Name: ______________________________________ Class: __________ Date: ___________

Sec 3 Physics

Worksheet 7: Vectors & 1-D Kinematics

SECTION A: CONCEPTUAL QUESTIONS

1. Does a car speedometer measure speed, velocity or both?

A speedometer measures the speed.

2. Can an object have a varying speed if its velocity is constant? If yes, give examples.

No. Constant velocity means that the magnitude and direction components are constant, as such, a varying speed is impossible.

3. When an object moves with constant velocity, does its average velocity during any time interval differ from its instantaneous velocity at any instant?

No. Average velocity = instantaneous velocity = constant velocity

4. If object A has a greater speed than object B, does object A necessarily have a greater acceleration?

No, speed and acceleration are two different physical quantities. We can give many counter-examples. E.g. A is thrown vertically downwards while B is dropped from rest at the same time; both objects will have the same acceleration but A will have a greater speed.

5. As a freely falling object speeds up, what is happening to its acceleration due to gravity – does it increase, decrease or stay the same?

Acceleration stays constant at 9.81 ms^{-2}.

6. Can an object have zero velocity and non-zero acceleration at the same time? Give examples.

Yes. An object thrown vertically upwards will have a zero velocity at the maximum height (turning point) but its acceleration at any instant is 9.81 m s^{-2} downwards. (The object is free-falling even if it is being thrown upwards.)

7. Can an object have zero acceleration and non-zero velocity at the same time? Give examples.

Yes, any object undergoing constant velocity satisfies the condition.

8. *Describe in words, the motion plotted in Figure 1 in terms of v, a etc. [Hint: try to think about the slope of the graph and how the slope varies with time.]

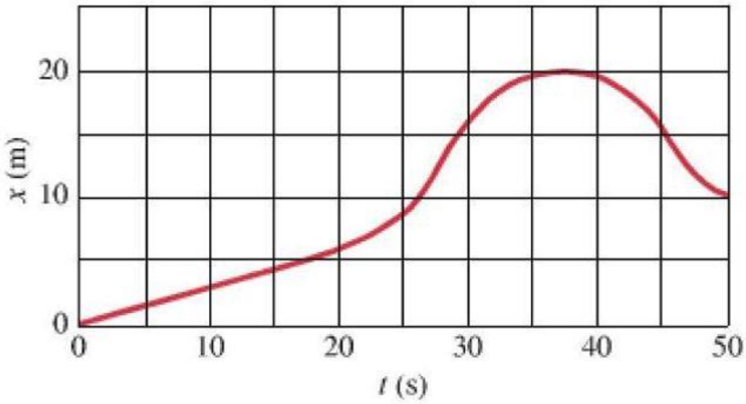


Figure 1

t = 0 to t = 20s:	Displacement: increases from 0 to about 6 m. Velocity: constant at about 0.3 m s^{-1}. Acceleration is zero.
t = 20s to t = 27.5s	Displacement increases to about 12 m. Velocity is increasing and positive with respect to displacement. Acceleration is positive with respect to displacement.
t = 27.5s to t = 37.5s	Displacement increases to 20 m. Velocity is decreasing but still positive with respect to displacement. At t = 37.5 s, velocity is zero. Acceleration is negative with respect to displacement.
t = 37.5s to t = 45 s	Displacement decreases to about 15 m. Magnitude of velocity is increasing and negative with respect to displacement. Acceleration is negative with respect to displacement.
t = 45s to t = 50s	Displacement decreases to 10 m. Velocity is increasing but still negative with respect to displacement. Acceleration is positive with respect to displacement.

9. **Describe in words, the motion of the object graphed in Figure 2.

