PHYSICS

MECHANICS AND PROPERTIES OF MATTER

Linear motion

General Objective: The learner should be able to use knowledge of motion and its equations to understand relationship between force, energy and motion.

SPECIFIC OBJECTIVES

The earner should be able to;

- Define speed and average speed.
- Calculate speed and average speed.
- Define displacement, velocity and acceleration.
- Define uniform velocity and uniform acceleration.
- Draw and interpret velocity graphs for linear motion.
- Use equations of motion to solve numerical problems.
- Use ticker-timer t, find velocity and acceleration.
- Define acceleration due to gravity, g.
- Describe a simple experiment to determine, g.

LINEAR MOTION

This involves study of motion of a body in a straight line.

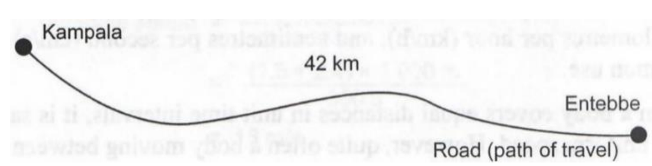
Distance

This is the total length of path travelled by a body.

Or

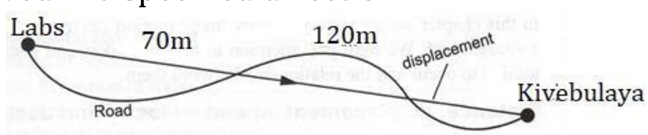
Is the measurement along the exact path followed by a moving body.

The SI unit of distance is metre (s)



Displacement

This is the distance moved in a specified direction.



If student followed the path from Labs, she would cover a distance of 120m. However, if she moved in a straight line, she would cover a displacement of 70 m.

If the student moved from Kivebulaya house to the Laboratory and back to the house along the path, she would have covered a total distance of 240 m, but her resultant displacement would be 0 m.
So, displacement is a vector because it is described by both magnitude and direction. On the other hand, distance is a scalar.

Speed
Speed is the rate of change of distance with time.

$$\text{Speed} = \frac{\text{distance}}{\text{time taken}}$$

Its SI unit is metre per second (ms^{-1}).
It is a scalar since it is specified by magnitude only.

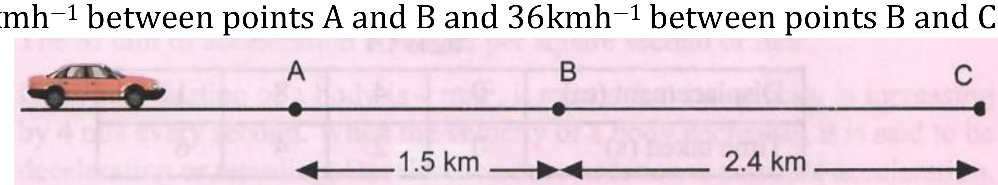
Uniform speed
A body is said to move with uniform speed if it covers equal distances in unit time intervals.

However, quite often a body moving between two points does so with varying speeds. Such a body is said to move with **non-uniform speed**. In such a case the speed between the two points is called average speed.

$$\text{Average speed} = \frac{\text{Total distance}}{\text{total time taken}}$$

Examples
1. What is the speed of a racing car in metres per second if the car covers 360km in 2 hours?
   ($50ms^{-1}$)

2. A car is moving along a straight road ABC as below maintains an average speed of $90kmh^{-1}$ between points A and B and $36kmh^{-1}$ between points B and C.



Calculate the:
(a) total time taken in seconds by the car between points A and C. (300s)
$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$

$\text{total time between A and B} = \frac{\text{total distance between AB}}{\text{average spedd}}$

$$= \frac{1.5}{90} \text{ hours} = \frac{1.5}{90} \times 3600 = 60 \text{ s}$$

$$\text{total time between B and C} = \frac{\text{total distance between BC}}{\text{average speed}}$$

$$= \frac{2.4}{36}\text{ hours} = \frac{2.4}{36} \times 3600 = 240 \text{ s}$$

Total time between A and C = 60 + 240 = 300 s.

(b) average speed in metres per second of the car between points (13ms^{-1})

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{(1.5+2.4)\times 1000 \text{ m}}{300 \text{ s}} = \frac{39}{3} = 13 \text{ ms}^{-1}.$$

Velocity

This is the rate of change of displacement with time.

$$\text{Velocity} = \frac{\text{distance moved in a particular direction (displacement)}}{\text{time taken}}$$

The SI unit is metres per second (ms^{-1}).
It is a vector, since it is specified by both magnitude and direction.

In some cases, the velocity of a moving body keeps on changing. In such cases, it is better to consider the average velocity of the body.

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{time taken}}$$

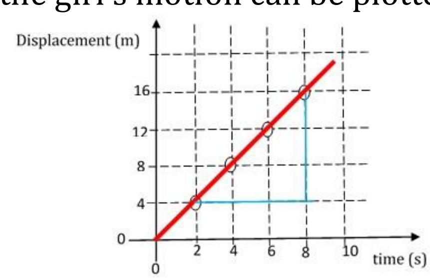
A particle is said to move with uniform velocity if its displacement changes by equal amounts in equal time intervals.

When the velocity in a particular direction is constant, the velocity is referred to as uniform velocity.

Uniform velocity is the constant rate of change of displacement with time.
For example, the table below shows the displacement of a girl and the corresponding time taken.

Displacement (m)	0	4	8	12
Time taken (s)	0	2	4	6

A displacement-time graph of the girl's motion can be plotted as below:



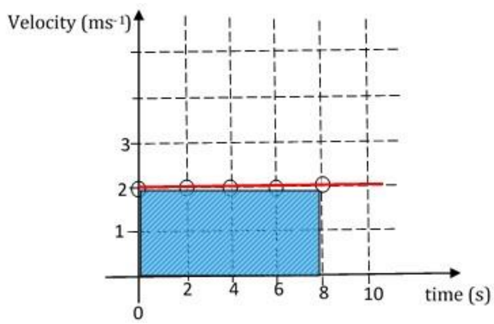
A straight line graph is obtained.
The slope of the graph is the constant velocity at which the girl is moving.

$$\text{Slope, v} = \frac{\text{change in displacement}}{\text{change in velocity}} = \text{velocity}$$

$$\text{Slope, v} = \frac{(16-4)\ \text{m}}{(8-2)\ \text{s}} = \frac{12}{6} = 2\ \text{ms}^{-1}.$$

The velocity after every two seconds is $2ms^{-1}$, hence its velocity is uniform.
The girls motion can also be represented on a velocity – time graph as below:

Displacement (m)	0	4	8	12
Time taken (s)	0	2	4	6
Velocity (ms^{-1})	0	2	2	2



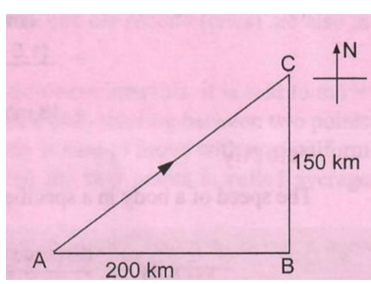
A straight line parallel to the time axis is obtained and this confirms that the girl is moving at a constant velocity and zero acceleration.

The **total displacement covered** by the girl in the 8 seconds can obtained as **the area under the velocity –time graph** as follows:

Displacement = area under velocity time graph

Displacement = velocity × time = 2 × 8 = 16m.

Example
A car travelled from town A to town B 200km east of A in 3hours. The car changed direction and travelled a distance of 150km due north from town B to town C in 2 hours as shown below.



Calculate the average;
(a) speed for the whole journey. (70 kmh^{-1})
(b) velocity for the whole journey. (50 kmh^{-1} from A to C.)

Acceleration

A body is said to be accelerating when its **velocity changes.**

Definition

This is the rate of change of velocity with time.

$$\text{Acceleration} = \frac{\text{change in velocity of body}}{\text{time taken}}$$

Its SI unit is metres per square second (ms^{-2}).

If the acceleration of a body is $4ms^{-2}$, it means that its velocity is increasing by $4ms^{-1}$ every second. NOTE

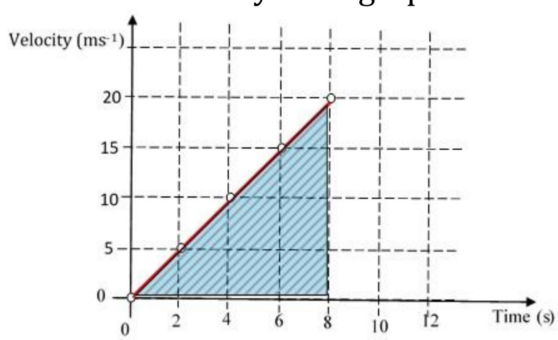
- Acceleration can be positive or negative. If the acceleration is increasing then it is taken to be positive and if it is decreasing (decelerating or retarding), it is taken to be negative.
- A body moving with **uniform velocity** has **zero acceleration** since there is **no change in velocity.**

When the rate of change of velocity with time is constant, the acceleration is referred as **uniform acceleration**.

