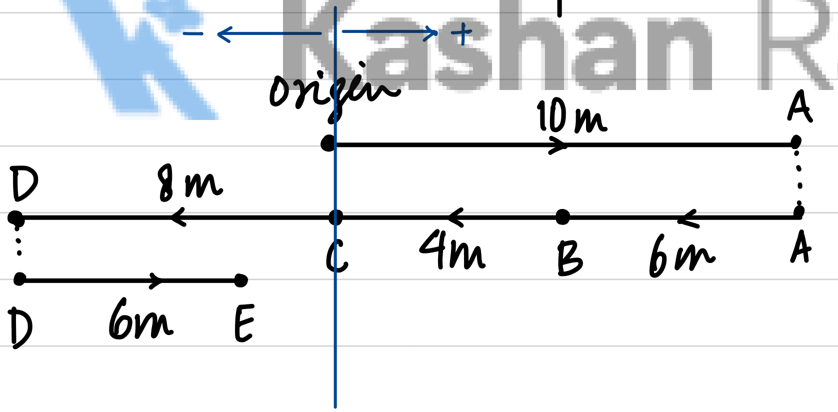
KINEMATICS

PHYSICS BY

Kashan Rashid

Distance	Displacement
i, Length of any arbitrary track between two points	i, Shortest possible distance between two points.
ii, Scalar (magnitude only)	ii, Vector (mag + direction)
iii, Example: distance between points A & B is 50m	iii, Example: Point B is 40m due North-East of A.

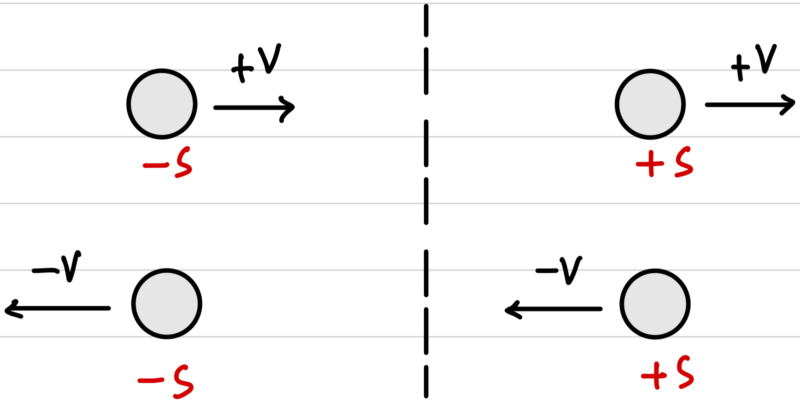


	Distance	Displ.
OA	10m	+10m
OB	16m	+4m
OC	20 m	0m
OD	28m	−8m
OE	34m	−2m

→ The sign of displacement DOES NOT tell you the direction of motion.

→ The sign of displacement tells about the position of object from the origin.

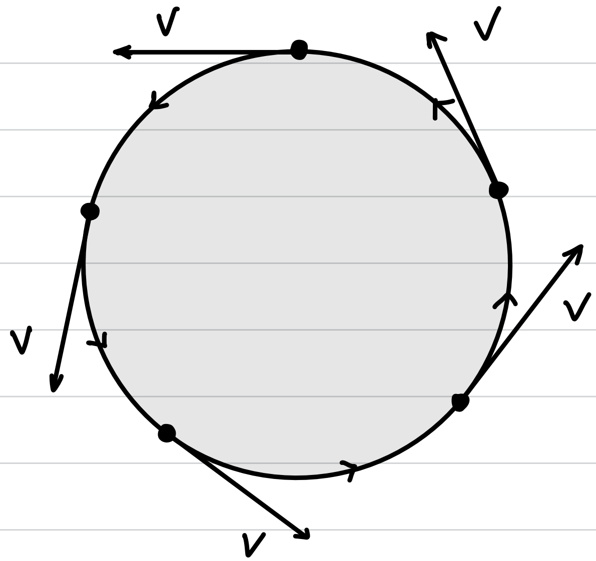
Speed	Velocity
i, Rate of change of distance OR distance travelled per unit time.	i, Rate of change of displacement OR Displacement per unit time.
ii, Scalar	ii, Vector
iii, $v = \frac{d}{t}$ d: distance	iii, $v = \frac{s}{t}$ s: displ.
iv, SI Unit: ms^{-1}	iv, SI Unit: ms^{-1}



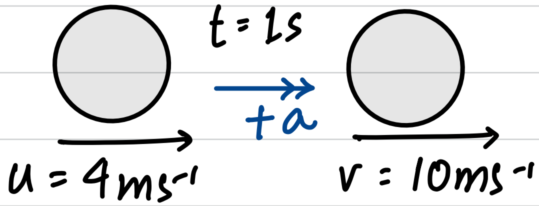
→ The sign of velocity tells about the direction of motion!

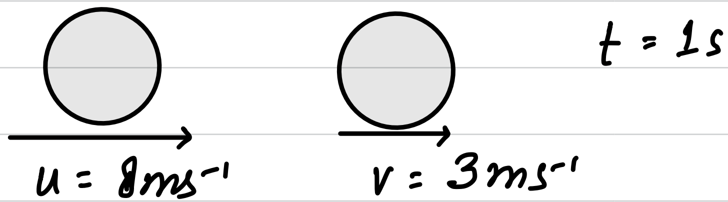
$$\text{Average Speed} = \frac{\text{total distance}}{\text{total time}}$$

$$\text{Average Velocity} = \frac{\text{total displ.}}{\text{total time}}$$



An object moving in a circle has instantaneous velocities but the average velocity is zero as total displ. is zero.





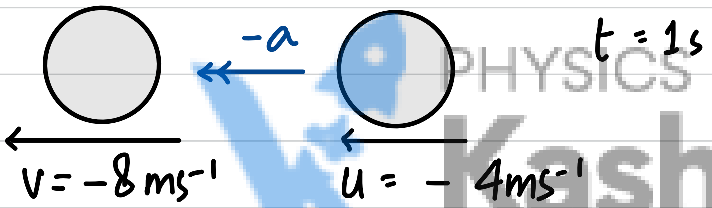
$a = \frac{10-4}{1} = +6\,ms^{-2}$

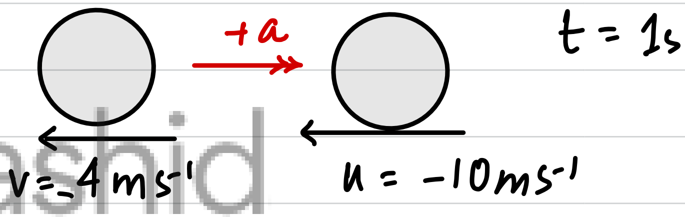
Acceleration

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

$a = \frac{3-8}{1} = -5\,ms^{-2}$

Deceleration





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

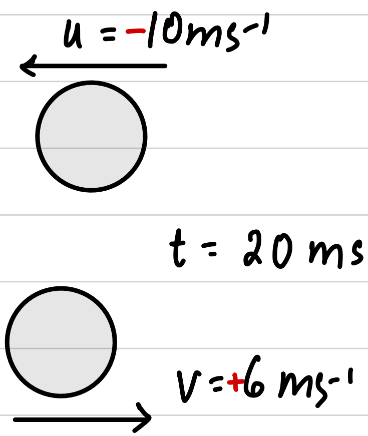
$a = \frac{-8-(-4)}{1}$

$a = -4\,ms^{-2}$

Acceleration

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

$a = \frac{-4-(-10)}{1} = +6\,ms^{-2}$



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

$a = \frac{6-(-10)}{20\times10^{-3}}$

$a = 800\,ms^{-2}$

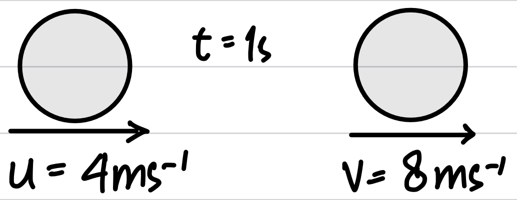
Acceleration

Rate of change of velocity OR Change in velocity with respect to time.

$a = \frac{v-u}{t}$ | SI Unit : ms^{-2} | Vector Quantity

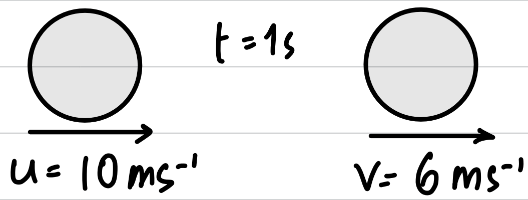
Acceleration occurs when object
1. Changes its speed
2. Changes its direction
3. Changes both speed and direction

- An object moving in a circle is continuously accelerating as its direction keeps changing.



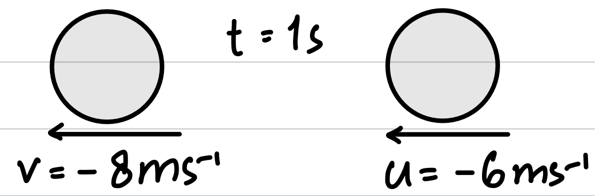
$a = \frac{v-u}{t}$ so $a = \frac{8-4}{1}$

$a = 4\ ms^{-2}$ (acceleration)



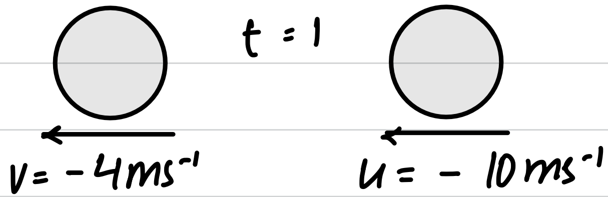
$a = \frac{v-u}{t}$ so $a = \frac{6-10}{1}$

$a = -4\ ms^{-2}$ (deceleration)



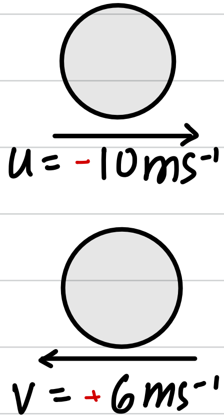
$a = \frac{v-u}{t}$ so $a = \frac{-8-(-6)}{1}$

$a = -2\ ms^{-2}$ (acceleration)



$$a = \frac{v - u}{t} \quad \text{so} \quad a = \frac{-4-(-10)}{1}$$

$a = +6\ ms^{-2}$ (deceleration)



t = 0.1 s

$$a = \frac{v-u}{t} \quad \text{so} \quad a = \frac{-6-(+10)}{0.1}$$

$a = -160\ ms^{-2}$ (acceleration)

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

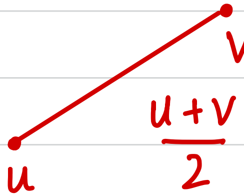
$$= \frac{6-(-10)}{0.1}$$

$$= 160\ ms^{-2}$$

Equations of Motion

1. $v = u + at$ ← $a = \frac{v-u}{t}$
2. $s = \left(\frac{u+v}{2}\right)t$

$s = V_{avg} \times t$



$\frac{u+v}{2} = V_{avg}$

3. $s = ut + \frac{1}{2}at^2$
4. $v^2 - u^2 = 2as$

Conditions for equations

1. Straight line motion
   Straight line analysis
2. Constant Acceleration

• $s = ut + \frac{1}{2}at^2$

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

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

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

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

• $v^2 - u^2 = 2as$

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

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

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

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

$s = \frac{v^2 - u^2}{2a}$ so

$$v^2 - u^2 = 2as$$

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

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

$$v^2 - u^2 = 2as$$

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

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

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

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

$$v - u = at$$

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

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

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

$$s = \frac{v^2 - u^2}{2a}$$

$$v^2 - u^2 = 2as$$

$$(v+u)(v-u) = v^2 - u^2$$

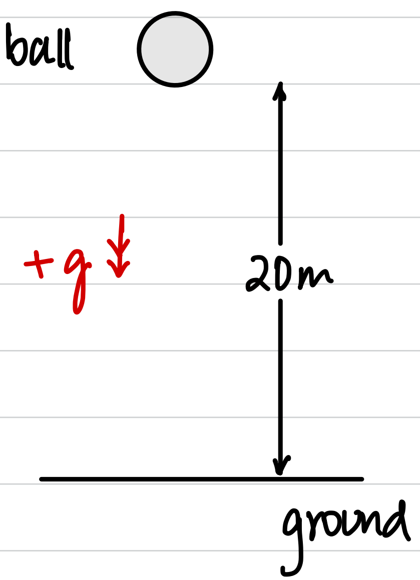
$$(a+b)(a-b)$$

Example #1

An object is dropped from rest from a height of 20m. Assuming air resistance as negligible, determine

i, time to fall to ground

ii, final velocity as it hits the ground.



