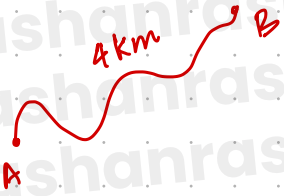
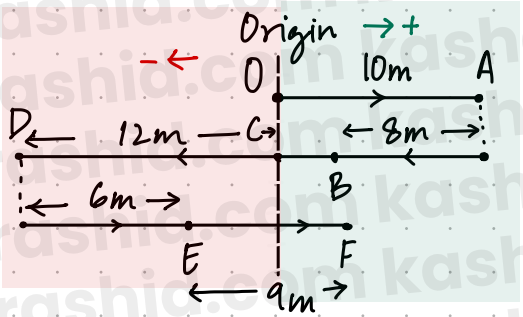
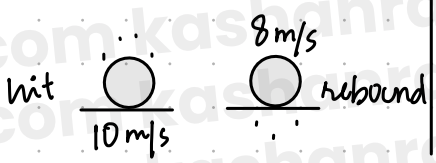
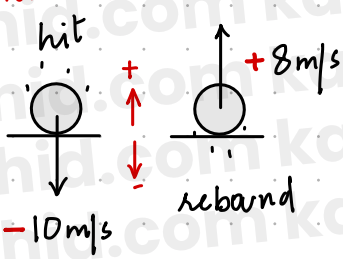
KINEMATICS

Distance	Displacement
1. Length of the path between two points.	1. Shortest possible distance between two points.
	
2. Scalar quantity	2. Vector
3. SI Unit: meter (m)	3. SI Unit: meter (m)
4. Car travelled a distance of 4km	4. Car displaced 3 km due South-East.

"Sign of displ tells about the position of the body from the origin."



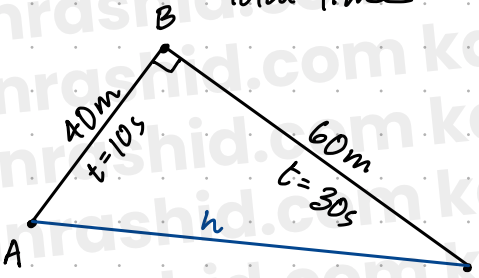
	distance	displ.
OA	10m	+10m
OB	18m	10-8 = +2m
OC	20m	0m
OD	32m	-12m
OE	38m	-6m
OF	47m	+3m

Speed (v)	Velocity (v)
1. Rate of change of distance.	1. Rate of change of displacement
2. $v = \frac{\Delta d}{\Delta t}$ | $v = \frac{d}{t}$	2. $v = \frac{\Delta s}{\Delta t}$ | $v = \frac{s}{t}$
3. SI Unit: m/s ms^{-1}	3. SI Unit: m/s ms^{-1}
4. Scalar quantity	4. Vector quantity
5. Mannal is walking at a speed of 0.5 m/s	5. Mannal is walking at 0.5 m/s due North/ towards the door.
	

s : displacement

average speed = $\frac{\text{total distance}}{\text{total time}}$

average velocity = $\frac{\text{total displ}}{\text{total time}}$



a) avg. speed

avg. speed = $\frac{40+60}{10+30}$

= 2.5 m/s

b) avg. velocity

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

$= \sqrt{40^2 + 60^2}$

= 72.11 m

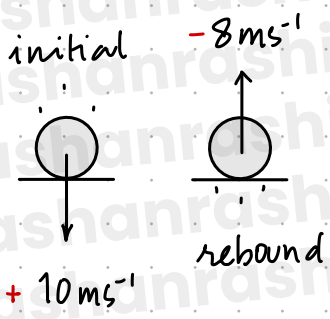
avg. vel = $\frac{72.11}{40}$

= 1.8 m/s

Acceleration

"It is the rate of change of velocity."

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



time of collision $\Delta t = 0.02s$

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

$$a = \frac{-8-10}{0.02}$$

$$a = -900\ m/s^2$$

Equations of Motion

1. $v = u + at$

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

$$at = v-u$$

$$v = u+at$$

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

$$s = v_{avg} \times t$$

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

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

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

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

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

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

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

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

s = height

a = grav. acc.

$s = \frac{1}{2}at^2$ (if $u = 0$)

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

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

$$\left(\frac{v-u}{a}\right) = t$$

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

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

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

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

$v^2 = 2as$ or $v = \sqrt{2as}$ (if $u = 0$)

Conditions to apply equations of motion

1. Straight line motion
2. Constant acceleration

Example #1

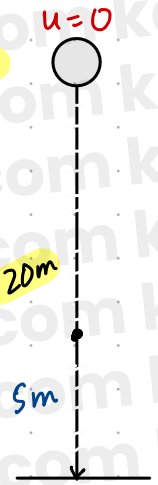
A ball is released from rest and falls 20m before it hits the ground. Assuming negligible air resistance, determine.

a) time to hit ground

b) speed as it hits ground

c) time to fall last 5m to ground

d) velocity 5m above the ground.



a) $u = 0$, $a = 9.8\ m/s^2$, $s = 20m$, $t = ?$

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

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

$t = 2.02\ s$ $(2.0\ s)$

b) $u = 0$, $a = 9.8\ m/s^2$, $s = 20m$, $t = 2.02s$, $v = ?$

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

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

$v = 19.8\ m/s$

$v = u + at$

$v = 0 + (9.8)(2.02)$

$v = 19.8\ m/s$

c) time to fall 15m

$u = 0$, $a = 9.8\ m/s^2$, $s = 15m$, $t = ?$

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

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

$t = 1.75\ s$

$t_{20} = 2.02\ s$

$t_{15} = 1.75\ s$

last 5m: $t = t_{20} - t_{15}$

$t = 2.02 - 1.75$

$t = 0.27\ s$

$s = \cancel{ut}^{0} + \frac{1}{2}at^2$

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

$s \propto t^2$

$20m \text{ — } (2.02)^2$

$15m \text{ — } x^2$

$x^2 = \frac{(2.02)^2 \times 15}{20}$

$x = 1.75\ s$

d) $u = 0$, $a = 9.8\ m/s^2$, $s = 15m$, $v = ?$

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

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

$v = 17.1\ m/s$

$v^2 \propto s$

Example #1

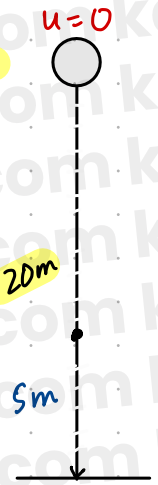
A ball is released from rest and falls 20m before it hits the ground. Assuming negligible air resistance, determine.

a) time to hit ground

b) speed as it hits ground

c) time to fall last 5m to ground

d) velocity 5m above the ground.



a) $u = 0$, $a = 9.8\ m/s^2$, $s = 20m$, $t = ?$

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

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

$t = 2.02\ s$ $(2.0\ s)$

b) $u = 0$, $a = 9.8\ m/s^2$, $s = 20m$, $t = 2.02s$, $v = ?$

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

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

$v = 19.8\ m/s$

$v = u + at$

$v = 0 + (9.8)(2.02)$

$v = 19.8\ m/s$

c) time to fall 15m

$u = 0$, $a = 9.8\ m/s^2$, $s = 15m$, $t = ?$

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

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

$t = 1.75\ s$

$t_{20} = 2.02\ s$

$t_{15} = 1.75\ s$

last 5m: $t = t_{20} - t_{15}$

$t = 2.02 - 1.75$

$t = 0.27\ s$

$s = \cancel{ut}^{0} + \frac{1}{2}at^2$

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

$s \propto t^2$

$20m \text{ — } (2.02)^2$

$15m \text{ — } x^2$

$x^2 = \frac{(2.02)^2 \times 15}{20}$

$x = 1.75\ s$

d) $u = 0$, $a = 9.8\ m/s^2$, $s = 15m$, $v = ?$

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

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

$v = 17.1\ m/s$

$v^2 \propto s$

8 A bicycle brakes so that it undergoes uniform deceleration from a speed of $8\,m\,s^{-1}$ to $6\,m\,s^{-1}$ over a distance of 7 m.

If the deceleration of the bicycle remains constant, what further distance will it travel before coming to rest?

A 7 m **B** 9 m **C** 16 m **D** 21 m

$s = ?$
$v = 0$
$a = -2\,ms^{-2}$
$u = 6\,ms^{-1}$

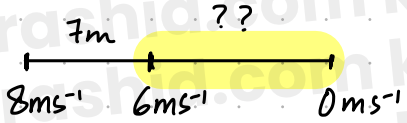
$v^2 - u^2 = 2as$

$0 - 6^2 = 2(-2)s$

$s = 9\,m$

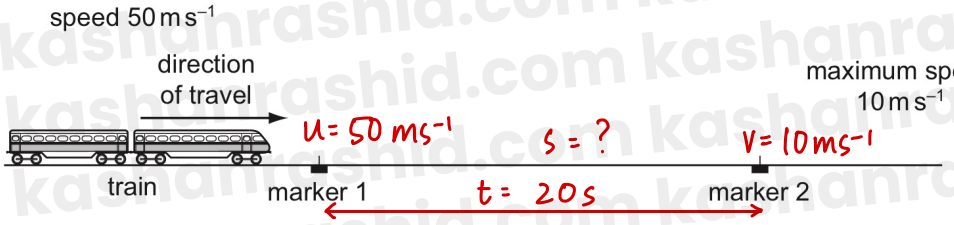
$u = 8\,ms^{-1}$ $v = 6\,ms^{-1}$ $s = 7\,m$ $a = ?$

$v^2 - u^2 = 2as$
$6^2 - 8^2 = 2a(7)$
$a = -2\,ms^{-2}$



7 The diagram shows an arrangement to stop trains that are travelling too fast.

9702/12
May/June 2013
1 hour



Trains coming from the left travel at a speed of $50\,m\,s^{-1}$. At marker 1, the driver must apply the brakes so that the train decelerates uniformly in order to pass marker 2 at no more than $10\,m\,s^{-1}$.

The train carries a detector that notes the times when the train passes each marker and will apply an emergency brake if the time between passing marker 1 and marker 2 is less than 20 s.

How far from marker 2 should marker 1 be placed?

A 200 m **B** 400 m **C** 500 m **D** 600 m

- $v = u + at$
- $s = ut + \frac{1}{2}at^2$
- $v^2 - u^2 = 2as$
- $s = \left(\frac{u+v}{2}\right)t$

$s = \left(\frac{50+10}{2}\right)20$

$s = 600\,m$

$u = 50\,ms^{-1}$
$v = 10\,ms^{-1}$
$t = 20s$
$s = ?$
$a = -2\,m/s^2$

$v = u + at$
$10 = 50 + a(20)$
$a = -2\,m/s^2$

$v^2 - u^2 = 2as$
$10^2 - 50^2 = 2(-2)s$
$\frac{10^2 - 50^2}{-4} = s$
$s = 600\,m$

9702/11
October/November 2009
1 hour

5 On a particular railway, a train driver applies the brake of the train at a yellow signal, a distance of 1.0 km from a red signal, where it stops.

The maximum deceleration of the train is $0.2\,m\,s^{-2}$.

$u = ?$ $s = 1000\,m$ $v = 0$

Y $a = -0.2\,m/s^2$ R

Assuming uniform deceleration, what is the maximum safe speed of the train at the yellow signal?

A $20\,m\,s^{-1}$ B $40\,m\,s^{-1}$ C $200\,m\,s^{-1}$ D $400\,m\,s^{-1}$

$\cdot v = u + at$ $\cdot s = \left(\frac{u+v}{2}\right)t$ $\cdot s = ut + \frac{1}{2}at^2$ $\cdot v^2 - u^2 = 2as$

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

$0 - u^2 = 2(-0.2)(1000)$

$u = \sqrt{400}$

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

9702/11
May/June 2012
1 hour

8 The diagram shows a laboratory experiment in which a feather falls from rest in a long evacuated vertical tube of length L.

$u = 0$ $a = g$

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

$s = 0 + \frac{1}{2}at^2$

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

as $a = g$ = constant so

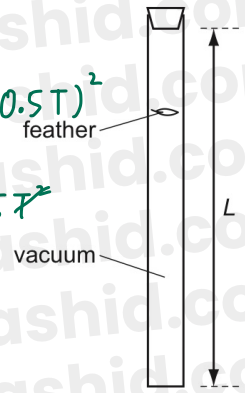
$s \propto t^2$

$L \propto (T)^2$

$x \propto (0.5T)^2$

$L \times 0.25T^2 = x \times T^2$

$x = 0.25L$



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

$L = \frac{1}{2}aT^2$

$a = \frac{2L}{T^2}$

$s = \frac{1}{2}\left(\frac{2L}{T^2}\right)(0.5T)^2$

$s = \frac{L}{T^2} \times 0.25T^2$

$s = 0.25L$

The feather takes time T to fall from the top to the bottom of the tube.

How far will the feather have fallen from the top of the tube in time $0.50\,T$?

A 0.13 L B 0.25 L C 0.38 L D 0.50 L

$\cdot v = u + at$

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

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

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

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1 hour

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?

u now 20% extra $u + 20\%u$

$u + 0.2u = 1.2u$

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

$\cdot v = u + at$

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

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

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

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

$0 - u^2 = 2as$

$u^2 = -2as$

"$u^2 \propto s$"

$u^2 \propto s$

$u^2 \quad x$

$(1.2u)^2 \quad s$

$u^2 \times s = 1.44u^2 \times x$

$s = 1.44x$

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.

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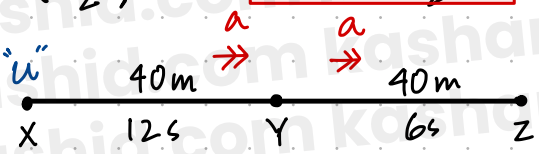
What is the acceleration of the body?

