Dr. Bbosa Science

This document is sponsored by
The Science Foundation College Kiwanga- Namanve
Uganda East Africa
Senior one to senior six
+256 778 633 682, 753 802709
Based on, best for sciences

Digital Teachers
Nurture your dreams

Motion in straight line

Distance and displacement

Distance is a length between 2 fixe points

Displacement is the distance covered in a specific direction

Speed and velocity

Speed is the rate of change of distance with time

Velocity is the rate of change of displacement with time

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

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

Example 1

Find the distance travelled in 5s by a body moving with a constant speed of 3.2ms^{-1}

Solution

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

3.2 = $\frac{total\ distance}{5}$

distance = 16m

Example 2

John ran 1500m in 3minutes and 33s, find his average speed.

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

speed = $\frac{1500}{(3\ x\ 60+33)}$ = 7.04ms^{-1}

Acceleration

It is the rate of change of velocity

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

a = $\frac{v-u}{t}$ where v = final velocity, u = initial velocity, t = time

Uniform acceleration

This is the constant rate of change of velocity with time

Equations of uniform acceleration

1st equation

Suppose a body moving in a straight line with uniform acceleration a, increases its velocity from u to v in time t, then from the definition of acceleration

a = $\frac{v-u}{t}$ | at = v -u | **v = u + at** 1

2nd equation

Suppose an object with velocity u moves with uniform acceleration a time t and attains a velocity v, the distance s travelled by the object is given by: s = average velocity x time

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

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

s = $\left(\frac{2ut+at^2}{2}\right)$

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

3rd equation

s = average velocity x time

s = $\left(\frac{v+u}{2}\right)t$ but t = $\frac{v-u}{a}$

s = $\left(\frac{v+u}{2}\right)\left(\frac{v-u}{a}\right)$ =

s = $\left(\frac{v^2-u^2}{2a}\right)$

$\boldsymbol{v^2 = u^2 - 2as}$ 3

Example 3

A car is initially at rest at a point O. The car moves from O in a straight line with an acceleration of $4ms^{-2}$. find how far the car

(i) is from O after 2s

From **s = ut +** $\boldsymbol{\frac{1}{2}at^2}$**;** **s =** 0 x 2 + $\frac{1}{2}x\ 4\ x\ 2^2$ = 8m

(ii) is from O after 3s

s = 0 x 2 + $\frac{1}{2}x\ 4\ x\ 2^2$ **= 1**8m

(iii) distance travelled in the third second = 18 – 8 = 10m

Example 4

A body at O moving with a velocity $10ms^{-2}$ decelerates at $2ms^{-2}$.

(a) find the displacement of the body from O after 7s
From s = ut + $\frac{1}{2}at^2$
s = 10 x 7 + $\frac{1}{2}x - 2\ x\ 7^2$ = 21m
(b) how far from O does the body come to rest and how long does it take
s = $\left(\frac{v^2-u^2}{2a}\right)$ = $\frac{0^2-10^2}{2\ x-2}$ = 25m
t = $\frac{v-u}{a} = \frac{0-10}{-2}$ = 5s

Example 5

A taxi approaching a stage runs two successive half kilometres in 16s and 20s respectively. Assuming the retardation is uniform, find

(i) Initial speed of the taxi

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

For the first half kilometre or 500m

$500 = 16u + \frac{1}{2}a(16)^2$ ……… (i)

for the kilometre or 1000m

$1000 = 36u + \frac{1}{2}a(36)^2$…….. (ii)

from eqn. (i) and eqn. (ii)

$a = \frac{25}{72}$ and $u = 34.028ms^{-1}$

(ii) the further distance, the taxi runs before stopping

$s = \left(\frac{v^2 - u^2}{2a}\right) = s = \left(\frac{0^2 - (34.028)^2}{2\left(\frac{25}{72}\right)}\right) = 1667.3m$

Extra distance = 1667.3 – 1000 = 667.3m

Example 6

An overloaded taxi travelling at constant velocity of 90km/h overtakes a stationary traffic police car. 2s later, the police car sets in pursuit, accelerating at a uniform rate of $6ms^{-2}$. How far does the traffic car travel before catching up with the taxi?