i, $u = 0\,ms^{-1}$ $s = 20m$ $a = 9.8ms^{-2}$ $t = ??$

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

$20 = 0 + \frac{1}{2}(9.8)t^2$

$t = 2.02s$

ii, $u = 0ms^{-1}$ $s = 20m$ $a = 9.8ms^{-2}$ $v = ?$

$v^2 - u^2 = 2as$

$v^2 - 0^2 = 2(9.8)(20)$ $V = 19.8\,ms^{-1}$

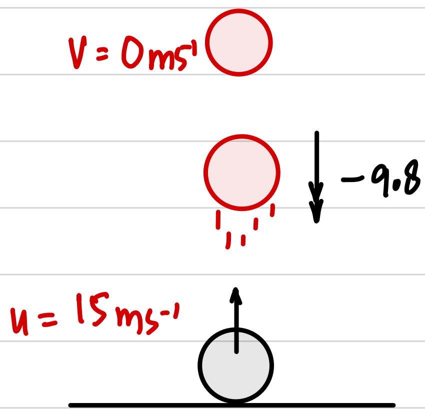
Example #2

An object is launched vertically upwards with a velocity of $15\,ms^{-1}$. Assuming no air resistance, determine

i, max height reached

ii, time to reach max height

iii, total time of flight



i, $u = 15ms^{-1}$ $a = -9.8\,ms^{-2}$ $v = 0$ $s = ??$

$v^2 - u^2 = 2as$

$0^2 - (15)^2 = 2(-9.8)s$

$s = 11.5\,m$

ii, $u = 15\,ms^{-1}$ $a = -9.8\,ms^{-2}$ $v = 0$ $t = ??$

$v = u + at$

$0 = 15 + (-9.8)t$

$t = 1.5\,s$

iii) $t = 1.5 \times 2$

$t = 3.0\,s$

$s = 0,\; u = 15\,ms^{-1},\; a = -9.8\,ms^{-2},\; t = ?$

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

$$0 = 15t + \frac{1}{2}(-9.8)t^2$$

$$0 = 15t - 4.9t^2$$

$$0 = t(15 - 4.9t)$$

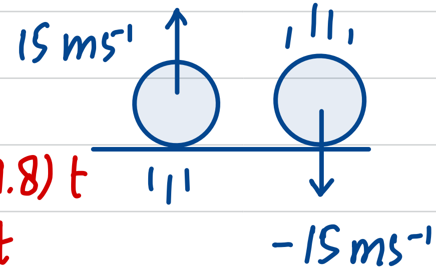
$t = 0\,s$

$15 - 4.9t = 0$

$t = 3.0\,s$

$u = 15\,ms^{-1}$ $\quad a = -9.8\,ms^{-2}$

$v = -15\,ms^{-1}$ $\quad t = ??$



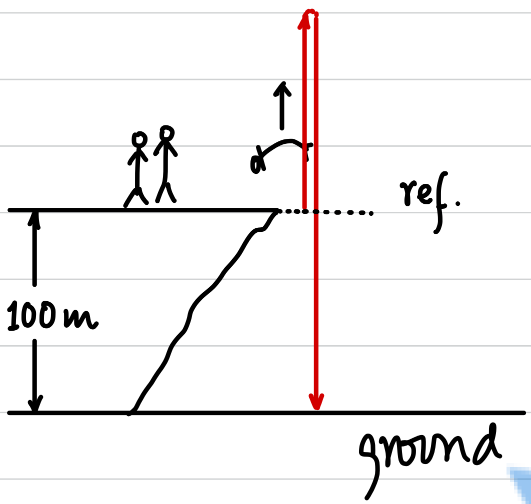
$$v = u + at$$

$$-15 = 15 + (-9.8)t$$

$$-30 = -9.8t$$

$t = 3.06\,s$

Example # 3



A man was launched from the top a 100m high cliff with a velocity of $20 ms^{-1}$ vertically upwards. Assuming negligible air resistance, calculate

i, time to reach max height

ii, max height reached
   a) from cliff top
   b) from ground

iii, time when he crosses the cliff top again

iv, speed before he faces a (maybe certain) death. i.e. hits the ground

v, the most thrilling seconds of his life i.e. time of flight.

i, $u = 20 ms^{-1}$, $a = -9.8 ms^{-2}$, $v = 0 ms^{-1}$, $t = ?$

$v = u + at$

$0 = 20 + (-9.8)t$

$t = 2.04 s$

ii, $u = 20 ms^{-1}$, $a = -9.8 ms^{-2}$, $v = 0 ms^{-1}$, $s = ?$

$v^2 - u^2 = 2as$

$0 - (20)^2 = 2(-9.8)s$

a) $s = 20.4 m$ b) $100 + 20.4 = 120.4 m$

iii) **Method #1**

$t = 2.04 \times 2$

$t = 4.08s$

Method #2

$u = 20ms^{-1}$, $a = -9.8ms^{-2}$

$s = 0$, $t = ?$

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

$0 = 20t + \frac{1}{2}(-9.8)t^2$

$0 = 20t - 4.9t^2$

$4.9t^2 - 20t = 0$

$t(4.9t - 20) = 0$

$t = 0$ $\qquad$ $t = \frac{20}{4.9}$

$t = 4.08s$

Method #3

$u = 20ms^{-1}$, $a = -9.8ms^{-2}$

$v = -20ms^{-1}$, $t = ?$

$v = u + at$

$-20 = 20 + (-9.8)t$

$\frac{-40}{-9.8} = t$

$t = 4.08s$

iv) $u = 20ms^{-1}$, $a = -9.8ms^{-2}$

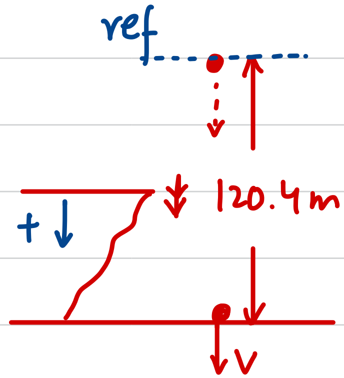
$s = -100m$, $v = ??$

$v^2 - u^2 = 2as$

$v^2 - (20)^2 = 2(-9.8)(-100)$

$v = 48.6\ ms^{-1}$

Another way..



$u = 0\ ms^{-1}$

$a = 9.8ms^{-2}$

$s = 120.4m$

$v = ??$

$v^2 - u^2 = 2as$

$v^2 - 0 = 2(9.8)(120.4)$

$v = 48.6ms^{-1}$

v. **Method # 1**

$u = 20\,ms^{-1}$, $a = -9.8\,ms^{-2}$

$t = ?$, $s = -100\,m$

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

$$-100 = 20t + \frac{1}{2}(-9.8)t^2$$

$$-100 = 20t - 4.9t^2$$

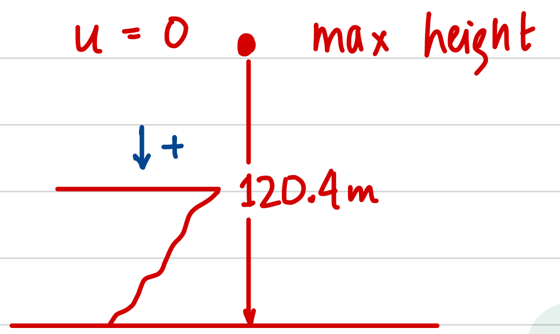
$$4.9t^2 - 20t - 100 = 0$$

$t_1 = -2.19s$ $t_2 = 7.0s$

Method # 2

$t_{rise} = 2.04s$

$t_{fall} = ?$



Either

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

$$120.4 = 0 + \frac{1}{2}(9.8)t^2$$

$$\frac{120.4 \times 2}{9.8} = t^2$$

$$t_{fall} = 4.96s$$

OR

$$* \; v = u + at \; *$$

$$48.6 = 0 + 9.8t$$

$$t_{fall} = 4.96s$$

$$t = t_{rise} + t_{fall}$$

$$= 2.04 + 4.96$$

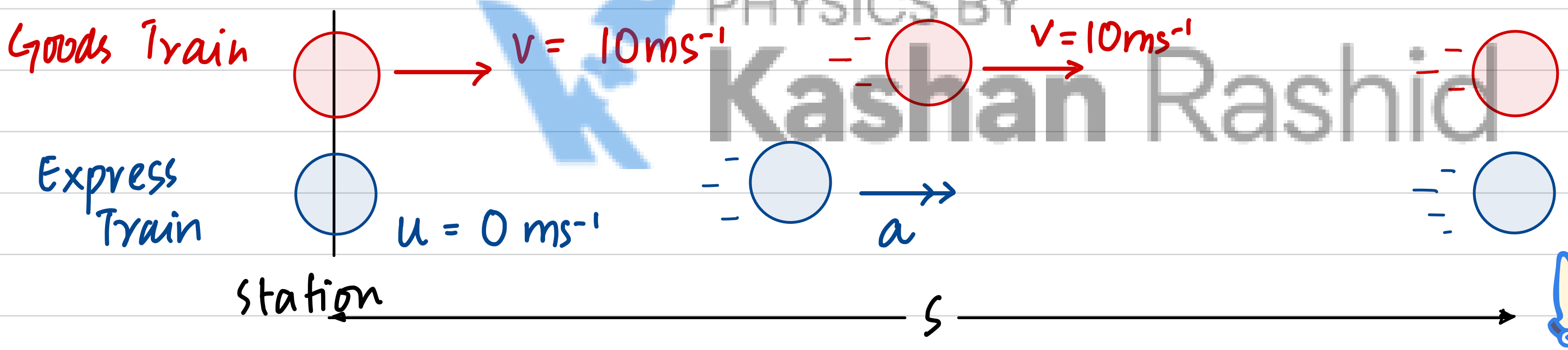
$$t = 7.00s$$

Overtaking during motion

8 A goods train passes through a station at a steady speed of $10\,\mathrm{m\,s^{-1}}$. An express train is at rest at the station. The express train leaves the station with a uniform acceleration of $0.5\,\mathrm{m\,s^{-2}}$ just as the goods train goes past. Both trains move in the same direction on straight, parallel tracks.

How much time passes before the express train overtakes the goods train?

A 6 s **B** 10 s **C** 20 s **D** 40 s



At overtake, both bodies must have travelled the same displ.

Goods Train

$v = \frac{s}{t}$

$10 = \frac{s}{t}$

Express Train

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

$s = 0 + \frac{1}{2}(0.5)t^2$

$s = 0.25t^2$

$s_G = s_E$

$10t = 0.25t^2$

$0.25t^2 - 10t = 0$

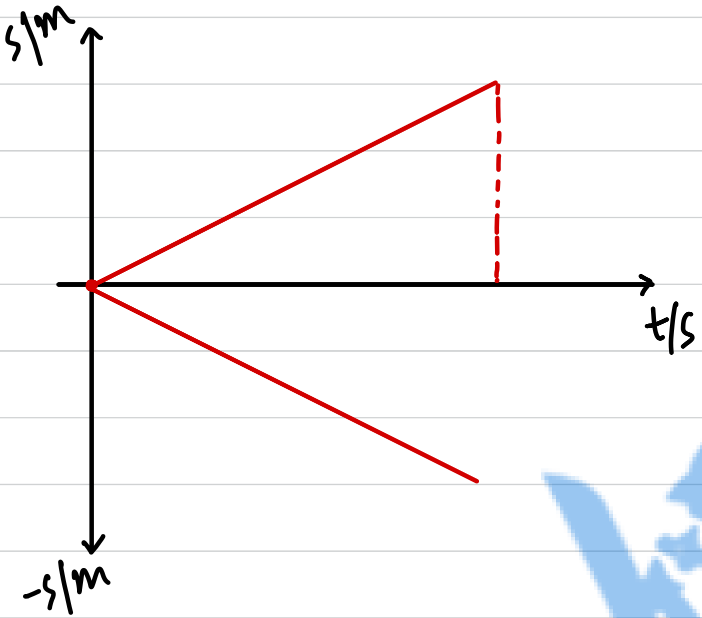
$t(0.25t - 10) = 0$

$t = 0\,s$

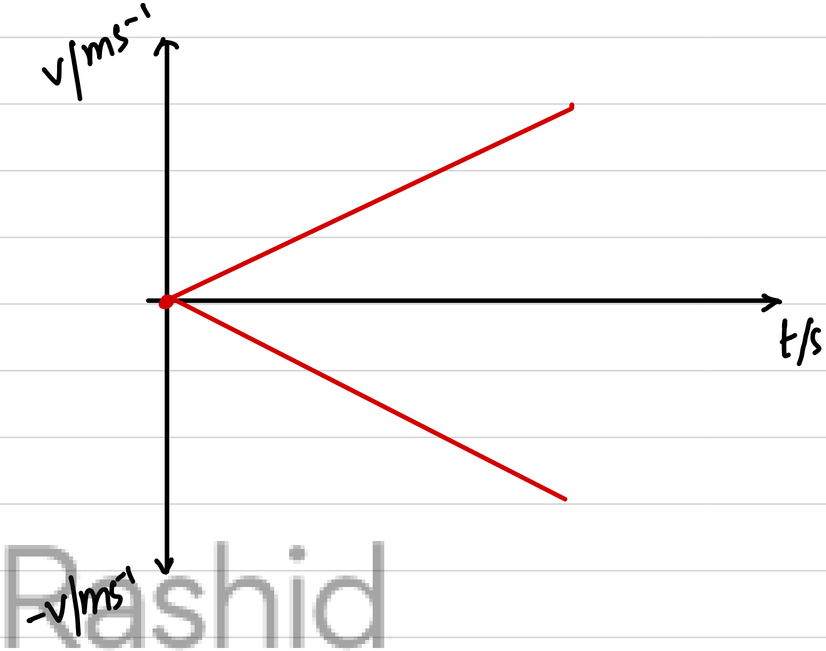
$0.25t - 10 = 0$

$t = 40\,s$

DISPLACEMENT – TIME GRAPHS



VELOCITY – TIME GRAPHS



GRADIENT : VELOCITY

$m = \frac{\Delta y}{\Delta x} = \frac{\Delta s}{\Delta t} = v$

AREA : MEANINGLESS

$A = \frac{1}{2} bh$ so $A = \frac{1}{2}(t \times s)$

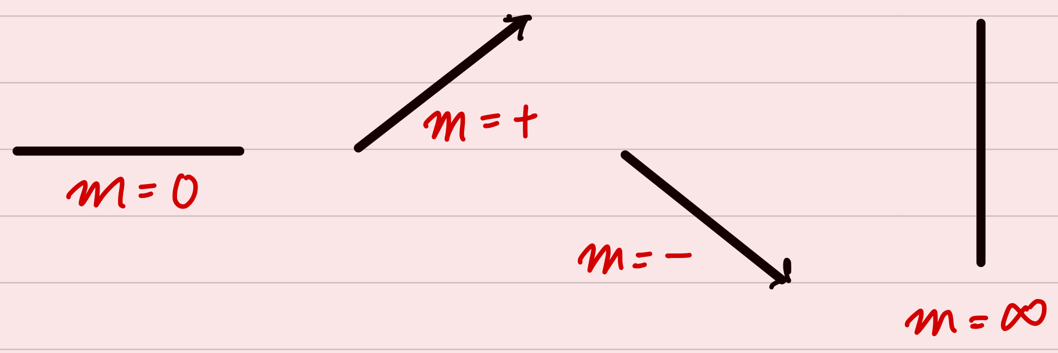
GRADIENT : ACCELERATION

$m = \frac{\Delta y}{\Delta x} = \frac{\Delta v}{\Delta t} = a$

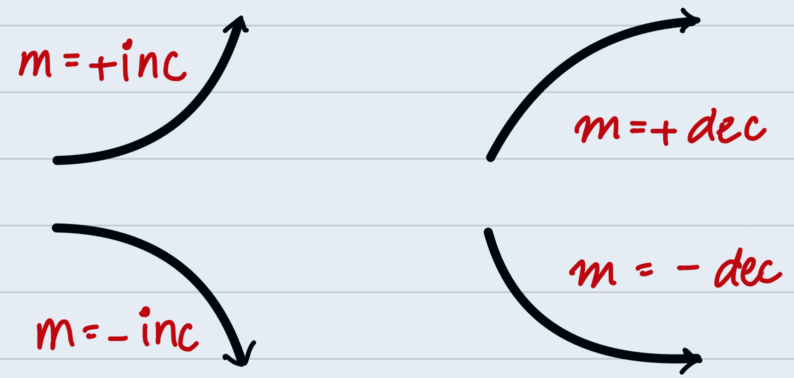
AREA : DISPLACEMENT

$A = \frac{1}{2} bh$ so $A = \frac{1}{2}(t \times v)$ ↳ S

CONSTANT GRADIENT
"LINE"