Consider a body moving with velocity, v, in time, t, as shown in the table below.

velocity (ms^{-1})	0	5	10	15	20
Time taken (s)	0	2	4	6	8

The information can be plotted on a velocity-time graph as below



A straight line graph is obtained. The slope of the graph is a constant value obtained as below:

$$\text{slope} = \frac{\text{change in velocity}}{\text{change in time}} = \text{acceleration, a}$$

$$\text{slope} = \frac{20-5}{8-2} = \frac{15}{6} = 2.5\ ms^{-2} = \text{acceleration, a}$$

i.e. the velocity increases by $5ms^{-1}$ for every 2 seconds. Thus, the body is said to be accelerating uniformly at $2.5\ ms^{-2}$

The **displacement of the body** in the 8 seconds is found as **the area under the velocity-time graph** as follows.

$$\text{Displacement, s} = \frac{1}{2} \times \text{velocity} \times \text{time} = \frac{1}{2} \times 8 \times 20 = 80\ \text{m}$$

Example:

The table below represents the velocity of a vehicle after a given time.

Velocity (ms^{-1})	0	3	6	9	12	15	15	15	15	15
Time taken (s)	0	1	2	3	4	5	6	7	8	9

(a) Plot a velocity – time graph representing the motion of the vehicle.

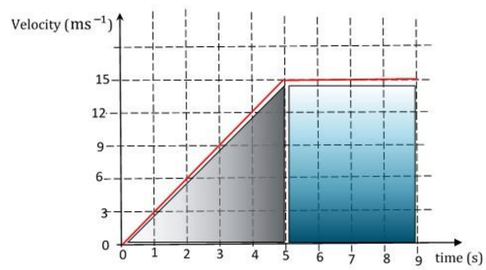
(b) Find the slope of the graph in the first 5 seconds of the vehicle's motion.

(c) Use the graph to describe the motion of the vehicle in the 9 seconds.

(d) Use the graph to determine the total displacement of the vehicle in the 9 seconds of its motion.

Solution.

(a)



(b) $\text{slope} = \frac{\text{change in velocty}}{\text{change in time}} = \frac{(15-0)\ ms^{-1}}{(5-0)\ s} = \frac{15}{5} = 3\ ms^{-2}$

(c) The vehicle starts from rest accelerates uniformly at 3 ms^{-2} until it attains a velocity of 15 ms^{-1} in the first 5 seconds. It then moves with this velocity constantly for the next 4 seconds.

(d) Displacement = area under the velocity— time graph

Displacement, s = area of the trapezium $= \frac{1}{2} \times 15 \times (9 + 4)$

Displacement, s = 97.5 m

Example

A car accelerates from rest to a velocity of $20ms^{-1}$ in 5s. thereafter it decelerates to rest in 8s. Calculate the acceleration of the car.

(a) in the first 5s, ($4ms^{-2}$)

$$\text{Acceleration} = \frac{\text{change in velocity of body}}{\text{time taken}}$$

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}}$$

(rest means velocity is zero)

$$\text{Acceleration} = \frac{20 - 0}{5} = 4ms^{-2}$$

(b) in the next 8s. (-2.5 ms^{-2})

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}} = \frac{0 - 20}{8}$$
-2.5ms^{-2} Or deceleration $= 2.5\text{ms}^{-2}$or retardation $= 2.5\text{ms}^{-2}$

MOTION –TIME GRAPHS AND THEIR INTERPRETATION.

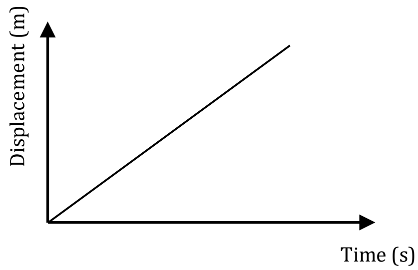
The motion of objects can be represented graphically. During the objects' motion, the displacement and velocity of the body usually changes with time. Consideration will be given to:

1. Displacement-time graphs.
2. Velocity-time graphs.

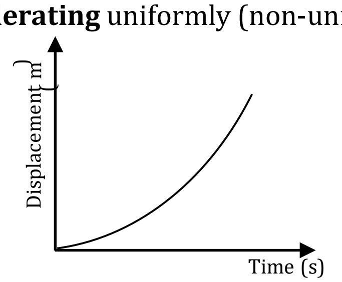
   and the information we derive from them.

1. Displacement –Time Graphs

(a) **Moving with constant velocity/uniform velocity/steady velocity**



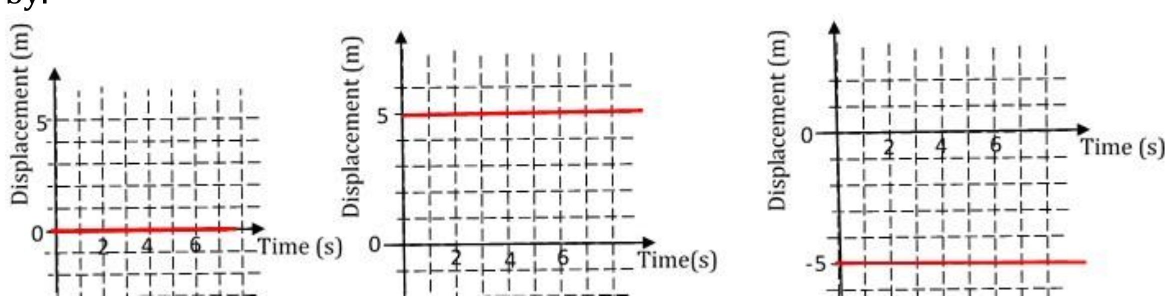
(b) Accelerating uniformly (non-uniform velocity)



This graph is an example of a stone that drops from rest, the displacement covered in each second is not equal but rather increasing.

(c) **A body at rest**.

When a body is at rest (stationary), its position remains the same even as time passes by.



(i) The displacement-time graph represents a body that is at rest at its original position.

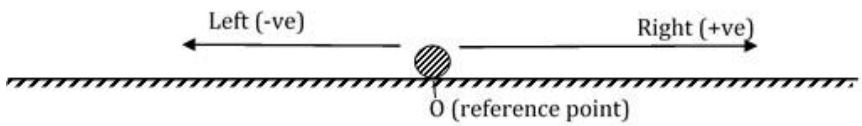
(ii) The displacement-time graph represents a body that is at rest 5 m after or away from its original position.

(iii) The displacement-time graph represents a body that is at rest and 5 m before its original position.

Note: (i) The **gradient of a displacement-time graph** gives the **velocity of the particle**.

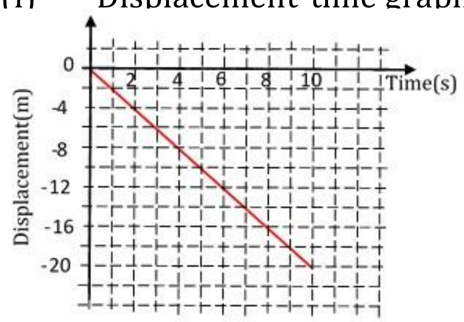
(ii) When the body is stationary the gradient of the graph is zero and hence the velocity is zero.

A body may be moving to the left or right away from the reference point, O.
The displacement to the right of the reference point is considered to be positive, while that to the left is negative.

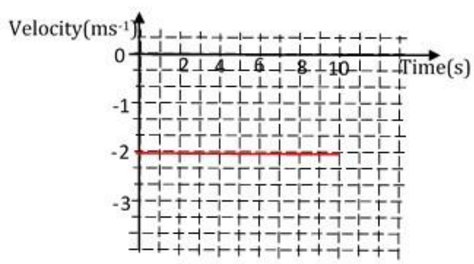


Suppose the body is moving to the left of its reference point, O, graphs are as shown below.

(i) Displacement-time graph



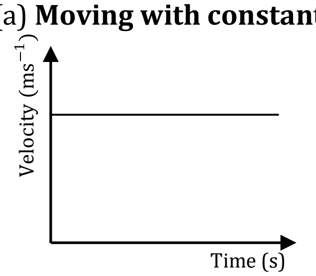
(ii) Velocity-time graph



The slope of the displacement-time graph is $\frac{\text{change in displacement}}{\text{change in time}} = \frac{-20}{10} = -2\text{ms}^{-1}$, the negative sign means the body is moving in the opposite direction.

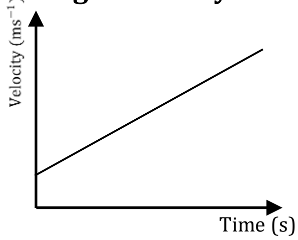
2. Velocity – Time Graphs

(a) **Moving with constant velocity/uniform velocity/steady velocity**



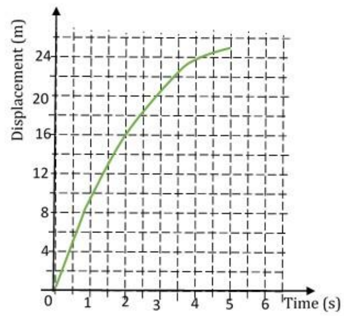
Here, the acceleration is zero Since the velocity is the same i.e. does not increase or decrease.

(b) **Accelerating uniformly**

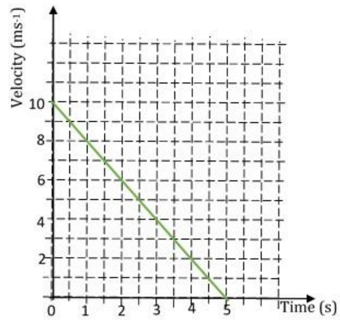


(c) The displacement-time and velocity-time graphs for a body that is decelerating uniformly are as below:

(i) Displacement-time graph



(ii) Velocity-time graph



Note:

(i) The slope of the displacement-time graph is non-uniform but decreases with time.