Solution

t_1 = time taken by the taxi

t_2 = time taken by the police car

$t_1 = 2 + t_2$

speed of the taxi in m/s

$90km/h = \frac{90 \times 1000}{3600} = 25ms^{-1}$

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

$s_T = 25t_1$

$s_C = 0 \times t_2 + \frac{1}{2} \times 6 \times t_2^2 = 3t_2^2$

For the car to catch taxi; $s_T = s_C$

$25t_1 = 3t_2^2$

$25(2 + t_2) = 3t_2^2$

$t = 10s$ or $t = \frac{4}{3}s$

the car leaves 2s later then 10s is the correct time since it gives positive distance

$s_C = 3t_2^2 = 3 \times 10^2 = 300m$

Example 7

A lorry starts from a point A and moves along a straight horizontal road with a constant acceleration of $2ms^{-2}$. At the same time a car moving with a speed of $20ms^{-1}$ and a constant acceleration of $3ms^{-1}$ is 400m behind the point A and moving in the same direction as the lorry. find:

(a) how far from A the car overtakes the lorry.
a car over takes the lorry; both move in the same time, t

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

distance moved by the car = 400 + distance moved by the lorry

20t + $\frac{1}{2}$ x $3x$ t^2 = 400 + $\frac{1}{2}$ x 2 x t^2

t^2 + 40t – 800 = 0; t = 14.64s or t = -54.64s

Hence t = 14.64s

sL = $\frac{1}{2}$ x 2 x $(14.64)^2$= 214.33m

(b) the speed of the lorry when it is being overtaken

v = u + at

= 0 + 2 x 14.64 = 29.28ms^{-1}

Example 8

The seed of a taxi decreases from 90kmh^{-1} to 18kmh^{-1} in a distance of 120 metres. Find the speed of the taxi when it had covered a distance of 50metres. (05marks)

Given u = 90kmh^{-1}, v = 18kmh^{-1}, s = 120m = 0.12km
Using $v^2 = u^2 + 2as$
$18^2 = 90^2 + 2a(0.12)$
a = -32400kmh^{-2}
When s = 50m = 0.05km, u = 90kmh^{-1}, a = -32400kmh^{-2}
Using $v^2 = u^2 + 2as$
$v^2 = 90^2 – 2 \times 32400 \times 0.05 = 4860$
v = $\sqrt{4860} = 69.71kmh^{-1}$

Example 9

(a) Show that the final velocity v of a body which starts with an initial velocity u and moves with uniform acceleration a consequently covering a distance x, is given by v = $[u^2 + 2ax]^{\frac{1}{2}}$

x = average velocity x time

x = $\left(\frac{v+u}{2}\right)t$ but t = $\frac{v-u}{a}$

x = $\left(\frac{v+u}{2}\right)\left(\frac{v-u}{a}\right)$ = $\left(\frac{v^2-u^2}{2a}\right)$

$\boldsymbol{v^2 = u^2 + 2ax}$

v = $[u^2 + 2ax]^{\frac{1}{2}}$

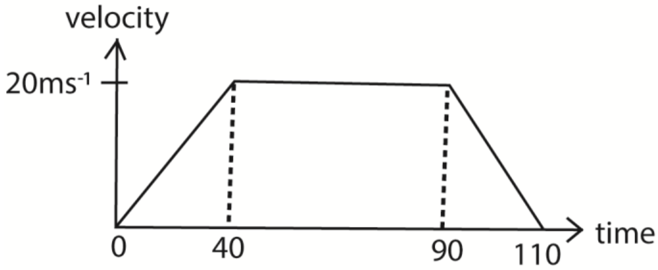
(b) Find the value of x in (a) if v = 300m/s, u = 10m/s and a = 5m/s
30 = $[10^2 + 2x\ 5x]^{\frac{1}{2}}$
900 = 100 + 10x
x =80m

Velocity-time graphs

Example 10

A car started from rest and attained a velocity of 20m/s in 40s. It then maintained the velocity attained for 50s. After that it was brought to rest by a constant breaking force in 20s.

(i) Draw a velocity-time graph for the motion



(ii) using the graph, find the total distance travelled by the car

Total distance = total area under the graph

$$= \frac{1}{2}bh + lw + \frac{1}{2}bh$$

$$= \frac{1}{2}x\ 40\ x\ 20 + 50x\ 20 + \frac{1}{2}x\ 20\ x\ 20 = 1600\text{m}$$

Method II (area of a trapezium)

$$A = \frac{1}{2}h(a+b) = \frac{1}{2}x\ 20(50+110) = 1600\text{m}$$

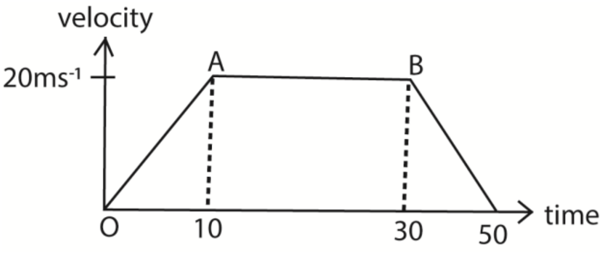
(iii) what is the acceleration of the car?

$$a = \frac{v-u}{t} = \frac{20-0}{40} = 0.5ms^{-2}$$

Example 11

A car from rest accelerates steadily to 10s up to a velocity f 20ms. It continues with uniform velocity for further 20s and then decelerates so that it stops in 20s.