VARIABLE GRADIENT
"CURVE"

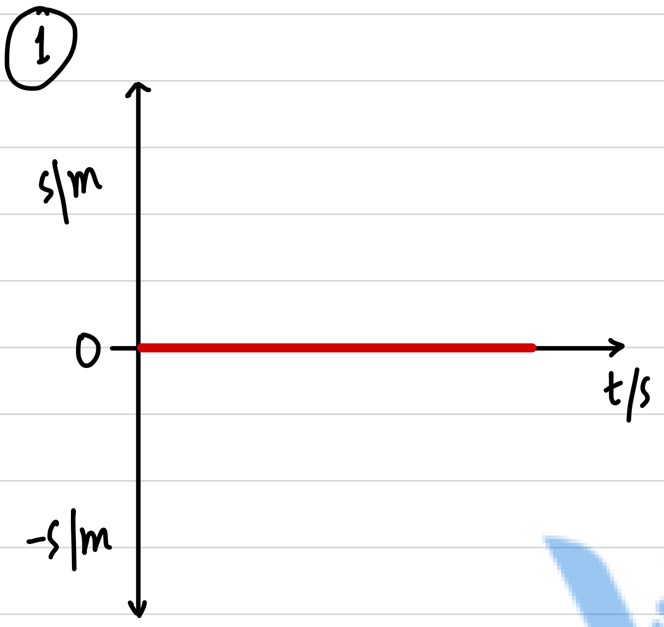


- If graph goes upwards its gradient is positive
- If graph goes downwards its gradient is negative.

If curve gets vertical → gradient increases

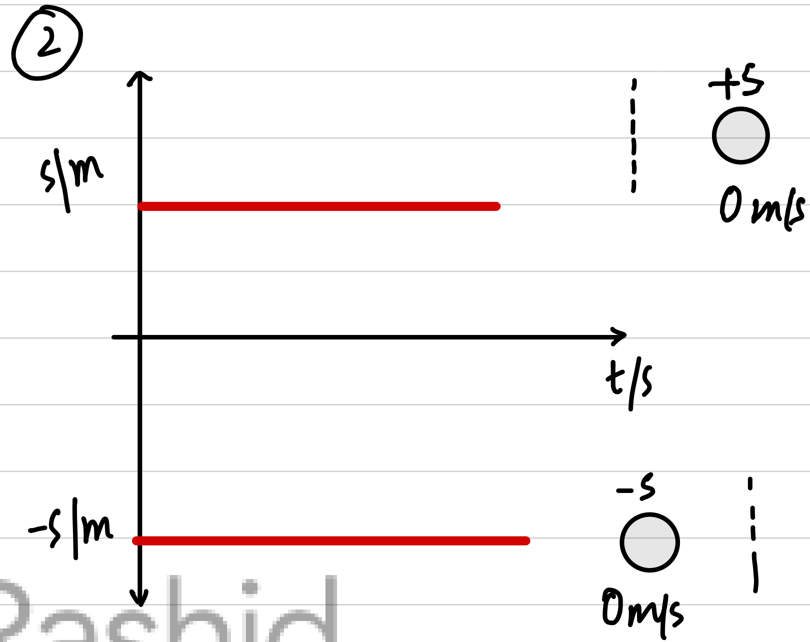
If curve gets horizontal → gradient decreases

DISPLACEMENT - TIME GRAPHS



GRADIENT / VELOCITY: zero

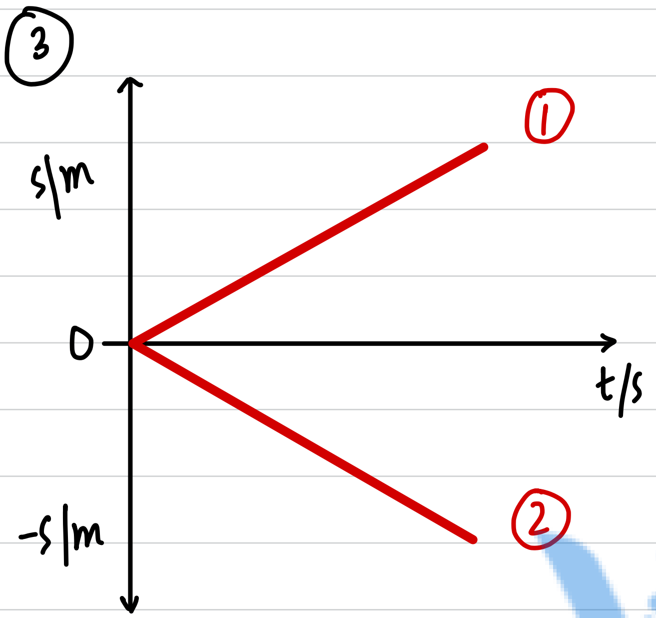
MOTION: object is at rest at the origin.



GRADIENT / VELOCITY: zero

MOTION: object is at rest ahead or behind origin.

DISPLACEMENT - TIME GRAPHS

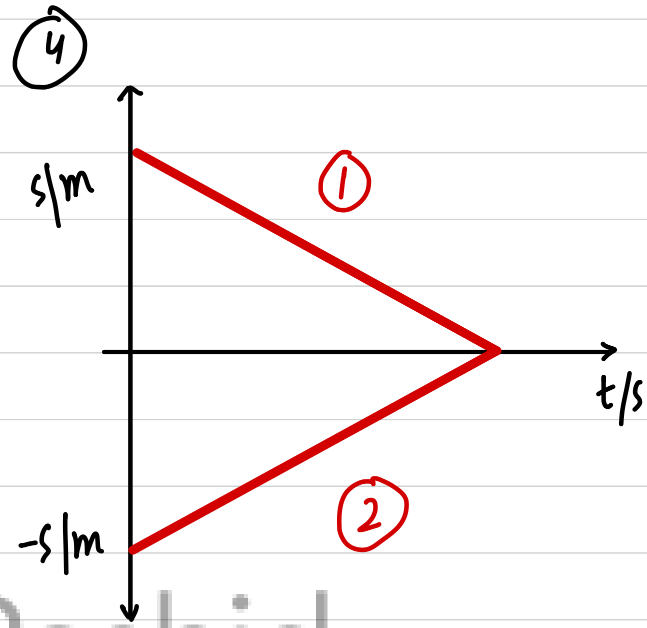


GRADIENT / VELOCITY:

(1) constant (+)

(2) constant (-)

MOTION: Object is moving at constant velocity away from origin.



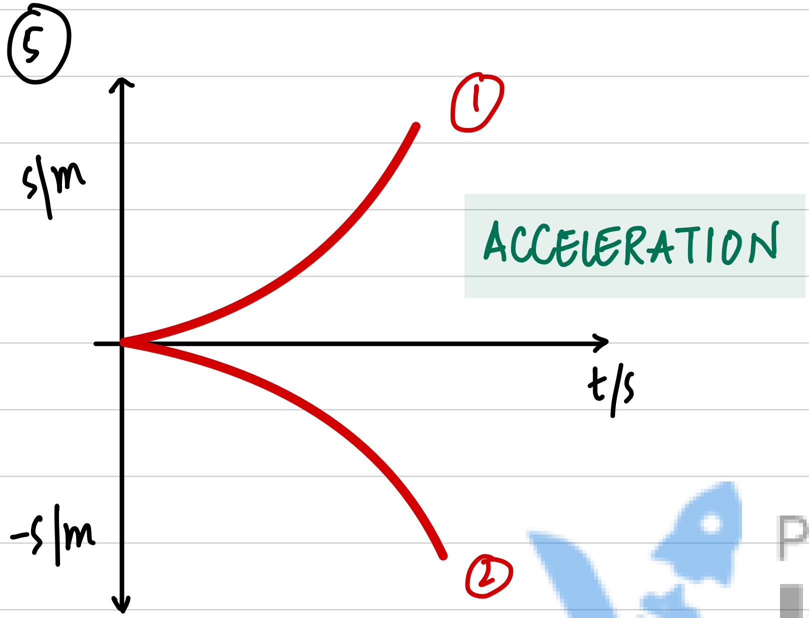
GRADIENT / VELOCITY:

(1) constant (-)

(2) constant (+)

MOTION: Object is moving at constant velocity towards origin.

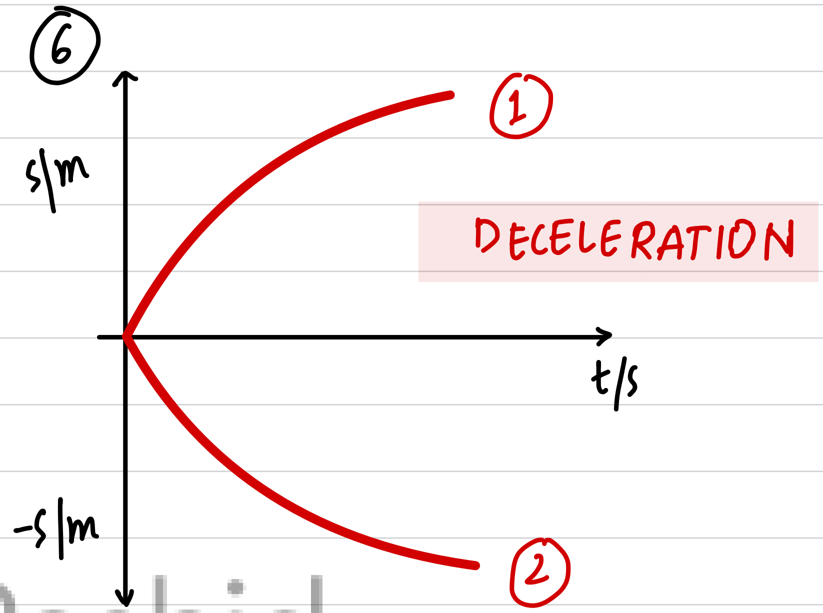
DISPLACEMENT - TIME GRAPHS



GRADIENT / VELOCITY:

1. increasing (+)
2. increasing (-)

MOTION: Object is accelerating away from the origin.



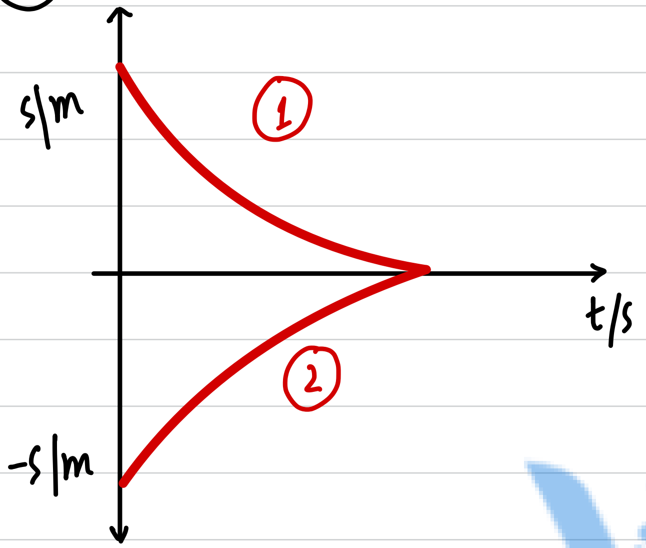
GRADIENT / VELOCITY:

1. decreasing (+)
2. decreasing (-)

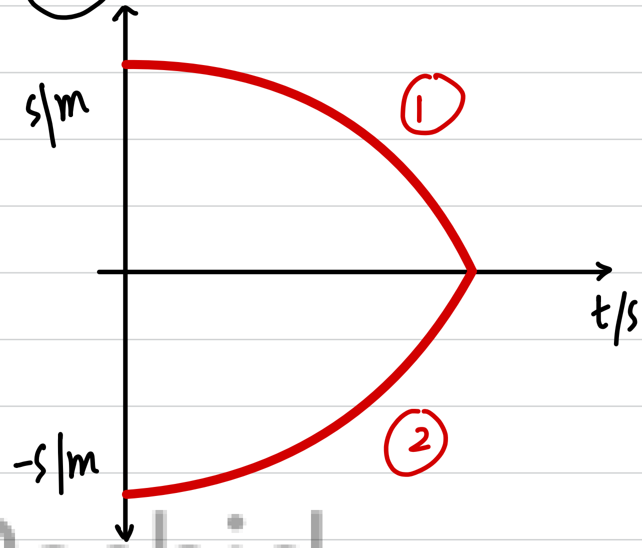
MOTION: Object is decelerating away from the origin.

DISPLACEMENT - TIME GRAPHS

7



8



GRADIENT / VELOCITY:

① decreasing (−)
② decreasing (+)

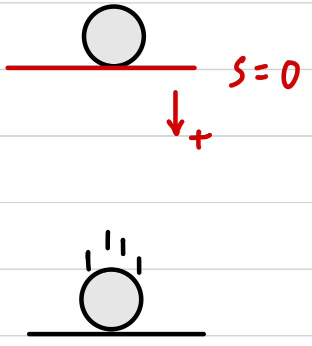
MOTION: Object is moving with decreasing velocity towards origin.

