CHAPTER 3: KINEMATICS

- Motion by graphs
- Derive equation of motion
- Free fall acceleration
- Projectiles
- Terminal Velocity
- Experiment – acceleration of free fall

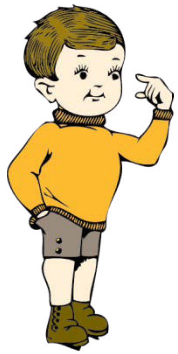
KINEMATICS

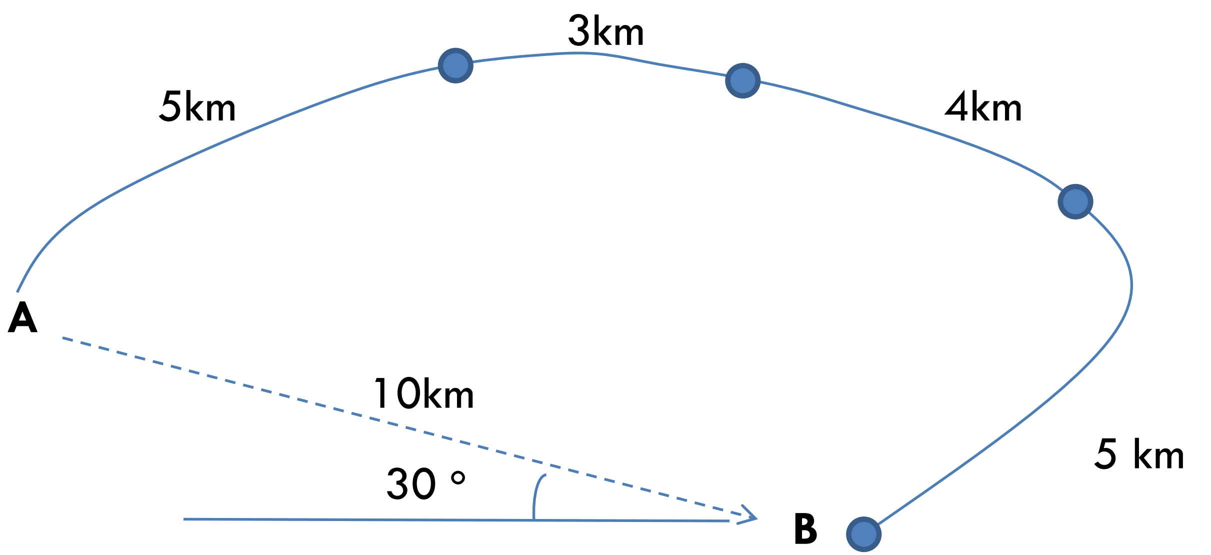
Study of the motion of bodies without regard to the forces acting on the body

Motion By Graphs

- Displacement-time (s-t)graph
- Velocity-time (v-t) graph
- Acceleration-time (a-t)graph

Distance and displacement





- **Distance** of the boy is total length of route covered from A to B $= 5 + 3 + 4 + 5$ km $= 17$ *km*
- **Displacement of the boy** is *10km, 30° anticlockwise to the horizontal* (magnitude of displacement is the shortest distance from A to B)

Displacement – time graphs

- **Represent the changing position of an object with time**

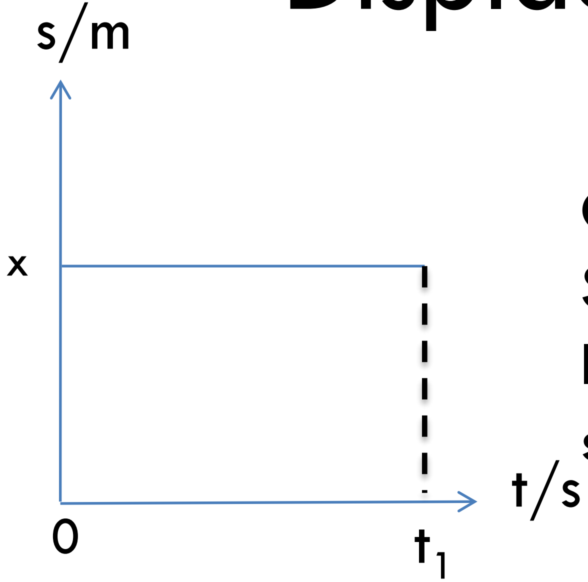
Velocity

- Gradient of the graph represent the velocity. The steeper the gradient, the greater the velocity.

Direction of motion (if forward is + ve)

- If gradient is positive, object velocity is positive. object moves forwards.
- If gradient is negative, object velocity is negative. Means, object moves backwards.

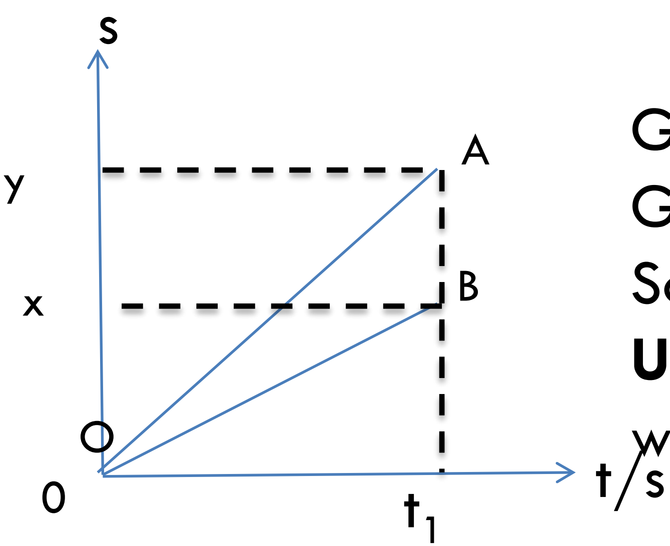
Displacement – time graphs



Gradient : $(x-x/t-0) = 0$

So **velocity is zero**

It means, after *t* second, **object is stationary** (remain at same position)