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

$v = u + at$ $s = \left(\frac{u+v}{2}\right)t$ $s = ut + \frac{1}{2}at^2$ $v^2 - u^2 = 2as$

s, t, "a"



XY
$s = ut + \frac{1}{2}at^2$
$40 = u(12) + \frac{1}{2}a(12)^2$
$40 = 12u + 72a$

XZ
$s = ut + \frac{1}{2}at^2$
$80 = u(18) + \frac{1}{2}a(18)^2$
$80 = 18u + 162a$

simultaneously solving
$u = 1.11\ m/s$
$a = 0.37\ m/s^2$

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

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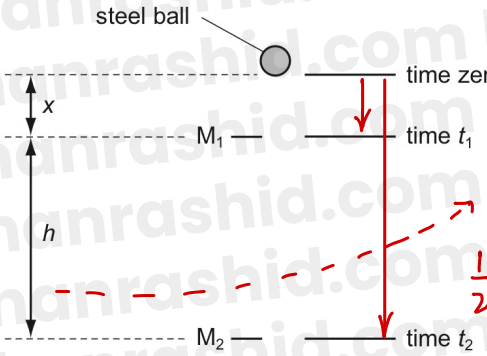
$s = ut + \frac{1}{2}at^2$
$x = 0 + \frac{1}{2}at_1^2$
$x = \frac{1}{2}at_1^2$



$s = ut + \frac{1}{2}at^2$
$x + h = 0 + \frac{1}{2}at_2^2$
$x + h = \frac{1}{2}at_2^2$
$\frac{1}{2}at_1^2 + h = \frac{1}{2}at_2^2$

$v = u + at$
$s = \left(\frac{u+v}{2}\right)t$
$s = ut + \frac{1}{2}at^2$
$v^2 - u^2 = 2as$

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

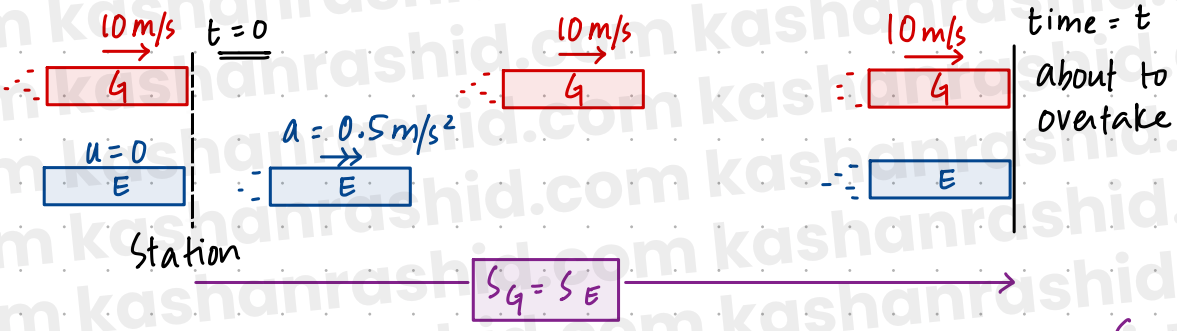
$h = \frac{1}{2}at_2^2 - \frac{1}{2}at_1^2$

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

8 A goods train passes through a station at a steady speed of $10\,m\,s^{-1}$. An express train is at rest at the station. The express train leaves the station with a uniform acceleration of $0.5\,m\,s^{-2}$ 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



s_G (constant speed)

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

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

$s_G = 10t$

s_E (accelerate)

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

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

$s_E = 0.25t^2$

$s_G = s_E$

$10t = 0.25t^2$

$0.25t^2 - 10t = 0$

$t(0.25t - 10) = 0$

$t = 0$ $\quad 0.25t - 10 = 0$

$t = 40\,s$

For Examiner's Use

2 **(a)** The distance s moved by an object in time t may be given by the expression

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

$s = ut + \frac{1}{2}at^2$, $u = 0$

where a is the acceleration of the object.

State two conditions for this expression to apply to the motion of the object.

1. Initial velocity = 0

2. Linear motion | constant acceleration

[2]

(b) A student takes a photograph of a steel ball of radius 5.0 cm as it falls from rest. The image of the ball is blurred, as illustrated in Fig. 2.1.
The image is blurred because the ball is moving while the photograph is being taken.

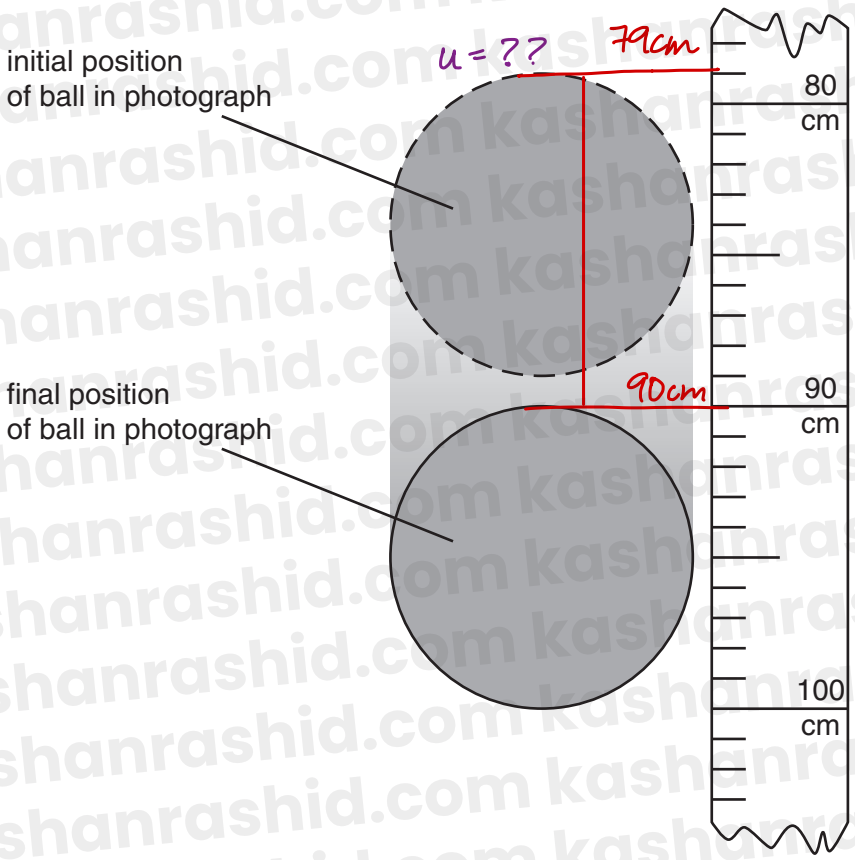


Fig. 2.1

The scale shows the distance fallen from rest by the ball. At time $t = 0$, the top of the ball is level with the zero mark on the scale. Air resistance is negligible.

7

Calculate, to an appropriate number of significant figures,

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(i) the time the ball falls before the photograph is taken,

$u = 0$
$s = 0.79\text{m}$
$a = 9.8\ \text{m/s}^2$
$t = ?$

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

$0.79 = 0 + \frac{1}{2}(9.8)t^2$

$t = 0.40152$

time = 0.40 s [3]

(ii) the time interval during which the photograph is taken.

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

$0.9 = 0 + \frac{1}{2}(9.8)t^2$

$t = 0.43\text{s}$

$t_{79} = 0.40\text{s}$

$t_{90} = 0.43\text{s}$

$\Delta t = 0.03\text{s}$

time interval = ... s [3]

(c) The student in **(b)** takes a second photograph starting at the same position on the scale. The ball has the same radius but is less dense, so that air resistance is not negligible.

State and explain the changes that will occur in the photograph.

The gap between the shadows will be less as there will be less acceleration and the ball would be slower. less blured.

..... [2]

For Examiner's Use

2 A car is travelling along a straight road at speed v. A hazard suddenly appears in front of the car. In the time interval between the hazard appearing and the brakes on the car coming into operation, the car moves forward a distance of 29.3 m. With the brakes applied, the front wheels of the car leave skid marks on the road that are 12.8 m long, as illustrated in Fig. 2.1.

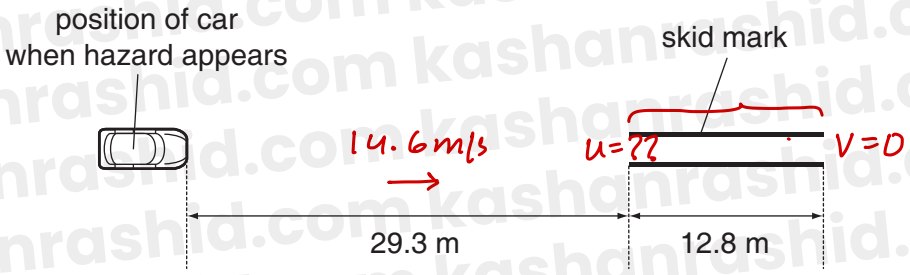


Fig. 2.1

$a = 0.85g$

It is estimated that, during the skid, the magnitude of the deceleration of the car is $0.85g$, where g is the acceleration of free fall.

(a) Determine

(i) the speed v of the car before the brakes are applied,

$v = 0$
$a = -0.85g$
$s = 12.8\ m$
$u = ?$

$v^2 - u^2 = 2as$
$0 - u^2 = 2(-0.85 \times 9.8)(12.8)$
$u = 14.6$

v = ... 14.6 ..... $m\,s^{-1}$ [2]

(ii) the time interval between the hazard appearing and the brakes being applied.

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

$14.6 = \frac{29.3}{t}$

$t = 2.0$

time = ... 2.0 ..... s [2]

7

(b) The legal speed limit on the road is 60 km per hour.
Use both of your answers in **(a)** to comment on the standard of the driving of the car.

For Examiner's Use

The driver was within the speed limit but his reaction time was too large.

[3]

$60\ \frac{km}{h} \xrightarrow[\times 3600]{\times 10^3} \frac{m}{s}$

$\frac{60 \times 10^3}{1 \times 3600} = 16.67\ m/s$

2 Fig. 2.1 shows an object M on a slope.

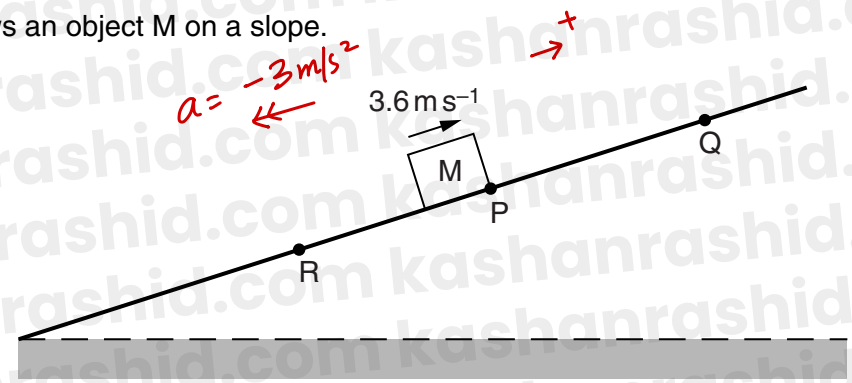


Fig. 2.1

M moves up the slope, comes to rest at point Q and then moves back down the slope to point R.
M has a constant acceleration of 3.0 m s^{-2} down the slope at all times.
At time $t = 0$, M is at point P and has a velocity of 3.6 m s^{-1} up the slope.
The total distance from P to Q and then to R is 6.0 m.

(a) Calculate, for the motion of M from P to Q,

(i) the time taken,

$u = 3.6$ m/s
$v = 0$ m/s
$a = -3$ m/s^2
$t = ?$

$a = \frac{v-u}{t}$
$-3 = \frac{0 - 3.6}{t}$
$t = 1.2$ s

time = ... s [2]

(ii) the distance travelled.

$u = 3.6$ m/s
$v = 0$
$a = -3$ m/s^2
$t = 1.2$ s
$s = ?$

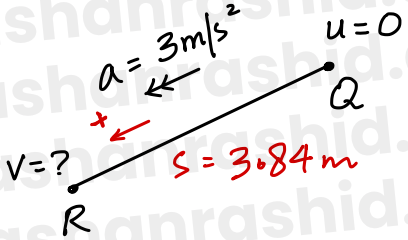
$v^2 - u^2 = 2as$
$0 - (3.6)^2 = 2(-3)s$
$s = 2.16$ m

distance = ... m [1]

(b) Show that the speed of M at R is 4.8 m s^{-1}.

$s_{QR} = 6 - 2.16$
$= 3.84$ m

$v^2 - u^2 = 2as$
$v^2 - 0 = 2(3)(3.84)$
$v = 4.8$ m/s



a & v direction opp : a "−"
a & v direction same : a "+"

[2]

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Acceleration

- Rate of change of velocity.
- $a = \frac{\Delta v}{\Delta t}$ or $a = \frac{v-u}{t}$
- SI Unit: ms^{-2}
- Vector

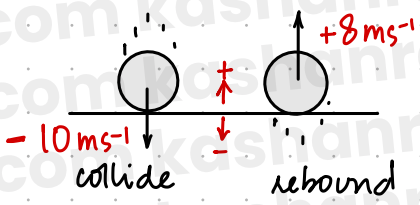
Acceleration
↓
change in velocity

change of magnitude	change of direction
• slow down • speed up	• turn about a point • collide and rebound

Example #1

A ball collides with a speed of $10ms^{-1}$ and rebounds with a speed of $8ms^{-1}$ from the floor.

If collision time is 0.1s, calculate average acceleration.