(a) Draw a velocity-time graph to represent the motion



(b) Calculate

(i) acceleration

$$a = \frac{v-u}{t} = \frac{20-0}{10} = 2ms^{-2}$$

(ii) deceleration

$$a = \frac{v-u}{t} = \frac{0-20}{20} = -1ms^{-2}$$

(i) Distance = area under the graph

$$A = \frac{1}{2}x\ 10\ x\ 20 + 20x\ 20 + \frac{1}{2}x\ 20\ x\ 20$$

$= 700$m

Method II (area of a trapezium)

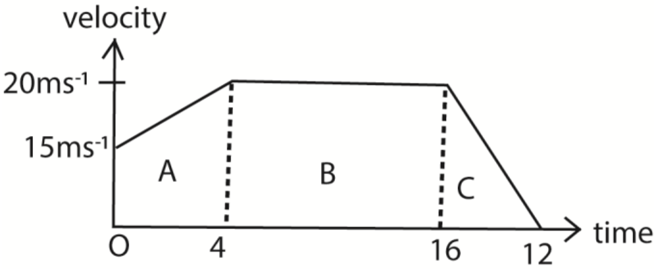
$$A = \frac{1}{2}\ x\ 20(50+20) = 700\text{m}$$

$$\text{Average speed} = \frac{distance}{time}$$

$$= \frac{700}{50} = 14m/s$$

Example 12

The graph below shows the motion in the body.



(a) Describe the motion of the body
A body with initial velocity of 15m/s accelerates steadily to a velocity of 20m/s in 4s, it then continues with a uniform velocity for 6s and brought to rest in 2s.

(b) Calculate the total distance travelled
Distance = 4 x 15 + $\frac{1}{2}x\ 4\ \ x\ 5 + 20\ x\ 6 + \ \frac{1}{2}x\ 20\ \ x\ 2$ = 210m

Revision exercise

1. P, Q and R are points on a straight road such that PQ = 20m and QR = 55m. A cyclist moving with uniform acceleration passes O and then notices that it takes him 10s and 15s to travel between P and Q and Q and R respectively. find the acceleration [a = $\frac{2}{15}ms^{-2}$]
2. A car travels from Kampala to Jinja and back. It takes average speed on the return journey is 4km/h greater than that on the outward journey and it takes 12 minutes less. Given that Kampala and Jinja are 80km apart, find the average speed on the outward journey.[30.05kmh]
3. Car A traveling at 35ms^{-1} along a straight horizontal road, accelerates uniformly at 0, 4ms^{-2}. At the same time, another car B moving at 44ms^{-1} and accelerating uniformly at 0.5ms^{-2} is 200m behind A
   (i) Find the time taken before car B over takes car A. [20s]
   (ii) speed with which B over takes A. [55m/s]
4. A car is being driven along a road at 72kmh^{-1} notices a fallen tree on the road 800m ahead and suddenly reduces the speed to 36kh^{-1} by applying brakes. For how long were the brakes applied [53.33s]
5. A train starts from station a with a uniform acceleration of 0.2ms^{-2} for 2 minutes and attains a maximum speed and moves uniformly for 15 minutes. it is then brought to rest at constant retardation of 5/3ms^{-2} at station B. find the distance between A and B. [23212.8m]
6. A motorcycle decelerated uniformly from 20kmh^{-1} to 8kmh^{-1} in travelling 896m. find the rate of deceleration in ms2 [0.0145ms^{-2}]
7. A body moves with a uniform acceleration and covers a distance of 27m in 3s; it then moves with a uniform velocity and covers a distance of 60m in 5s. Find the initial velocity and acceleration of the body. [6ms^{-1}, 2ms^{-2}]
8. A particle is projected away from an origin O with initial velocity of 0.25ms^{-1}. The particle travels in a straight line and accelerates at 1.5ms^{-2}. find
   (i) how far the particle is from O after 4s [7.5m]
   (ii) the distance travelled by the particle during the fourth second after projection. [5.5m]
9. A taxi which is moving with a uniform acceleration is observed to take 20s and 30s to travel successive 400m. find
   (i) initial speed of the taxi. [$\frac{68}{3}ms^{-1}$]

(ii) the further distance it covers before stopping [163.3m]

10. Two cyclist A and B are 36m apart on a straight road. Cyclist B starts from rest with an acceleration of $6ms^{-2}$ while A is in pursuit of B with velocity of $20ms^{-1}$ and acceleration of $4ms^{-1}$. Find the time taken when A overtakes B [13466s]

Thank You

Dr. Bbosa Science