Gradient OA: $(y-0/t_1-0) = (y/t_1)$

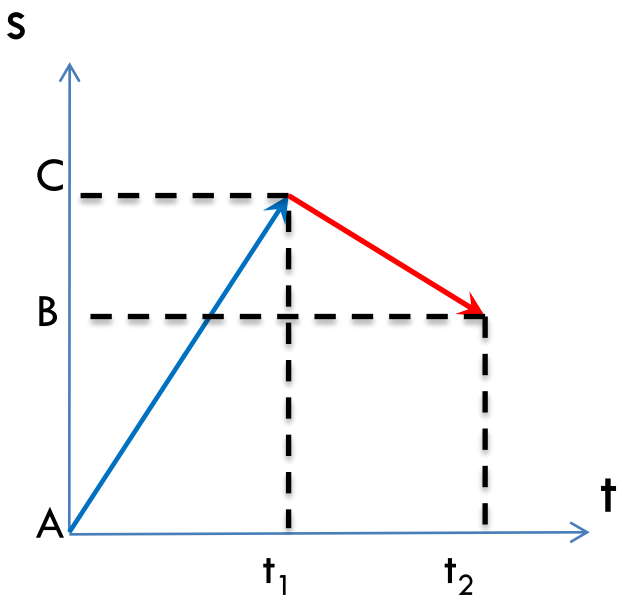
Gradient OB: $(x-0/t_1-0) = (x/t_1)$

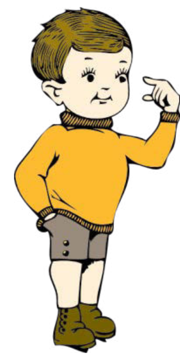
So, gradient OA > Gradient OB

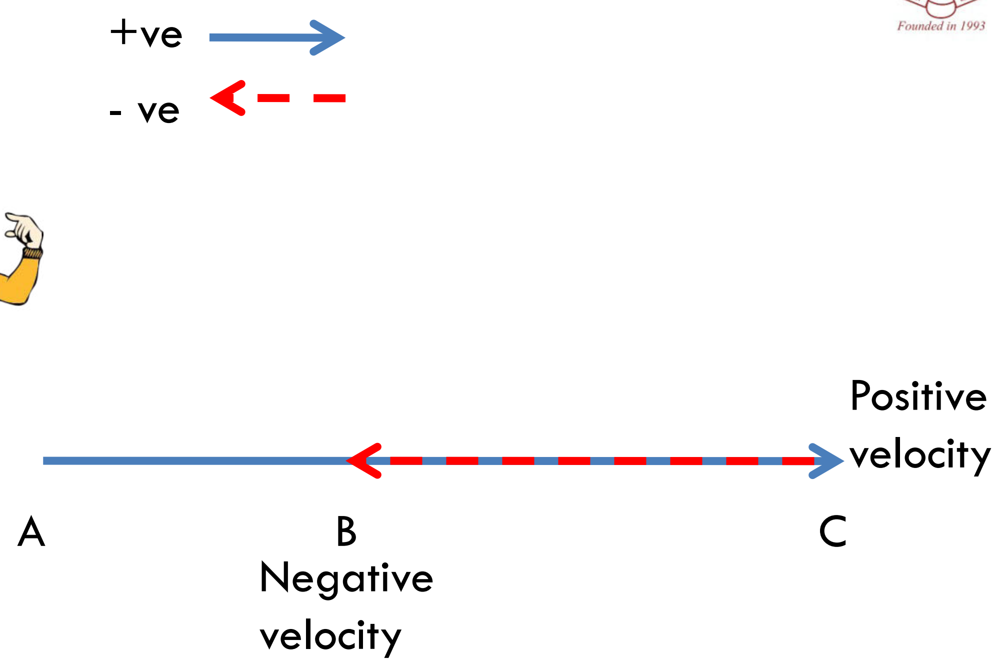
Uniform/constant velocity

with **A is faster than B**

Displacement – time graph



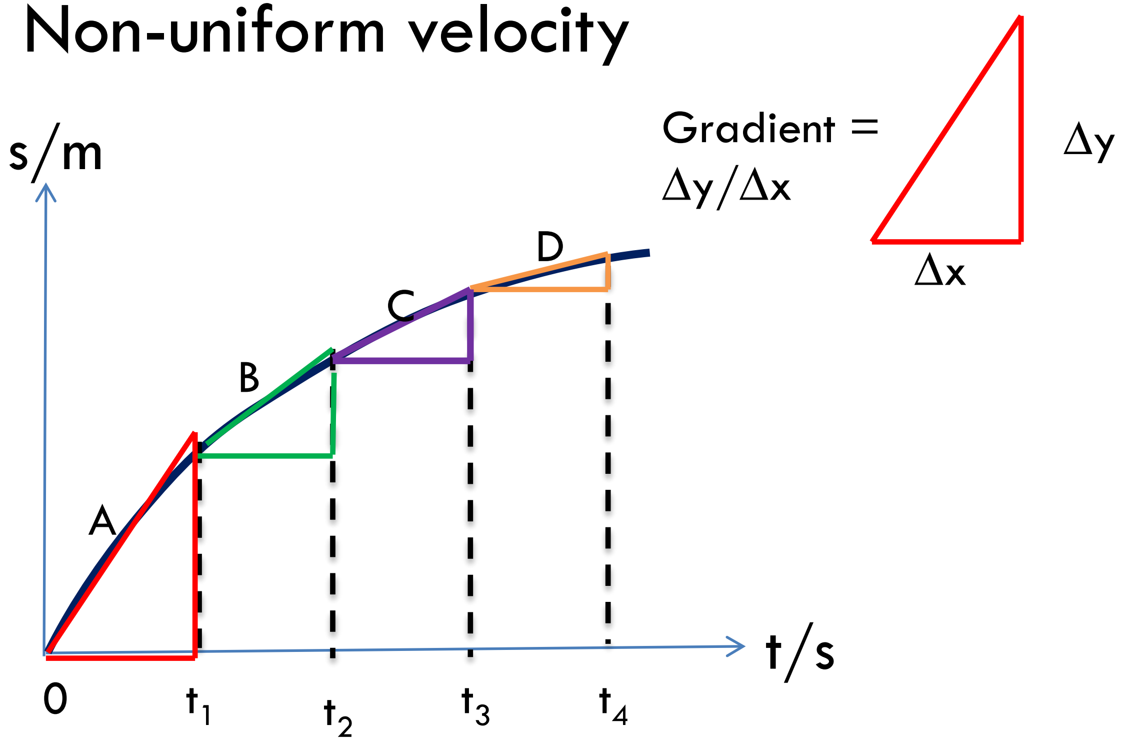




- From A to C, the boy move in +ve direction, so, means, gradient of graph from A to C is +ve
- The slope of graph become negative from C to B
- Means, the object moving backward (or in an opposite direction from AC)

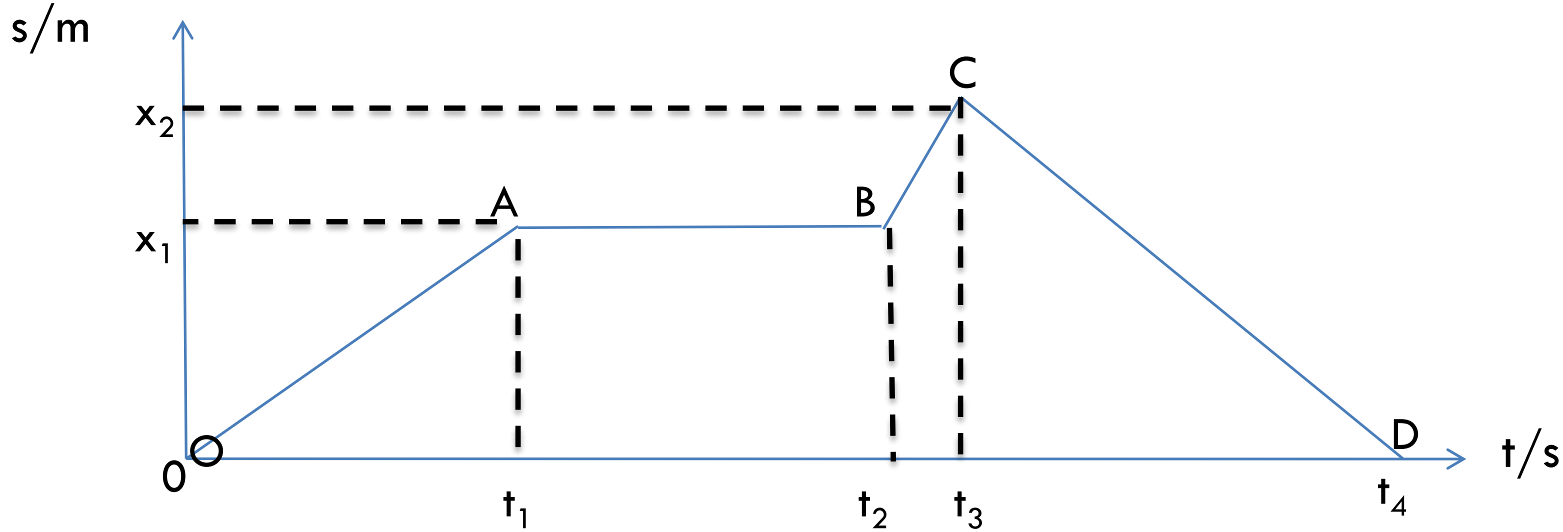
Displacement – time graphs

Non-uniform velocity



- Gradient of graph decreasing from A to D
- Means, the object moves with decreasing velocity

Displacement – time graphs



OA	**BC**
•Velocity = $(x_1-0)/(t_1-0) = x_1/t_1$ •gradient = +ve, so, object move forward	•Velocity = $(x_2-x_1)/(t_3-t_2)$ •Direction = +ve, so, object move forward
AB Velocity = $(x_1-x_1)/(t_1-t_2) = 0$ And object remains at same position as A	**CD** •Velocity = $(0-x_1)/(t_4-t_3) = -x_1)/(t_4-t_3)$ •Direction = -ve, so, object move backward

Velocity and acceleration

- We know speed is distance in a unit time
- While velocity can be thought as speed in a particular direction. So, velocity is a vector quantity and since it has direction. It is defined in terms of displacement

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

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

$$\Delta s = \vec{v}\Delta t$$

- Speed v also use the same equation

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

$$\text{speed, v} = \frac{d}{t}$$

Velocity and acceleration

- Any object whose its magnitude of velocity is changing or which is changing its direction has acceleration
- So, it means, acceleration is a vector quantity.
- Acceleration is defined as follows

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

$$a = \frac{\Delta v}{\Delta t}$$

Velocity and acceleration

- We write u as initial velocity and v as final velocity.
- If a moving object accelerates from u to v from time t_1 to t_2,
- Its acceleration can be calculated as

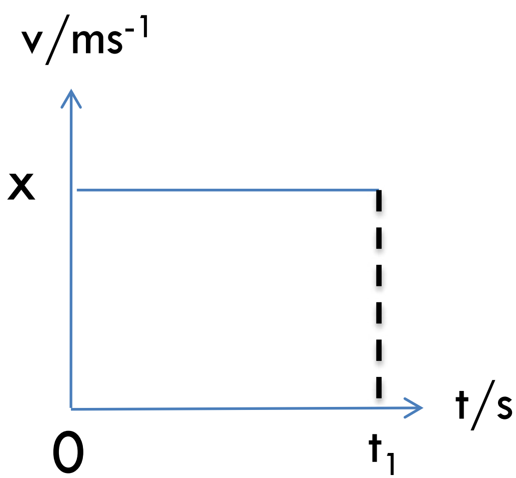
$$\text{average acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

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

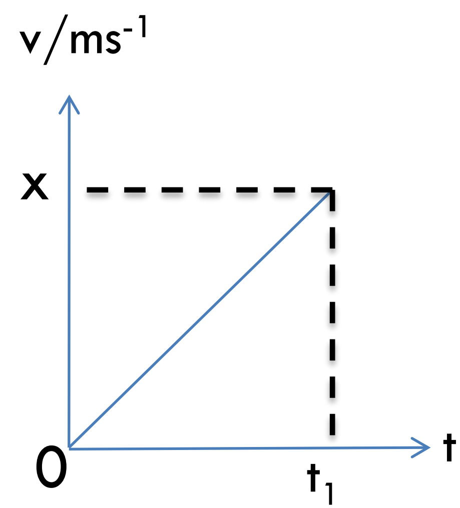
$$a = \frac{v-u}{t_2 - t_1}$$

Deducing acceleration from v-t graphs

- Gradient of velocity – time graphs gives acceleration of object.
- Area under velocity – time graphs give displacement of object.