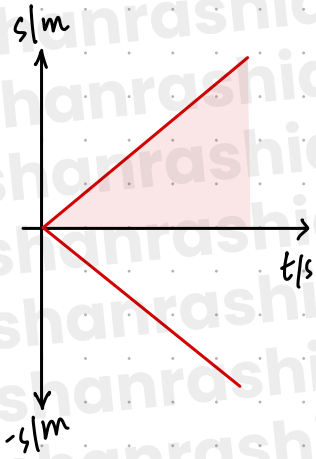
$a = \frac{v-u}{t}$

$a = \frac{8-(-10)}{0.1}$

$a = 180\ ms^{-2}$

Graphs

1. Displacement-time Graph

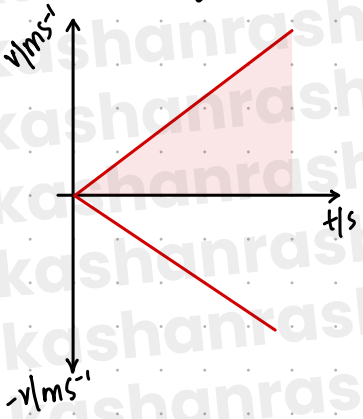


x-axis: time
y-axis: displacement

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

Area: meaningless
$A = \frac{1}{2}bh$
$= \frac{1}{2}(t \times s)$

2. Velocity-time Graph

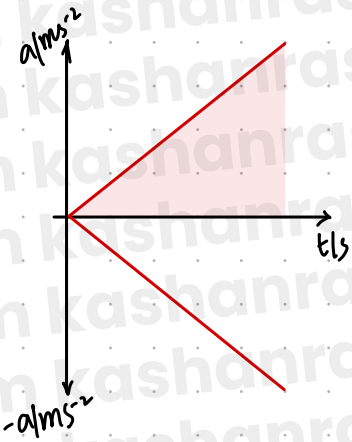


x-axis: time
y-axis: velocity

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

Area: Displacement
$A = \frac{1}{2}bh$
$= \frac{1}{2}(t \times v)$

3. Acceleration-time Graph



x-axis: time
y-axis: acceleration

gradient: rate of change of acc.
$m = \frac{\Delta y}{\Delta x} = \frac{\Delta a}{\Delta t}$

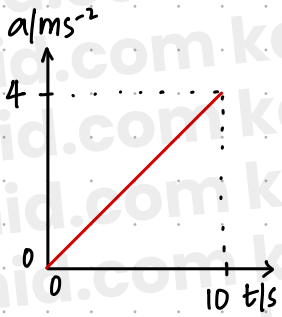
Area: change of velocity
$A = \frac{1}{2}bh$
$= \frac{1}{2}(t \times a)$

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

$a \times t = v-u$

Example

A car travelling at 5 ms^{-1} undergoes non-uniform acceleration as shown in the graph.
Determine the final velocity of car after 10s.



Area = $\Delta v = \frac{1}{2} b h$

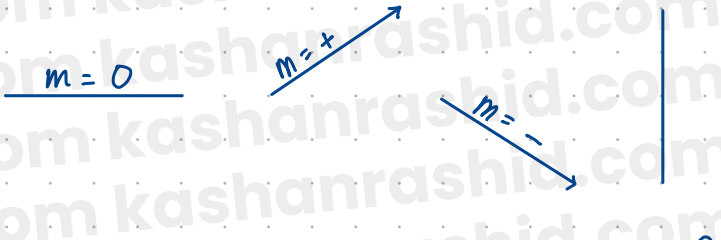
$\Delta v = \frac{1}{2}(10)(4)$

$\Delta v = 20$ ms^{-1}

as $\Delta v = v - u$ so $20 = v - 5 \Rightarrow v = 25$ ms^{-1}

Types of Graphs

1. LINE GRAPHS (CONSTANT/UNIFORM Gradient)

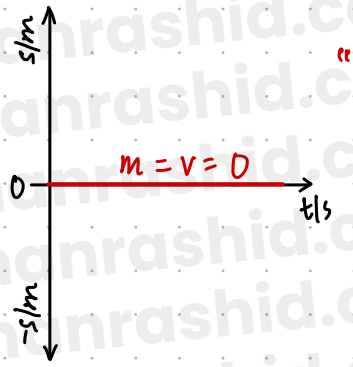


"more vertical ⟶ more gradient"

2. CURVE (VARIABLE GRADIENT)

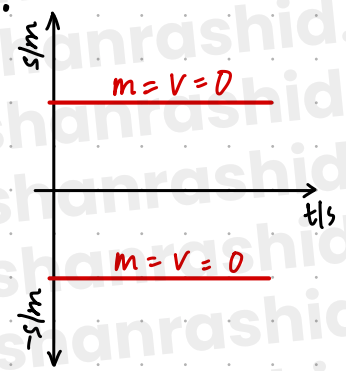
Displacement-time Graphs

1.



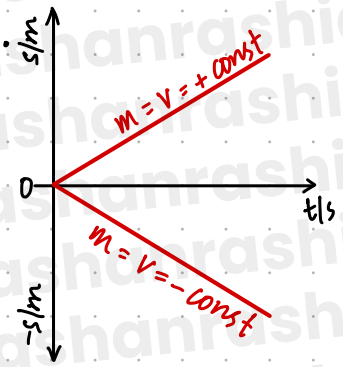
"Object is at rest at the origin."

2.



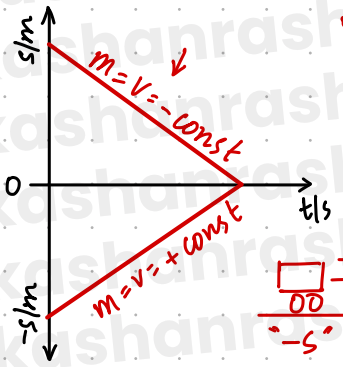
"Object is at rest ahead/behind the origin."

3.

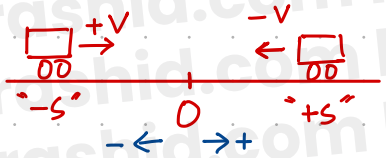


"Object is moving at constant velocity, away from origin."

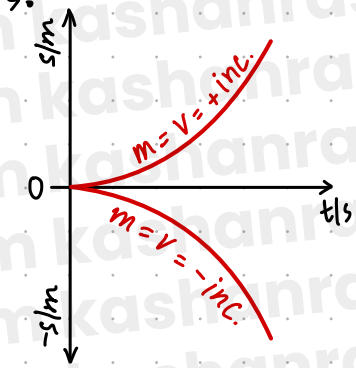
4.



"Object is moving at constant velocity, towards the origin."

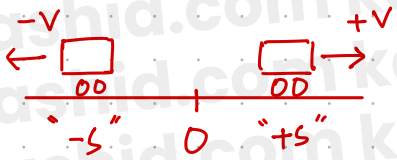


5.

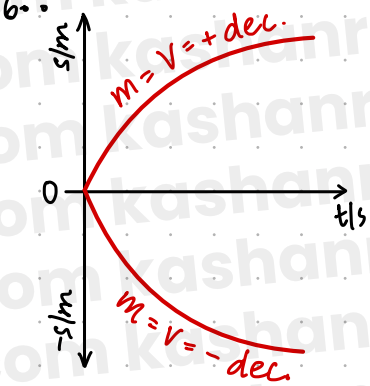


"Object is moving at increasing velocity, away from origin."

"Acceleration"



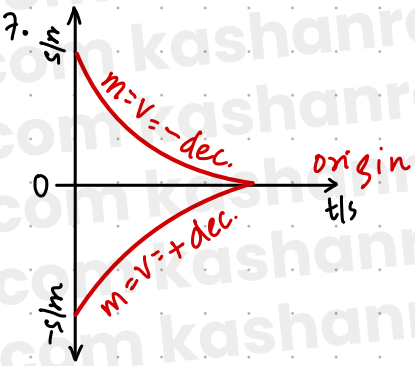
6.



"Object is moving with decreasing velocity, away from the origin."

"deceleration"

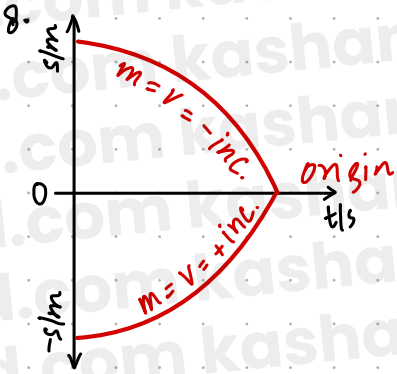
7.



"Object is moving with decreasing velocity, towards the origin."

"deceleration"

8.



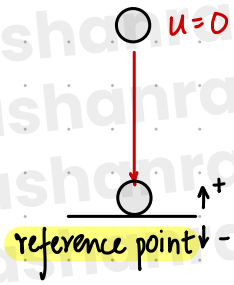
"Object is moving at increasing velocity, towards the origin."

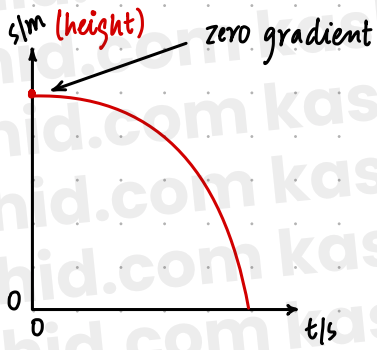
"acceleration"

Example #1

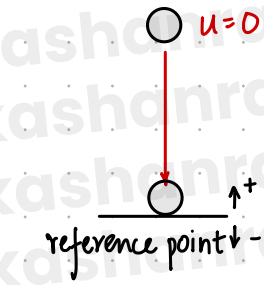
Object is released from rest and falls to the ground.

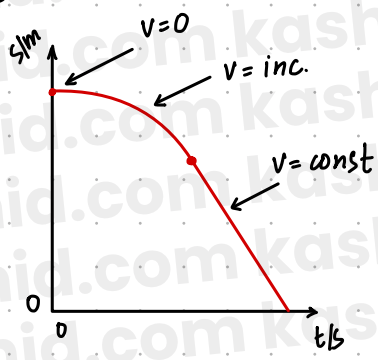
a) Negligible Air Resistance



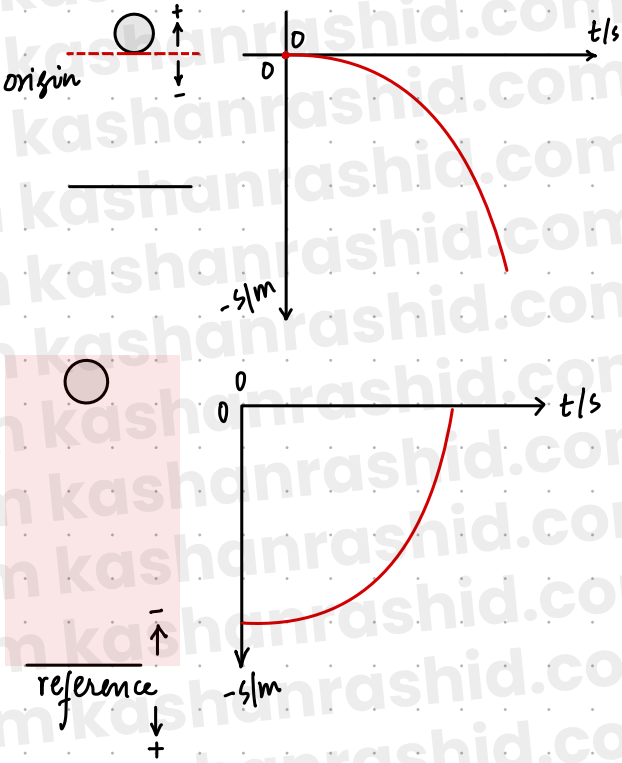


b) Air Resistance exists



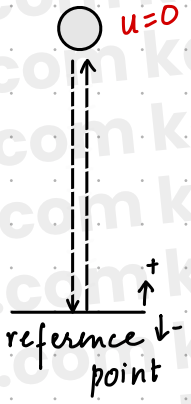


c) Negligible Air Resistance

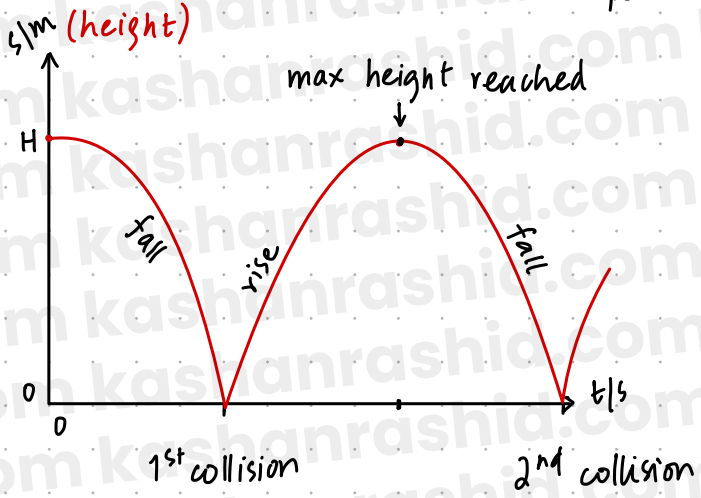


Example #2

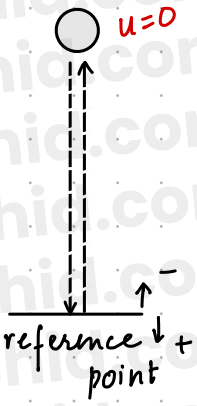
Object is released from rest, falls down, hits the ground and rebounds.