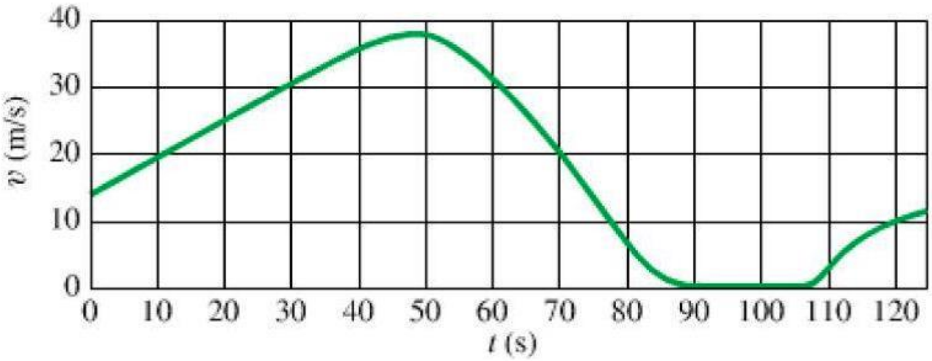


Figure 2

t = 0 to t = 30s	Displacement increases to about $\frac{1}{2}(15+30)(30) = 675$ m and positive with respect to velocity. Velocity increases linearly from about 15 m s^{-1} to 30 m s^{-1}. Acceleration is constant and positive with respect to velocity.
t = 30s to t = 50s	Displacement increases to about 1350 m. (Estimate by area of squares) Velocity is still increasing and reaches a maximum of about 38 m s^{-1} at about t = 48s. Acceleration is decreasing but positive with respect to velocity.
t = 50s to t = 70s	Displacement continues to increase to about 1930 m. (Estimate by area of squares) Velocity is decreasing and is about 20 m s^{-1} at t = 70 s. Acceleration is decreasing and negative with respect to velocity.
t = 70s to t = 90s	Displacement continues to increase to about 2130 m. (Estimate by area of squares) Velocity is decreasing and is zero at t = 90 s. Acceleration is decreasing and negative with respect to velocity.
t = 90s to t ~ 107s	Displacement remains at about 2130 m. (object stops) Velocity is zero. Acceleration is zero.
t ~ 107s to t = 125s	Displacement increases to about 2230 m. (Area estimate) Velocity increases to about 11 m s^{-1}. Acceleration has a decreasing trend and is positive with respect to

	velocity.

10. Sometimes, a word used in layman's speech can be different when it is used in a Physics context. Explain how the words *inertia* and *acceleration* can mean differently when used in Physics and in layman's speech.

Inertia in layman's speech often refers to a state of rest or a state of reluctance to move / act. In Physics, the law of inertia describes the motion of objects either in a state of rest or moving with constant velocity; the latter state is not used in layman's speech.

Acceleration in layman's speech is often associated with objects moving faster and faster. In Physics, acceleration can refer to both the object speeding up or slowing down.

SECTION B: STRUCTURED QUESTIONS

1 An airplane travels 3100 km at a speed of 790 km h^{-1}, and then encounters a tailwind that boosts its speed to 990 km h^{-1} for the next 2800 km.

a What was the total time for the trip?

$$\text{Total time} = \frac{3100}{790} + \frac{2800}{990}$$
$$= 6.8 \text{ h}$$

b What was the average speed of the airplane for the trip?

$$\langle v \rangle = \frac{\text{Total distance}}{\text{Total time}}$$
$$= \frac{3100 + 2800}{6.8}$$
$$= 874$$
$$= 870 \text{ km h}^{-1} \qquad \text{(corrected to 2sf)}$$

2 *A car travelling 88 km h^{-1} is 110 m behind a truck travelling 75 km h^{-1}. How long will it take the car to reach the truck?

$$\text{Relative speed} = \frac{(88 - 75)}{3.6}$$
$$= 3.61 \text{ m s}^{-1}$$

$$\text{Time taken to overtake} = \frac{\text{Relative distance}}{\text{Relative speed}}$$
$$= \frac{110}{3.61}$$
$$= 30 \text{ s} \qquad \text{(corrected to 2sf)}$$

3 ** A bowling ball travelling with a constant speed hits the pins at the end of a bowling lane 16.5 m long. The bowler hears the sound of the ball hitting the pins 2.50 s after the ball is released from his hands. What is the speed of the ball? The speed of sound is 340 m s^{-1}.

$$\text{Time taken for the ball to roll} = 2.50 - \frac{16.5}{340}$$
$$= 2.451 \text{ s}$$

$$\text{Speed of the ball} = \frac{\text{Length of bowling lane}}{\text{Time taken for ball to roll}}$$
$$= \frac{16.5}{2.451}$$
$$= 6.73 \text{ m s}^{-1} \qquad \text{(corrected to 3sf)}$$