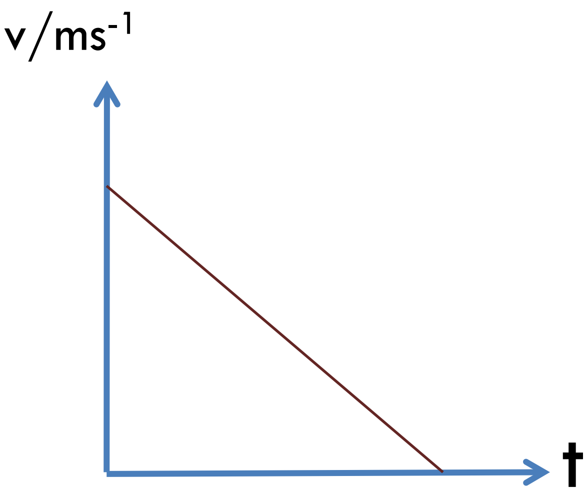


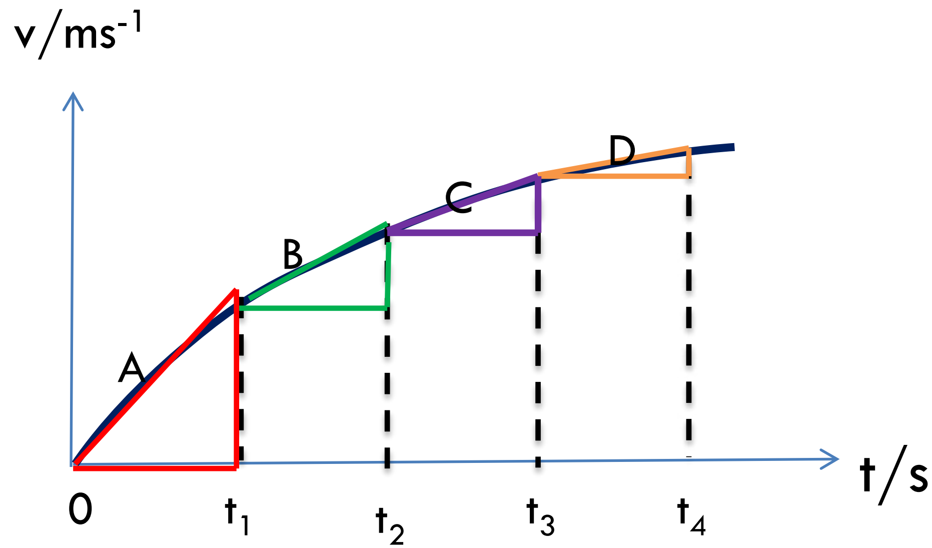
Object is moving with uniform/constant velocity
Gradient of graph = 0
So, zero acceleration



Gradient of graph is $\mathbf{x/t_1}$
So, object move with uniform acceleration

Velocity-time graph





Gradient of slope **a** is negative shows uniform deceleration

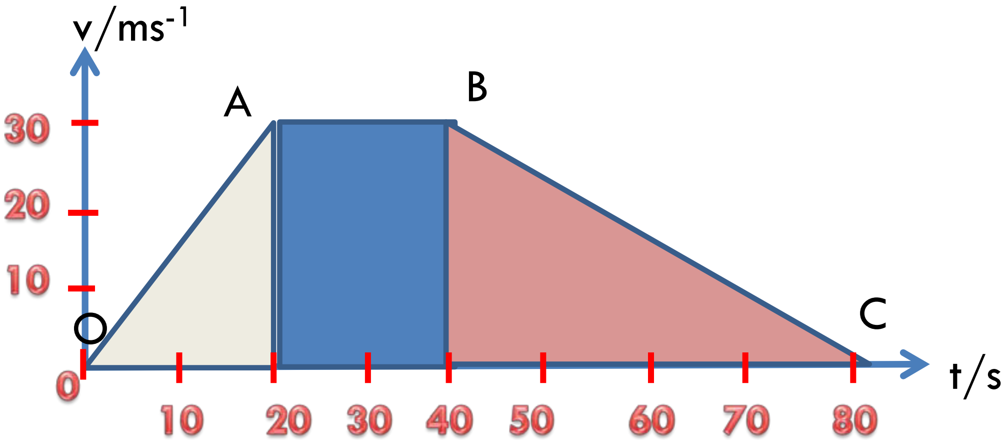
Gradient of slope decreasing with time.

Decelerate non-uniformly

Deducing displacement

- Displacement of a moving object can be calculated from the area under its velocity - time graph.
- Displacement = area under velocity-time (v-t) graph.

Deducing s and a from v-t graph



- Acceleration OA

$$a = \frac{30\ \text{ms}^{-1}}{15\text{s}} = \underline{2ms^{-2}}$$

- Displacement OA

$$s = \frac{1}{2} \times 30 \times 20 = \underline{300m}$$

- Acceleration AB

$$a = \frac{30-30}{20\text{s}} - = \underline{0\ ms^{-2}}$$

- Displacement AB

$$s = 30 \times (40-20) = \underline{600\ m}$$

- Acceleration BC

$$a = \frac{0-30}{40\text{s}} - = \underline{-0.75\ ms^{-2}}$$

- Displacement OA

$$s = \frac{1}{2} \times 30 \times (80-40) = \underline{600\ \text{m}}$$

Definition

- Displacement
  - Distance moved by an object in a particular direction
- Speed
  - Distance in a unit time
- Velocity
  - Change in displacement in a unit time
- Acceleration
  - Rate of change of velocity

Equations of motion

- There are a set of equations which allows us to calculate the quantities involved when for object moves with constant acceleration in a straight line.
- These quantities we are concerned are:
  - s = displacement
  - u = initial velocity
  - v = final velocity
  - a = acceleration
  - t = time taken

Equations of motion

- There are 4 set equations applied for object **moves in a straight line** with a **uniform acceleration** (*a* constant).

1. $v = u + at$

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

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

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

Choosing equation

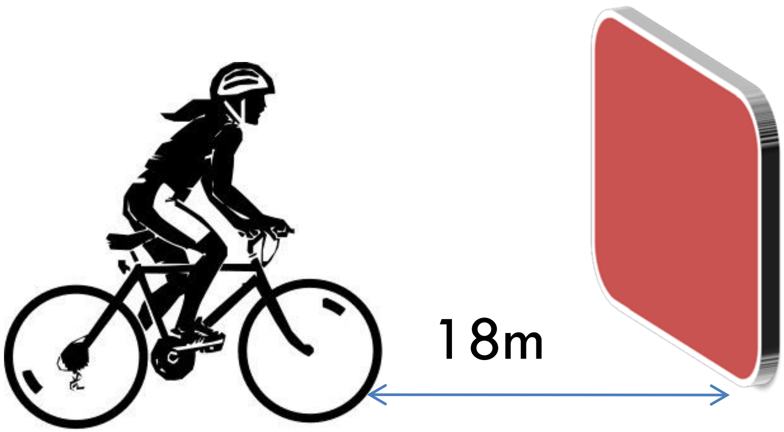
- How to choose suitable equation in a problem

Step

1. Write the known or given quantities & write quantities we want to find (unknown quantities)
2. Choose the equation which link all known and unknown quantities & substitute the values
3. Calculate the unknown quantities

Example

1. The cyclist in figure below is travelling at 15 ms^{-1}. She brakes so that she doesn't collide with the wall. Calculate the magnitude of her deceleration



S1. What are given

- Initial velocity, u = 15 ms^{-1}
- Final velocity, v =0
- Displacement taken = 8m
- What we want to know = a

S2. Equation we need is eq. 4 : $v^2 = u^2 + 2as$

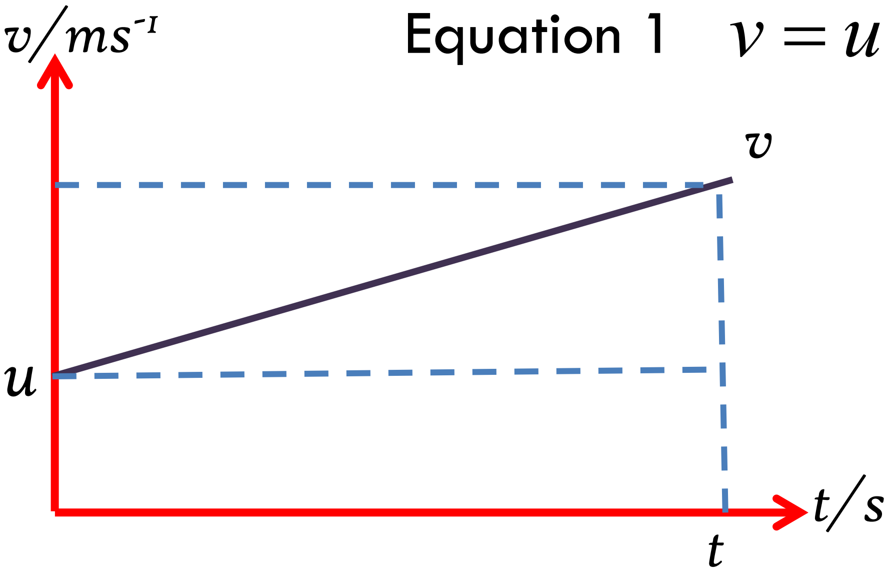
S3. $a = (v^2 - u^2)/2s$

$a = (0 - 15^2) \text{ x } 2(18) =$ **<u>- 6.25 ms^{-2}</u>**

DERIVING EQUATIONS OF MOTION

Deriving equations of motion

Equation 1 $v = u + at$



- *This graph represents the motion of an object with initial velocity, u and increase to velocity v in t time.*
- *Object 's acceleration a is constant and can be calculated as:*