(ii) The slope of the velocity-time graph is uniform and is obtained as below:

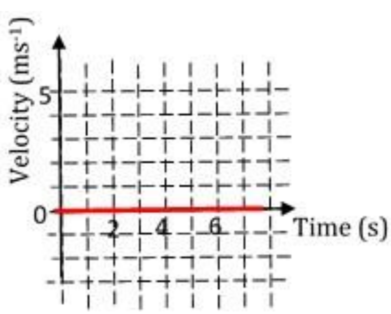
$$\text{slope of velocity} - \text{time graph} = \frac{\text{change in velocity}}{\text{change in time}} = \frac{10-0}{0-5} = -2\ \text{ms}^{-2}$$

The negative sign means the body is decelerating at a rate of 2 ms^{-2}.

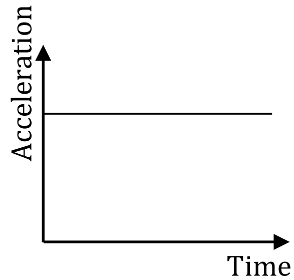
The two graphs above represent motion of a body **decelerating uniformly.**

Velocity-time graph for a body at rest.

When a body is at rest or stationary, its velocity is 0 ms^{-1}. The velocity-time graph representing its motion is as below:



Acceleration-time graph for a body moving with uniform acceleration.

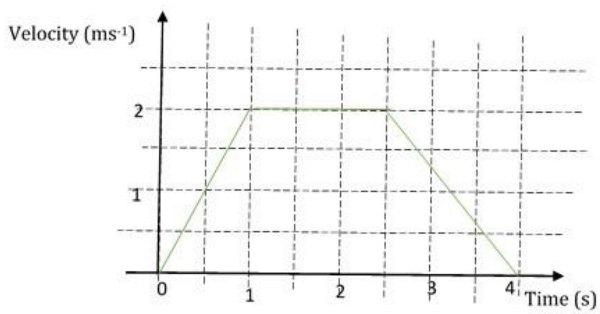


The Area under the velocity-time graph:

- The area under a velocity-time graph is equivalent to displacement of the object.
- The distance covered by object can also be obtained from the velocity-time graph if the direction of the motion is ignored.

Example 1.

The figure below is a velocity-time graph of a car. Use the graph to find (a) the acceleration of the car.
(b) the deceleration of the car.
(c) the total displacement of the car.



Solution:

(a) $\text{Acceleration, a} = \frac{\text{change in velocity}}{\text{time}} = \frac{2-0}{1} = 2\ \text{ms}^{-2}$.

(b) $\text{Deceleration} = \frac{\text{change in velocity}}{\text{time}} = \frac{0-2}{4-2.5} = \frac{-2}{1.5} = 1.33\ \text{ms}^{-2}$

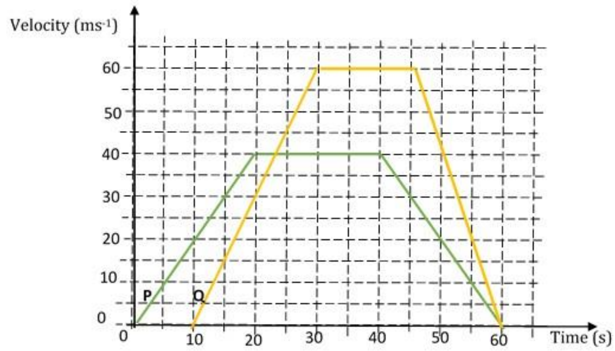
.

The deceleration $= 1.33\ \text{ms}^{-2}$.

(c) Total displacement = area under the velocity − time graph
Total displacement = area of trapezium
Total displacement $= \frac{1}{2} \times 2 \times (1.5 + 4) = 5.5\text{m}$.

Example 2.

The velocity – time graph below represents the motion of two cars P and Q which start from the same place and move in the same direction.



Use the graph to answer the following questions.

(a) Calculate the accelerations of cars P and Q.

(b) Determine how far apart the cars are from each other at the end of their accelerations.

(c) Find the total distance covered by each car.

Solution:

(a) Acceleration of car P:

$a = \frac{v-u}{t} = \frac{40-0}{20-0} = 2\ ms^{-2}$.

Acceleration of car Q:

$a = \frac{v-u}{t} = \frac{60-0}{30-10} = 3\ ms^{-2}$.

(b) Distance moved by car P during its acceleration:

$s_p = \frac{1}{2} \times 20 \times 40 = 400\ m$

Distance moved by car P during its acceleration:

$s_q = \frac{1}{2} \times (30-10) \times 60 = \frac{1}{2} \times 20 \times 60 = 600\ m$.

The distance between the cars by the end of their accelerations is $(600 - 400) = 200$ m. (c) Total distance moved by car P:

$s_p = \frac{1}{2} \times 40 \times (60+20) = 20 \times 80 = 1600\ m$.

Total distance moved by car Q:

$s_q = \frac{1}{2} \times 60 \times (50+15) = 30 \times 65 = 1950\ m$.

Example three.

A body is moving at a velocity of $5ms^{-1}$ for 6s. Draw a velocity time graph for the body's motion and use the graph to calculate the distance it covers in 6s. (30m)

Example four.

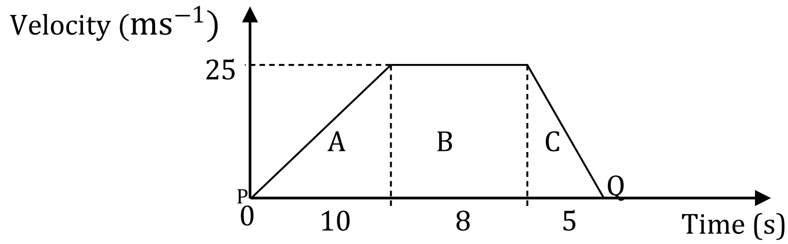
A car starting from rest at P accelerates uniformly for 10 s to a velocity 25 ms^{-1}. It then moves at this constant velocity for 8 s before retarding uniformly for 5 s so as to stop at Q. Sketch the velocity-time graph for the car's motion between points P and Q and find

(i) the distance covered during each of the parts of the journey described.

(ii) the acceleration of the car

(iii) the retardation of the car.

Solution



(i) The distance covered during acceleration is the area A

$= \frac{1}{2} \times 10 \times 25 \quad = 125$ m

The distance covered at constant speed is the area B

$= 8 \times 25 \quad = 200$ m

The distance covered during retardation is the area C

$= \frac{1}{2} \times 5 \times 25 \quad = 62.5$ m

(ii) Acceleration $= \frac{25}{10} = 2.5\ ms^{-2}$

(iii) Retardation $= \frac{25}{5} = 5.0\ ms^{-2}$

Example five.

A car initially at rest accelerates at $2ms^{-2}$ for 10s. It then maintains this new velocity for another 10s before retarding (decelerating) to rest in 5s.

(a) Draw a velocity – time graph for the motion of the car.

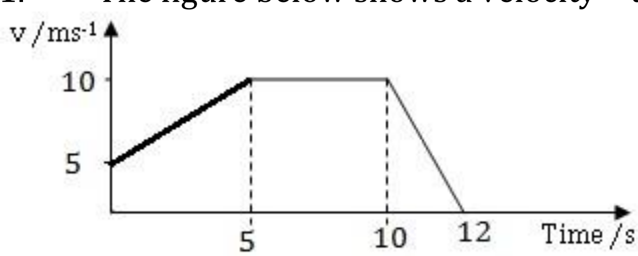
(b) Find the velocity of the car after the first 10s. ($20\ ms^{-1}$)

(c) Find the total distance covered by the car. (350m)

(d) Find the average velocity of the car. ($14\ ms^{-1}$)

Exercise.

1. The figure below shows a velocity – time graph for the motion of the body.



(a) Describe the motion of the body.

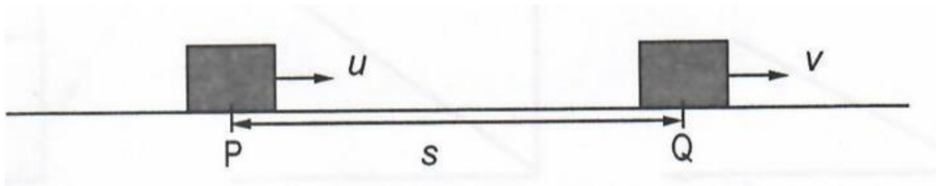
(b) Find the acceleration of the body. ($1\ ms^{-2}$)

(c) Find the deceleration of the body. ($-5ms^{-2}$)

(d) Find the average velocity of the body. ($8.125ms^{-1}$))

Equations of Uniformly Accelerated Motion.

Suppose a body, originally moving with a velocity **u**ms^{-1} accelerates uniformly at a rate **a** ms^{-2} for **t** seconds such that its final velocity is **v** ms^{-1} after moving through a displacement of **s** metres as shown below,



then;

The first equation of linear motion is obtained as follows:

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

$$= \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}}$$

$$a = \frac{v - u}{t}$$

$$\therefore \quad at = v - u$$

$$\therefore \ \mathbf{v = u + at} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \mathbf{(1)}$$

The second equation of linear motion:

The displacement, **s**, of the particle during this time is given by

Displacement $=$ Average velocity $\times$ time

$$\therefore \quad s = \left(\frac{v + u}{2}\right)t$$

$$\text{but } v = u + at \ \therefore$$

$$s = \left(\frac{u + at + u}{2}\right)t$$

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

$$\therefore \quad \mathbf{s = ut + \frac{1}{2}at^2} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \mathbf{(2)}$$

Third equation of linear motion.