GRADIENT / VELOCITY:

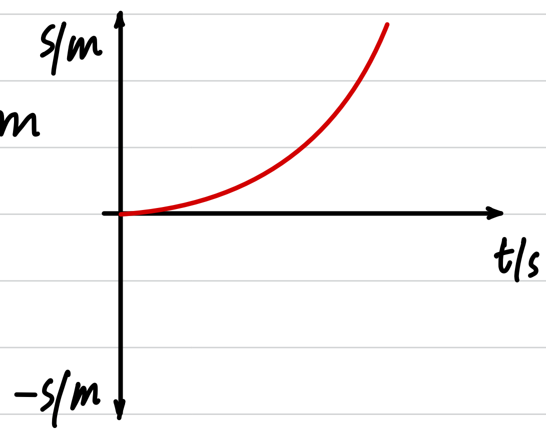
① increasing (−)
② increasing (+)

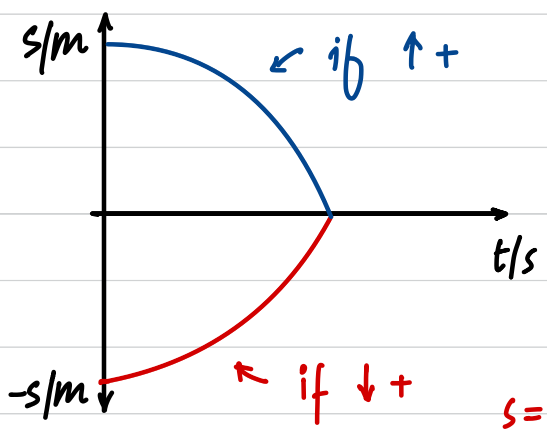
MOTION: object is moving with increasing velocity towards the origin.

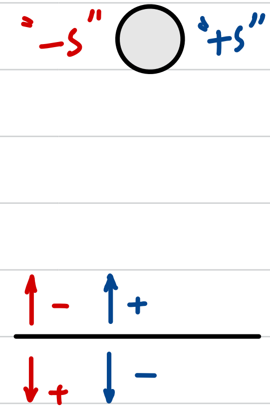
Example #1



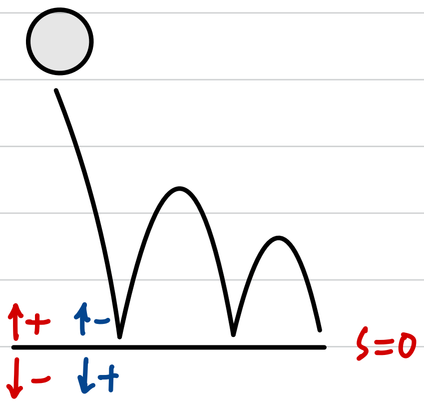
released from rest

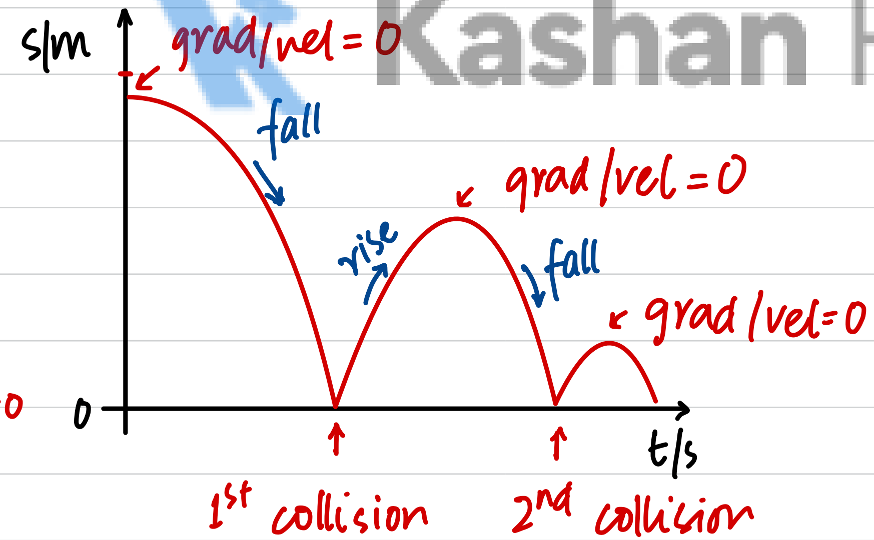


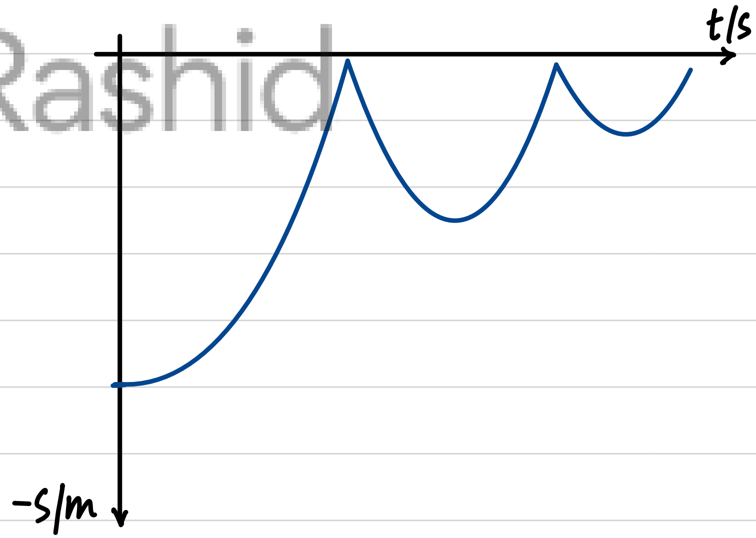




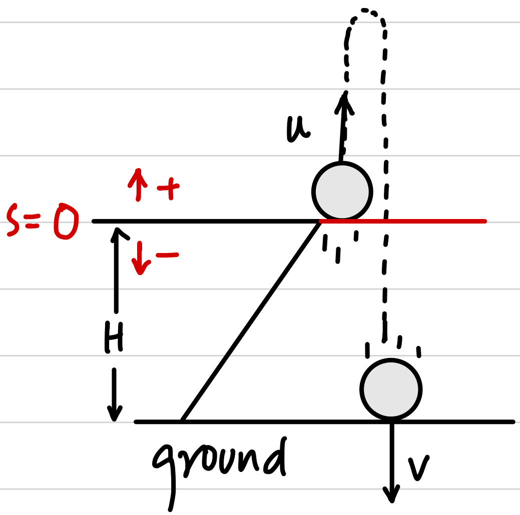
Example #2

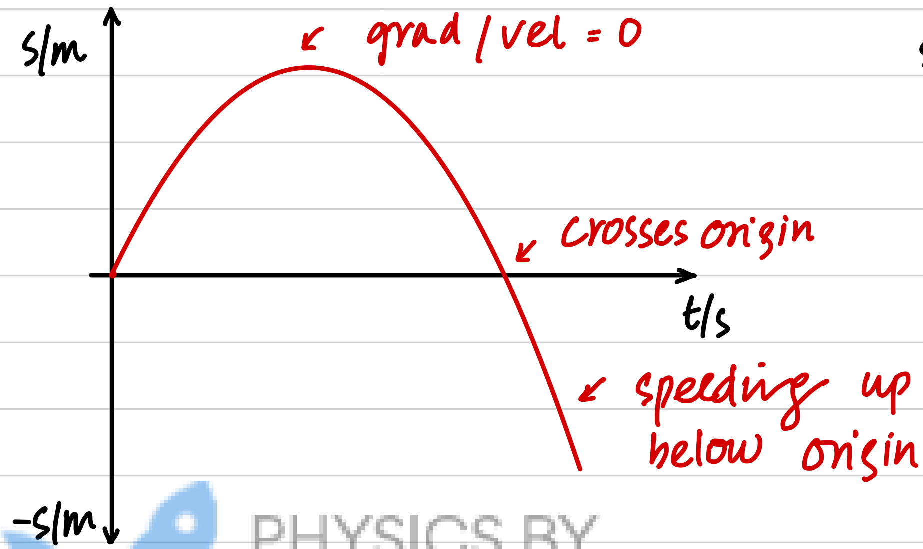


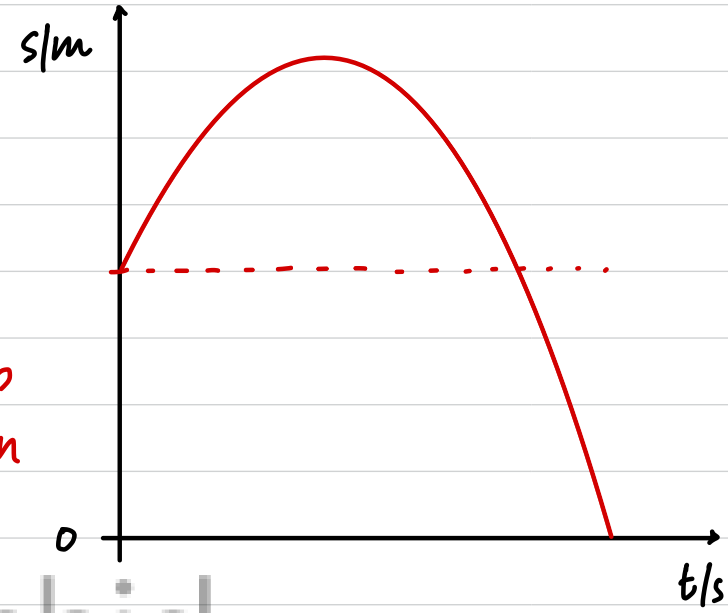




Example # 3

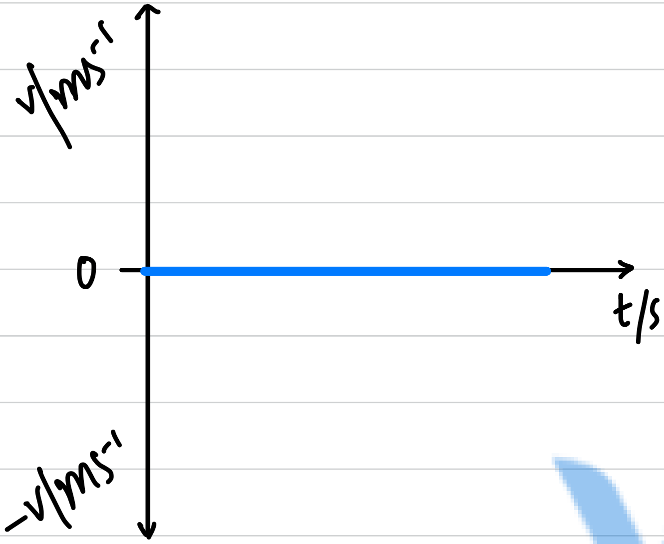


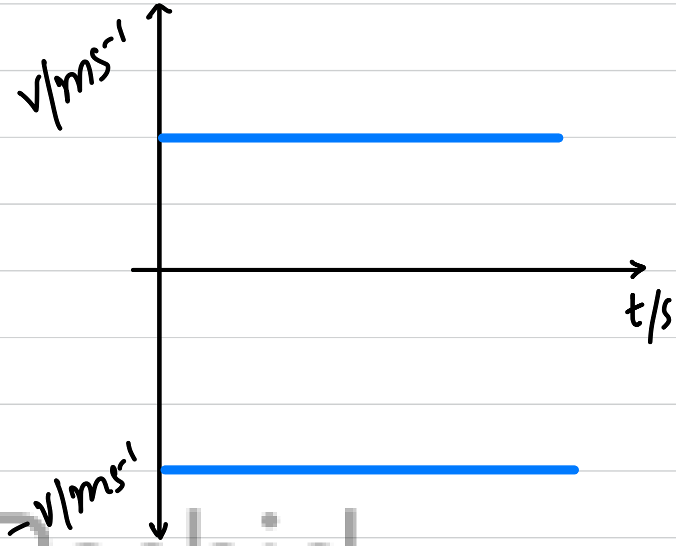




if ground was taken as origin

VELOCITY-TIME GRAPHS





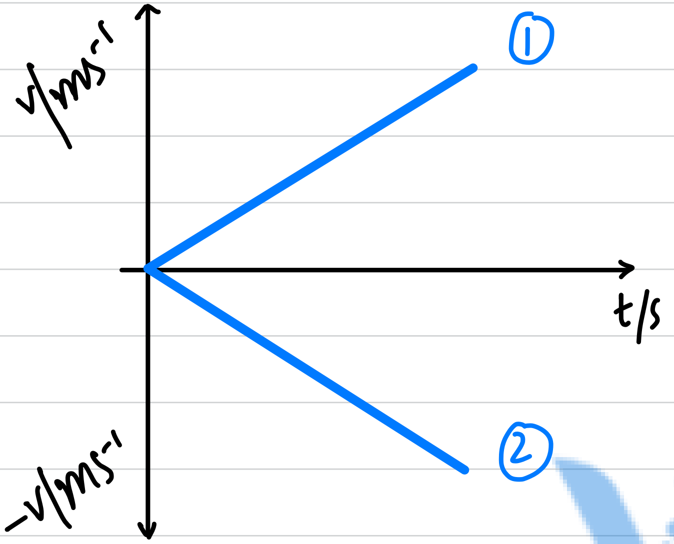
GRADIENT / ACCELERATION:
ZERO

MOTION:
REST

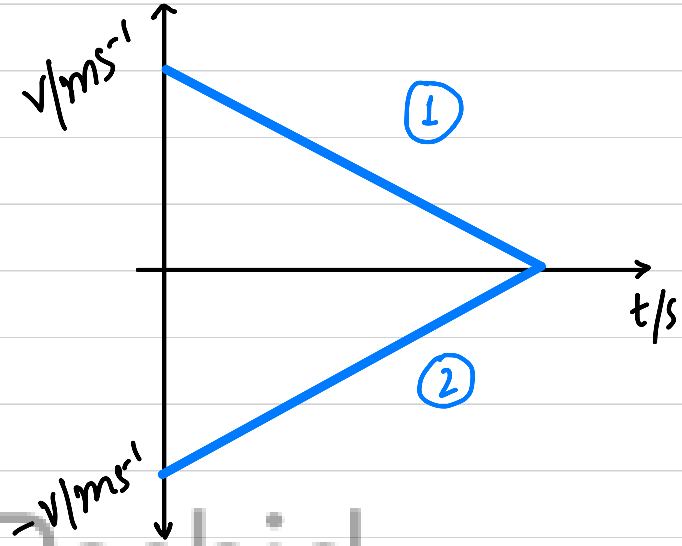
GRADIENT / ACCELERATION:
ZERO

MOTION:
OBJECT IS MOVING AT CONSTANT VELOCITY.