4 *At highway speeds, a particular automobile is capable of an acceleration of about 1.6 m s^{-2}. At this rate, how long does it take to accelerate from 80 km h^{-1} to 110 km h^{-1}?

$$\text{Acceleration} = \frac{\Delta v}{\Delta t}$$
$$1.6 = \frac{(110-80)/3.6}{\Delta t}$$
$$\Delta t = \frac{(110-80)/3.6}{1.6}$$
$$= 5.2 \text{ s} \qquad \text{(corrected to 2sf)}$$

5 A car accelerates from 13 m s^{-1} to 25 m s^{-1} in 6.0 s. Assume constant acceleration.

a What was its acceleration?

$$\langle a \rangle = \frac{\Delta v}{\Delta t}$$
$$= \frac{25-13}{6.0}$$
$$= 2.0 \text{ m s}^{-2}$$

b How far did it travel in this time?

$$s = ut + \frac{1}{2}at^2$$
$$= (13)(6.0) + \frac{1}{2}(2.0)(6.0)^2$$
$$= 114 \text{ m} \qquad \text{(since the last operation is addition, we looked to the decimal place)}$$

6 A car travelling 85 km h^{-1} strikes a tree. The front end of the car compresses and the driver comes to rest after travelling 0.80 m. What was the average acceleration of the driver during the collision? Express the answer in terms of "*g*'s" where 1.00 *g* = 9.81m s^{-2}.

$$v^2 = u^2 + 2as$$
$$0 = \left(\frac{85}{3.6}\right)^2 + 2(a)(0.80)$$

$$a = 350 \text{ ms}^{-2}$$
$$= \frac{350 \text{ ms}^{-2}}{9.81 \text{ ms}^{-2}}$$
$$= 36 \text{ g}$$

7 ** A falling stone takes 0.28 s to travel past a window 2.2 m tall (see Figure 3). From what height above the top of the window did the stone fall?

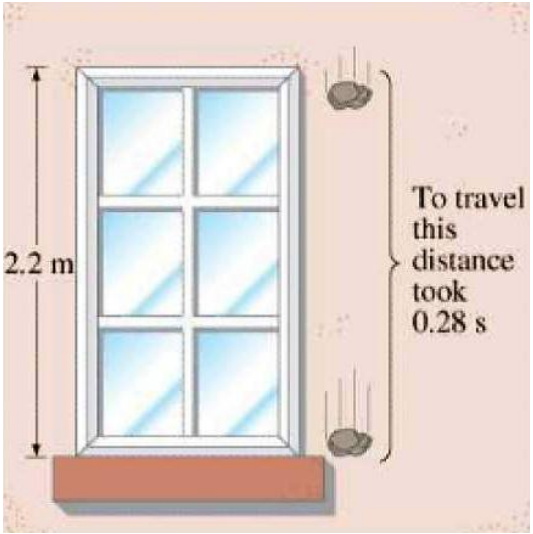


Figure 3

First, find the velocity of the stone when it reaches the top of the window, taking downwards as positive:

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

$$2.2 = u(0.28) + \frac{1}{2}(9.81)(0.28)^2$$

$u = 6.48$ m s^{-1} (*we can take to 1 more sf during intermediate steps*)

The value for u is going to be the final velocity of the first part of the journey,