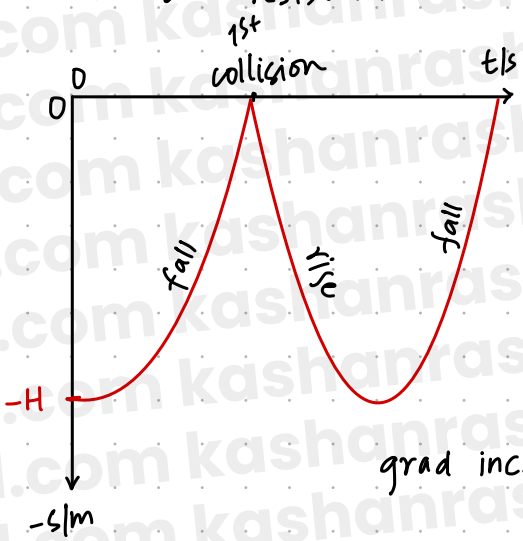


a) • No air resistance
• No energy loss upon collision (Elastic collision)

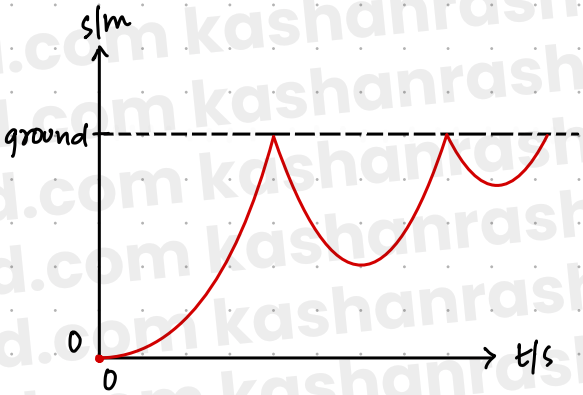


b) Elastic collision
No air resistance

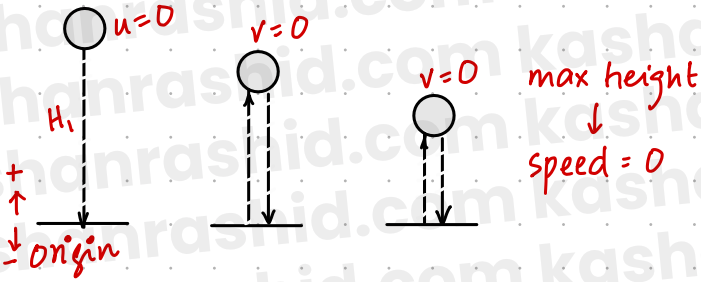


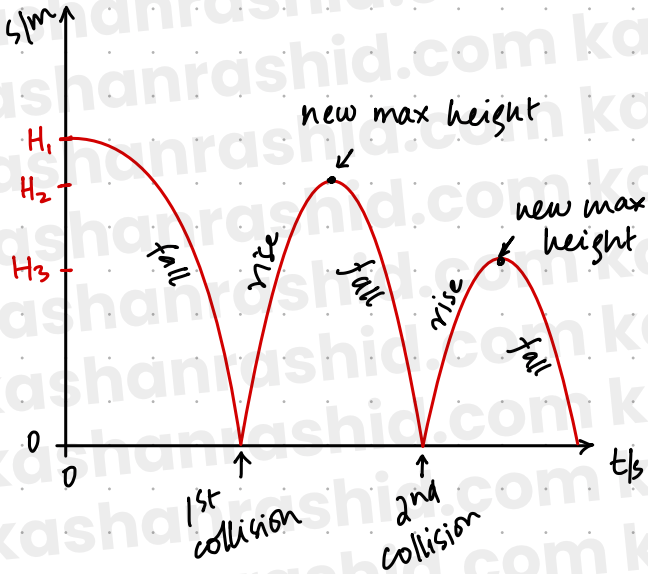


grad inc. → speed inc.

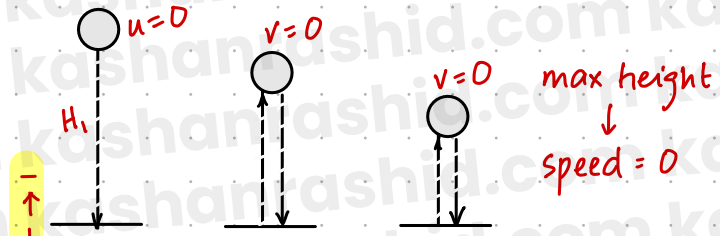


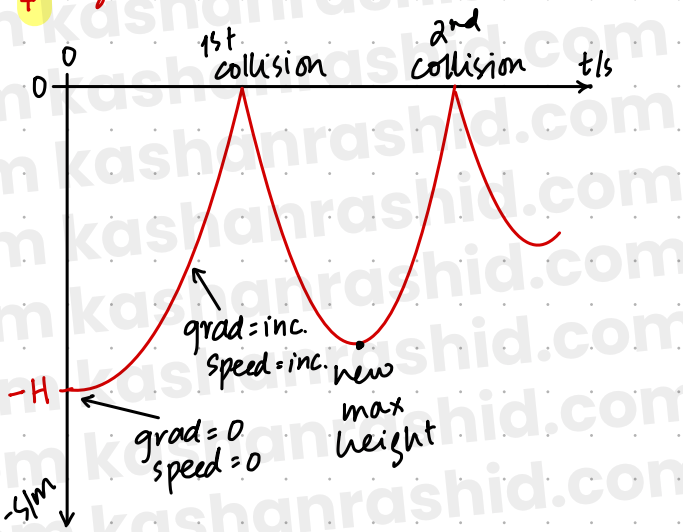
c) • Energy loss during collision
(Inelastic collision)
• No air resistance



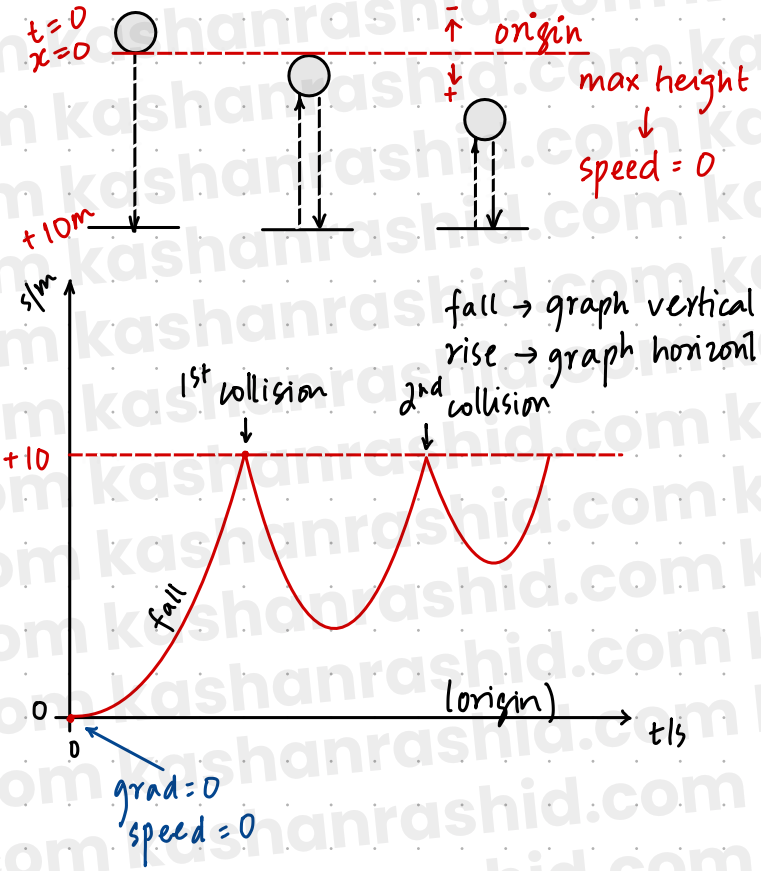


d) • Energy loss during collision
(Inelastic collision)
• No air resistance



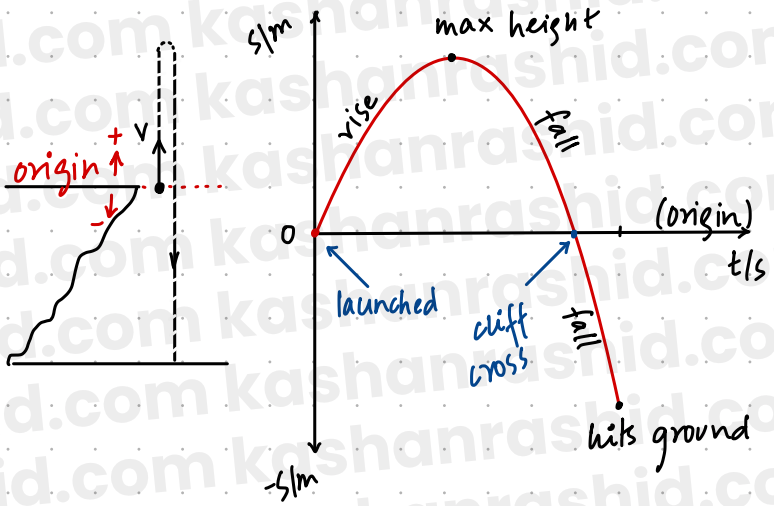


e) • Energy loss during collision
(Inelastic collision)
• No air resistance



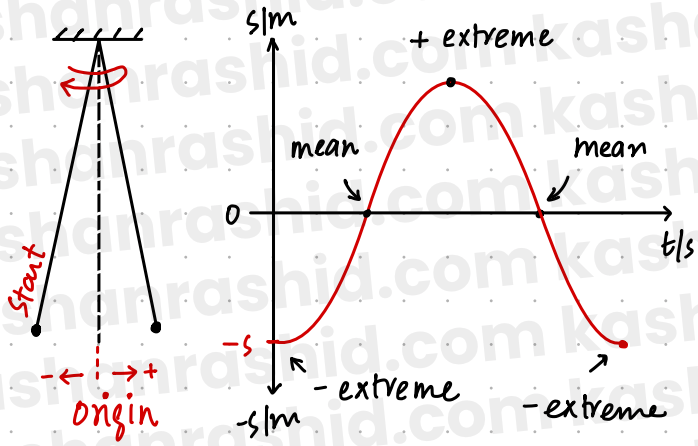
Example #3

A ball is launched upwards from a cliff, reaches max height and falls back to the ground.



Example #4

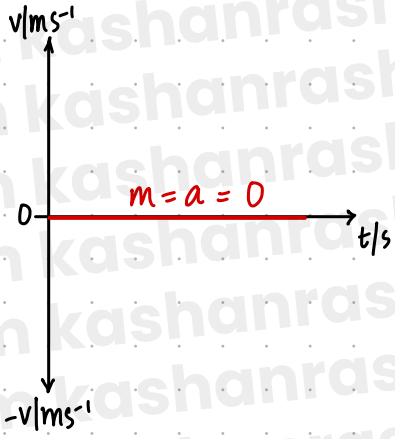
Oscillation of a simple pendulum



" No air resistance "

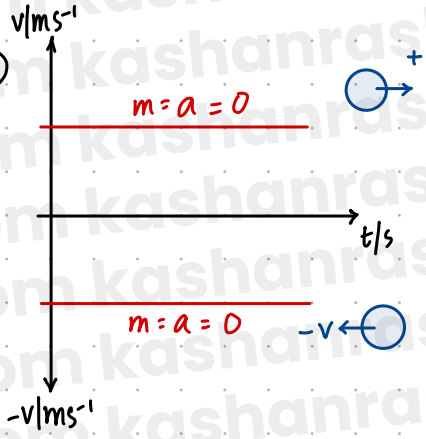
+ extreme = - extreme

Velocity - time Graphs

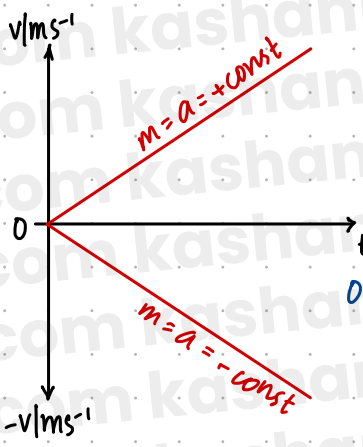


"Object is at rest"

(2)



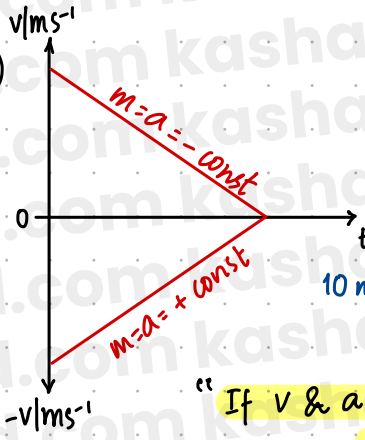
"Object is moving at constant/uniform velocity."



"Object is moving at constant acceleration."

0 → 2m/s → 4m/s → 6m/s → 8m/s

(4)

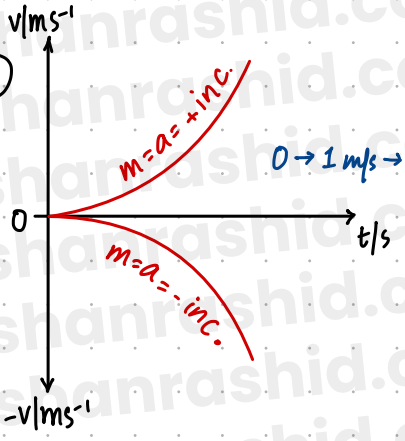


"Object is moving at constant deceleration."

10 m/s → 8 m/s → 6m/s → 4m/s

"If v & a have opp. signs, object decelerates!"

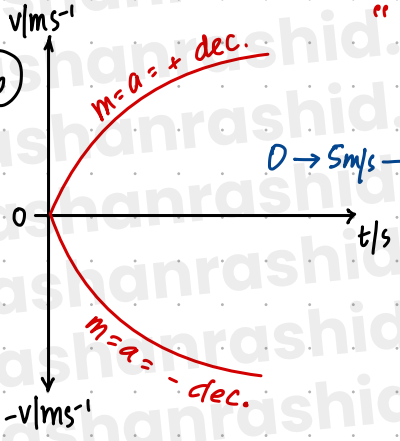
(5)



"Object is moving at increasing acceleration."