VELOCITY-TIME GRAPHS



- Sign of velocity tells about the direction of motion.



GRADIENT / ACCELERATION:

① CONSTANT (+)

② CONSTANT (-) (Its -ve acceleration, not deceleration)

MOTION:

OBJECT IS MOVING WITH CONSTANT ACCELERATION.

0 m/s $\xrightarrow{+2}$ 2 m/s $\xrightarrow{+2}$ 4 m/s $\xrightarrow{+2}$ 6 m/s $\xrightarrow{+2}$ 8 m/s

GRADIENT / ACCELERATION:

① CONSTANT (-)

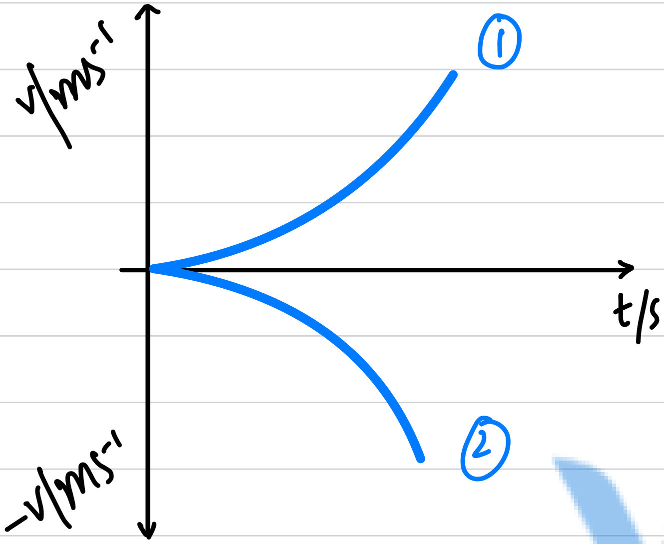
② CONSTANT (+)

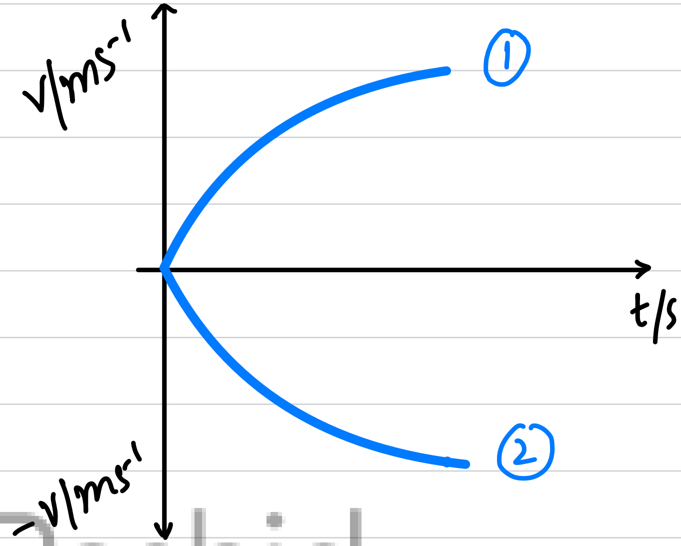
MOTION:

OBJECT IS MOVING WITH CONSTANT DECELERATION.

8 m/s → 6 m/s → 4 m/s → 2 m/s → 0 m/s

VELOCITY-TIME GRAPHS





GRADIENT / ACCELERATION:

① INCREASING (+)
② INCREASING (−)

MOTION:

OBJECT IS MOVING WITH INCREASING ACCELERATION.

0 m/s $\xrightarrow{+1}$ 1 m/s $\xrightarrow{+2}$ 3 m/s $\xrightarrow{+3}$ 6 m/s $\xrightarrow{+4}$ 10 m/s

GRADIENT / ACCELERATION:

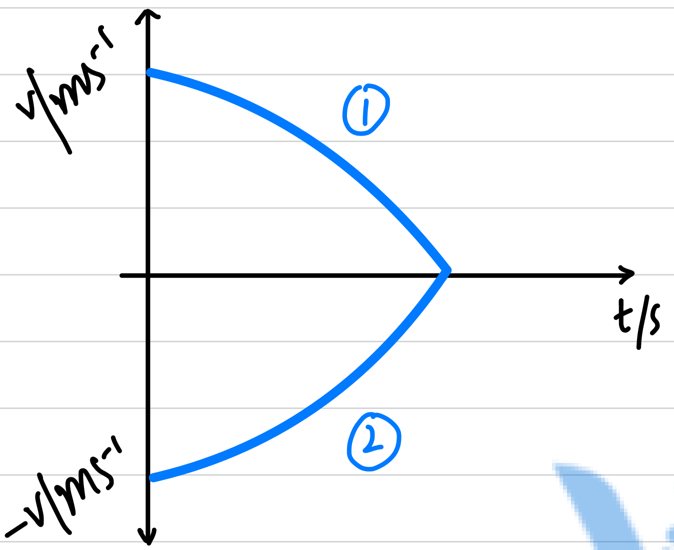
① DECREASING (+)
② DECREASING (−)

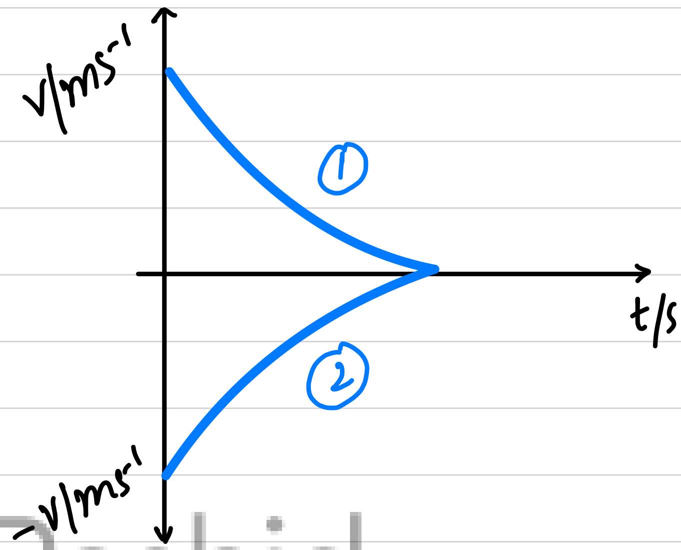
MOTION:

OBJECT IS MOVING WITH DECREASING ACCELERATION.

0 m/s $\xrightarrow{+5}$ 5 m/s $\xrightarrow{+4}$ 9 m/s $\xrightarrow{+3}$ 12 m/s $\xrightarrow{+2}$ 14 m/s

VELOCITY-TIME GRAPHS





GRADIENT / ACCELERATION:

① INCREASING (-)
② INCREASING (+)

MOTION:

OBJECT IS MOVING WITH INCREASING DECELERATION.

10 m/s $\xrightarrow{-1}$ 9 m/s $\xrightarrow{-2}$ 7 m/s $\xrightarrow{-3}$ 4 m/s

GRADIENT / ACCELERATION:

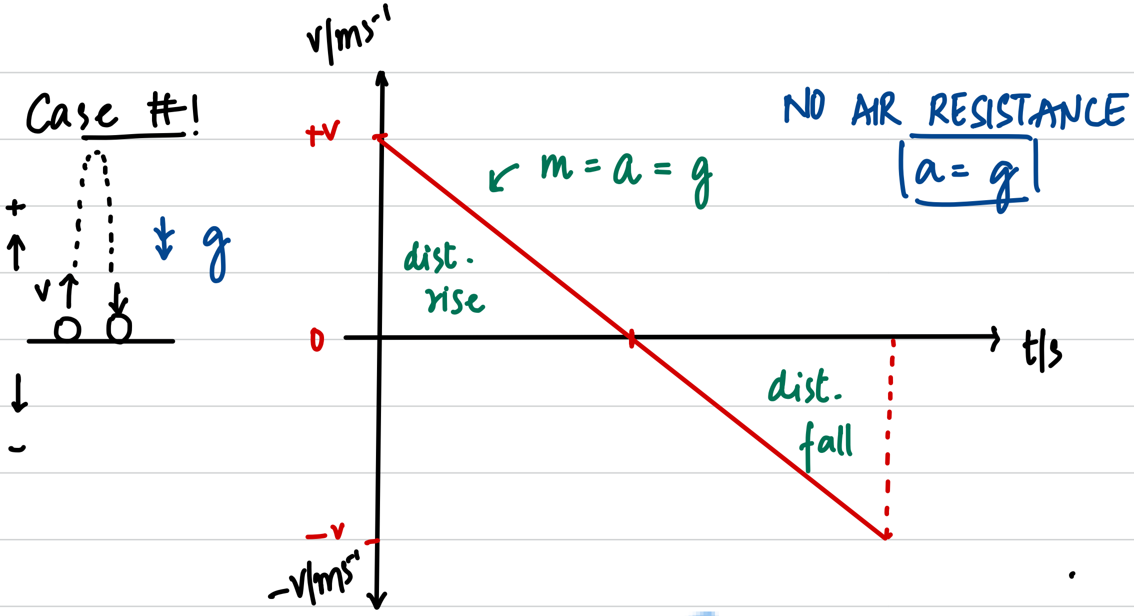
① DECREASING (-)
② DECREASING (+)

MOTION:

OBJECT IS MOVING WITH DECREASING DECELERATION.

15 m/s $\xrightarrow{-5}$ 10 m/s $\xrightarrow{-4}$ 6 m/s $\xrightarrow{-3}$ 3 m/s