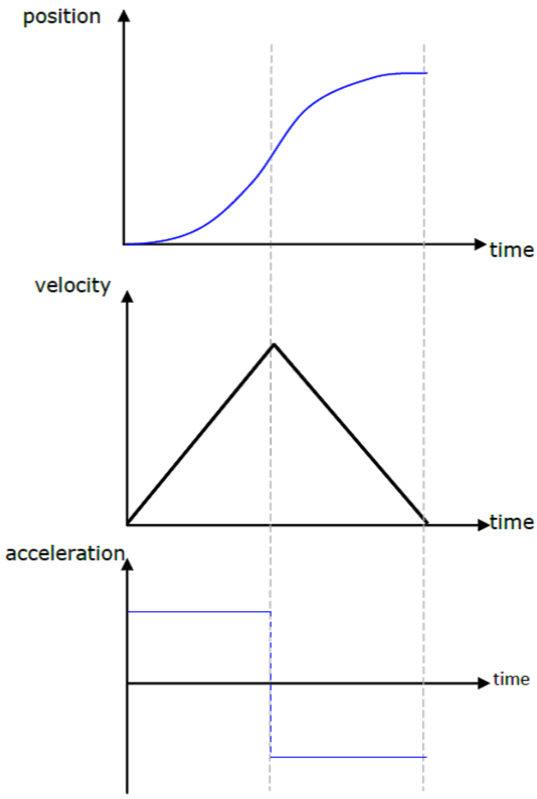
$$v^2 = u^2 + 2as$$

$$6.48^2 = 0^2 + 2(9.81)(s)$$

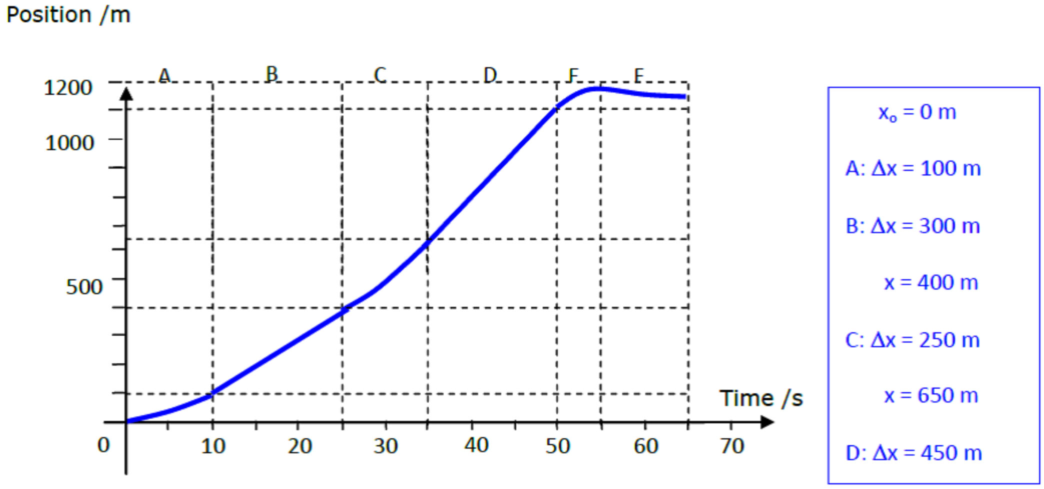
$s = 2.1$ m (corrected to 2 sf)

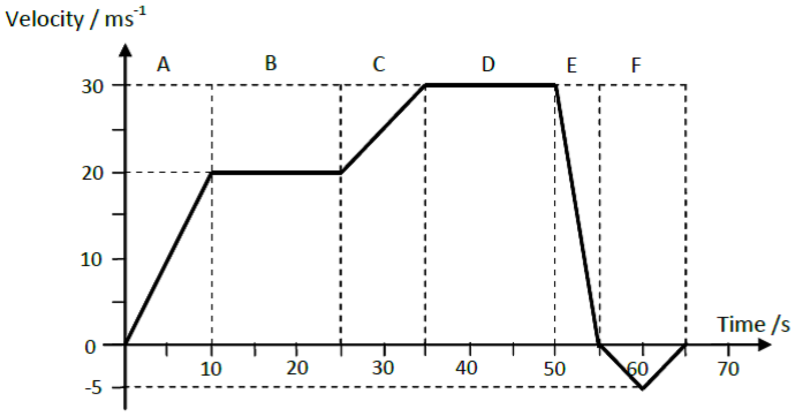
8 A car starts moving as the traffic light turns green. The road it is on is relatively horizontal and straight. The velocity of a car varies with time as shown in the figure below.

Sketch the corresponding acceleration-time and position-time graphs.