0 → 1 m/s → 3m/s → 6m/s → 10m/s

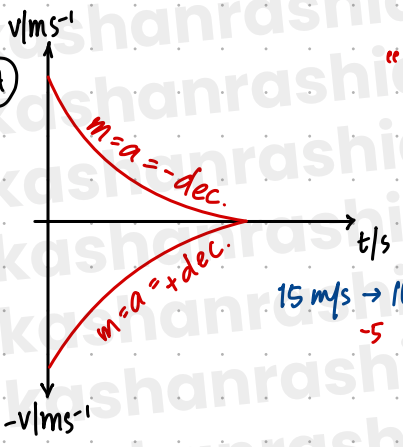
(6)



"Object is moving at decreasing acceleration."

0 → 5m/s → 9 m/s → 12m/s → 14m/s

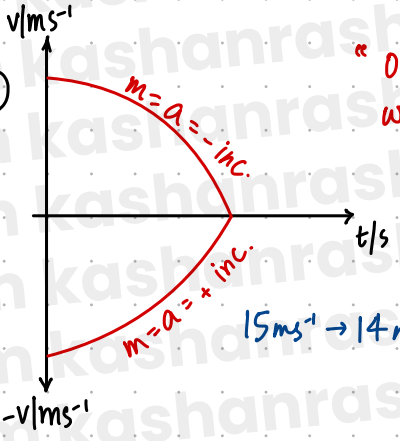
(7)



"Object is moving at decreasing deceleration."

15 m/s → 10m/s → 6m/s → 3m/s → 1m/s
-5 -4 -3 -2

(8)



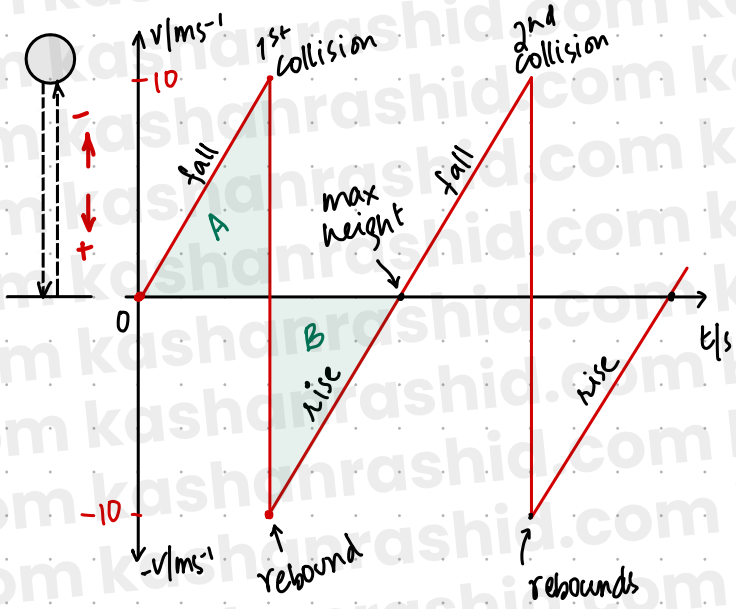
"Object is moving with increasing deceleration."

15ms⁻¹ → 14 m/s → 12m/s → 9m/s → 5m/s

Example #1

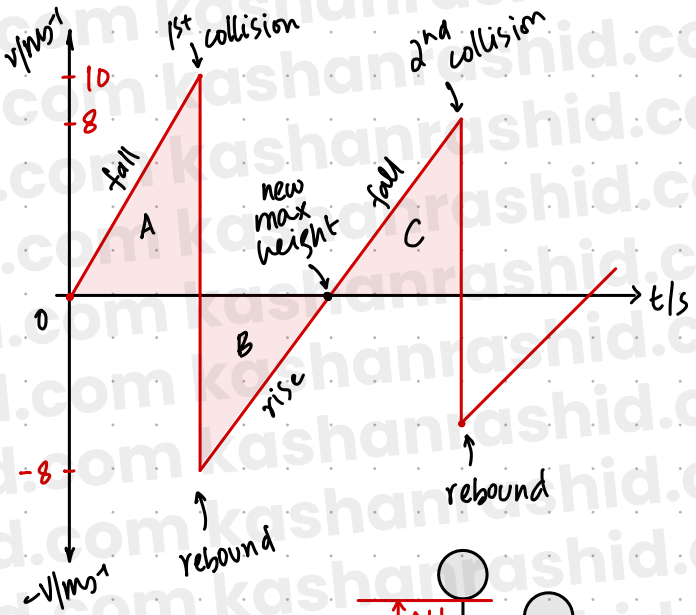
Ball falls from rest, hits the ground and rebounds.

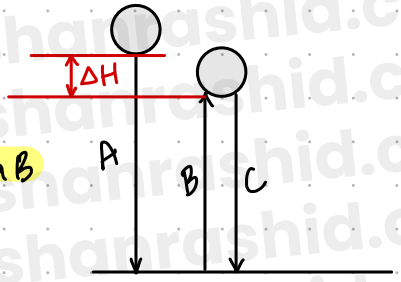
a) No air resistance, No collision time
Elastic collision



Area A = Area B
height fallen = height rose
(rebound height)

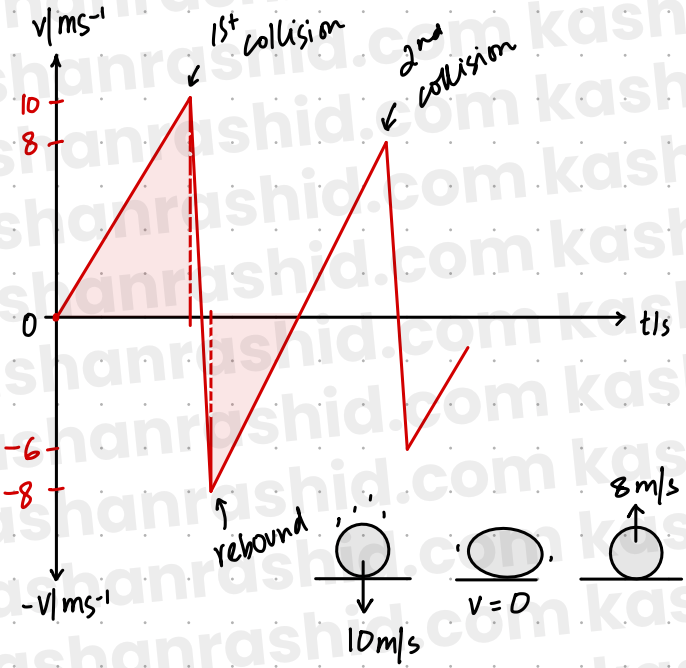
b) No air resistance, No collision time
Inelastic collision





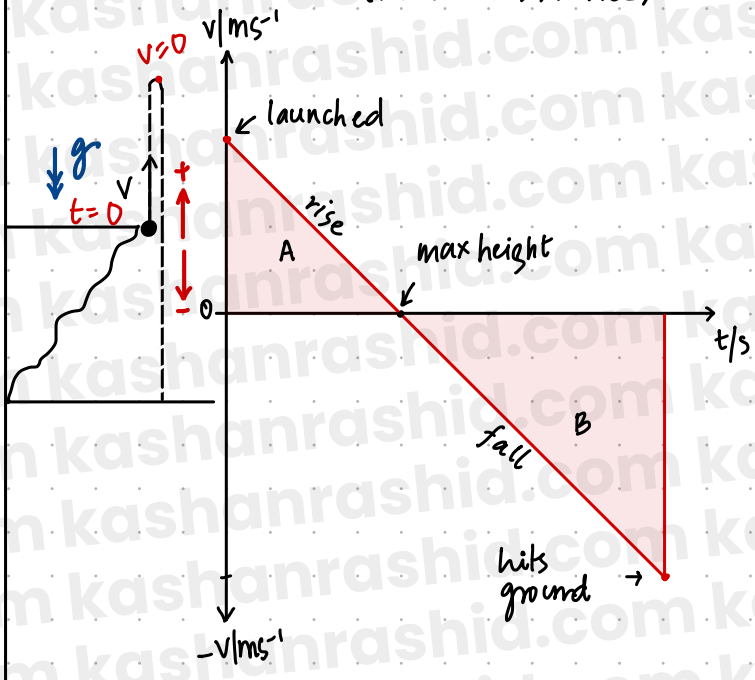
ΔH = Area A - Area B

c) No air resistance, Collision time considered, Inelastic collision



Example #2

A ball launched from a cliff, reaches max height and hits the ground.
(No air resistance)



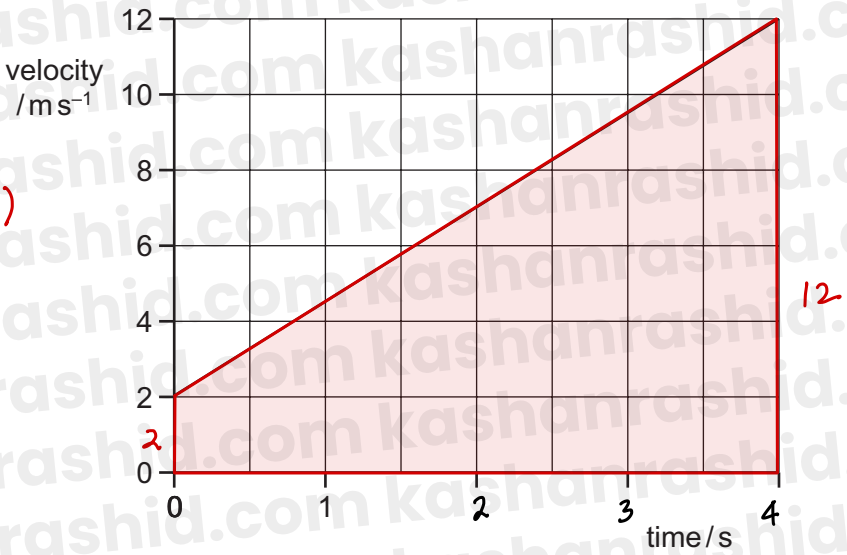
height of cliff = Area B - Area A

Additional Materials:

Which ammeter reading will be nearest to the correct value?

A 0.2 A **B** 0.4 A **C** 0.6 A **D** 0.8 A

6 The diagram shows a velocity-time graph for a car.

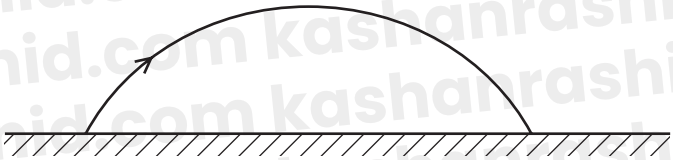


$A = \frac{1}{2}(2+12)(4)$
$= 28\,m$

What is the distance travelled during the first 4.0 s?

A 2.5 m **B** 3.0 m **C** 20 m **D** 28 m

8 The diagram shows the path of a golf ball.

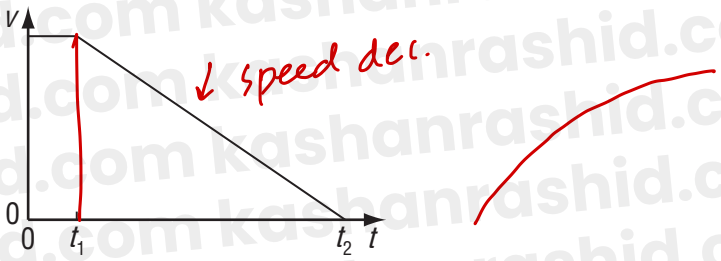


Which row describes changes in the horizontal and vertical components of the golf ball's velocity, when air resistance forces are ignored?

	horizontal	vertical
A	constant deceleration	constant acceleration downwards
B	constant deceleration	acceleration decreases upwards then increases downwards
C	constant velocity	constant acceleration downwards
D	constant velocity	acceleration decreases upwards then increases downwards

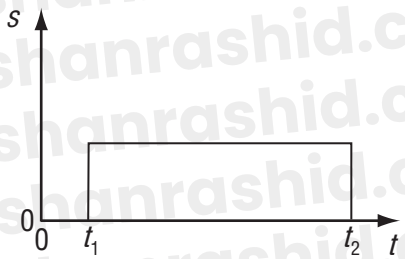
6 When a car driver sees a hazard ahead, she applies the brakes as soon as she can and brings the car to rest.

The graph shows how the speed v of the car varies with time t after she sees the hazard.



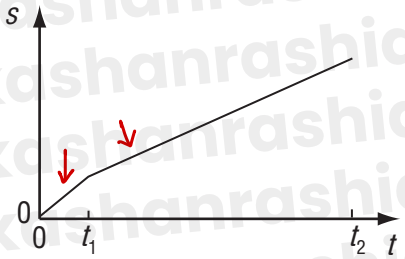
Which graph represents the variation with time t of the distance s travelled by the car after she has seen the hazard?

A



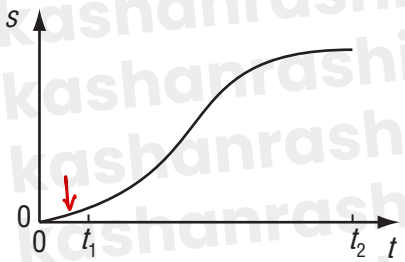
grad dec.

B



C

D



8 The diagram shows a velocity-time graph for a vehicle.

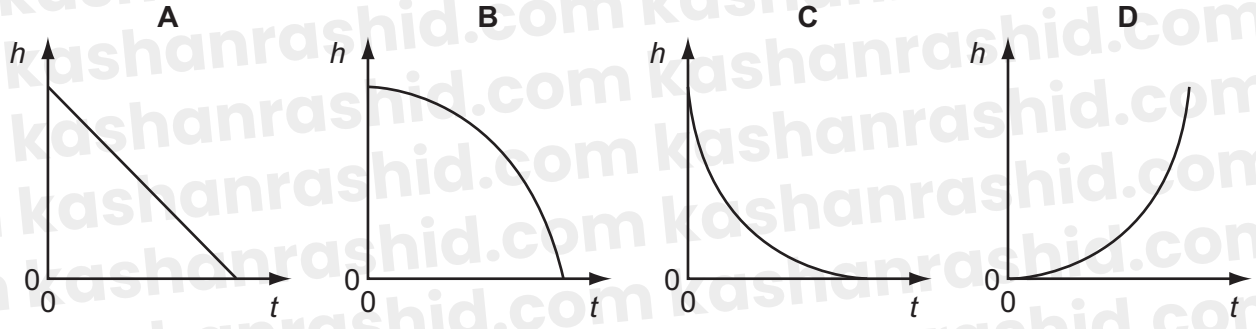
The vehicle, moving at $4.0\,m\,s^{-1}$, begins to accelerate at time = 0.