Displacement $=$ Average velocity $\times$ time

$$\therefore \quad s = \left(\frac{v + u}{2}\right)t$$

From the first equation of motion, $t = \frac{v-u}{a}$

$$□\, s = \frac{(v + u)}{2}\,\frac{(v - u)}{a} = \frac{v^2 - u^2}{2a}$$

$$\therefore \mathbf{v^2 = u^2 + 2as} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

The three **equations of uniformly accelerated motion** can be summarized as below:

$$v = u + at \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$s = ut + \frac{1}{2}at^2 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$v^2 = u^2 + 2as \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

NB: **Retardation**

If the velocity of a moving particle **decreases with time,** then it is said to be **retarding** (**decelerating**). In this case, **the acceleration is negative.**

Examples

1. A particle initially moving with a velocity of $5ms^{-1}$ accelerates uniformly at $4ms^{-2}$. Find:
   (i) The velocity of the particle after 8s.
   (ii) the displacement of the particle after 10 s.
   (iii) the displacement by the time its velocity is $25\ ms^{-1}$.

   Solution

   (i) Using $v = u + at$, we have
   $v = 5 + (4 \times 8) = 37\ ms^{-1}$

   (ii) Using $s = ut + \frac{1}{2}at^2$, we have
   $s = (5 \times 10) + (\frac{1}{2} \times 4 \times 10^2) = 50 + 200 = 250m$

   (iii) Using $v^2 = u^2 + 2as$, we have
   $s = \frac{v^2 - u^2}{2a} = \frac{25^2 - 5^2}{2 \times 4} = \frac{600}{8} = 75\ m$

2. A car, moving with a velocity of $25\ ms^{-1}$ retards uniformly at $2ms^{-2}$. Find:
   (i) the velocity after 8s.
   (ii) the time it takes to come to rest.
   (iii) the distance covered by the time it comes to rest.

   Solution

   (i) Using $v = u + at$, we have
   $v = 25 + (-2)(8) = 25 - 16 = 9\ ms^{-1}$

   (ii) Using $v = u + at$, we have
   $0 = 25 + (-2 \times t)$
   $0 = 25 - 2t$
    $t = 12.5\ s$

   (iii) Using $v^2 = u^2 + 2as$, we have

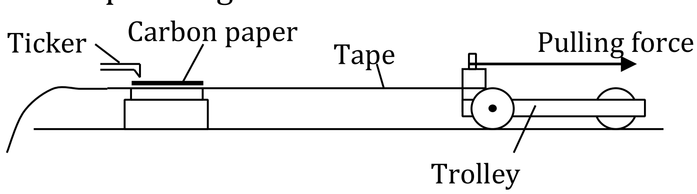
$$0 = 25^2 + 2(-2)s$$
$$\therefore \quad 4s = 625$$
$$s = \frac{625}{4} = 156.25 \text{ m}$$

3. A car on a straight road accelerates from rest to a speed of 30 ms^{-1} in 5s. It then travels at the same speed for 5minutes and then brakes for 10s in order to come to stop. Calculate the;
   (a) acceleration of the car during the motion. (6ms^{-2})
   (b) deceleration of the car. (-3ms^{-2})
   (c) total distance travelled. (9225m)

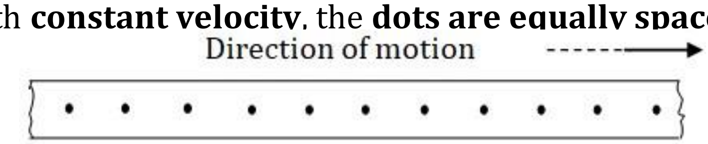
4. The driver of a bus initially travelling at 72kmh^{-1}applies the brakes on seeing a crossing herd of gazelles. The bus comes to rest in 5 seconds. Calculate;
   (a) the average retardation of the bus. (-4ms^{-2})
   (b) the distance travelled in this interval. (50m)

Ticker – tape timer Experiments

A ticker-timer makes it possible to measure the acceleration of a moving body.
A tape, attached to the body whose motion is being studied, is passed beneath a carbon paper above which is a point that rocks on it at regular time intervals. This way, dots are printed on the tape at regular time intervals.

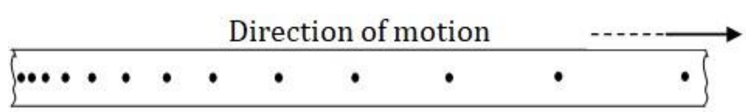


- If the body is moving with **constant velocity**, the **dots are equally spaced** along the tape.

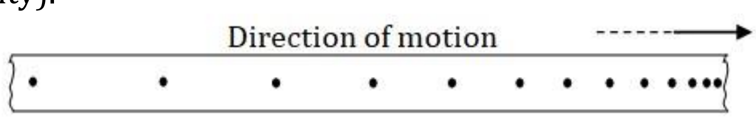


2

- If the body is **accelerating**, the **dot spacing increases** progressively (increasing velocity).



- If the body is **decelerating/retarding**, the **dot spacing decreases** progressively (decreasing velocity).



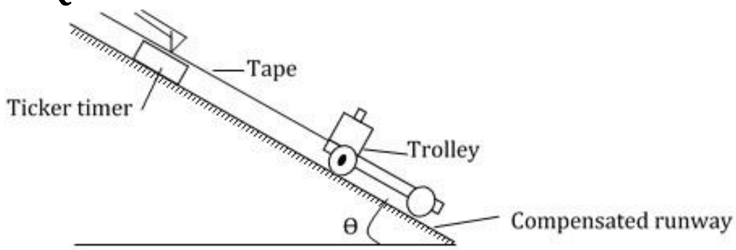
By using different values of the pulling force on the trolley, it can be shown that

$$\mathbf{a} \propto F$$

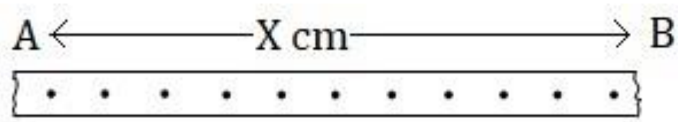
Where, F = force, a = acceleration, **m** = mass of the body.

By altering the mass loaded on the trolley, but maintaining the same pulling force, it can be shown that $\mathbf{a} \propto \frac{1}{m}$

AN EXPERIMENT TO DETERMINE THE UNIFORM VELOCITY OF A BODY USING A TICKER TMER OF FREQUENCY 50Hz.



- The apparatus is set up as shown above.
- A trolley with a ticker timer attached to it is placed on a horizontal runway (plane).
- The run way is then tilted (inclined) until a point is reached such that when the trolley is given a slight push, **the dots printed on the tape by the vibrating ticker timer are equally spaced.**
- When the dots are equally spaced, then the trolley is moving with uniform velocity. The tape with printed dots is cut out.



- The distance between the dots A and B say 10 dot-spaces apart is measured. Let the distance be x cm.
- Now the calculation is as follows.
- Distance between A and B is x cm $= \frac{x}{100}$ m
- Number of spaces between A and b = 10 dot-spaces

$$f = 50\text{Hz}$$

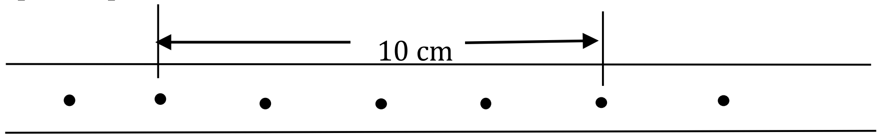
$$T = \frac{1}{f}$$

$$T = \frac{1}{50} = 0.02\text{s}$$

- Time interval between A and B $= nT = 10 \times 0.02 = 0.2s$
- Now using; $\text{Velocity} = \frac{\text{Distance moved in a given direction}}{\text{time taken}}$
- Uniform velocity of the trolley $= \frac{x/100}{0.2} = \frac{x}{20}\text{ms}^{-1}$
- Hence the uniform velocity of body is $\frac{x}{20}\text{ms}^{-1}$

Examples

1. The ticker tape shown below was pulled through a ticker-timer which makes 50 dot spaces per second.

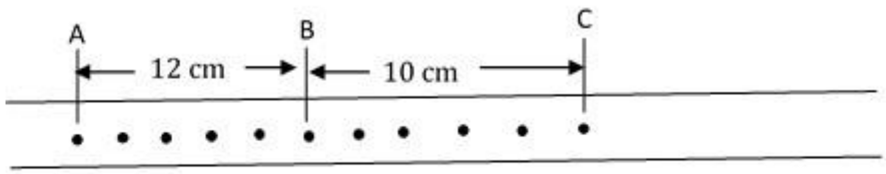


Find the speed at which the tape is being pulled.

Answer:

$$\text{Speed, v} = \frac{\text{distance}}{\text{time}} = \frac{10}{100} \times \frac{50}{4} = 1.25\ \text{ms}^{-1}$$

2. The figure below shows a tape produced by a ticker timer of frequency 50Hz.



(a) Calculate the time taken to cover distance AB.