$\boxed{\text{equivalent to} : y = mx + c}$

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

$so,$

$$v = u + at$$

Quantity y-axis

y-Intercept

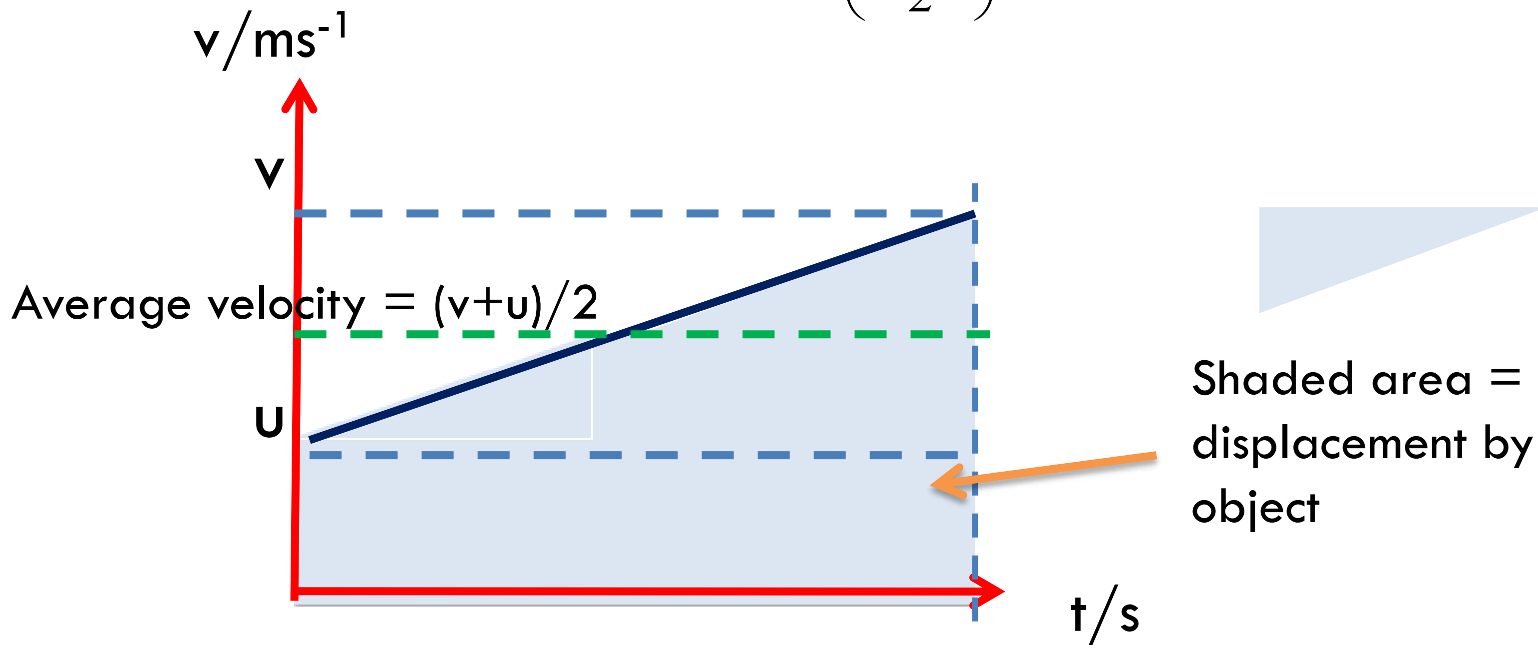
gradient

Quantity x-axis

Deriving equations of motion

Equation 2

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



$$\text{average velocity} = \frac{(v+u)}{2}$$

$$\text{displacement} = \text{average velocity} \times \text{time taken}$$

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

Deriving equations of motion

- **Derive equation 3: $s = ut + (at^2)$**

From eq. 1: $v = u + at$

From eq. 2: $s = [(u + v)/2]t$

So, substitute eq. 1 into eq. 2, and we get:

$$s = [(u + u + at)/2]t$$

$$s = (2u + at^2)/2$$

$$s = (u + at^2)$$

Deriving equations of motion

- **Derive equation 4 :** $\boldsymbol{v^2 = u^2 + 2as}$

eq. 1 : $v = u + at$, *we get t*

$$\boldsymbol{t = (v - u)/a}$$

substitute

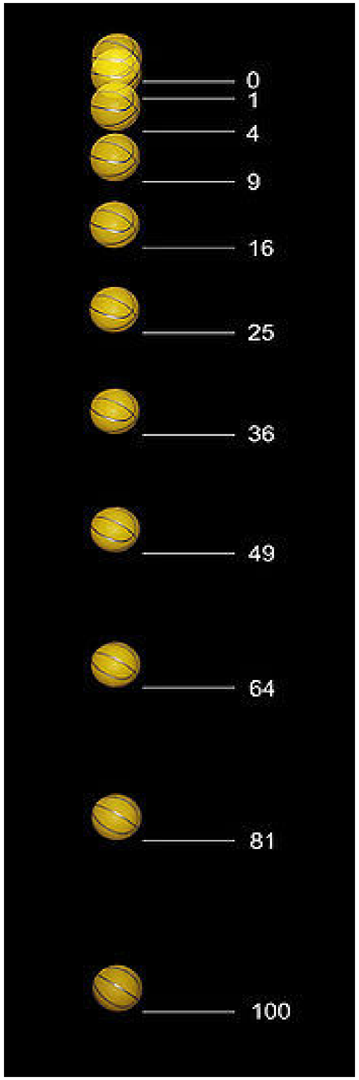
eq. 2 : $s = [(u+v)/2]t$

Then we get: $s = [(u+v)/2] \times [(v - u)/a]$

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

Rearrange and we get : $\boldsymbol{v^2 = u^2 + 2as}$

Acceleration caused by gravity



- If we drop a ball or stone near the surface of Earth, it falls to the ground
- Based on a **multiflash photograph**, which shows position of the ball at equal intervals of time,
- The spaces between the images of the ball increase steadily

Acceleration caused by gravity

- It means, the **ball's velocity increases** as it falls.
- If we measure the rate of change of this ball's velocity, we find a value of about 9.81 ms^{-}.
- This is known as **acceleration of free fall.**
- Because of the gravitational attraction of the Earth, all objects fall with the same uniform acceleration,
- It's value is **9.81 m/s^2 and is directed downward**
- This value is true when air resistance is assumed to be absent/ negligible

Example: Free fall

0 m

+ve

0.8 m

1. An egg falls off a table. The floor is 0.8 m from the table top.
   a) Calculate the time taken to reach the ground **(0.40 s)**
   b) Calculate the velocity of impact with the ground **($3.9ms^{-1}$)**

Solution

a) Given s =0.8 m, g = 9.81 ms^{-2},

- From $s = ut + ½ at^2$
- s =0.8 m, g = 9.81 ms^{-2},
- $0.8 = 0 + (1/2)(9.81)(t^2)$
- **t = 0.40 s**

b) v= u + at

- $v = 0 + (9.81\ ms^{-2})\ (0.40s)$
- $= \underline{\mathbf{3.9\ ms^{-1}}}$

Why mass is unimportant in free fall

- If you have already looked at energy you will be familiar with
- Potential Energy = mgh
- Kinetic Energy = ½ mv^2
- PE lost = KE gained (conservation of energy)
- mgh = ½ mv^2
- So, gh = ½ v^2 and therefore,

$$v = \sqrt{2gh}$$

Motion in two dimensions

PROJECTILES

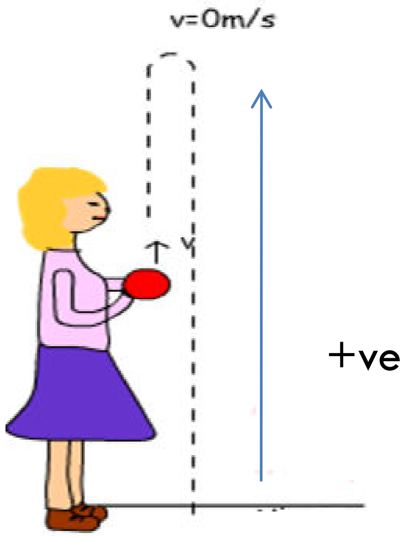
Air Resistance and Mass

- The acceleration due to gravity does not depend on the mass of the object which is falling.
- Air creates friction that resists the motion of objects moving through it.
- All of the formulas and examples discussed in this **projectile** section are exact only in a vacuum (no air).

Projectile

- **A projectile** is any object which, once projected, continues its motion by its own inertia and **is influenced only by the downward force of gravity without influenced of air resistance.**
- There are two type of projectile
  1. Projectile in vertical direction
  2. Projectile in horizontal and vertical direction simultaneously

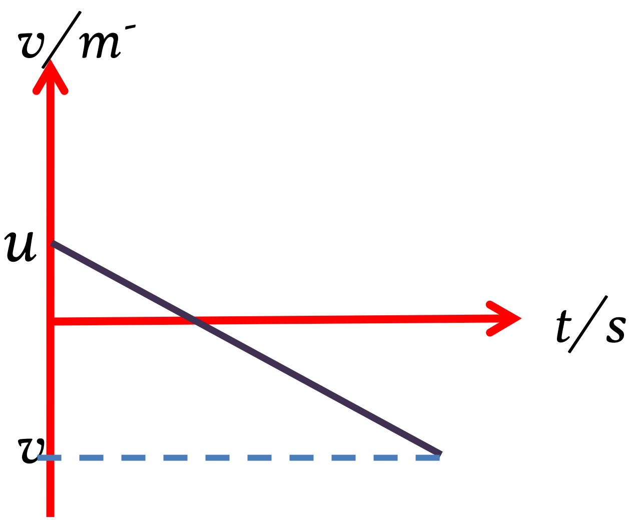
1. Type of projectiles : vertical direction



A stone is **thrown upwards** with an initial velocity of 20ms^{-1}. (air resistance is negligible).

Q1: How high the stone will go before it fall downward.

Q2: How long will it take for the stone from leaving the girl's hand to return to its same launched position?

