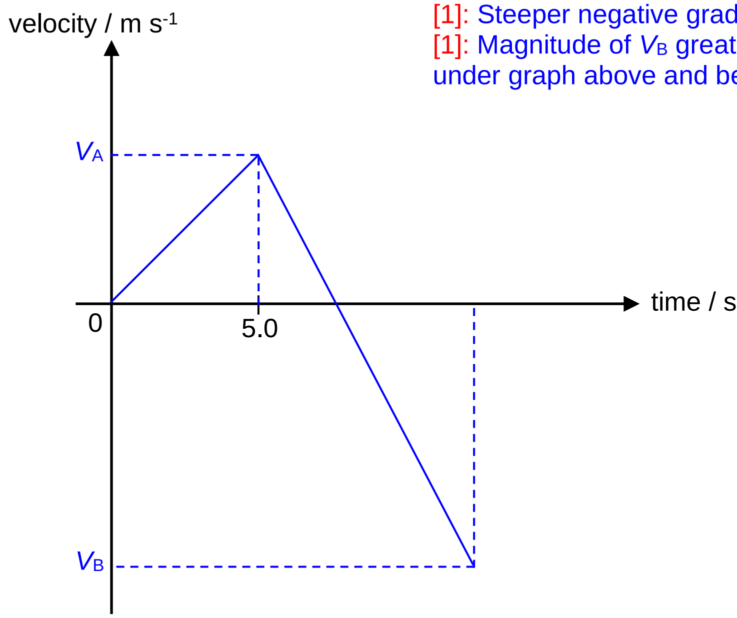
Sub $\Delta t = 8.571$ s: $v = 0 + (7.0)(8.571)$
$= \underline{60 \text{ m s}^{-1}}$ (to 2 s.f.)

(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.




[1]: Positive gradient line from v = 0 m $s^{-1}$ to $V_A$.
[1]: Steeper negative gradient line from $V_A$ to $V_B$.
[1]: Magnitude of $V_B$ greater than $V_A$. (about same area under graph above and below time axis.)

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

$V_A$ = (0 m $s^{-1}$) + (8.2 m $s^{-2}$)(5.0 s) [1]
= 41 m $s^{-1}$

When the fuel is used up after 5.0 s, the rocket continues to move up with an acceleration of -10 m $s^{-2}$.

Let $\Delta t$ be time taken from 5.0 s to the time rocket reaches maximum height.

0 m $s^{-1}$ = (41 m $s^{-1}$) + (- 10 m $s^{-2}$)($\Delta t_1$) [1]
$\Delta t_1$ = 4.1 s

Maximum height = ½ (5.0 s + 4.1 s)(41 m $s^{-1}$) [1]
= 186.55
= <u>190 m</u> (to 2 s.f.) [1]

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

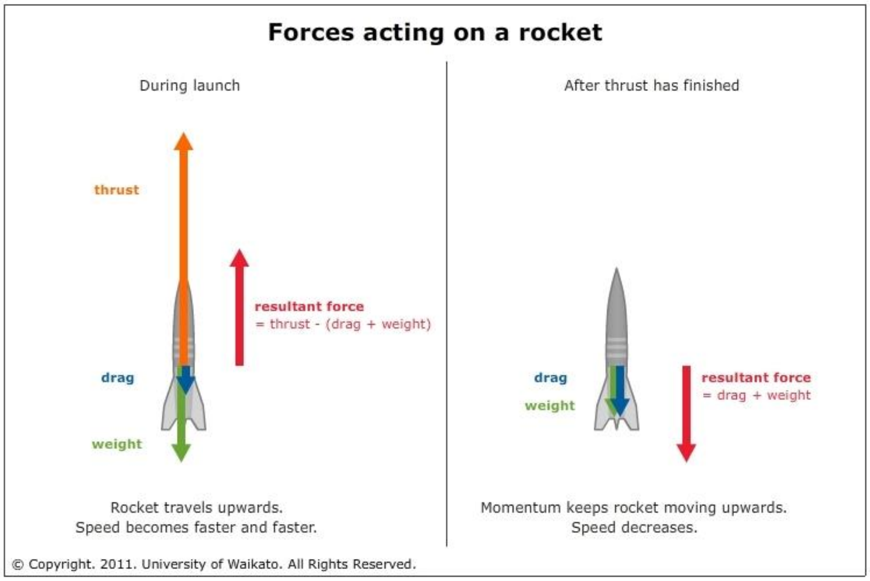
The rocket travelled up and down by the same distance. Let $\Delta t_2$ be the time taken for the rocket to reach the ground from the maximum height.

$\Delta s = (u)(\Delta t) + ½ (a)(\Delta t)^2$

-186.55 m = (0 m $s^{-1}$)($\Delta t$) + ½ (-10 m $s^{-2}$)($\Delta t$)$^2$ [1]
$\Delta t$ = 6.108 s

Total time rocket is in flight = 6.108 s + 9.1 s [1]
= 15.2 s (to 1 d.p.) [1]

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]

$\Delta s$ = ½ $(\Delta t)(u + v)$
= ½ (11)(44 + 22) [1]
= 360 m (to 2 s.f.) [1]

(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

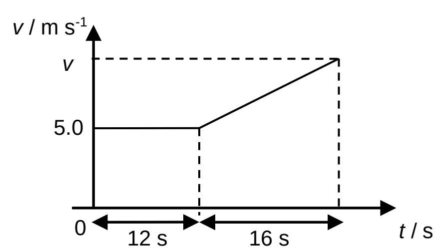
(a) the total distance travelled by the truck, in m, [2]

18 km h$^{-1}$ = (18 000 m) / 3600 s = 5.0 m s$^{-1}$ (Don't miss out ".0" during conversion.)

total distance travelled = $\Delta s_1$ (constant velocity) + $\Delta s_2$ (constant acceleration)
= $[v_1(\Delta t_1)] + [u_2(\Delta t_2) + \frac{1}{2} a_2 (\Delta t_2)^2]$
= [5.0 x 12] + [5.0 x 16 + ½ (1.5)16$^2$] [1]
= 60 + [80 + 192] (gives 190 to 2 s.f.)
= 330 m (to 2 s.f.) [1] [Accept 332 m.]

Alternatively, draw a *v*-*t* graph and find the area under the graph.

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




$v$ = $u + a(\Delta t)$
= 5.0 + (1.5 x 16) [1]
= 29 m s$^{-1}$ (to 0 d.p.) [1]

(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]

$\Delta s = u(\Delta t) + ½\, a(\Delta t)^2$
10.0 = ½ (10)$(\Delta t)^2$ [1] [$u$ = 0][Take 10 m $s^{-2}$ to be a constant ∴ ignore s.f.]
$\Delta t$ = 1.41 s (to 3 s.f.) [1]

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

$v^2 = u^2 + 2a(\Delta s)$
$v^2$= 2(10)(10.0) [1]
$v$ = 14.1 m $s^{-1}$ (to 3 s.f.)[1]