What is the vehicle's acceleration at time = 3.0 s?

A $0.67\,m\,s^{-2}$ **B** $1.0\,m\,s^{-2}$ **C** $1.3\,m\,s^{-2}$ **D** $2.0\,m\,s^{-2}$

9 A small steel ball falls freely under gravity after being released from rest.

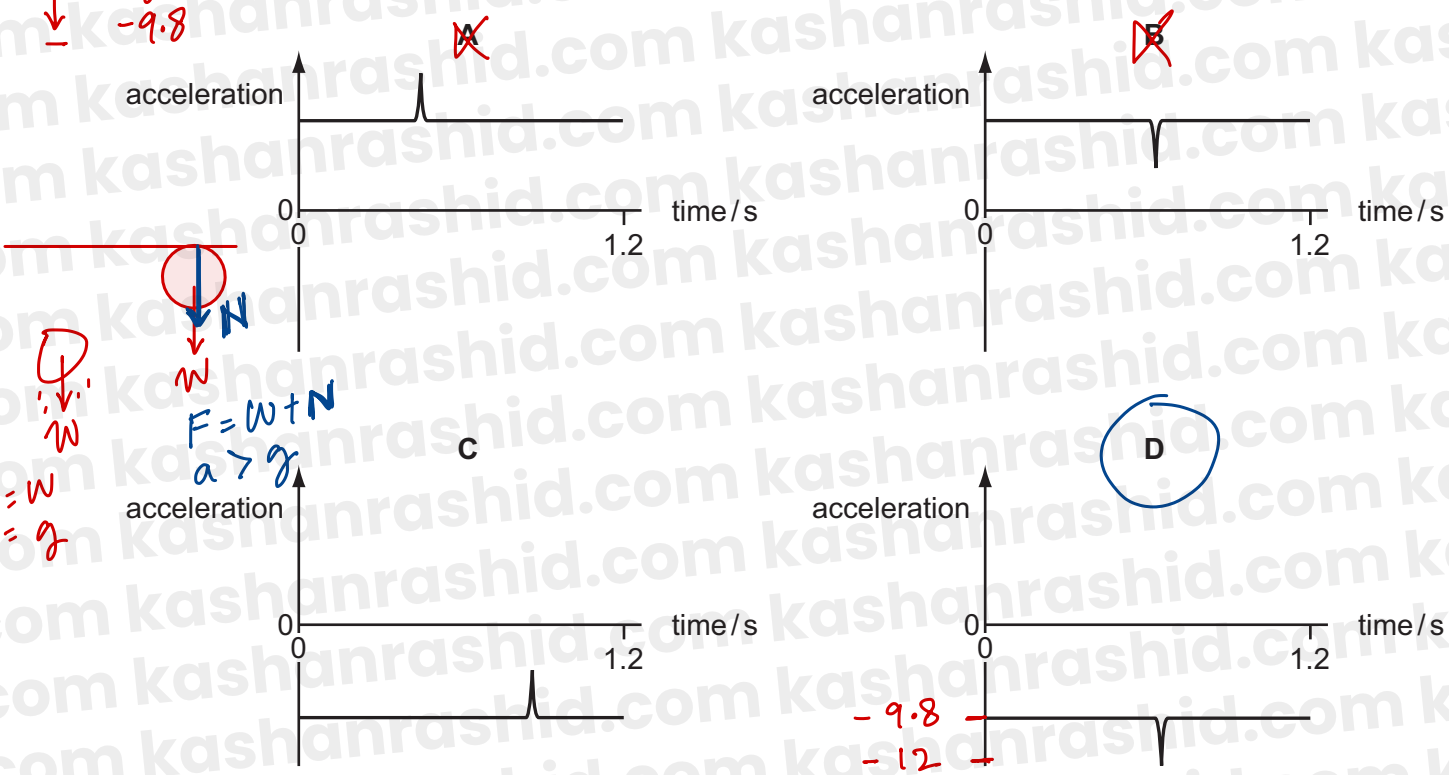
Which graph best represents the variation of the height h of the ball with time t?



7 A student throws a ball in the positive direction vertically upwards.

The ball makes an elastic collision with the ceiling, rebounds and accelerates back to the student's hand in a time of 1.2 s.

Which graph best represents the acceleration of the ball from the moment it leaves the hand to the instant just before it returns to the hand?



Additional Materials:

8 A bicycle brakes so that it undergoes uniform deceleration from a speed of $8\,m\,s^{-1}$ to $6\,m\,s^{-1}$ over a distance of 7 m.

If the deceleration of the bicycle remains constant, what further distance will it travel before coming to rest?

A 7 m **B** 9 m **C** 16 m **D** 21 m

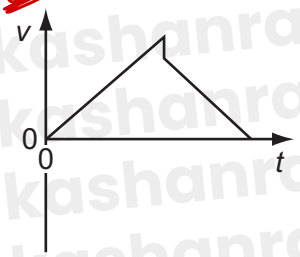
$u = 0$

9 A ball is released from rest above a horizontal surface. It bounces once and is caught.

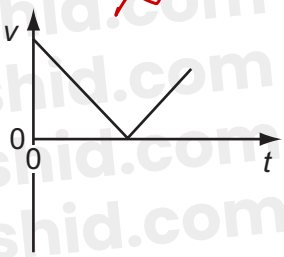
Which graph represents the variation with time t of the velocity v of the ball?

speed

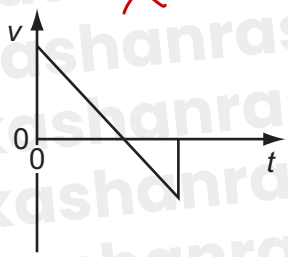
A



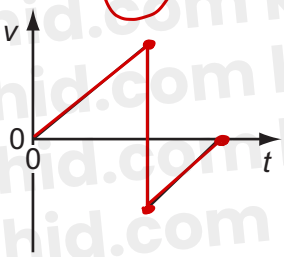
B

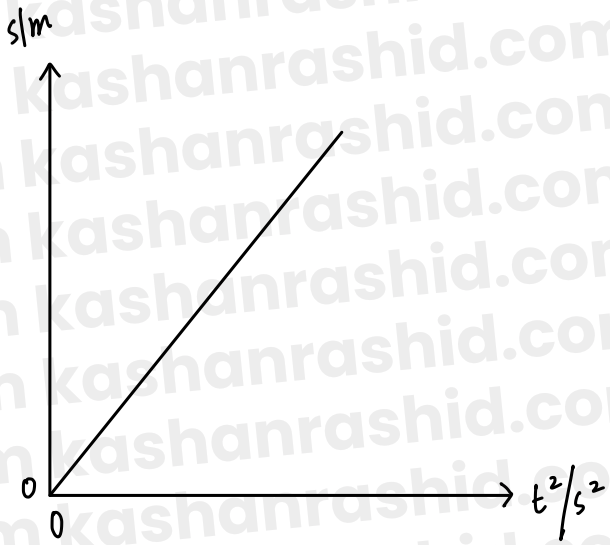


C



D





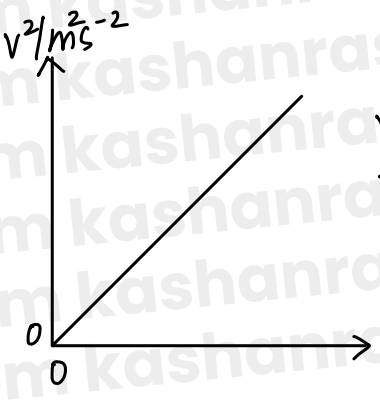
$s = ut + \frac{1}{2}at^2$

if $u = 0$, then

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

$Y = mX + c$

grad $= \frac{1}{2}a$



$u = 0$

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

$v^2 = 2as$

$Y = mX + c$

grad $= 2a$

6 One object moves directly from P to R.

In a shorter time, a second object moves from P to Q to R.

Which statement about the two objects is correct for the journey from P to R?

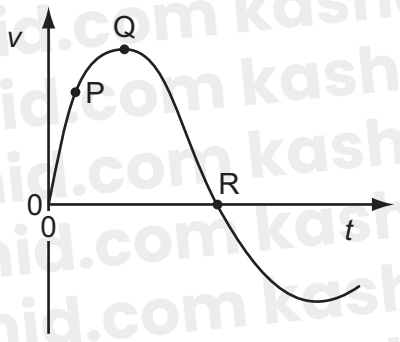
A They have the same average speed.

B They have the same average velocity.

C They have the same displacement.

D They travel the same distance.

7 The graph shows how velocity *v* varies with time *t* for a bungee jumper.



At which point is the bungee jumper momentarily at rest and at which point does she have zero acceleration?

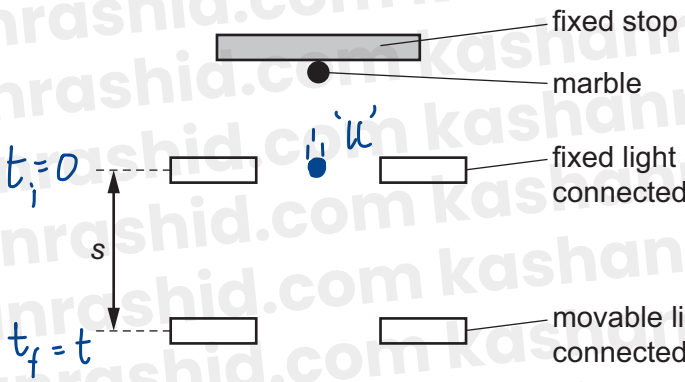
	jumper at rest	jumper with zero acceleration
A	Q	
B	Q	
C	R	
D	R	

Additional Materials:

7 One of the equations of uniformly accelerated motion is shown.

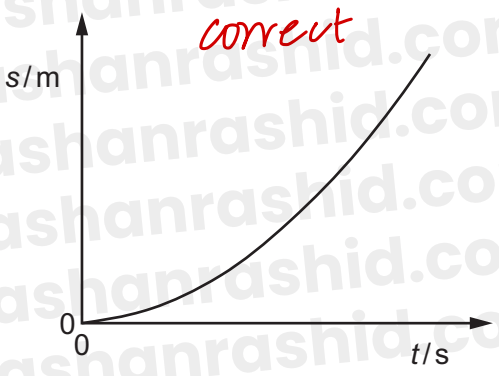
$$s = ut + \tfrac{1}{2}at^2$$

Apparatus is arranged to record the time t taken for a marble to fall between two light gates connected to timers. The marble touches the stop before it is released. The vertical distance s between the light gates is measured.

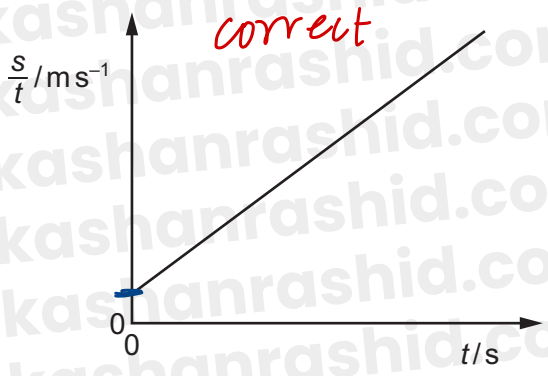


Which graph does **not** show a correct relationship when light gate 2 moves up to light gate 1 which is fixed?

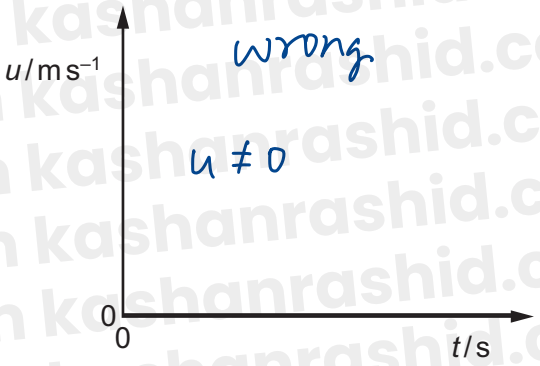
A



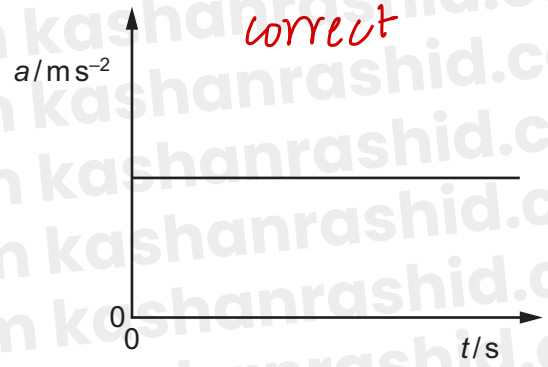
B



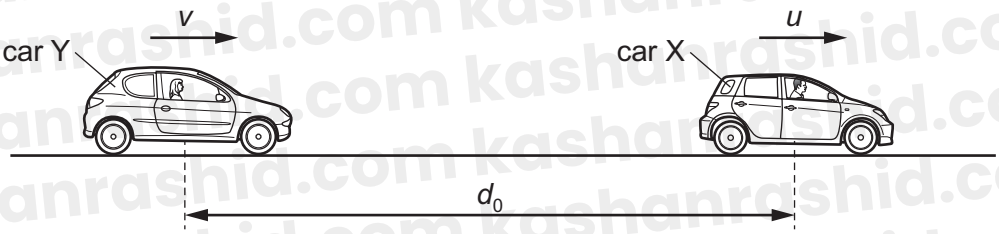
C



D



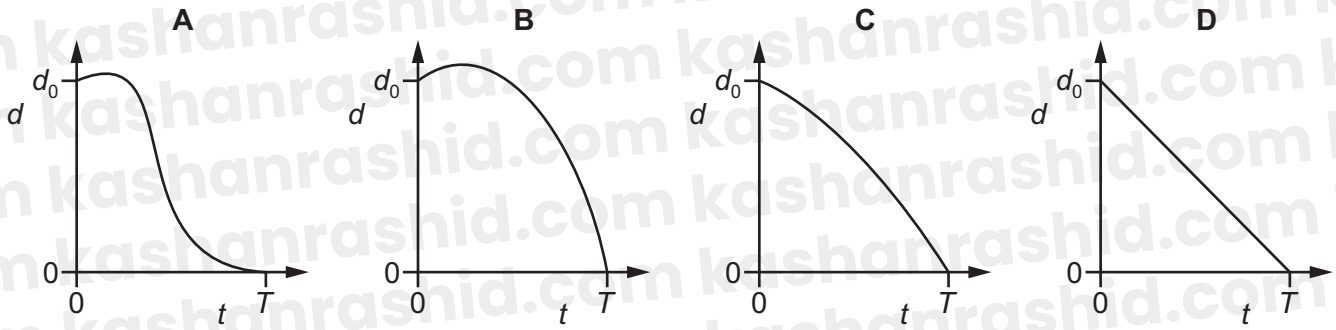
6 A car X is travelling at a constant speed u along a straight road. At time $t = 0$ a second car Y is a distance d_0 behind car X and travelling at a speed v in the same direction. Speed v is less than speed u.