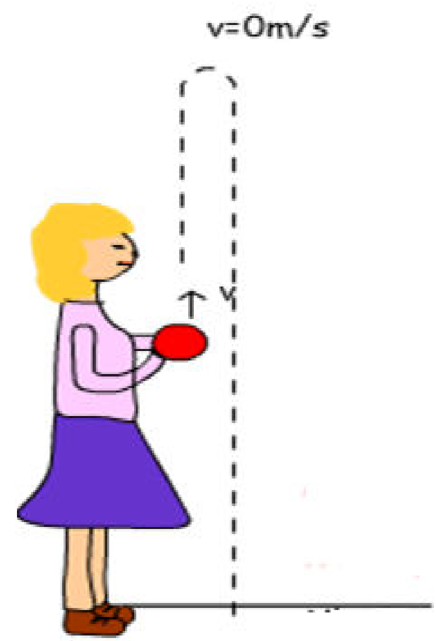


STEP 1. Determine sign of direction

- Take upwards as positive
- So, the stone's initial velocity is +ve and downwards as –ve
- But, acceleration due to gravitational pull is -ve

1. Type of projectiles : vertical direction

Q1: How high the stone will go before it fall downward



- As the stone rises upwards, it moves more and more slowly, because force of gravity act downward, thus, it decelerates.
- At the highest point, the stone's velocity, v is zero.

S1: Quantity given

- ❑ Initial velocity, u = +20 ms-1,
- ❑ Final velocity, $v = 0$
- ❑ Acceleration = $-g = -9.81\ ms^{-2}$

S2: Choose suitable equation. We want to find displacement, s. so, use equation 4: $v^2 = u^2 + 2as$

- ❑ $0 = (20)^2 + [\ 2\ (-9.81) \times s\ ]$

S3: Solve equation.

- ❑ **s = 20 m (above initial position)**

1. Type of projectiles : vertical direction

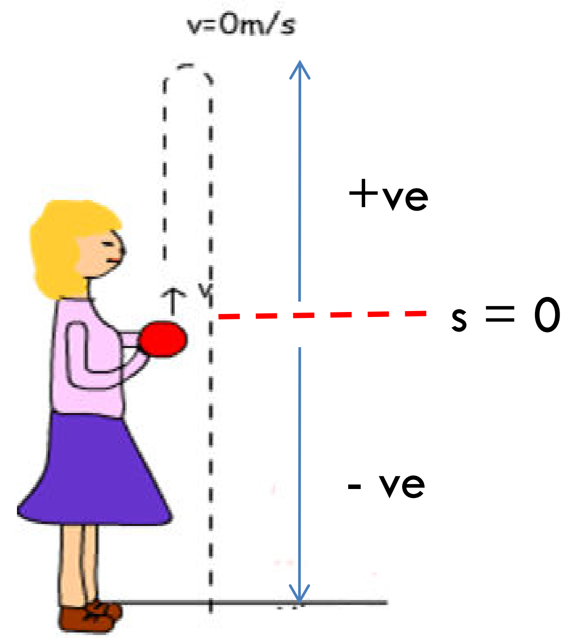
Q2.How long will it take for the stone from leaving the girl's hand to return to its same launched position?

- When the stone returns to the point from which it was thrown, its displacement is zero.

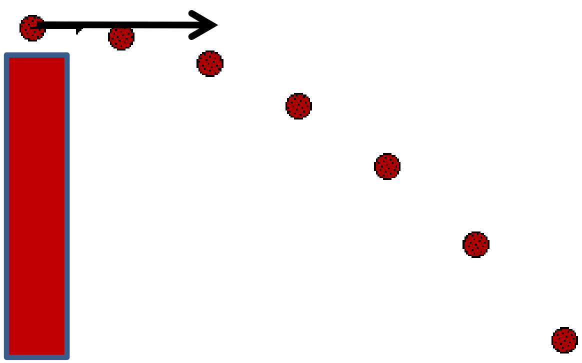
1. $s = 0$, $u = 20\text{ms}^{-1}$, $a = -9.81\text{ ms}^{-2}$ $t = ?$
2. Suitable equation: Eq 3 : $\mathbf{s = ut + \frac{1}{2}at^2}$
3. Solve equation:

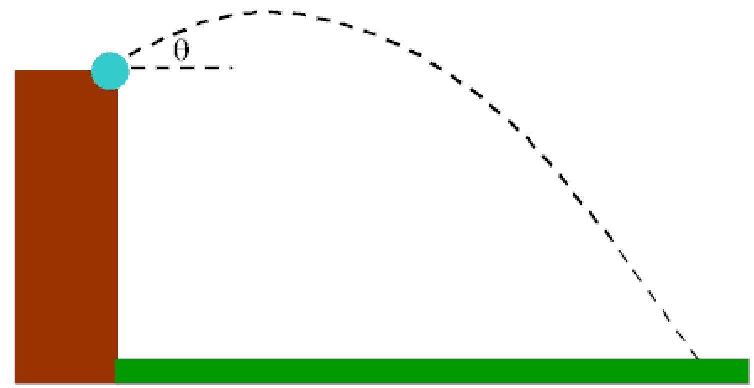
$$\mathbf{0 = 20t + \tfrac{1}{2}(-9.81)t^2}$$

   1. $t = 0$. and $t = 4.1$ s.
   2. ($t = 0$ is the time when the stone was initially thrown)
   3. So, the answer is **<u>t = 4.1 s</u>**



2. Projectiles: x & y direction

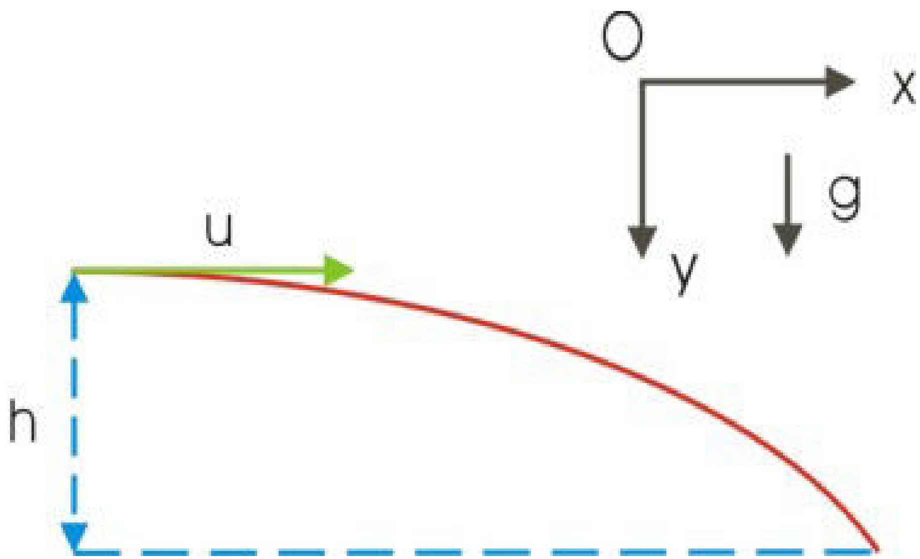


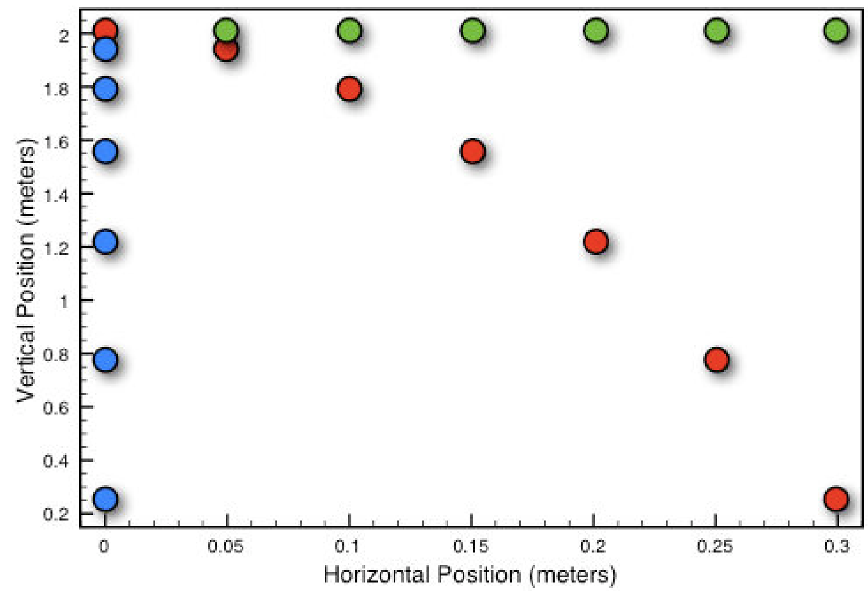


1. Projectile launch horizontally
2. Projectile launch at an angle

The path (**trajectory**) traced out by this projectile has a mathematical shape known as a **parabolic**