Case #1



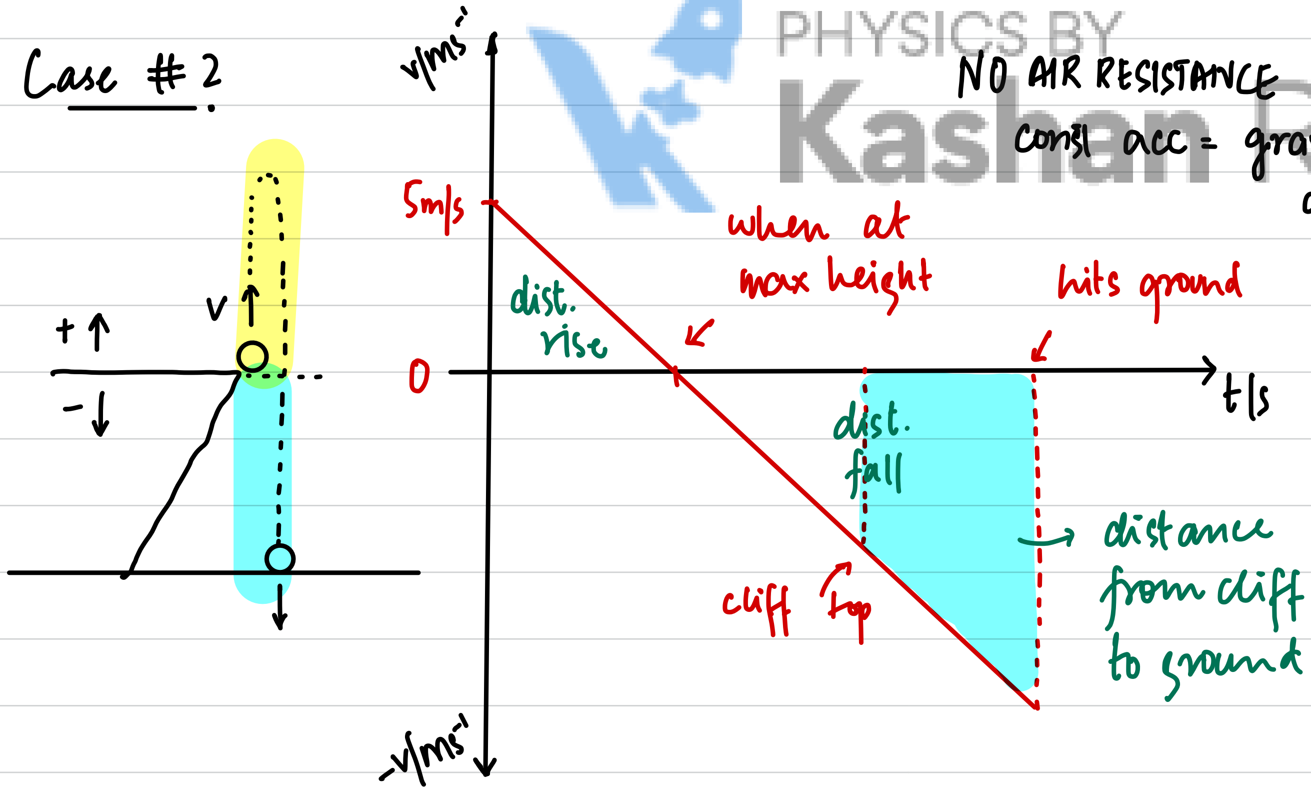
NO AIR RESISTANCE

$a = g$

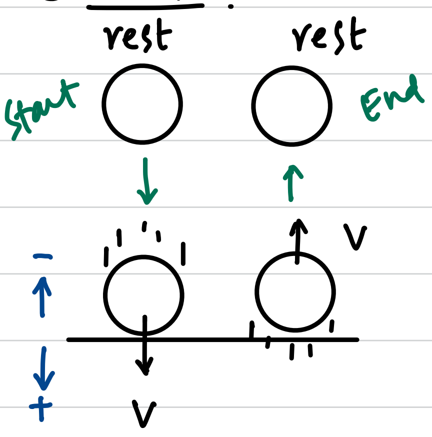
Case #2

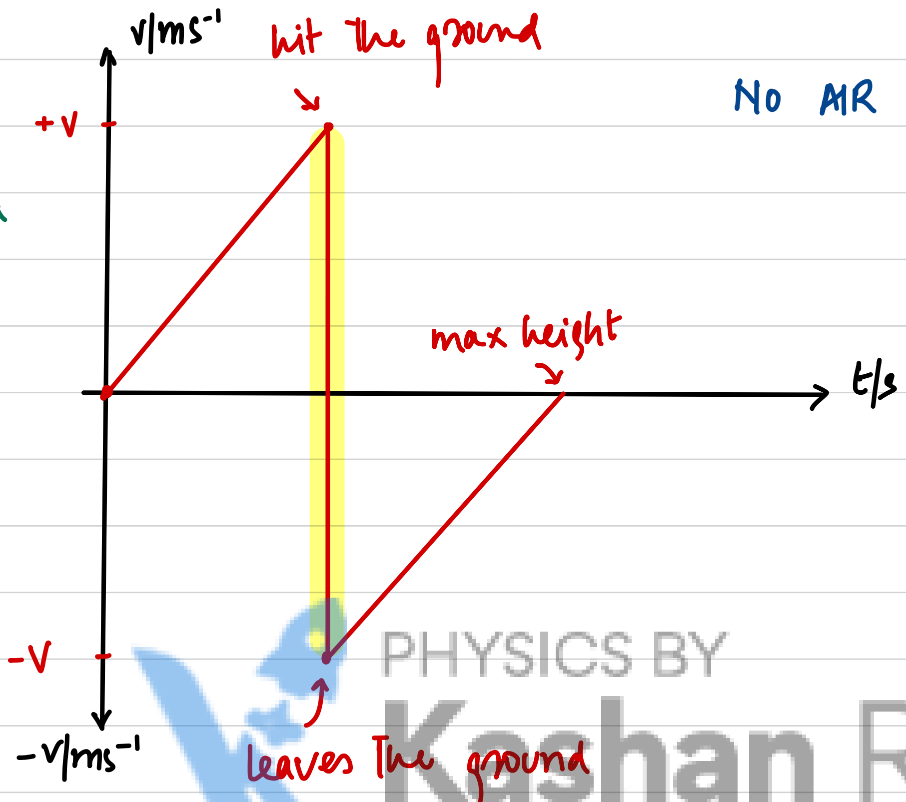
NO AIR RESISTANCE

const acc = gravitational acceleration ← gradient tell acc.



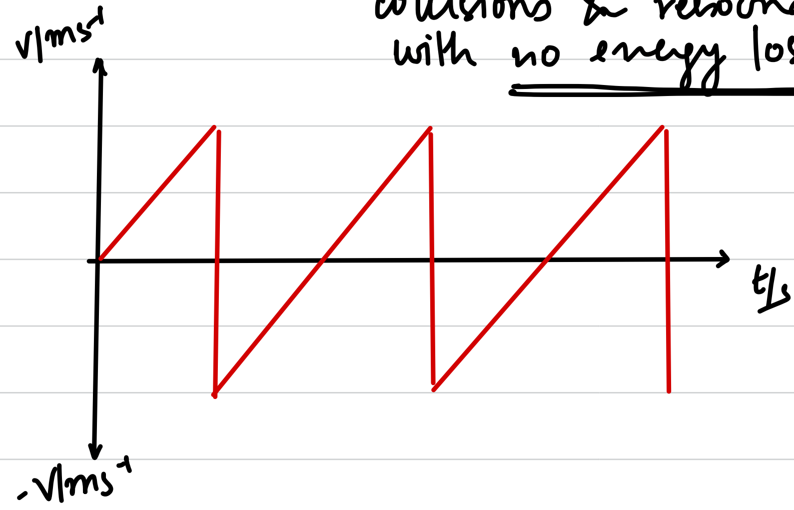
Case #3

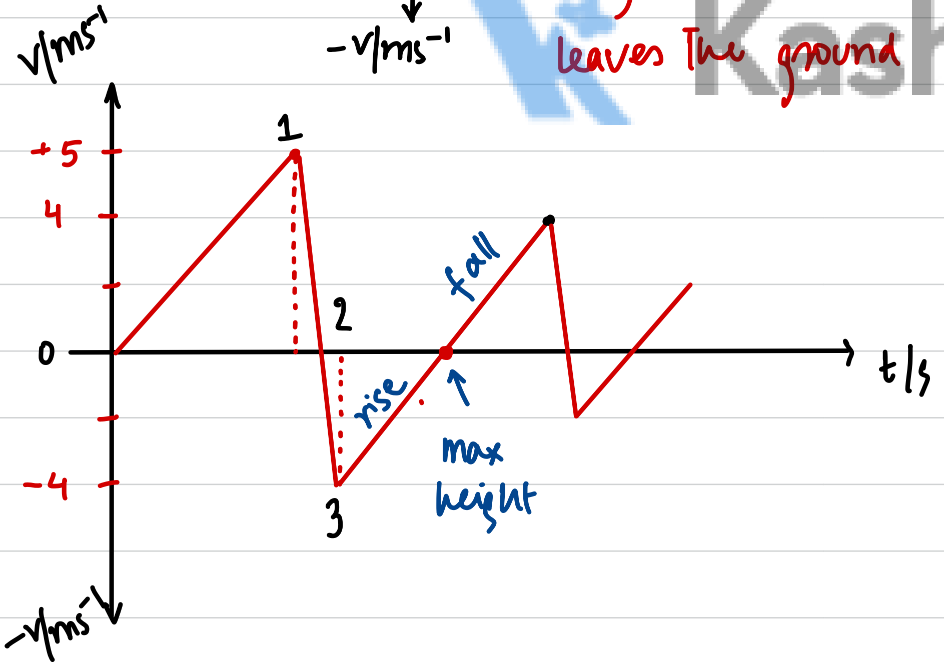


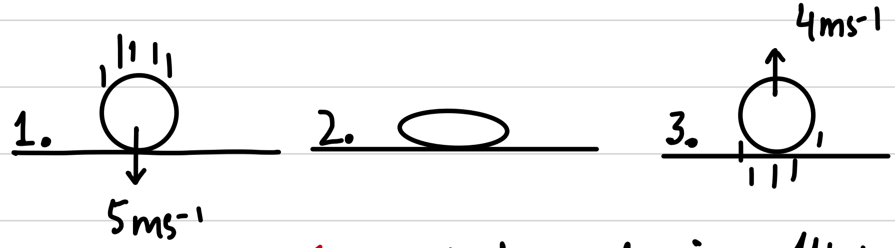


No AIR RESISTANCE

collisions & rebounds with no energy loss.



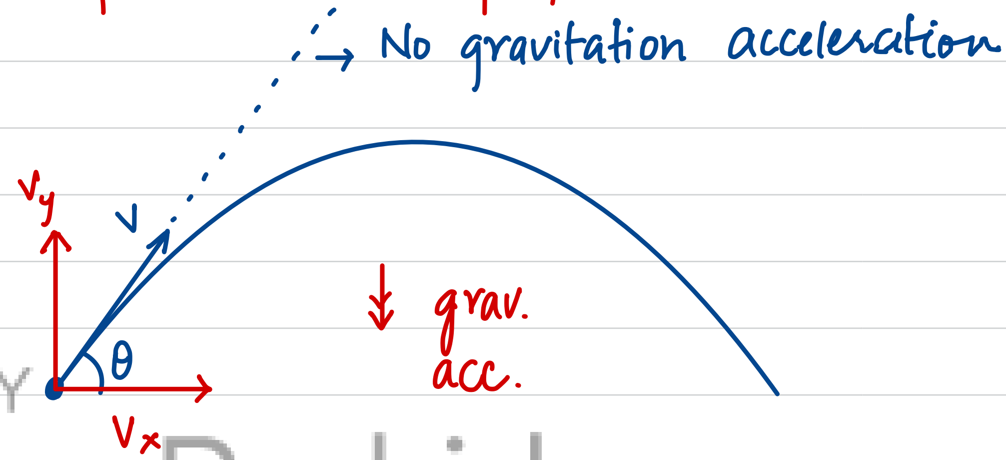




- [x] energy loss during collision
- [x] collision time

PROJECTILE MOTION

A 2D motion under the effect of gravity is called projectile motion.



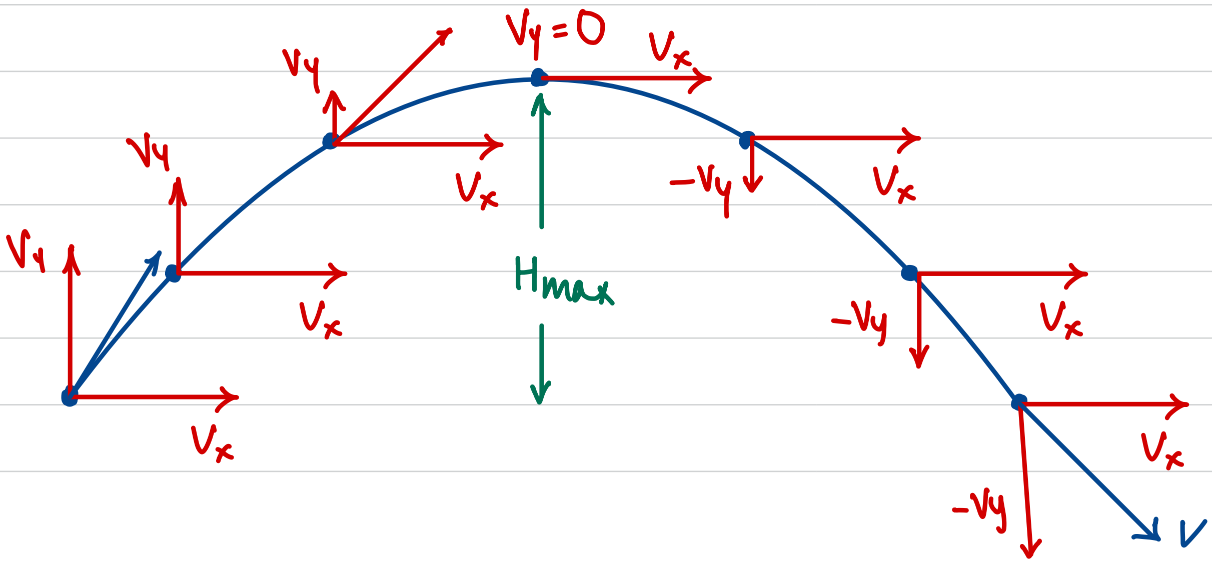
Assumptions

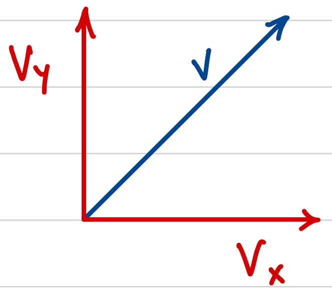
1. No air resistance
   a) No external force
   b) No loss of energy as heat

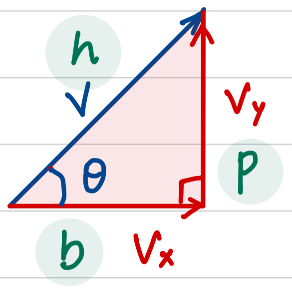
2. Acceleration is constant and equal to gravitational acceleration in the vertical direction

☑ V_x will stay constant throughout motion as there is no force along x-axis to change it.

☑ V_y decreases as object rises and increases as it falls.







$h^2 = p^2 + b^2$

$V^2 = V_y^2 + V_x^2$

$\tan\theta = \frac{V_y}{V_x}$

$\cos\theta = \frac{b}{h}$

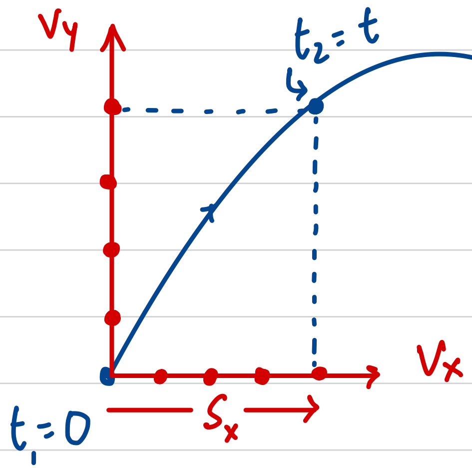
$\cos\theta = \frac{V_x}{V}$

$V_x = V\cos\theta$

$\sin\theta = \frac{P}{h}$

$\sin\theta = \frac{V_y}{V}$

$V_y = V\sin\theta$



Equations of motion cannot be applied on the curved track!

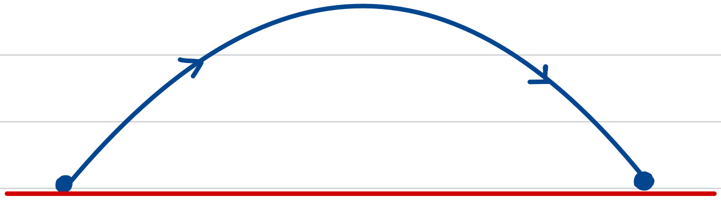
- They can only work on straight line

We breakdown the analysis along x-axis & y-axis!!

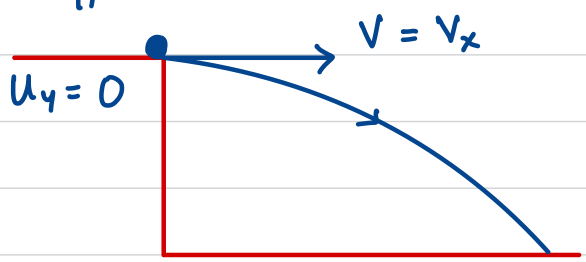
X-axis	Y-axis
constant velocity	constant acceleration
$V_x = \frac{S_x}{t}$	$V_y = u_y + at$ $S_y = u_y t + \frac{1}{2}at^2$ $V_y^2 - u_y^2 = 2as_y$

- Time links both x-axis & y-axis
- Time found from x-axis can be used in y-axis and vice versa.