At time $t = 0$ car Y begins to accelerate with a constant acceleration.

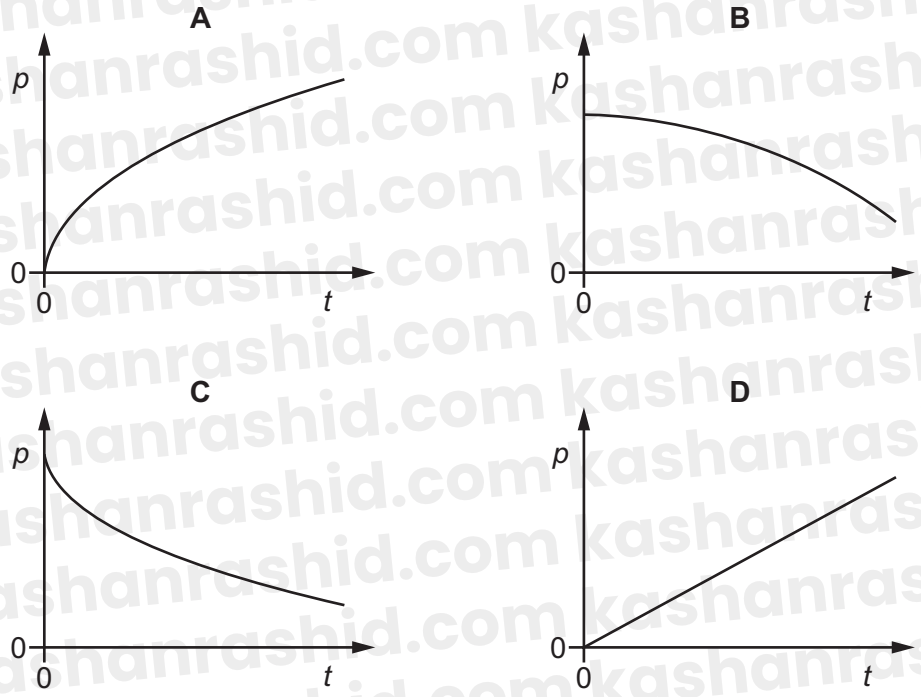
Car Y overtakes car X at time $t = T$.

Which graph could best show the variation with time t of the distance d between the cars?

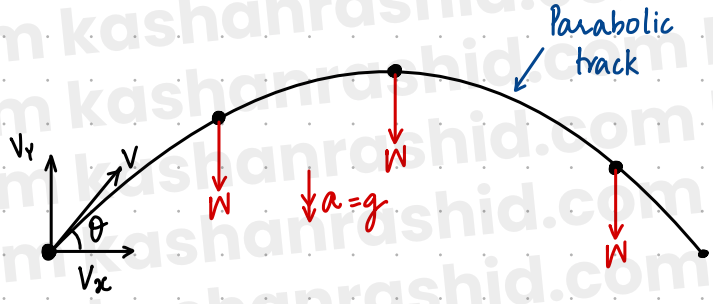


7 The resultant force acting on an object is slowly increased.

Which graph could show the variation with time t of the momentum p of the object?



Projectile Motion



☑ No air resistance
→ $F_x = 0$ (horizontal force = 0) → $a_x = 0$ (horizontal acc = 0)

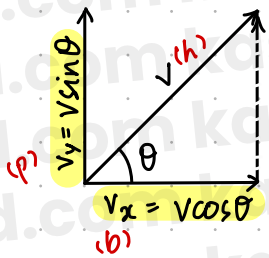
☑ Weight acts in the vertical direction. (downwards)

F_y = Weight (vertical force = W) $a_y = g$ (vertical acc = g)

As only one force acts on the body in projectile, so resultant force is equal to Weight of body

* V_x = constant (horizontal velocity)
  • No force in horizontal

* V_y = changes (vertical velocity)
  • decreases as ball rises and increases as it falls)



☑ $h^2 = p^2 + b^2$
$V^2 = V_y^2 + V_x^2$

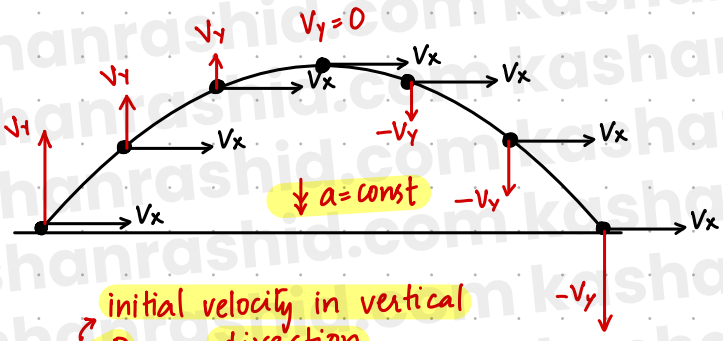
☑ $\sin\theta = \frac{p}{h}$ $\sin\theta = \frac{V_y}{V}$
$V_y = V\sin\theta$

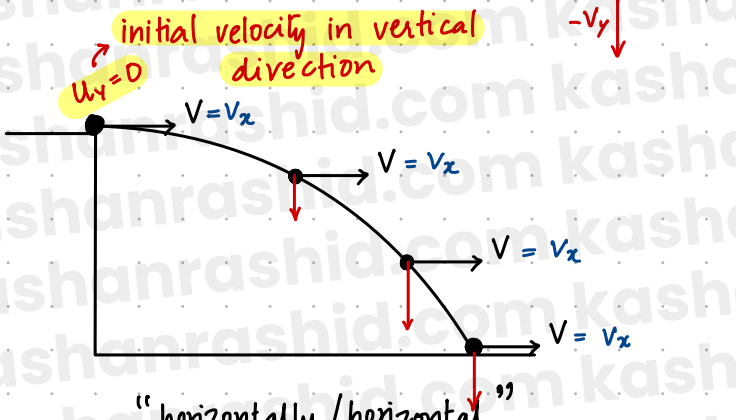
☑ $\cos\theta = \frac{b}{h}$ $\cos\theta = \frac{V_x}{V}$
$V_x = V\cos\theta$

☑ $\tan\theta = \frac{p}{b}$ $\tan\theta = \frac{V_y}{V_x}$

"Component with θ, is cos component"
"Component opp to θ, is sin component"

Velocity Profile

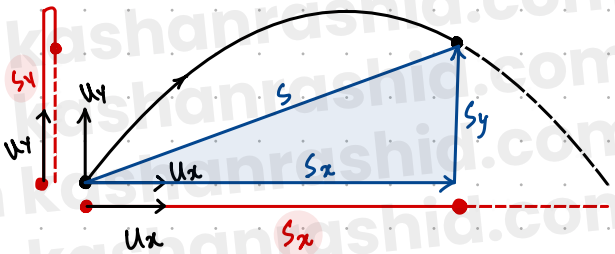




"horizontally / horizontal projected surface"

$u_y = 0$ (vertical velocity = 0)

Analyzing Projectile Motion



Horizontal

• $V_x = \frac{s_x}{t}$

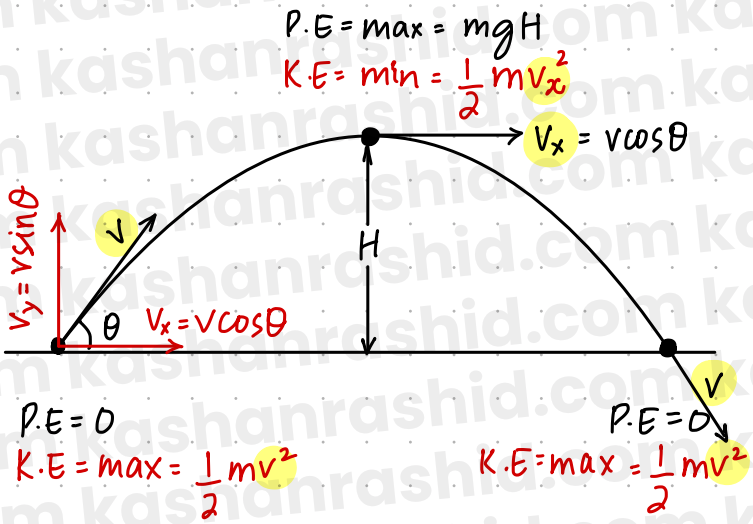
$h^2 = p^2 + b^2$
$s^2 = s_y^2 + s_x^2$
resultant displ.

Vertical

• $V_y = u_y + at$
• $s_y = ut_y + \frac{1}{2}at^2$
• $V_y^2 - u_y^2 = 2as_y$

$V^2 = V_x^2 + V_y^2$
↓
resultant velocity (speed)

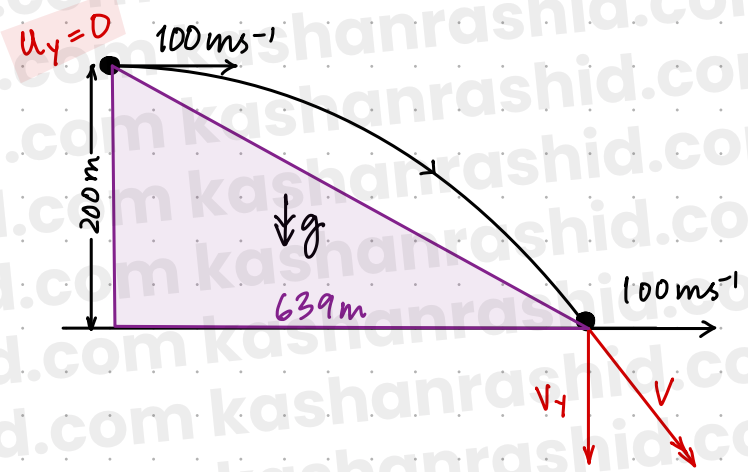
Energy of a body in a projectile



Example

A bomber plane travelling horizontally at 100 ms^{-1} drops a package from a height of 200 m above the ground.
Assuming negligible air resistance, determine

a) time to hit the ground
b) speed as the package hits the ground
c) Horizontal distance travelled before package hits ground.
d) Resultant displacement of the package from start till end.



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

$200 = 0 + \frac{1}{2}(9.81)t^2$

$t = 6.39\,s$

b) $v_y = u_y + at$

$v_y = 0 + (9.81)(6.39)$

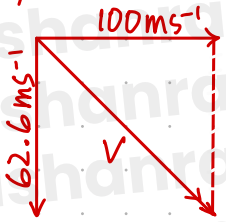
$v_y = 62.6\ ms^{-1}$

$v^2 - u_y^2 = 2as$

$v_y^2 - 0 = 2(9.81)(200)$

$v_y = 62.6\ ms^{-1}$

for resultant velocity (speed)



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

$v^2 = (62.6)^2 + (100)^2$

$v = 118\ ms^{-1}$

c) $v_x = \frac{s_x}{t}$

$100 = \frac{s_x}{6.39}$ so $s_x = 639\,m$

d) for resultant displacement, apply pythagorous theorem.

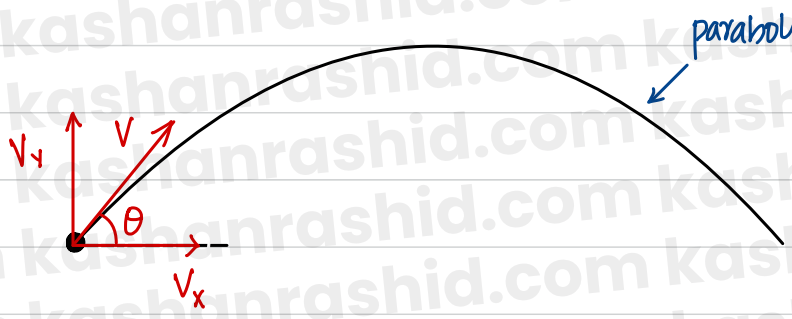
$h^2 = p^2 + b^2$

$h^2 = (200)^2 + (639)^2$

h = resultant displ. = 670 m

Projectile Motion

☑ A 2D-motion under the effect of gravity.