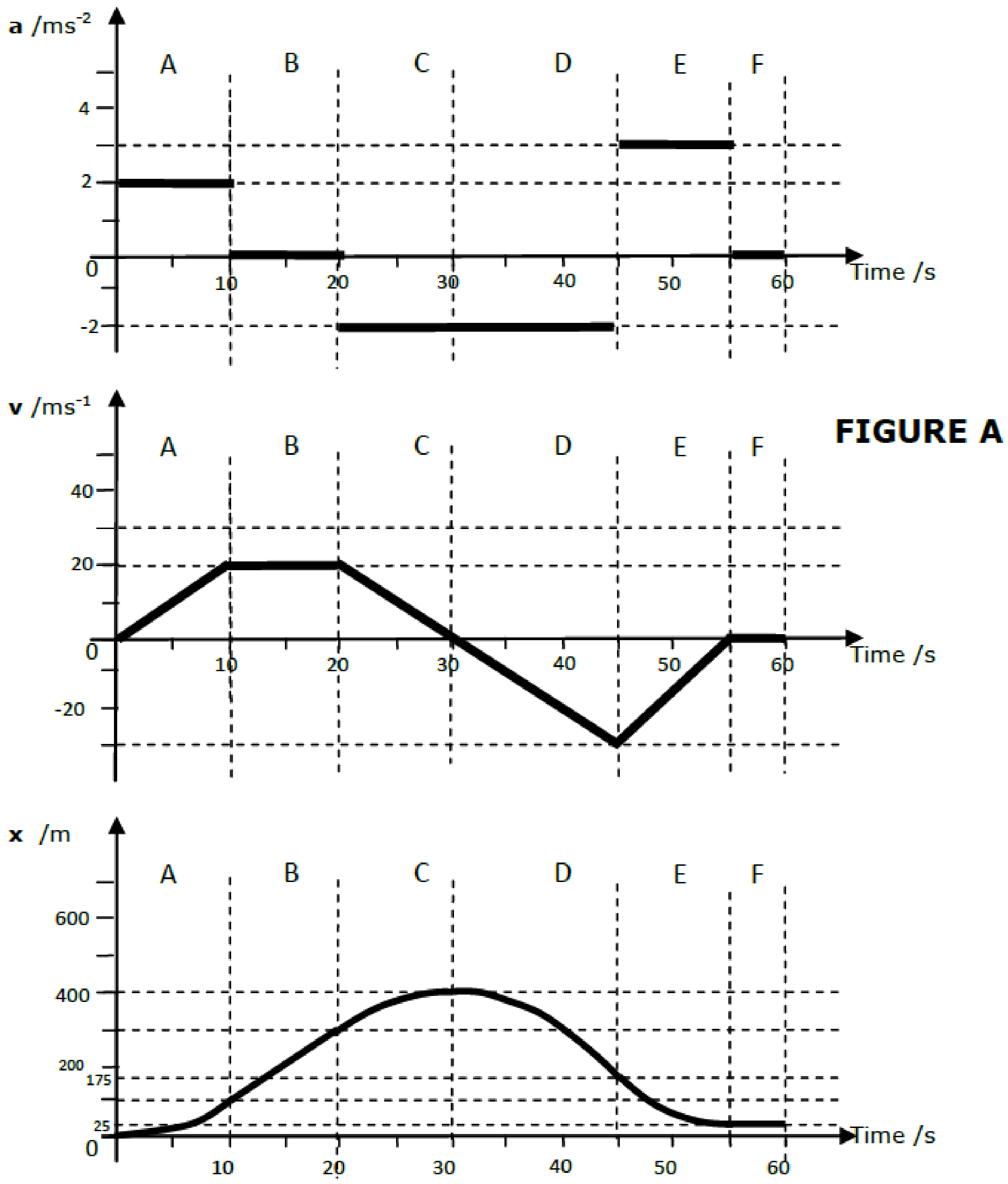


9 The figure shows a velocity-time graph for a journey lasting 65 s that **starts from the origin**. Sketch the corresponding acceleration-time and position-time graphs. Label the axes with the corresponding values.





10 Figure A shows the v – t graph of an object starting from rest at the x = 0. Sketch the corresponding x – t and a – t graphs.



Describe the motion for section C to F.

11 庄周梦蝶

One afternoon Chuang Tzu awoke after dreaming that he was a butterfly. He wondered if he was really a butterfly dreaming of being a person. Let's suppose he dreamt this: Chuang Tzu was an exceptionally fast and agile butterfly. One day, he looked up and saw an anvil poised 2.00 m above his head. Just as the anvil began to fall, Chuang Tzu flew up toward it at 20.0 m s^{-1} (a very fast butterfly). When he reached the anvil, he instantly changed direction and flew toward the ground at the same speed. Upon reaching the ground, he instantly changed direction and flew toward the anvil,…, and so forth, until he awoke just as the dream anvil crushed the dream butterfly. How far did he fly?