Type # 1



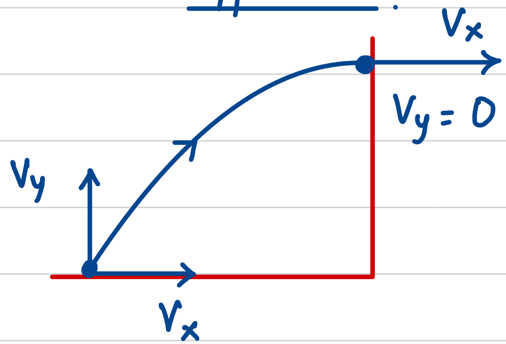
Type # 2



"projected horizontally"

$u_y = 0$

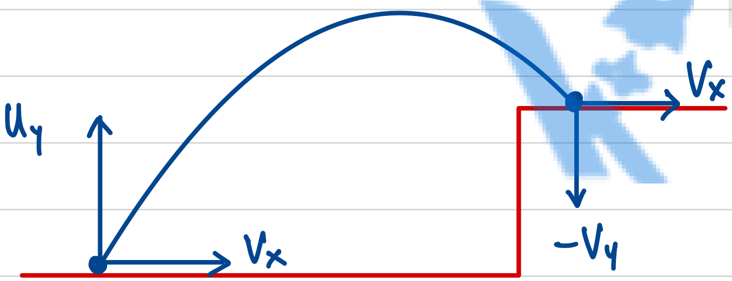
Type # 3



"max height"

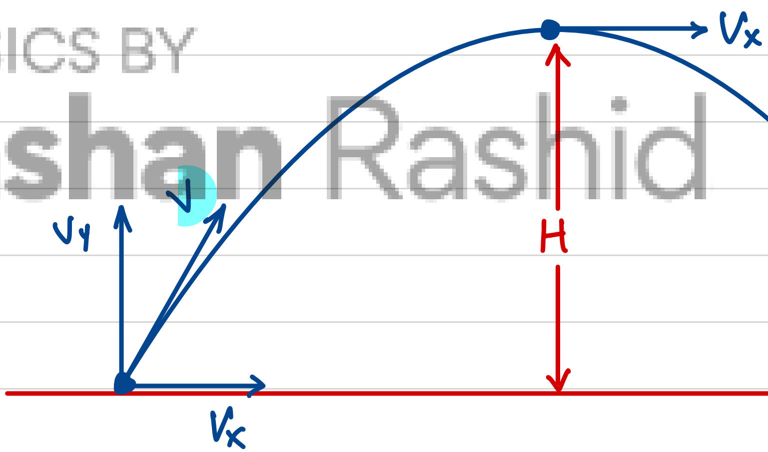
$V_y = 0$

Type # 4



$P.E_{max} = mgH$

$K.E_{min} = \frac{1}{2} m v_x^2$



- $K.E\ max = \frac{1}{2} mv^2$
- $P.E = 0$

- $K.E\ max = \frac{1}{2} mv^2$
- $P.E = 0$

9 A boy throws a stone with a horizontal velocity of $10\,m\,s^{-1}$ from the top of a building. The height of the building is 8.0 m. The stone travels along a curved path until it hits the ground, as shown in the diagram.

Y-axis

$u_y = 0\ ms^{-1}$
$a = +9.8\ ms^{-2}$
$s = 8m$
$t = ?$

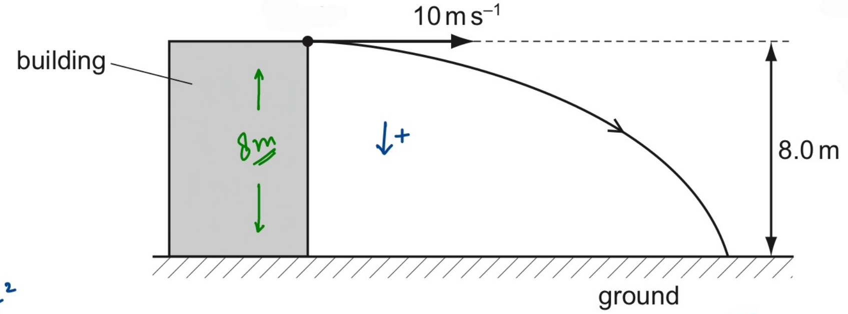
$s = ut + \frac{1}{2}at^2$

$8 = 0 + \frac{1}{2}(9.8)t^2$

X-axis

$V_x = \frac{S_x}{t}$

$10 = \frac{S_x}{t}$?? ??



$t = 1.3s$ How long does it take the stone to reach the ground? (Air resistance can be neglected.)

A 0.61 s **B** 0.80 s **C** 1.3 s **D** 1.6 s

6 A cyclist pedals along a raised horizontal track. At the end of the track, he travels horizontally into the air and onto a track that is vertically 2.0 m lower.

X-axis

$V = \frac{S}{t}$

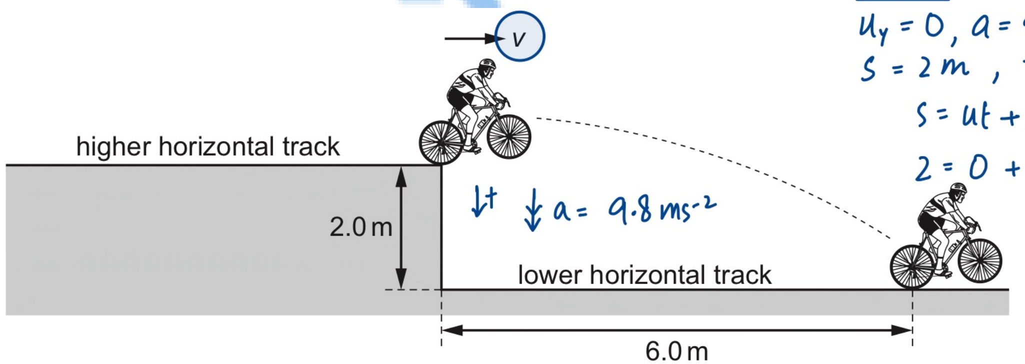
$V = \frac{6}{t\,??}$

$V = \frac{6}{0.639}$

$V = 9.4\ ms^{-1}$

Y-axis

$u_y = 0,\ a = 9.8ms^{-2}$
$s = 2m,\ t = ??$
$s = ut + \frac{1}{2}at^2$
$2 = 0 + \frac{1}{2}(9.8)t^2$
$t = 0.639s$

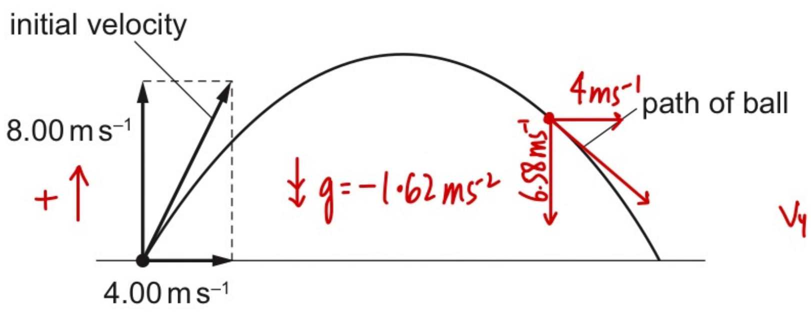


The cyclist travels a horizontal distance of 6.0 m in the air. Air resistance is negligible.

What is the horizontal velocity *v* of the cyclist at the end of the higher track?

A $6.3\,m\,s^{-1}$ **B** $9.4\,m\,s^{-1}$ **C** $9.9\,m\,s^{-1}$ **D** $15\,m\,s^{-1}$

7 An astronaut on the Moon, where there is no air resistance, throws a ball. The ball's initial velocity has a vertical component of $8.00\,\text{m s}^{-1}$ and a horizontal component of $4.00\,\text{m s}^{-1}$, as shown.



$v = u + at$

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

$v^2 - u^2 = 2as$

$h^2 = p^2 + b^2$

$v^2 = v_y^2 + v_x^2$

The acceleration of free fall on the Moon is $1.62\,\text{m s}^{-2}$.

What will be the (resultant) speed of the ball 9.00 s after being thrown?

A $6.6\,\text{m s}^{-1}$ **B** $7.7\,\text{m s}^{-1}$ **C** $10.6\,\text{m s}^{-1}$ **D** $14.6\,\text{m s}^{-1}$

after 9s

$V_x = 4\,\text{ms}^{-1}$

for V_y

$u_y = 8\,\text{ms}^{-1}$

$a = -1.62\,\text{ms}^{-2}$

$t = 9\,\text{s}$

$V_y = ?$

$v = u + at$

$v = 8 + (-1.62)(9)$

$v = -6.58\,\text{ms}^{-1}$

$h^2 = p^2 + b^2$

$v^2 = (6.58)^2 + (4)^2$

$v = 7.7\,\text{ms}^{-1}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 (a) Distinguish between *scalar* quantities and *vector* quantities.

Scalar have magnitude only.

Vectors have both magnitude and direction

.... [2]

(b) In the following list, underline **all** the scalar quantities.

acceleration   force   kinetic energy   mass   power   weight   [1]

(c) A stone is thrown with a horizontal velocity of $20\,m\,s^{-1}$ from the top of a cliff 15 m high. The path of the stone is shown in Fig. 1.1.

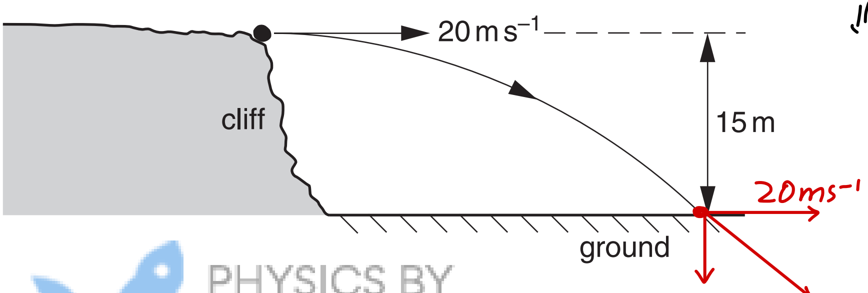


Fig. 1.1

iii) find the horizontal displ.

$V_x = \frac{S_x}{t}$

$20 = \frac{S_x}{1.75}$

$S_x = 35\,m$

Air resistance is negligible.

For this stone,

(i) calculate the time to fall 15 m,

$s = 15\,m$
$u_y = 0$
$a = 9.8\,ms^{-2}$
$t = ?$

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

$15 = 0 + \frac{1}{2}(9.8)t^2$

$t = 1.75\,s$

time = 1.75 s [2]

(ii) calculate the magnitude of the resultant velocity after falling 15 m,

$u_y = 0$
$a = 9.8\,ms^{-2}$
$s = 15\,m$
$v = ?$

$v^2 - u^2 = 2as$

$v^2 - 0 = 2(9.8)(15)$

$v = 17.1\,ms^{-1}$

20m/s, 17.1m/s

$h^2 = p^2 + b^2$

$h = \sqrt{(17.1)^2 + (20)^2}$

$= 26.3\,ms^{-1}$

resultant velocity = 26.3 $m\,s^{-1}$ [3]

2 **(a)** Explain what is meant by a *scalar* quantity and by a *vector* quantity.

scalar: They have magnitude only

vector: They have both magnitude and direction

[2]

(b) A ball leaves point P at the top of a cliff with a horizontal velocity of 15 m s^{-1}, as shown in Fig. 2.1.

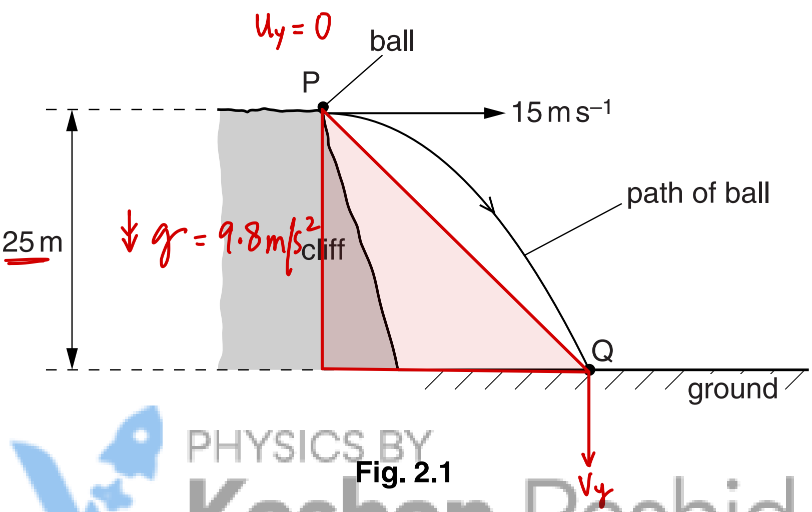


Fig. 2.1

The height of the cliff is 25 m. The ball hits the ground at point Q.
Air resistance is negligible.

(i) Calculate the vertical velocity of the ball just before it makes impact with the ground at Q.

Y-axis
$u_y = 0$
$a = +9.8 ms^{-2}$
$s = 25 m$
$V_y = ??$

$v^2 - u^2 = 2as$
$v^2 - 0^2 = 2(9.8)(25)$
$v = 22.1$

vertical velocity = 22.1 m s^{-1} [2]

(ii) Show that the time taken for the ball to fall to the ground is 2.3 s.

$V = u + at$
$22.1 = 0 + (9.8)t$
$t = 2.3$

[1]

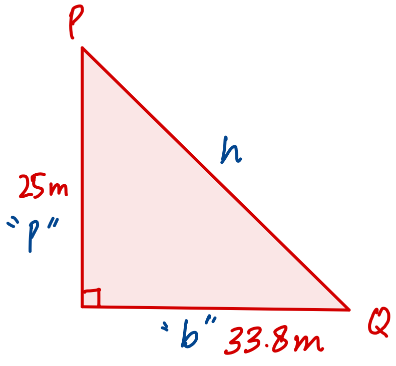
(iii) Calculate the magnitude of the displacement of the ball at point Q from point P.

x-axis

$v = \frac{s}{t}$

$15 = \frac{s_x}{2.255}$

$s_x = 33.8\,m$



$h^2 = p^2 + b^2$

$h^2 = (25)^2 + (33.8)^2$

$h = 42\,m$

displacement = ...42...... m [4]

(iv) Explain why the distance travelled by the ball is different from the magnitude of the displacement of the ball.