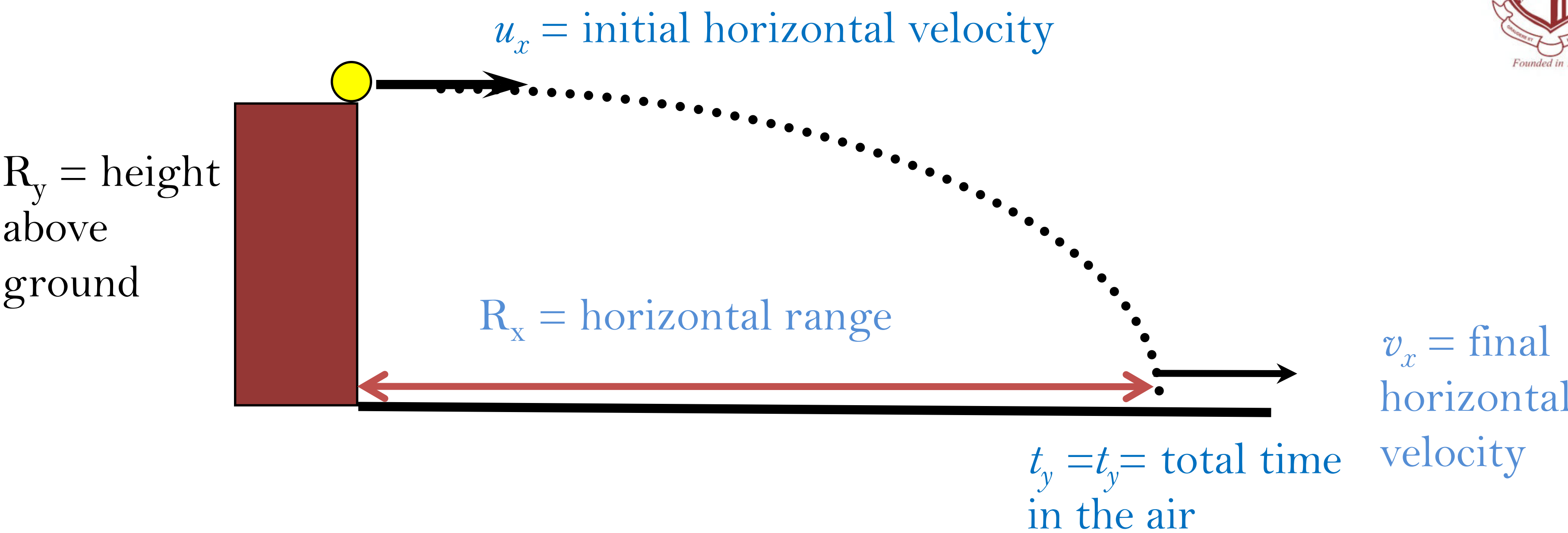
Projectile launch horizontally





- Gravity only affects vertical motion. So,
  - The horizontal velocity (x-component) is unaffected
  - The vertical velocity (y-component) accelerating downwards

Object Launched Horizontally



IMPORTANT

1. The **horizontal velocity is constant.** $(u_x = v_x)$
2. **No horizontal acceleration.** $(a_x = 0)$**.**
3. Vertical **acceleration** $(a_y = g)$**.**
4. Launch horizontally with velocity u_x, no initial vertical velocity $(u_y = 0)$
5. Time is the same for both vertical & horizontal $(t_x = t_y)$.

Horizontal Range (R_x)

Use equation 3:

- s = ut + ½ at^2
- Here, $s = R_x$

So,

- $R_x = u_x t + \frac{1}{2} a_x t_x^{\,2}$
- *(all components in equation is put with subscript x)*
- We know that horizontal acceleration, $a_x = 0$, so, the formula become

$$R_x = u_x t_x$$

- *Or, as* $u_x = v_x$, R_x can also be calculated as

$$R_x = v_x t_x$$

Vertical height, R_y

Use equation 3:

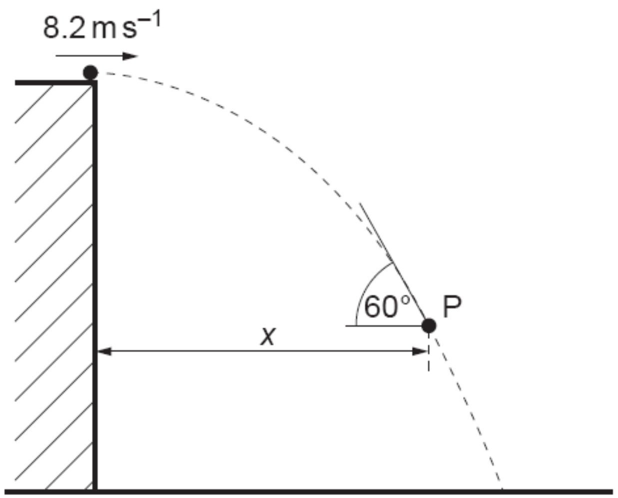
- $s = ut + ½ at^2$
- But here, s = vertical height (R_y)
- $R_y = u_y t + ½ a_y t^2$

(all components in equation is put with subscript y)

- Here, $u_y = 0$, $a_y = g$
- Thus, the equation become

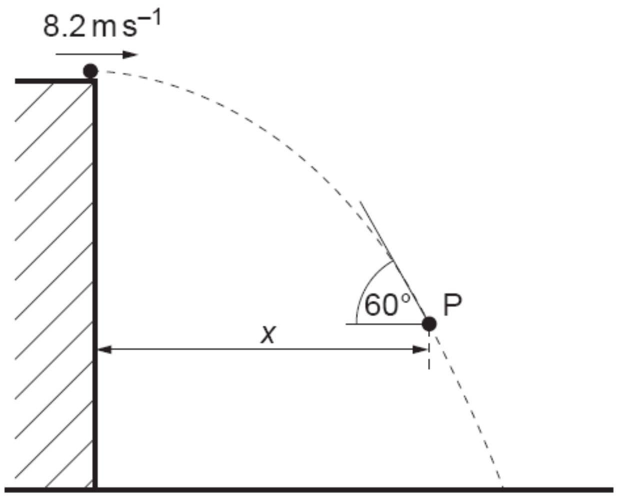
$$R_y = ½ g t_y^{\,2}$$

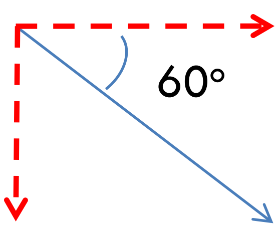
Example



- A ball is thrown horizontally from the top of a building 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.

Example





$V_x = 8.2\ ms^{-1}$

V_y

- For the ball at point P;
  - a) **show that the vertical component of its velocity is 14.2 m s^{-1},**
  - b) determine the vertical distance through which the ball has fallen,
  - c) Determine the horizontal distance x.

answer (a)

- $u_x = v_x$ = horizontal speed constant at 8.2 m s^{-1}

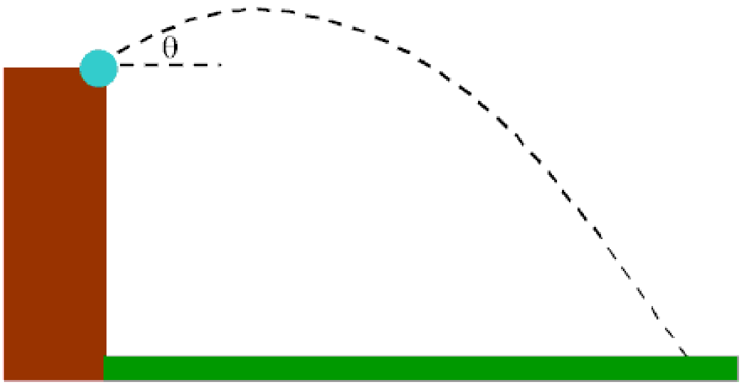
So, vertical component of speed, v_y

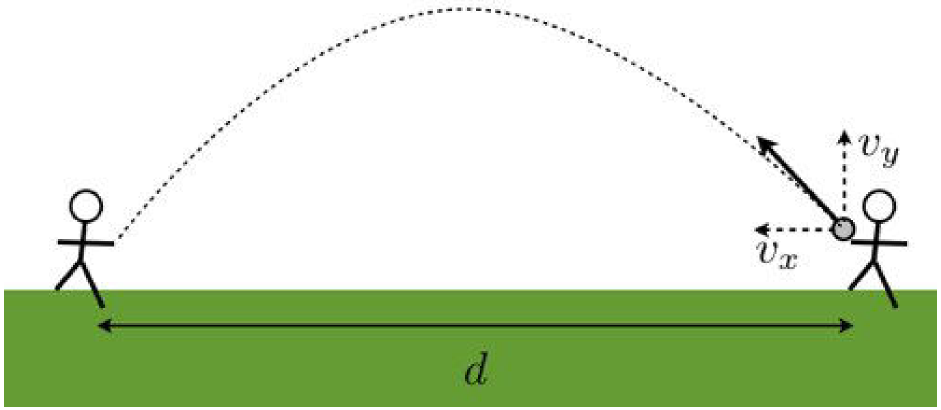
- $v_y = 8.2 \tan 60° = 14.2$ m s^{-1}

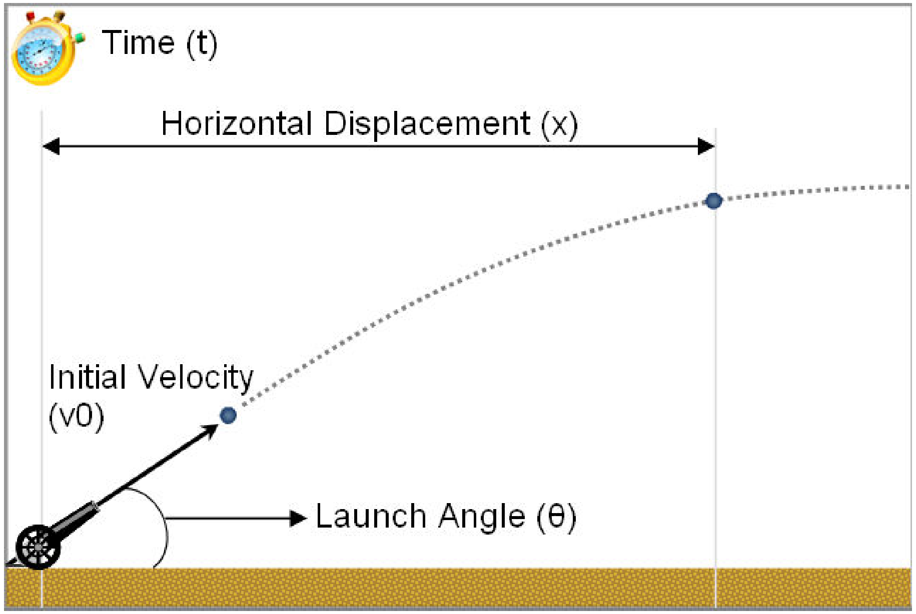
Example

- The vertical distance through which the ball has fallen (s_y)
- From eq 4:
- $v^2 = u^2 + 2as$
- $v_y{}^2 = u_y{}^2 + 2a_y s_y$
- $(14.2)^2 = 0 + 2\,(9.81)s_y$
- $\underline{s_y = 10.3 \text{ m}}$