Condition: Time of flight of the anvil = Time of flight of butterfly

Let t be time of flight, we have

$$s = \frac{1}{2}gt^2$$

$$2.00 = \frac{1}{2}(9.81)(t)^2$$

$$t = 0.6386 \text{ s}$$

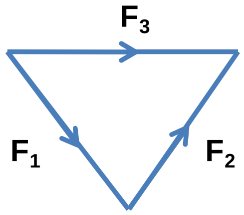
Distance travelled by butterfly $= vt$

$$= (20.0)(0.6386)$$

$$= 12.8 \text{ m} \qquad \text{(corrected to 3sf)}$$

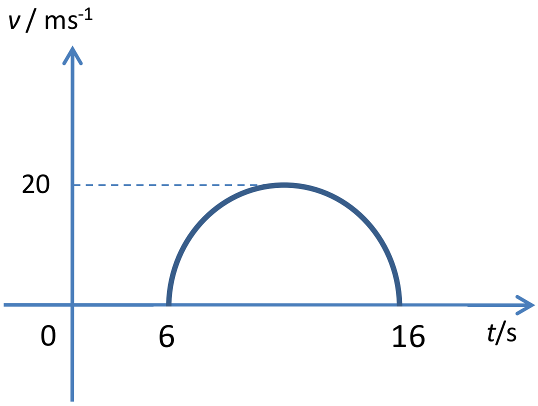
12 Past Olympiad Question

F_1, **F_2** and **F_3** are three separate forces acting on an object. The magnitude and direction of the forces are shown below. Which of the following answers correctly describe the resultant force?



A zero
B **F_2**
C **F_3**
D 2**F_3**

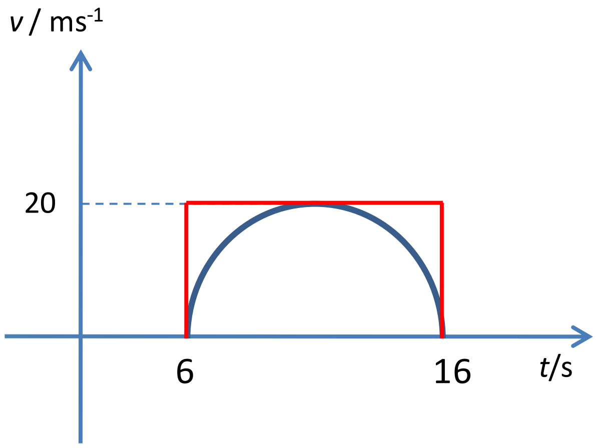
13 What is the displacement of the object between 6 and 16 seconds according to the velocity - time graph below? You may assume that the curvature is circular. [Give answers to 3 s.f.]



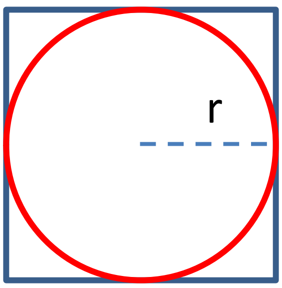
Reasoning:
There are two ways to find the area under the graph.

The first way is to use the area of an ellipse but most students are not skilled in the use of the equation. $A = \pi ab$

The second way is to find the area enclosed by the rectangle as shown:



We also know that there is a relation between the area of a circle enclosed by a square.



$$\frac{Area\ of\ circle}{Area\ of\ square} = \frac{\pi r^2}{4r^2} = \frac{\pi}{4}$$

$$Area\ of\ circle = \frac{\pi}{4}(Area\ of\ square)$$

Using this idea, we can first find the area of the rectangle and then multiply that value with a factor of $\frac{\pi}{4}$.

The final answer should be $\frac{\pi}{4}(20 \times 10) = 157m$

14 A cliff diver is in the air for 2.00 s before hitting the water. Calculate the following quantities for his dive:

a The height from which he fell.

b His average velocity over the entire dive.

c His average velocity over the last half second.