(b) The average velocity over the entire motion.

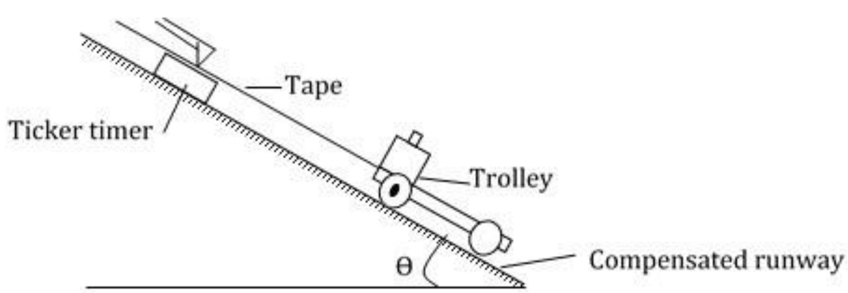
ANSWER:

(a) $\text{time, } t_1 = \text{number of spaces from A to B} \times \text{period}$

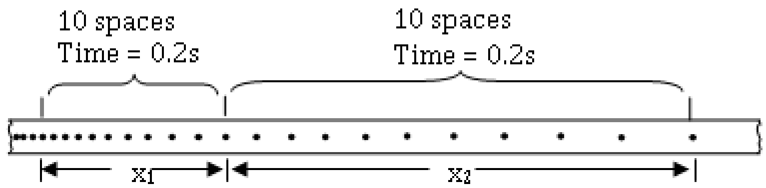
$$\text{time, } t_1 = 5 \times \frac{1}{50} = 0.1\ \text{s}$$

(b) $\text{average velocity} = \frac{\text{total distance}}{\text{total time taken}} = \frac{(12+10)}{100} \times \frac{50}{10} = 1.1\ \text{ms}^{-1}$.

AN EXPERIMENT TO DETERMINE ACCELERATION OF A BODY USING A TICKER TIMER OF 50HZ.



- The apparatus is set up as shown above.
- A ticker timer tape is attached to a trolley.
- The trolley is placed on an inclined plane and the trolley is allowed to run down the plane while pulling the tape through the ticker timer. The tape with printed dots is as shown below.



- The distances x_1 and x_2 between the successive 10 dot spaces are measured.
- The timer has a frequency of 50Hz.
- The time taken to print one dot space,

$$f = 50\text{Hz}$$
$$T = \frac{1}{f}$$
$$T = \frac{1}{50} = 0.02\text{s}$$

- Now, the time taken by a 10 dot-space $= 10 \times 0.02 = 0.2$ s Average velocity over the distance $x_1 = \frac{x_1}{0.2}$
- And the average velocity over distance $x_2 = \frac{x_2}{0.2}$
- Hence, change in velocity in 0.2s $= \frac{x_2}{0.2} - \frac{x_1}{0.2} = \frac{x_2 - x_1}{0.2}$
- Now, the acceleration $= \frac{\text{Change in velocity}}{\text{Time}} = \frac{\frac{x_2 - x_1}{0.2}}{0.2}$

$$\therefore \text{Acceleration} = \frac{x_2 - x_1}{(0.2)^2}$$

Examples

1. The figure below shows a tape produced by a ticker – timer operating at a frequency of 50 Hz.

If the trolley was accelerating.

(a) In which direction was it moving?

ANS: A to B, because the dot spacing increase as one moves from A towards B.

(b) Calculate the acceleration of the trolley that pulled the paper tape through the ticker- tape timer.

ANS:

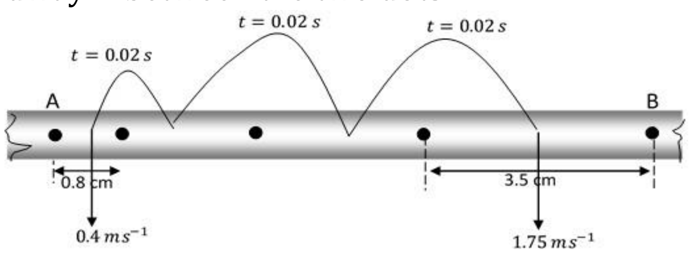
The interval between dots is increasing from A to B, hence the velocity is increasing in the same direction, i.e. the trolley is accelerating. To determine the acceleration, we need to obtain the average initial and final velocities. These are the velocities between the first two dots and the last two dots respectively.

Frequency, $= 50 \text{ Hz} \quad \therefore \quad \text{period}, T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ s}$, the time interval between two successive dots.

Initial average velocity between first two dots, $u = \frac{x_1}{t} = \frac{0.008}{0.02} = 0.4\ ms^{-1}$.

Final average velocity between last two dots, $v = \frac{x_2}{t} = \frac{0.035}{0.02} = 1.75\ ms^{-1}$.

Note: the average velocity between any two dots is equal to the velocity midway between the two dots.



Though there are 4 time intervals between the dots A and B, there are 3 time intervals between
the instances of average initial and final velocities (the acceleration period). Thus,

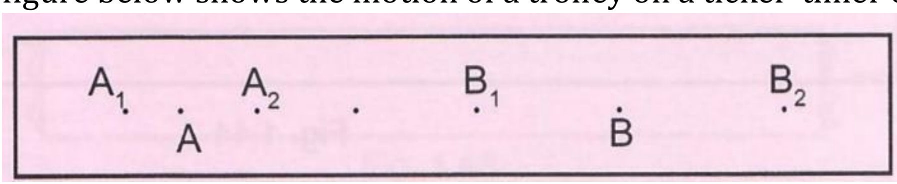
$$\text{Total time taken, t} = \text{period} \times (\text{number of spaces between all dots} - 1)$$

$$\text{Total time taken, t} = \frac{1}{f} \times (n - 1)\text{spaces}$$

$$\text{Total time taken, t} = 0.02 \times (4 - 1) = 0.02 \times 3 = 0.06\ s$$

$$\text{acceleration, a} = \frac{v - u}{t} = \frac{1.75 - 0.4}{0.06} = 22.5\ ms^{-2}$$

2. The figure below shows the motion of a trolley on a ticker-timer of 50Hz.



$A_1A_2 = 1.2cm$ and $B_1B_2 = 2.8cm$

(a) Find the velocity at points A and B. ($30cms^{-1}$ and $70cms^{-1}$)

(b) Calculate the acceleration between points A and B. ($500cms^{-2}$ or$5.0ms^{-2}$)

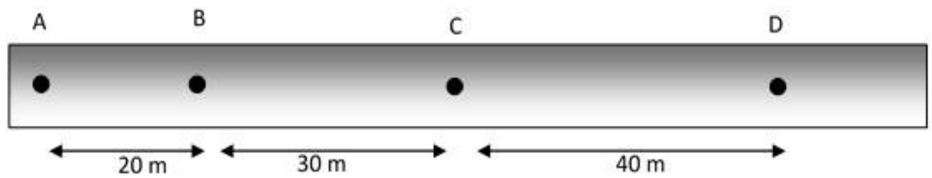
3. In a ticker-timer experiment the distance occupied by a 6-dot space on the tape is 5.1 cm, while the adjacent 6-dot space occupies 6.3 cm. find the acceleration of the body to which the tape is attached, if the ticker frequency is 50 Hz.

Solution

Time taken by 6-dot space = $6 \times \frac{1}{50} = 0.12$ s

$\therefore$ Acceleration $= \frac{6.3-5.1}{(0.12 \times 0.12)} = \frac{1.2}{0.0144} = 83.3 \text{ cm s}^{-1}$

4. Oil was leaking from a car as it travelled along a road. One oil drop fell on the road after every 2 seconds. The figure below shows the pattern formed by the drops on the road. Calculate the acceleration of the car.



Solution.

In terms of time, instances B and C are midway between the time intervals AC and BD respectively.

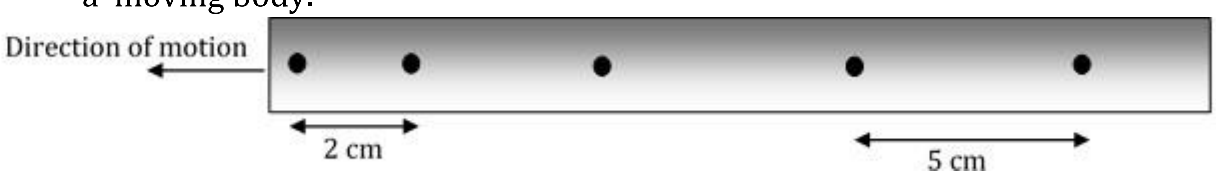
Time interval between any two drops = 2s.

Velocity at point B $= \frac{\text{displacement AC}}{\text{time taken}} = \frac{50 \text{ m}}{4 \text{ s}} = 12.5 \text{ ms}^{-1}$

Velocity at point C $= \frac{\text{displacementBD}}{\text{time taken}} = \frac{70 \text{ m}}{4 \text{ s}} = 17.5 \text{ ms}^{-1}$

Acceleration between B and C $= \frac{V-U}{t} = \frac{17.5-12.5}{2 \text{ s}} = \frac{5}{2} = 2.5 \text{ ms}^{-2}$.

5. The figure below shows dots produced on a tape pulled through a ticker – timer by a moving body.



The frequency of the ticker timer is 50 Hz. Calculate the acceleration of the body.

Solution:

time interval between two sucessive, $T = \frac{1}{f} = \frac{1}{50} = 0.02$ s.