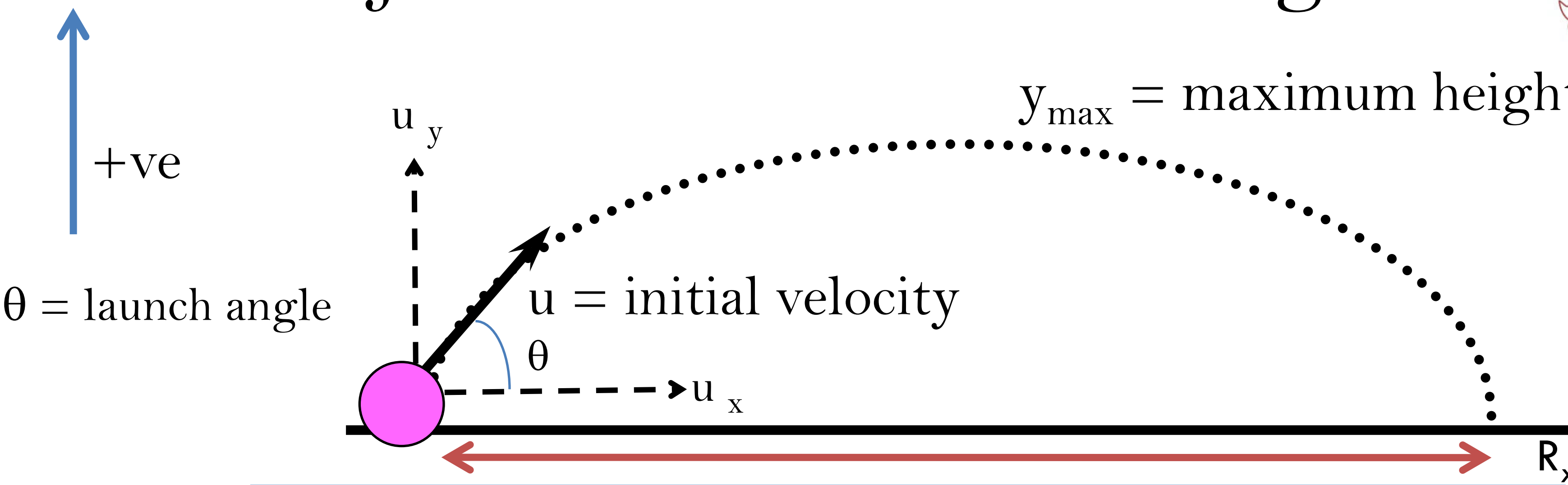
2. Projectiles at an angle







Object Launched at an Angle



t = total time in air $\qquad R_x$ = horizontal range

It reaches maximum height in half the total time.
Gravity only effects the vertical motion.

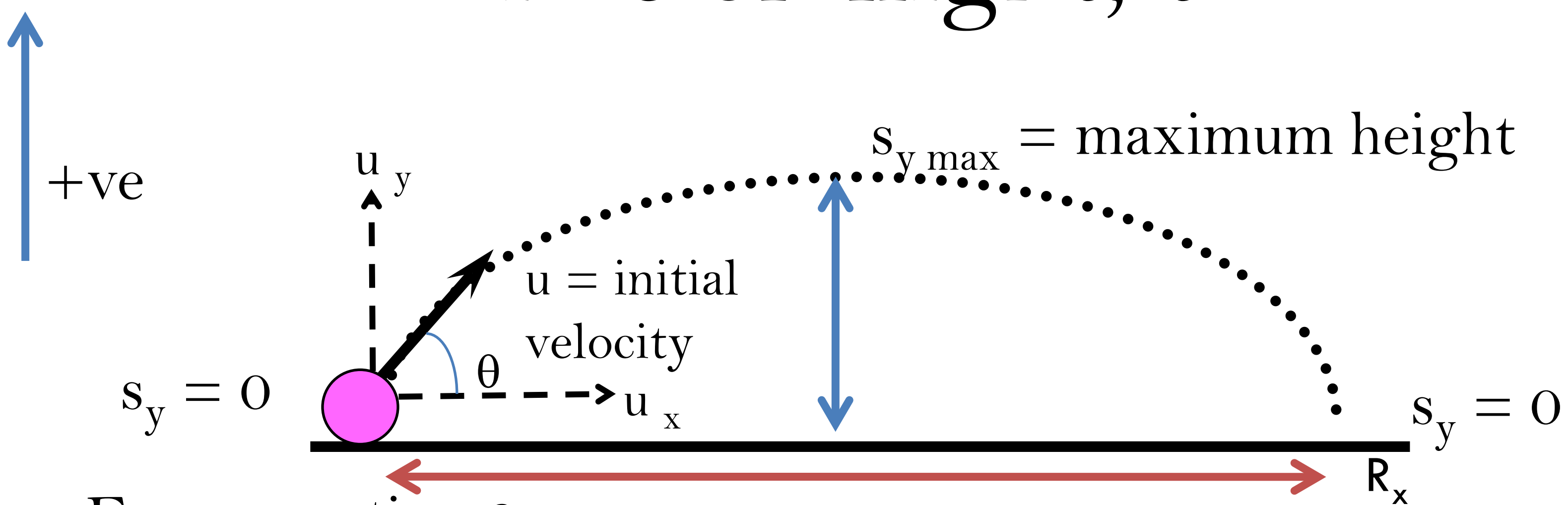
<u>horizontal</u>

$$u_x = u\ cos\ \theta$$

<u>vertical</u>

$$u_y = u\ sin\ \theta$$

Time of flight, t



- From equation 3:
- $s = ut + \frac{1}{2} at^2$; *now* $s = s_y$
- *Add subscript y to equation*

$s_y = u_y t + \frac{1}{2} a_y t^2$

$s_y = (u \sin \theta)t + \frac{1}{2} a_y t^2$

$0 = (u \sin \theta)t + \frac{1}{2} a_y t^2,\ a_y = -g$

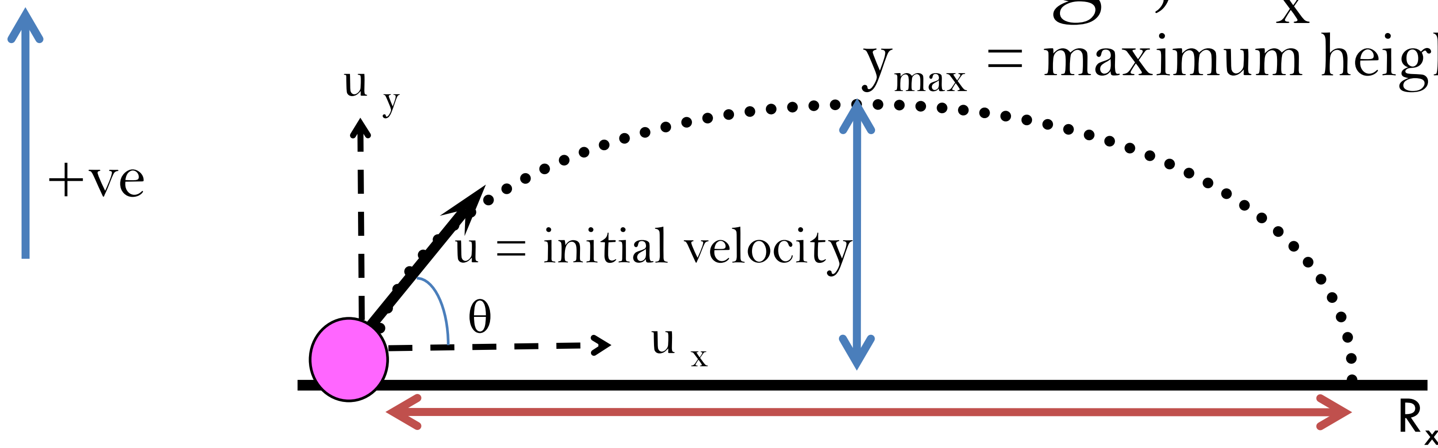
$0 = t[(u \sin \theta) - \frac{1}{2} gt]$