Distance travelled was the length of a curved track. Displ. was a straight line from P to Q

..........[2]

2 A ball is thrown from a point P with an initial velocity u of 12 m s^{-1} at 50° to the horizontal, as illustrated in Fig. 2.1.

• $v = u + at$
• $s = ut + \frac{1}{2}at^2$
• $v^2 - u^2 = 2as$
• $v = \frac{s}{t}$

$t \rightarrow s_x \rightarrow$ "h"

b) max height reached
c) displ. P to Q

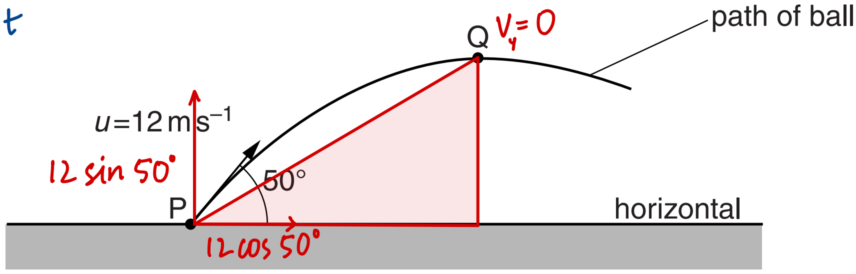


Fig. 2.1

The ball reaches maximum height at Q.

Air resistance is negligible.

(a) Calculate

(i) the horizontal component of u,

12 cos 50°

horizontal component = ...7.7.......... m s^{-1} [1]

(ii) the vertical component of u.

vertical component = ...12 sin 50° = 9.2 m/s.......... m s^{-1} [1]

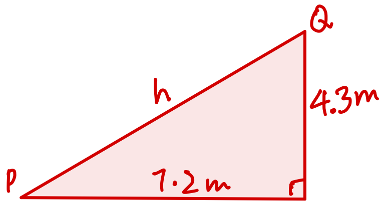
(b) Show that the maximum height reached by the ball is 4.3 m.

$u_y = 9.2\ ms^{-1}$
$V_y = 0\ ms^{-1}$
$a = -9.8\ ms^{-2}$
$s = ?$

$v^2 - u^2 = 2as$
$0^2 - (9.2)^2 = 2(-9.8)s$
$s = 4.3m$

[2]

(c) Determine the magnitude of the displacement PQ.



$v = u + at$
$0 = 9.2 + (-9.8)t$
$t = 0.94\ s$

$v = \frac{s}{t}$
$7.7 = \frac{S_x}{0.94}$
$S_x = 7.2m$

$h^2 = p^2 + b^2$
$h^2 = (4.3)^2 + (7.2)^2$
$h = 8.4m$

displacement = ... m [4]

[Total: 8]

For Examiner's Use

3 A ball is thrown against a vertical wall. The path of the ball is shown in Fig. 3.1.

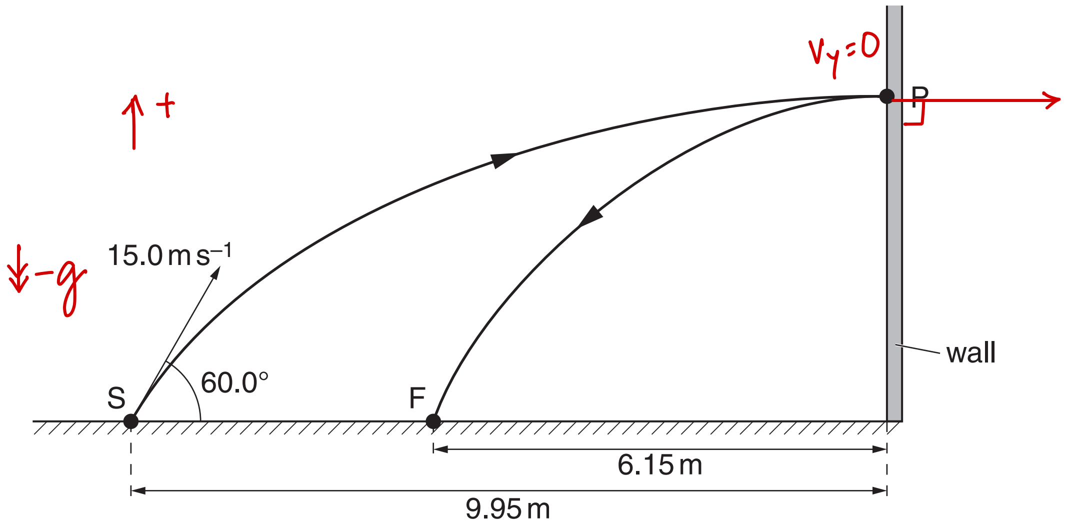


Fig. 3.1 (not to scale)

The ball is thrown from S with an initial velocity of 15.0 m s^{-1} at 60.0° to the horizontal. Assume that air resistance is negligible.

(a) For the ball at S, calculate

(i) its horizontal component of velocity,

horizontal component of velocity = $15 \cos 60° = 7.5$ m/s .... m s^{-1} [1]

(ii) its vertical component of velocity.

vertical component of velocity = $15 \sin 60° = 12.9 \simeq 13$ m/s .... m s^{-1} [1]

(b) The horizontal distance from S to the wall is 9.95 m. The ball hits the wall at P with a velocity that is at right angles to the wall. The ball rebounds to a point F that is 6.15 m from the wall.

Using your answers in **(a)**,

(i) calculate the vertical height gained by the ball when it travels from S to P,

$u_y = 13$ m/s
$v_y = 0$
$a = -9.8$ m/s
$s = ?$

$v^2 - u^2 = 2as$
$0^2 - 13^2 = 2(-9.8)s$

height = $s = 8.6$ m .... m [1]

For Examiner's Use

(ii) show that the time taken for the ball to travel from S to P is 1.33 s,

$v = \frac{s}{t}$

$7.5 = \frac{9.95}{t}$

$t = 1.33$

[1]

(iii) show that the velocity of the ball immediately after rebounding from the wall is about 4.6 m s^{-1}.

$V = \frac{s}{t}$ $\quad v = 4.6$ m/s

same time to rise & fall

$V = \frac{6.15}{1.33}$

[1]

(c) The mass of the ball is 60 × 10^{-3} kg.

(i) Calculate the change in momentum of the ball as it rebounds from the wall.

change in momentum = ... N s [2]

(ii) State and explain whether the collision is elastic or inelastic.

....

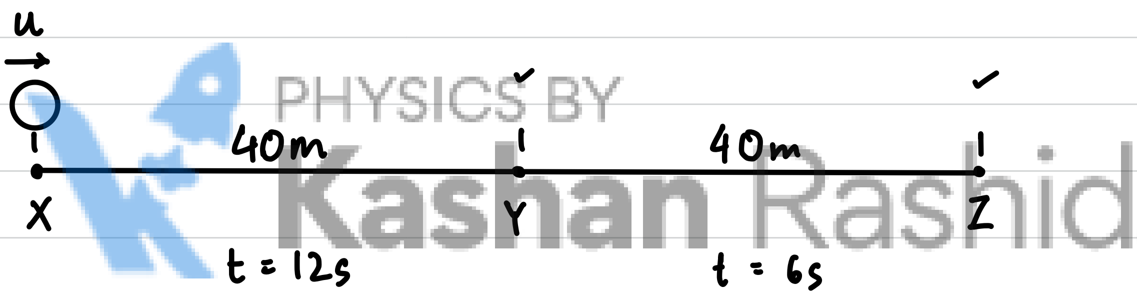
....

.... [1]

8 A moving body undergoes uniform acceleration while travelling in a straight line between points X, Y and Z. The distances XY and YZ are both 40 m. The time to travel from X to Y is 12 s and from Y to Z is 6.0 s.

What is the acceleration of the body?

A $0.37\,\mathrm{m\,s^{-2}}$ **B** $0.49\,\mathrm{m\,s^{-2}}$ **C** $0.56\,\mathrm{m\,s^{-2}}$ **D** $1.1\,\mathrm{m\,s^{-2}}$



XY.

$s = 40\,m$

$t = 12\,s$

$u = ??$

$* \; a = ??$

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

$40 = u(12) + \frac{1}{2}a(12)^2$

$40 = 12u + 72a \quad —①$

XZ.

$s = 80\,m$

$t = 18\,s$

$u = ??$

$a = ??$

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

$80 = u(18) + \frac{1}{2}a(18)^2$

$80 = 18u + 162a \quad —②$

$u = 1.1\,ms^{-1}$

$a = 0.37\,ms^{-2}$

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

8 Two markers M_1 and M_2 are set up a vertical distance h apart.

M_1: $s = ut + \frac{1}{2}at^2$

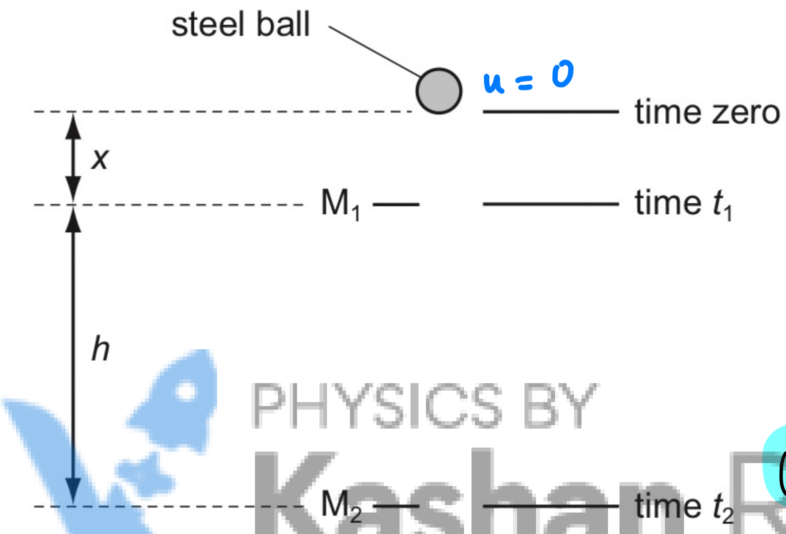
$x = 0 + \frac{1}{2}at_1^2$

$x = \frac{1}{2}at_1^2$

M_2: $s = ut + \frac{1}{2}at^2$

$x + h = 0 + \frac{1}{2}at_2^2$

$x + h = \frac{1}{2}at_2^2$



$x + h = \frac{1}{2}at_2^2$

$\frac{1}{2}at_1^2 + h = \frac{1}{2}at_2^2$

$h = \frac{1}{2}at_2^2 - \frac{1}{2}at_1^2$

$h = \frac{1}{2}a(t_2^2 - t_1^2)$

$\frac{2h}{(t_2^2 - t_1^2)} = a$

A steel ball is released at time zero from a point a distance x above M_1. The ball reaches M_1 at time t_1 and reaches M_2 at time t_2. The acceleration of the ball is constant.

Which expression gives the acceleration of the ball?

A $\dfrac{2h}{t_2^{\,2}}$ **B** $\dfrac{2h}{(t_2 + t_1)}$ **C** $\dfrac{2h}{(t_2 - t_1)^2}$ **D** $\dfrac{2h}{(t_2^{\,2} - t_1^{\,2})}$

9 In order that a train can stop safely, it will always pass a signal showing a yellow light before it reaches a signal showing a red light. Drivers apply the brake at the yellow light and this results in a uniform deceleration to stop exactly at the red light.

The distance between the red and yellow lights is x.

What must be the minimum distance between the lights if the train speed is increased by 20 %, without changing the deceleration of the trains?

A $1.20x$ **B** $1.25x$ **C** $1.44x$ **D** $1.56x$

$v^2 - u^2 = 2as$

$0 - u^2 = 2ax$

$-\frac{u^2}{2x} = a$ ✓

$u + 20\%\,u$

$u + 0.2u$

$1.2u$

new u

$v^2 - u^2 = 2as$

$0^2 - (1.2u)^2 = 2\left(-\frac{u^2}{2x}\right)s$

$1.44u^2 = \frac{u^2}{x} \times s$

$1.44 = \frac{s}{x}$

$s = 1.44x$

Method #2

$v^2 - u^2 = 2as$

$u^2 \propto s$

u^2	s
$(u)^2$	x
$(1.2u)^2$	s

$u^2 \times s = (1.2u)^2 x$

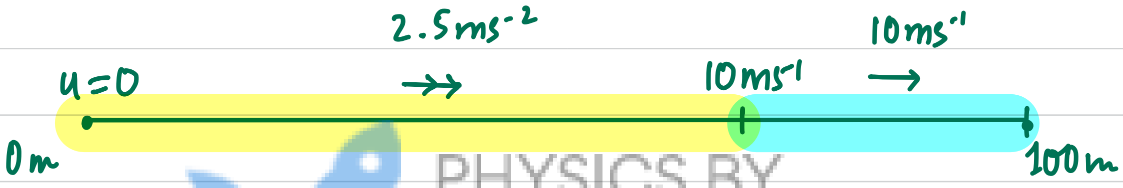
$s = \frac{1.44u^2}{u^2}x$

$s = 1.44x$

9 A sprinter runs a 100 m race in a straight line. He accelerates from the starting block at a constant acceleration of $2.5\,\text{m s}^{-2}$ to reach his maximum speed of $10\,\text{m s}^{-1}$. He maintains this speed until he crosses the finish line.

Which time does it take the sprinter to run the race?

A 4 s **B** 10 s **C** 12 s **D** 20 s



$v = u + at$

$10 = 0 + 2.5t$

$t = 4s$

$v^2 - u^2 = 2as$

$10^2 - 0^2 = 2(2.5)s$

$s = 20m$

ACCELERATED

$v = \frac{s}{t}$

$10 = \frac{?}{t}$

const speed dist = 80m

$10 = \frac{80}{t}$

$t = 8s$

total time for race

$4 + 8 = 12s$