$x_2 = 5 \text{ cm} = 0.05\text{m}, \quad x_1 = 2 \text{ cm} = 0.02 \text{ m}$

Average initial velocity, $v = \frac{x_1}{T} = \frac{0.05}{0.02} = 2.5 \text{ ms}^{-1}$

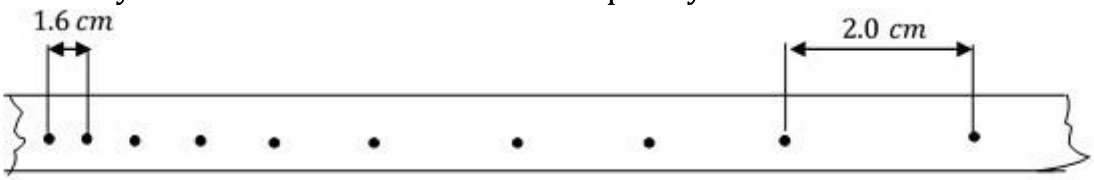
Average final velocity, $v = \frac{x_2}{T} = \frac{0.02}{0.02} = 1.0 \text{ ms}^{-1}$

Total time taken between the average initial and final velocities:

$t = \text{period} \times (n - 1)\text{spaces}$ $t = 0.02 \times (4 - 1)\text{spaces} = 0.06$ s

Acceleration, $a = \frac{v-u}{t} = \frac{1.0-2.5}{0.06} = \frac{1.5}{0.06} = -25 \text{ ms}^{-2}$

6. The figure below figure below shows a section of a tape used to study the motion of a body. The ticker timer used has a frequency of 50 Hz.



Determine the acceleration of the body.

ANSWER:

time interval between two dots = period, $T = \frac{1}{f} = \frac{1}{50} = 0.02\ \text{s}$

initial velocity, $u = \frac{x_1}{T} = \frac{0.016}{0.02} = 0.8\ \text{ms}^{-1}$

final velocity, $v = \frac{x_2}{T} = \frac{0.020}{0.02} = 1.0\ \text{ms}^{-1}$

Total time taken between the average initial and final velocities:

$t = \text{period} \times (n - 1)\text{spaces}$ $t = 0.02 \times (9 - 1)\text{spaces} = 0.16\ \text{s}$

Acceleration, $a = \frac{v-u}{t} = \frac{1.0-0.8}{0.16} = \frac{0.2}{0.16} = 1.25\ \text{ms}^{-2}$

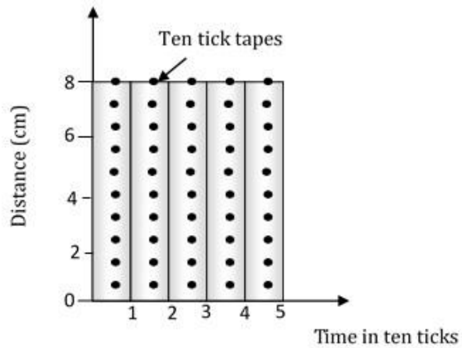
7. 2012 p1 no.41 (t=0.20s)

8. 2014 p1 no.40 (speed=0.53ms^{-1})

TAPE CHARTS

Tape charts are made by sticking successive strips of tape, usually tentick lengths, side by side.

1. **Tape chart representing Uniform velocity**:



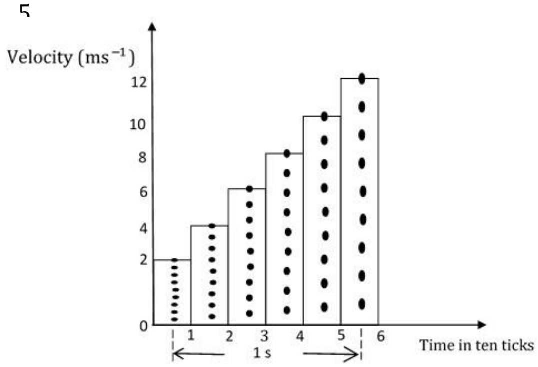
The chart represents motion of a body moving with uniform velocity since equal distance has been moved in each ten tick interval.

$$\text{Velocity} = \frac{\text{distance}}{\text{time}} = \frac{\text{distance}}{\text{period} \times \text{no. of spaces}}$$

$$\text{Velocity} = \frac{8}{\frac{1}{50} \times 10} = 40\ \text{cms}^{-1}$$

2. **Tape chart representing uniform acceleration**.

If the difference in length of tentick tapes is the same, then the tape chart represents motion of a body moving with uniform acceleration (i.e. the speed increased by the same amount in every ten tick interval of $\frac{1}{5}$



s).

The speed during the first tentick is $\mathbf{2\ cm/\frac{1}{5}\,s}$ or $\mathbf{10\ cms^{-1}}$. During the sixth tentick, it is $\mathbf{12\ cm/\frac{1}{5}\,s}$ or $\mathbf{60\ cms^{-1}}$. Therefore during this interval of 5 tenticks i.e 1 second ($\mathbf{5 \times 0.2}$ $=$ $\mathbf{1.0\ s}$), the change of speed is $(\mathbf{60} - \mathbf{10})\ \mathbf{cms^{-1}} = \mathbf{50\ cms^{-1}}$.

$$\text{acceleration} = \frac{\text{change of speed}}{\text{time taken}} = \frac{50\ \text{cms}^{-1}}{1\ \text{s}} = 50\ \text{cms}^{-2}$$

.

Motion under Gravity

Anybody left to fall freely accelerates at a rate g ms^{-2} towards the centre of the Earth. So, if the body is moving upwards, it retards at this rate, in which case the acceleration is –g. i.e. if the upward direction is taken to be positive, the gravitational acceleration is negative (because it is a retardation).

Definition:

Acceleration due to gravity is the rate of change of velocity of a body falling freely under the influence of the earth's pull on it.

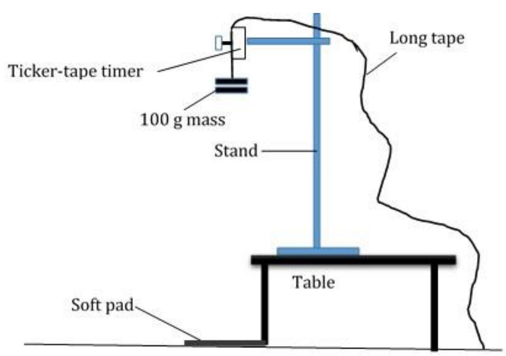
Or

Acceleration due to gravity is the acceleration due to the pull of the earth on the objects.

Experiments to determine acceleration due to gravity:

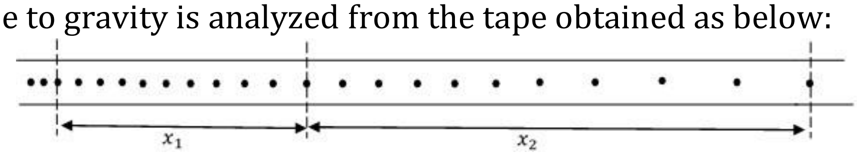
1. Experiment to determine acceleration due to gravity using a ticker-tape timer.

A ticker-tape timer is clamped as shown in the diagram at a height of about 2m above the ground.



A 100 g mass attached to one end of the tape passing through a ticker-tape timer is **released to fall freely under gravity** and at the same time, the ticker-tape timer is switched on.

The acceleration due to gravity is analyzed from the tape obtained as below:



The first few dots are ignored because they are too close to be distinguished from each other. The distances x_1 and x_2 occupied by successive 10 dot-spaces are measured.

The time taken by a 10 dot-space = 10×0.02

$= 0.2$ s average velocity over the distance

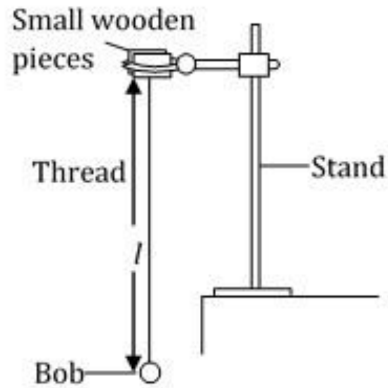
$x_1 = \frac{x_1}{0.2\text{ s}}$ similarly, the average velocity over

distance $x_2 = \frac{x_2}{0.2\text{ s}}$

hence, change in velocity in 0.2 s $= \frac{x_2}{0.2} - \frac{x_1}{0.2} = \frac{x_2 - x_1}{0.2}$

Now, the acceleration due to gravity. $g = \frac{\text{Change in velocity}}{\text{Time}} = \frac{x_2 - x_1}{(0.2s)^2}$

An experiment to determine acceleration due to gravity using a simple pendulum.

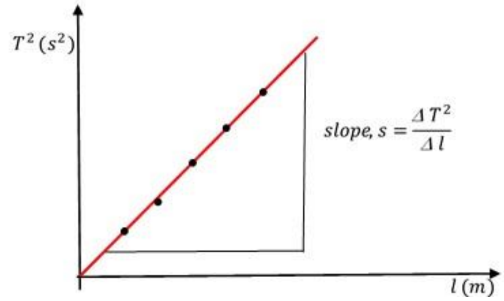


The apparatus is assembled as shown in the diagram.