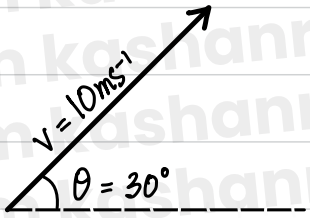


V_x: effect of velocity along horizontal

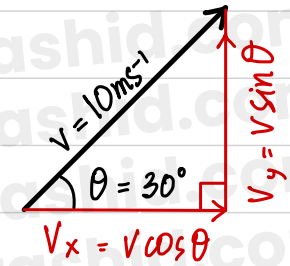
V_y: effect of velocity along vertical

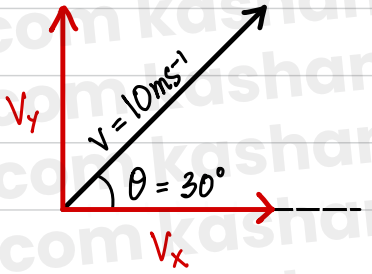
☑ Due to the effect of gravity, the ball slows down when rising and speeds up when falling.

☑ Assuming negligible Air resistance – hence acceleration is constant and due to gravity i.e. $a = g = 9.8\ ms^{-2}$.



Find horizontal & vertical component of velocity.





Angle k sath vala component cos aur samnay vala sin hota hai.

for V_x.

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

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

$V_x = V\cos\theta$

$V_x = 10\cos 30°$

$V_x = 8.6\ ms^{-1}$

for V_y

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

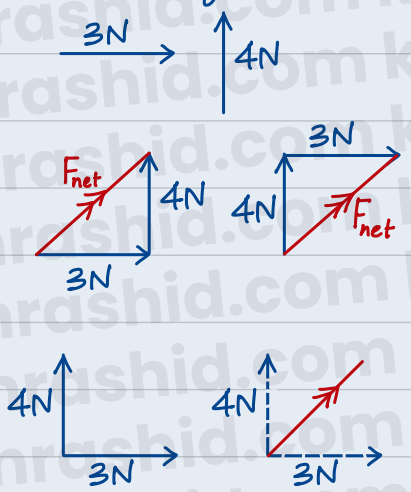
$\sin\theta = \frac{V_y}{V}$

$V_y = V\sin\theta$

$V_y = 10\sin 30°$

$V_y = 5\ ms^{-1}$

Recalling....



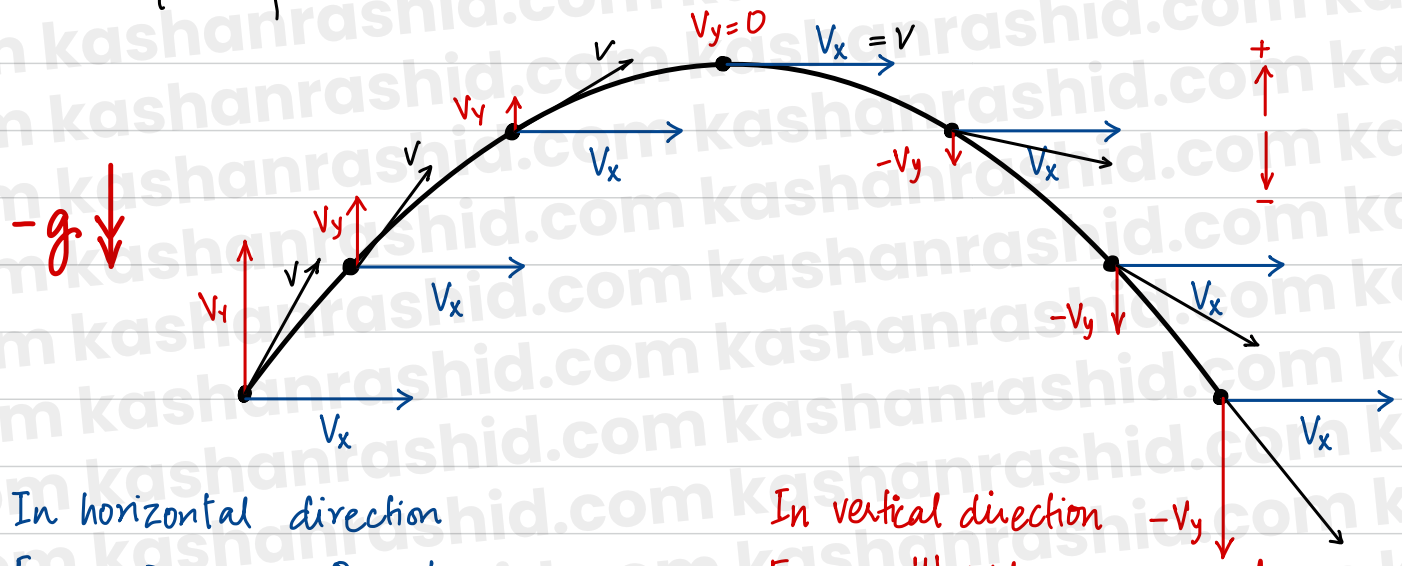
Pythagorous theorem

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

$= \sqrt{4^2 + 3^2}$

$h = F_{net} = 5N$

Velocity Profile



In horizontal direction
Force = 0 , a = 0 , hence
velocity (V_x) = constant
{In case of air resistance, V_x would also decrease}

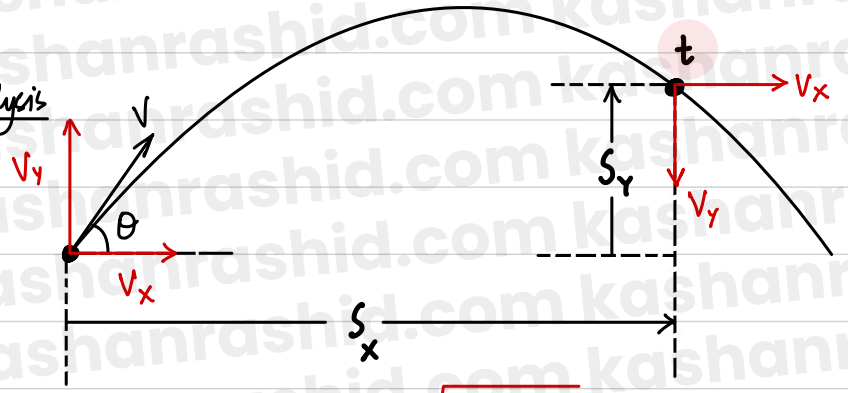
In vertical direction $-V_y$
Force = Weight ; a = -g hence
Velocity (V_y): change
- rise → decreases to zero
- fall → increases!

resultant velocity or speed

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

$$\boxed{V = \sqrt{V_x^2 + V_y^2}}$$

- Speed of the ball decreases when rising and increases when falling because V_y dec. and inc. during motion.



Horizontal Analysis

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

V_x , S_x , t

Vertical Analysis

a = const. = g

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

S_y , U_y , V_y , t

speed : $V = \sqrt{V_x^2 + V_y^2}$

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

scalar: .....

.....

vector: .....

.....

[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.

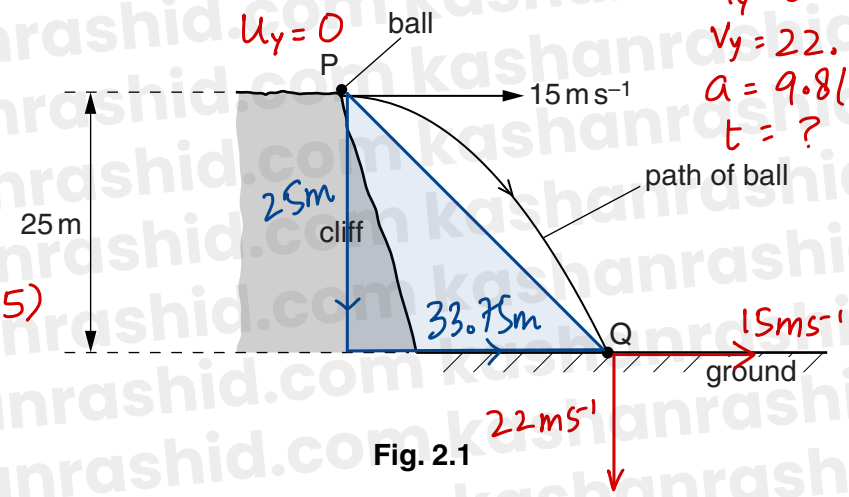


Fig. 2.1

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.

vertical velocity = ... $m\,s^{-1}$ [2]

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

[1]

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.

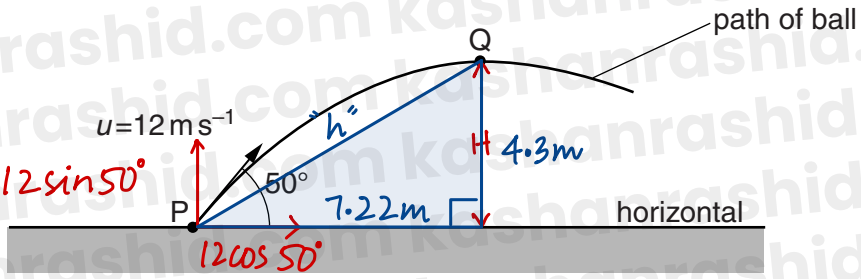


Fig. 2.1

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.

12 sin 50°

vertical component = ... 9.2 ..... $m\,s^{-1}$ [1]

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

$u_y = 9.2\ ms^{-1}$
$v_y = 0$
$a = -9.81\ ms^{-2}$
$s = ?$

$v^2 - u^2 = 2as$
$0 - (9.2)^2 = 2(-9.81)s$
$s = 4.3m$

[2]

(c) Determine the magnitude of the displacement PQ.

$u_y = 9.2\ ms^{-1}$
$v_y = 0$
$a = -9.81\ ms^{-2}$
$t = ?$
$v = u + at$
$0 = 9.2 + (-9.81)t$
$\frac{-9.2}{-9.81} = t \quad t = 0.938\ s$

$v = \frac{s}{t}$
$7.7 = \frac{s_x}{0.938}$
$s_x = 7.22\ m$

$h^2 = p^2 + b^2$
$h^2 = (4.3)^2 + (7.22)^2$
$= 8.4m$

displacement = ... m [4]

[Total: 8]

2 A ball is thrown horizontally from the top of a building, as shown in Fig. 2.1.

For Examiner's Use

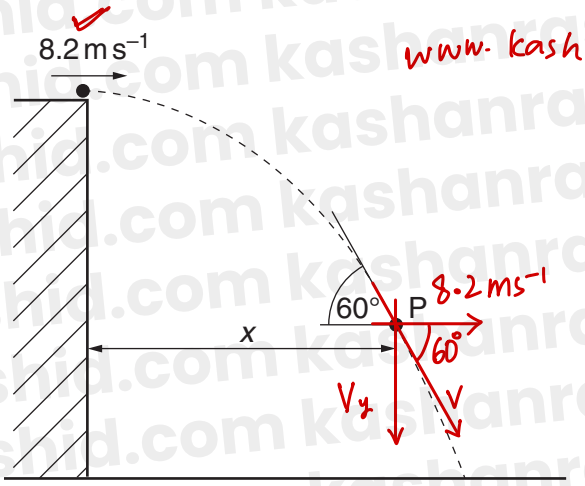


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Fig. 2.1

The ball is thrown with a horizontal speed of $8.2\,m\,s^{-1}$. The side of the building is vertical. At point P on the path of the ball, the ball is distance *x* from the building and is moving at an angle of 60° to the horizontal. Air resistance is negligible.

(a) For the ball at point P,

(i) show that the vertical component of its velocity is $14.2\,m\,s^{-1}$,

$\tan\theta = \frac{p}{b}$

$\tan 60^\circ = \frac{V_y}{8.2}$

$V_y = 8.2 \tan 60^\circ$

$V_y = 14.2\ ms^{-1}$

[2]

(ii) determine the vertical distance through which the ball has fallen,

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

$a = 9.81\ ms^{-2}$

$s = ?$

$V = 14.2\ ms^{-1}$

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

$(14.2)^2 - 0 = 2(9.81)(s)$

$s = 10.3\,m$

distance = ... m [2]

(iii) determine the horizontal distance x.

For Examiner's Use

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

$8.2 = \frac{x}{1.45}$

$x = 11.9\ m$

$u = 0$
$a = 9.81\ ms^{-2}$
$v = 14.2\ ms^{-1}$
$t = ?$

$v = u + at$
$14.2 = (9.81)t$
$t = 1.45\ s$

$x =$ ..... 11.9 ..... m [2]

(b) The path of the ball in **(a)**, with an initial horizontal speed of $8.2\,m\,s^{-1}$, is shown again in Fig. 2.2.

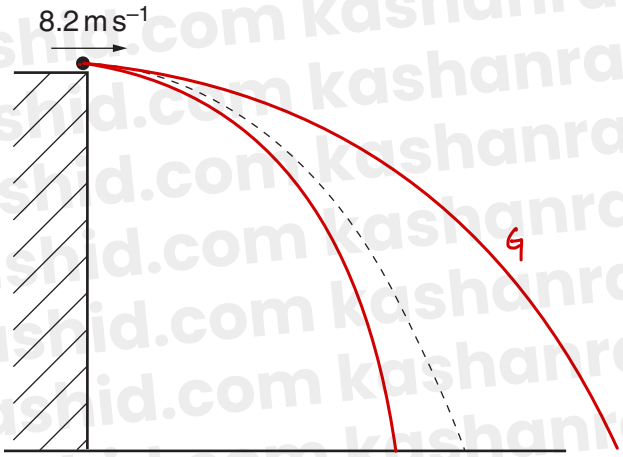

Fig. 2.2

On Fig. 2.2, sketch the new path of the ball for the ball having an initial horizontal speed

(i) greater than $8.2\,m\,s^{-1}$ and with negligible air resistance (label this path G), [2]

(ii) equal to $8.2\,m\,s^{-1}$ but with air resistance (label this path A). [2]