(a) Taking downwards as positive,

$$\begin{aligned} h &= \frac{1}{2}gt^2 \\ &= \frac{1}{2}(9.81)(2.00)^2 \\ &= 19.6 \text{ m} \end{aligned}$$

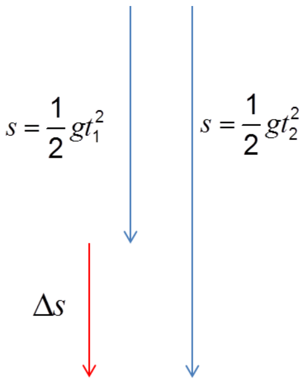
Clearly, we must make the assumption that the initial velocity is zero.

(b)

$$\begin{aligned} v_{avg} &= \frac{s_f - s_i}{t_f - t_i} \\ &= \frac{19.62}{2.00} \\ &= 9.81 \text{ m s}^{-1} \end{aligned}$$

(c) Let $t_1 = 1.50$ s and $t_2 = 2.00$ s, then the displacement during the last half second is

$$\begin{aligned} \Delta s &= \frac{1}{2}g\left(t_2^2 - t_1^2\right) \\ &= \frac{1}{2}(9.81)\left(2.00^2 - 1.50^2\right) \\ &= 8.58 \text{ m} \end{aligned}$$



$$\begin{aligned} v_{avg} \text{ during last half-second} &= \frac{8.58}{0.5} \\ &= 17.2 \text{ m s}^{-1} \end{aligned}$$

Alternatively, guided by the relation $v = at$ (since $u = 0$) and the fact that the average velocity is the velocity of the object at the middle of the time interval. i.e. the average velocity of the entire journey is equal to the velocity at $t = 1.00$ s, and the average velocity of the last half-second of the journey is the velocity at $t = 1.75$ s. We can apply the following proportion:

$$\frac{v_{avg} \text{ for last half-second}}{v_{avg} \text{ for entire journey}} = \frac{1.75}{1.00}$$

$$\frac{v_{avg} \text{ for last half-second}}{9.81} = 1.75$$

$$v_{avg} \text{ for last half-second} = 1.75(9.81) = 17.2 \text{ m s}^{-1}$$

15 A train moves along a horizontal track with a constant speed of 20.0 m s^{-1}. A passenger drops a ball from the ceiling, which is 2.50 m above the floor of the train.

a According to the passenger, how long does it take for the ball to reach the floor?

b According to passenger, where does the ball hit the floor?

c According to someone standing by the tracks, how far does the train move while the ball is in the air?

d What horizontal distance does a person on the track see the ball move while it falls?

(a) To find the time of flight, use

$$h = \frac{1}{2}gt^2$$

$$2.50 = \frac{1}{2}(9.81)t^2$$

$$t = 0.714 \text{ s}$$

(b) The ball will hit the floor directly below the point of drop from ceiling.

(c)
$$s_{horizontal} = v_{horizontal}t$$

$$= (20.0)(0.714)$$

$$= 14.3 \text{ m}$$

(d) The ball will move a horizontal distance of 14.3 m while it is in the air, from the point of view of a person by the track.

16 Suppose you are speeding along at 120 km h^{-1} on a highway and pass a Ferrari parked at a roadside restaurant. Twenty minutes later, the Ferrari leaves the restaurant and follows you at 150 km h^{-1}.

a How fast is the Ferrari moving relative to you?

b How fast are you moving relative to the Ferrari?

c How long does it take for the Ferrari to catch up with you?

(a) The Ferrari is moving at 30 km h^{-1}, along the forward direction of motion.

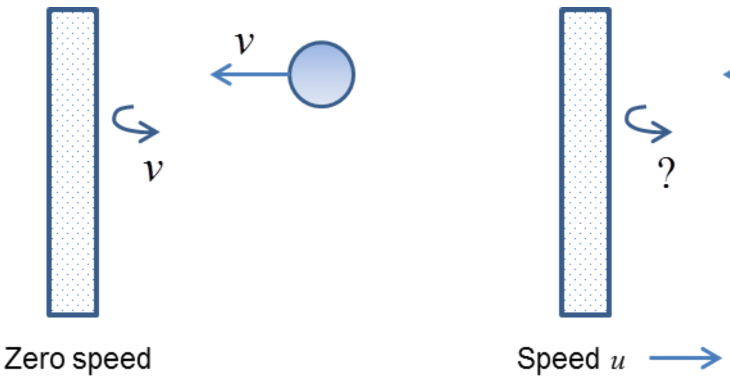
(b) From the perspective of the Ferrari, you are moving 30 km h^{-1}, in the opposite to the direction of motion.