Starting, with a string length of $l = 100$ cm, the pendulum bob is displaced through a small angle, θ and then released to oscillate freely.
A stop watch is used to time 20 oscillations of the pendulum and the time taken is recorded as t second.
The time, T, taken for one oscillation is calculated as $T = \frac{t}{20}$ s.
The experiment is repeated for at least five different string lengths, that is l = 90cm, 80 cm, 70 cm, 60 cm, 50 cm and 40 cm respectively.
The results are recorded in a suitable table including values of T^2, as below.

l(m)	t(s)	T(s)	$T^2(s^2)$
1.000			
0.900			
0.800			
0.700			
0.600			
0.500			

A graph of T^2 against l is plotted as below.

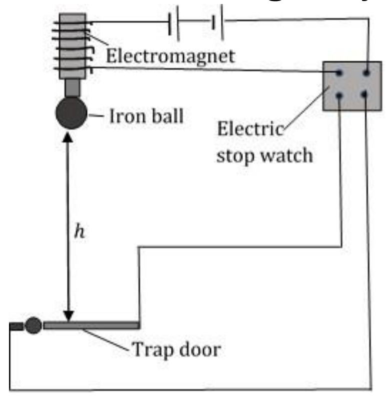


The acceleration due to gravity, g is calculated from the formula

$$g = \frac{4\pi^2}{s}.$$

Experimental results show that the average value of acceleration due to gravity, g is 9.8 ms^{-2}. For purposes of easing calculations, g is approximated to 10 ms^{-2}.

Experiment: To determine acceleration due to gravity using an electromagnet.



The apparatus is set up as shown in the diagram.
When the switch is closed, the electromagnet holds the iron ball in position.
When the switch is opened, the ball falls freely and the clock starts to count at the same time.
The stop clock stops immediately the iron ball hits the trap door and breaks the circuit.
The time recorded, t is the time taken by the iron ball to fall through the distance, h. The acceleration due to gravity, g is calculated from the equation

$$h = \frac{1}{2}gt^2, \left(\text{i.e.} \;\; g = \frac{2h}{t^2}\right).$$

The equations of motion under gravity are:

The equations of motion for a body moving under the influence of gravitational force are.

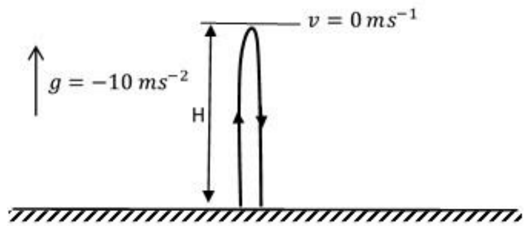
$$\mathbf{v = u + gt}$$

$$\mathbf{h = ut + \frac{1}{2}gt^2}$$

$$\mathbf{v^2 = u^2 + 2gh}$$

- If the body is moving vertically upwards against the force of gravity, it will be decelerating at $g = -10\ ms^{-2}$.
- If the body is moving vertically downwards in the direction of the force of gravity, it will be accelerating at $g = 10\ ms^{-2}$.
- All displacements above the point of projection are considered as positive, while those below the point of projection are negative.

Key terms:



1. **Maximum/greatest height, H,**
   This the greatest vertical displacement of the object from the point of projection.

2. **Trajectory.**
   This is the path described by a body in flight or motion.

3. **Time of flight**, T.
   This the total time taken by an object to move from its point of projection and back.
   Note:
   1. At maximum height, the velocity of the object is zero, since the object is momentarily at rest. $(\text{i. e. } v = 0\text{ ms}^{-2})$.
   2. The time taken to reach maximum height, t is half the time of flight, T.
   i.e. $t = \frac{1}{2}T$.

Examples

1. A particle is projected vertically upwards with a velocity of 20ms^{-1}. Find:
   (i) the greatest height the particle attains.
   (ii) the time taken to attain the greatest height.
   (iii) the velocity and direction of motion after 3 s of motion.
   (iv) the height 3 s after projection.
   (v) the time of flight.
   [Take g to be 10 ms^{-2}]

   Solution

   (i) **At the maximum height, the velocity of the particle is zero**.
   Let $h = \text{greatest height}$
   Then, using $\mathbf{v^2 = u^2 + 2gh}$, , we have
   $0 = 20^2 + 2 \times (-10)$
   ∴$h = 20$ m

   (ii) Using $\mathbf{v = u + gt}$, where t is the time required to reach the greatest height, we have
   $0 = 20 + (-10)t$
   $\therefore t = 2$ s

   (iii) Using $v = u + gt$, where v_1 is the velocity after 3 s, we have
   $v = 20 - 10 \times 3 = -10\text{ ms}^{-}$
   Since we chose the upward direction to be positive, the negative sign implies that the particle is moving downwards.

(iv) Using $h = ut + \frac{1}{2}gt^2$, we have

$$h = 20 \times 3 + \frac{1}{2} \times (-10) \times 3^2 = 15 \text{ m}$$

(v) The total displacement of the stone during the time of flight is zero.

From $h = ut - \frac{1}{3}gt^2$

$0 = 20T - \frac{1}{2} \times 10 \times T^2$

$0 = 5T(4 - T)$

either $T = 0$ or $T = 4$

The time of flight, $T = 4$ s.

2. A stone released from the top of a tree hits the ground after 3s. Find:
   (i) the height of the tree.
   (ii) the velocity with which it hits the ground.

Solution

(i) We may take the downward direction as positive. So, the acceleration is

$g = 10 \text{ ms}^{-2}$. Using $h = ut + \frac{1}{2}gt^2$, where $u = 0 \text{ ms}^{-1}$, we have

$h = 0 + \frac{1}{2} \times 10 \times 3^2 = 45 \text{ m}$

The tree is 45 m tall.

(ii) Using $v = u + gt$, we have

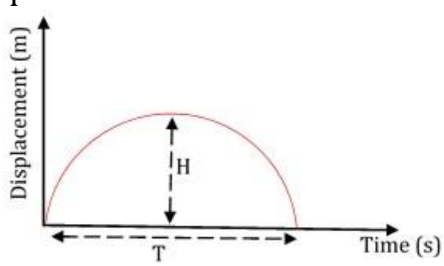
$v = 0 + 10 \times 3$

$= 30 \text{ ms}^{-1}$

The stone hits the ground with a velocity of 30 ms^{-1}.

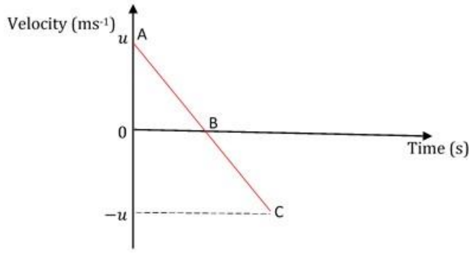
Graphs of motion under gravity.

1. Displacement –Time graph.



The object decelerates on its upward journey until it reaches maximum height, H when it is momentarily at rest. It the changes direction as it accelerates downwards.

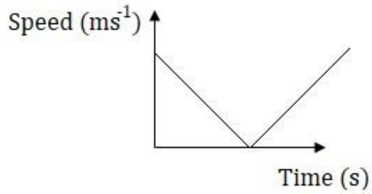
2. Velocity-time graph for a body projected vertically upwards.



At A, the body is projected vertically upwards with an initial velocity of u ms^{-1}.

It then decelerates uniformly at a rate of 10 ms^{-2} until it comes to momentarily at rest at B. It then changes direction and accelerates downwards until it comes back to its original position of projection.

3. Speed-time graph for a body projected vertically upwards.



Effects of variation in force of gravity.

The gravitational force varies from planet to planet. Therefore,

1. different planets have different accelerations due to gravity.
2. the weight of a body varies from one planet to the other (i. e. w = mg).
3. the mass of the body remains constant on all planets.

Examples

1. A particle is projected vertically upwards with a velocity of 30ms^{-1}. Find:
   (i) the greatest height the particle attains (h = 45m)
   (ii) the time taken to attain the greatest height (t = 3s)
   (iii) the velocity and direction of motion after 4s of motion (v = 10ms^{-1} downwards) (iv) the height 4s after projection. (h = 40m)
   [Take g to be 10ms^{-2}]

   Solution

   (i) At the highest point the velocity of the particle is zero
   Let h = greatest height
   Then, using $v^2 = u^2 - 2gs$, we have
   $0^2 = 30^2 - 2 \times 10s$,
   h = 45m

   (ii) Using v = u − gt , where t is the time required, we have v = u – gt 0 = 30 − 10t
   t = 3s

   (iii) Using v = u − gt, where v is the velocity after 3 s, we have
   v = 30 – 10 x 4

$v = -10ms^{-2}$

Since we chose the upward direction to be positive, the negative sign implies that the particle is moving downwards.

(iv) Using $h = ut - \frac{1}{2}gt^2$, we have

$$h = 30 \times 4 - \frac{1}{2} \times 10 \times 4^2$$

$$h = 40m$$

2. A stone is released from the top of a tree and hits the ground after 3s. Find:

(i) the height of the tree

(ii) the velocity with which it hits the ground

Solution

(i) We may take the downward direction as positive. So, the acceleration is $g = 10ms^{-2}$.