Relative distance between the cars $= \frac{20}{60}(120) = 40$ km

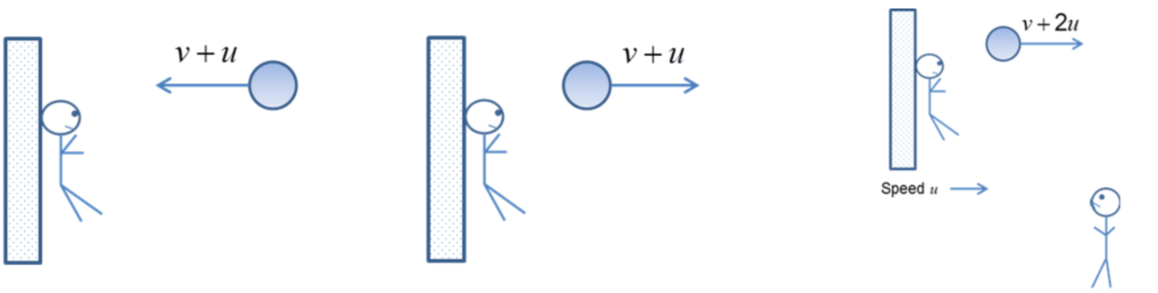
(c) Relative speed between the cars $= 30$ km h^{-1}

Time taken to catch up $= \frac{\text{relative distance}}{\text{relative speed}} = \frac{40 \text{ km}}{30 \text{ km h}^{-1}} = 1.3$ h

17 A ball of speed v strikes a massive, stationary wall at normal incidence, and rebounds with a final speed v in the opposite direction. This is an example of an elastic collision. In a second situation, the only change is that is also moving with speed u towards the ball. If the ball's initial speed is again v directed normally to the wall, and it rebounds elastically from the moving wall, what is the ball's final speed?



Imagine yourself moving together with the wall, then you should see the ball approach you at $v+u$ .Hence, from the perspective of the wall, the ball will rebound at $v+u$. Now, switch the perspective from the moving wall to the stationary frame, the ball will rebound at $(v+u)+u = v+2u$.



Before the collision, an observer moving together with the wall will see the ball moving towards it at $v+u$

After the collision, an observer moving together with the wall will see the ball moving away from it at $v+u$

A stationary observer will see the ball moving away from it at $v+2u$

18 (a) (i) $h = \dfrac{v^2}{2g}$;

to give h = 3.2 m; 2

(ii) 0.80 s; 1

(b) time to go from top of cliff to the sea = 3.0 – 1.6 = 1.4 s;
recognize to use $s = ut + \frac{1}{2}at^2$ with correct substitution,
$s = 8.0 \times 1.4 + 5.0 \times (1.4)^2$;
to give s = 21 m; 3

Answers might find the speed with which the stone hits the sea from $v = u + at$, (42 m s^{-1}) and then use $v^2 = u^2 + 2as$.

19 (a) change in velocity / rate of change of velocity;
per unit time / with time; *(ratio idea essential to award this mark)* 2

(b) (i) acceleration is constant / uniform; 1

(ii) $t = \dfrac{2s}{(u+v)}$ and $t = \dfrac{(v-u)}{a}$;

clear working to obtain $v^2 = u^2 + 2as$; 2

(c) (i) $1.96 = \frac{1}{2} \times 9.81 \times t^2$;
t = 0.632s; 2

(ii) time to fall (1.96 + 0.12)m is 0.651s;
shutter open for 0.019s; 2
If the candidate gives a one significant digit answer treat it as an SD-1.

*Award **[0]** if the candidate uses $s = \frac{1}{2}at^2$ and s = 12cm.*

NUMERICAL ANSWERS TO SECTION B

1a	6.8 h	**1b**	874 km h^{-1}	**2**	30.5 s	**3**	6.73 ms^{-1}	**4**	5.2s
5a	2.0 ms^{-1}	**5b**	114 m	**6**	36 *g*'s	**7**	2.1 m	**11**	12.8 m
13	157 m								