Using $h = ut + \frac{1}{2}gt^2$, where u = 0, we have

$$h = 0 + \frac{1}{2} \times 10 \times 3^2 = \underline{\underline{45m}}$$

(ii) Using $v = u + gt$, we have

$$v = 0 + 10 \times 3 = \underline{\underline{30}}ms^{-1}$$

3. A body is thrown vertically upwards with an initial velocity of $20ms^{-1}$. Given that the gravitational pull $g = 10ms^{-2}$, find

(i) the time the body takes to reach the maximum height. (2s)

(ii) the maximum height reached above the starting point. (20m)

(iii) the total time of flight. (4s)

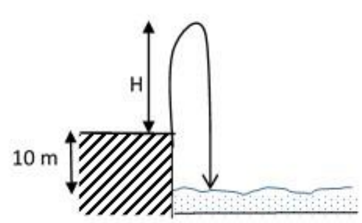
4. A particle is projected vertically upwards with a velocity of 20 ms^{-1} from the edge of a cliff that is 10 m above the sea level. Find

(i) the maximum height reached by the particle.

(ii) the velocity at which the particle hits the water.

(iii) the total time taken for the particle to hit the sea. (acceleration due to gravity, $g = 10$ ms^{-2})

Solution:



$v^2 = u^2 + 2gh$

$0 = 20^2 + 2(-10)H$

Maximum height, $H = \frac{400}{20} = 20\text{ m}$.

(ii) The resultant displacement of the particle by the time it hits the water is 10 m below the edge of the cliff

i. e. $h = -10\text{ m}$

Applying equation : $v^2 = u^2 + 2gh$

$v^2 = 20^2 + 2 \times (-10) \times (-10)$

$v^2 = 400 + 200 = 600$

$v = \sqrt{600} = 24.2949\ \text{ms}^{-1}$

(iii) From the equation $h = ut + \frac{1}{2}gt^2$

$h = -10\text{ m},\ g = -10\text{ ms}^{-2}, u = 20\text{ ms}^{-1}$

$-10 = 20t + \frac{1}{2}(-10)t^2$

$\therefore\ 5t^2 - 20t - 10 = 0$ then

Simplifying:

$t^2 - 4t - 2 = 0$

Solving for t:

$t = \frac{4 \pm \sqrt{16 + 4 \times 2}}{2} = \frac{4 \pm \sqrt{24}}{2} = \frac{4 \pm 2\sqrt{6}}{2}$

$\therefore\ t = \left(2 + \sqrt{6}\right)\text{ s}$

Or

Time taken to reach

NON-LINEAR MOTION

Projectile Motion

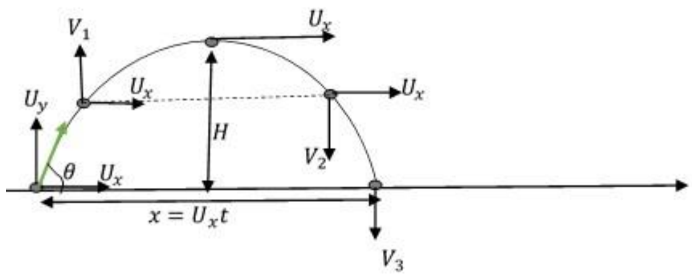
A **projectile** is a body given an initial velocity and allowed to move freely under the influence of gravitational force only.

Applications of projectile motion:

Projectile motion is applied in:

1. in ball games like football, netball, volleyball, basketball, etc.
2. in launching of missiles, cannons, etc.
3. in dropping of cargo from planes.

If a particle is projected at an angle, θ to the horizontal, its path will be a parabolic curve.



The particle's velocity at any instant will consist of two parts – the horizontal and vertical components.

The projectile will experience both horizontal and vertical motion at the same time. However, the horizontal motion is independent of the vertical motion.

Horizontal motion

The horizontal velocity, U_x remains constant throughout the motion. This is because there is no force of gravity acting in the horizontal direction.

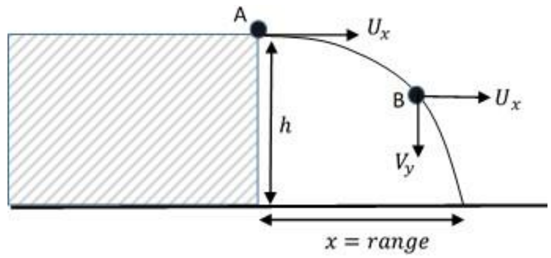
The maximum horizontal distance moved by the projectile during the time of flight, T is known as the **range**.

Vertical motion.

The vertical motion of the projectile is influenced by the force of gravity which acts against it during its upward motion causing it to decelerate. At maximum height, H, the velocity of the projectile becomes zero. The projectile then changes direction and starts accelerating downwards.

Horizontal projection:

If an object is thrown horizontally, say from the top of a platform as shown below, with an initial velocity of U_x;



The object describes both horizontal and vertical motions that are independent of each other at the same time.

Horizontal motion

The horizontal motion is independent of the gravitational force, therefore the horizontal velocity, U_x remains constant throughout the motion.

horizontal distance = velocity × time of flight

$\mathbf{x = U_xt}$

Vertical motion.

When the object is at A, its initial vertical velocity is zero. However, the object accelerates uniformly under the influence of the gravitational force. Therefore, the vertical distance, h it covers in the time of flight is given by the equation $\mathbf{h = \frac{1}{2}gt^2}$.

Examples

1. A girl throws a ball horizontally from a window of a room on the 8th floor of a certain building. If it takes the ball 4 seconds to hit the ground below, find
   (i) the vertical height above the ground of the point of projection.
   (ii) the velocity with which the ball was projected given that it landed 50 m away from the building. (acceleration due to gravity, $g = 10\ ms^{-2}$) **Solution:**
   (i) Equation of vertical motion:
   $$h = \frac{1}{2}gt^2.$$
   Substituting in the equation;
   $$h = \frac{1}{2} \times 10 \times 4^2 = 80\ m.$$

   (ii) Equation of horizontal motion:
   $x = U_xt$
   Substituting in equation:
   $50 = U \times 4$ horizontal velocity of projection, $U = 12.5\ ms^{-1}$.

2. A UN plane travelling with a horizontal speed of $180\ ms^{-1}$ drops a parcel of supplies from a height of 2000 m above the ground. If acceleration due to gravity is $10\ ms^{-2}$, find, (i) the time taken by the parcel to reach the ground.

(ii) the horizontal distance moved by the parcel from the time it was dropped from the plane. **Solution:**

(i) From $h = \frac{1}{2}gt^2$,

$$2000 = \frac{1}{2} \times 10 \times t^2$$
$$t^2 = 400$$
$$t = 20\ s$$

(ii) From $x = U_xt$ $x = 180 \times 20 = 3600$ m.

3. A body is projected horizontally off the cliff at a velocity of $15ms^{-1}$. The height of the cliff is 20m.
   (a) Find the time it takes to reach the ground. (t = 2s)
   Leave 5 lines
   (b) Find the distance from the cliff to where it falls. (x = 30m) Leave 5 lines

Test yourself (In your revision book)

1. A helicopter delivering relief food is travelling at $200ms^{-1}$ at a height of 500m.
   (i) Calculate the time food takes to reach the ground. (t = 10s)
   (ii) Calculate the distance the food travels before it reaches the ground. (x = 2000m)

2. A ball goes down a ramp and is projected horizontally off the end of the table. If it falls a vertical height of 0.45m and hits the ground 2.1m away at point G.
   (a) How long does it take to fall 0.45m?
   (b) What is its horizontal velocity as it leaves the ramp?

3. A stone is thrown horizontally at $15ms^{-1}$from the top of a building of a height 125 m to a target on the ground. Calculate.
   (i) The time taken for the stone to hit the target. (t = 5s)
   (ii) How far is the target from the foot the of the building. (x = 75m)

$5ms^{-1}$

4. A train travelling at a constant acceleration of $2ms^{-2}$ passes a point A with a speed of and passes another point B 80 m ahead of A. Find the velocity of the body at B. ($18.56\ ms^{-1}$)

5. Two vehicles P and Q, originally at the same place, accelerate uniformly from rest. P attains a maximum velocity of $25ms^{-1}$ in 10 s while B attains a maximum velocity of $40ms^{-1}$ in the same time. Both vehicles maintain the same velocities respectively for 8s. They then undergo uniform retardation such that P comes to rest in 4 s while Q comes to rest in 6 s. Find:
   (i) the velocity of each vehicle 18s after start.
   (ii) the distance between the two vehicles when Q comes to rest.

6. A particle, which is retarding uniformly, passes a point A with a velocity of 40 m s^{-1} and after 4 s seconds it passes another point B 100m ahead. Find
   (i) the acceleration of the particle
   (ii) how far the particle is from B when it comes to rest.

7. The table below shows the distance, x, in metres covered after time, t, in seconds for a moving particle.

t(s)	0	2	4	6	8	10
x(m)	4	14	24	34	44	54

   Plot a graph of distance against time and find the speed of the particle.

8. The table below shows the velocity v ms^{-1} attained after time t seconds for a particle.

t(s)	0	2	4	6	8	10	12	14	16	18
v(ms^{-1})	5	13	21	29	39	39	39	27	15	3

   Draw the velocity-time graph for the motion and describe the motion of the particle during its motion. Find:
   (i) The distance covered throughout the journey
   (ii) the acceleration of the particle
   (iii) the retardation
   (iv) the distance moved while accelerating
   (v) the time that will have elapsed when it stops

6. A particle is projected vertically upwards with a velocity of 30 m s^{-1}. Find:
(i) the time taken for the particle to attain the greatest height.
(ii) the displacement of the particle 5 s after projection.

THE END.