$t = 0$, and $t = \mathbf{(2u \sin \theta / g)}$

- t = 0 when the ball is launched
- So, time of flight, *t* is

$$t = (2u \sin \theta / g)$$

Horizontal range, R_x



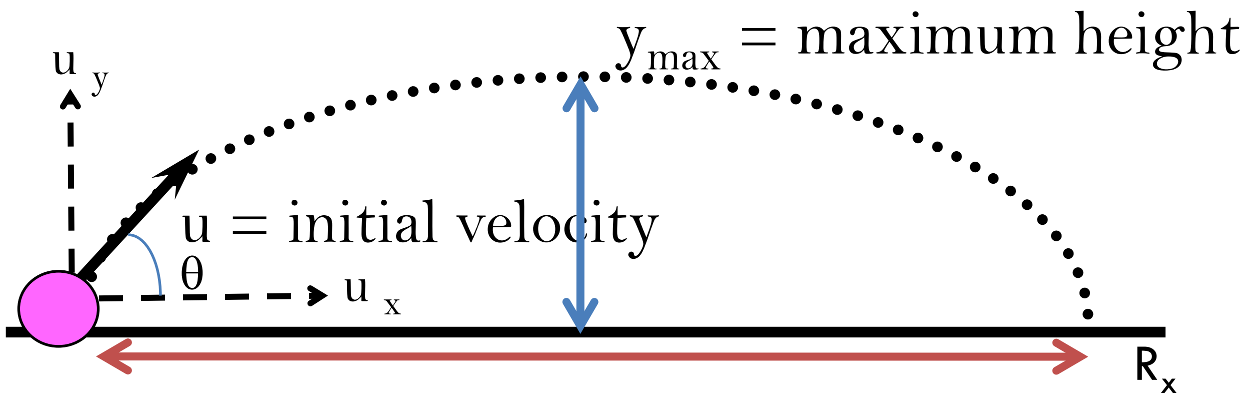
- We know that time of flight t is

$$t = (2u \sin \theta / g)$$

- From equation 3:
  - $s = ut + ½ at^2$; now $s = R_x$
  - $R_x = u_x t + ½ a_x t^2$, but $a_x = 0$, so,
  - $R_x = u_x t$,
  - we know, $u_x = u \cos \theta$ and $t = (2u \sin \theta / g)$
  - $R_x = u \cos \theta \ (2u \sin \theta / g)$, becomes

$$R_x = u^2 \sin 2\theta / g$$

Maximum height , Y_{max}



- Maximum height, y_{max} is when $v_y = 0$
- *From equation 4:* $v^2 = u^2 + 2as$
- $v_y{}^2 = u_y{}^2 + 2a_y y_{max}$, $a_y = -g$
- $0 = (u \sin \theta)^2 + (-2g y_{max})$
- *So,*

$$\mathbf{y_{max} = (u \sin \theta)^2 / 2g}$$

A ball is kicked with initial velocity of 20 ms^{-1} at an angle 32^o from a field

Calculate

i. Its initial velocity at x-component & y component (16.96ms^{-1} and 10.60 ms^{-1})

ii. Time of flight of the ball on the air (2.16 s)

iii. Maximum range achieved (36.69 m)

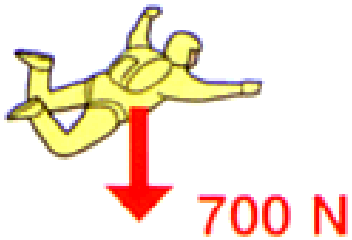
iv. Maximum height and time to reach that height (5.73 m, 1.08 s)

v. Maximum range that possibly reach (40.82 m)

TERMINAL VELOCITY (MOTION THROUGH FLUID)

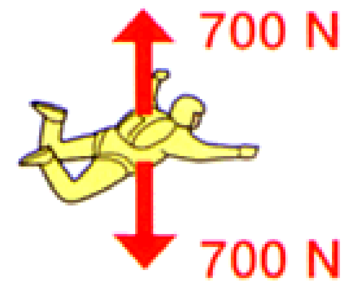
Terminal Velocity

- For objects falling with air resistance influence as such parachutist;
- The **resistance from air friction increases as a falling object's velocity increases**.
- Thus, the velocity is not increase indefinitely, but reach a maximum velocity)
- This maximum velocity is called **terminal velocity.**
- This is **when the force due to air resistance** reach an **equal value to the weight** of the falling object.

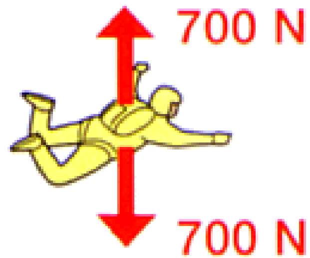


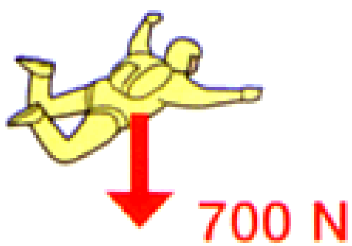
Terminal velocity

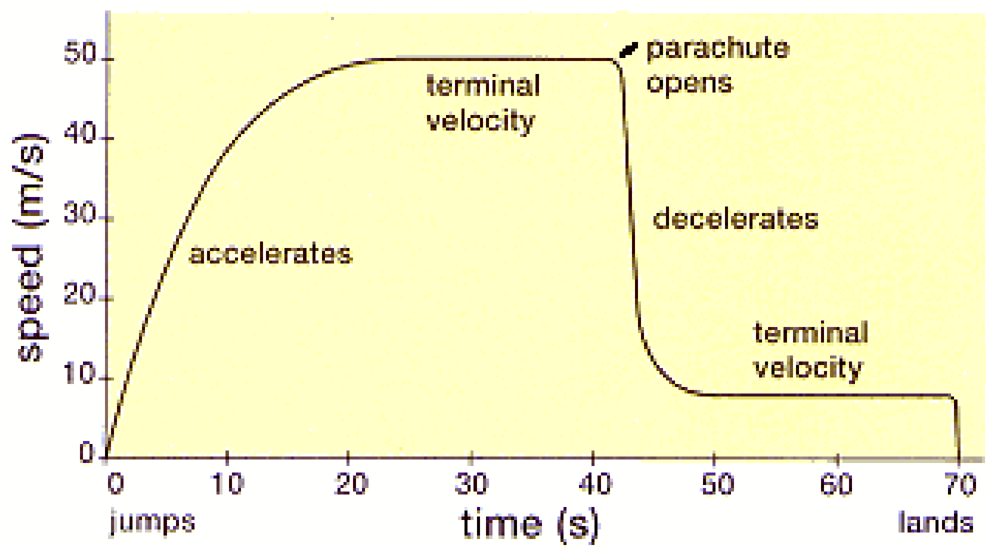
When
$F_{up} = F_{down}$
$F_{net} = F_{up} - F_{down} = 0$
$F_{net} = ma$ when $F = 0$,
Thus, acceleration *a* also 0



- Thus, acceleration is reduced to zero (g =0) and the object falls with constant velocity


700 N
700 N


700 N

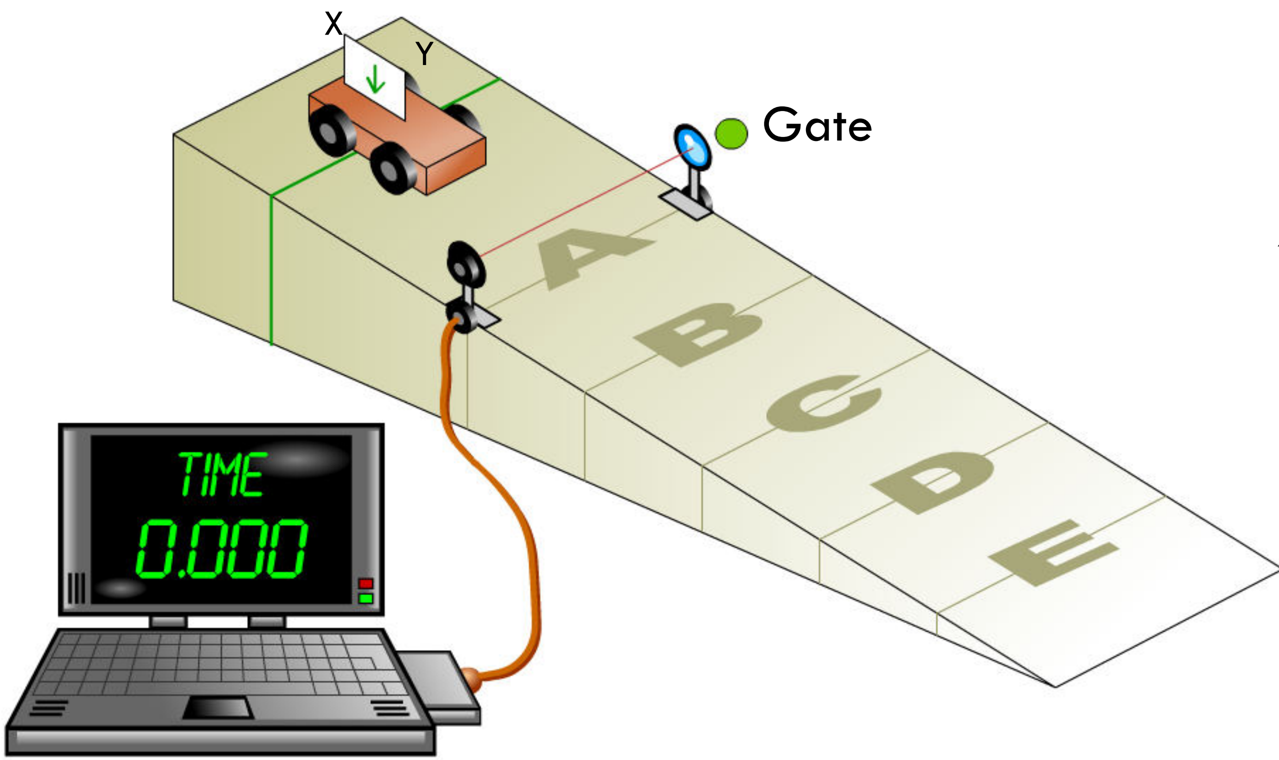

speed (m/s)
50
40
30
20
10
0
0
10
20
30
40
50
60
70
jumps
time (s)
lands
accelerates
terminal
velocity
parachute
opens
decelerates
terminal
velocity

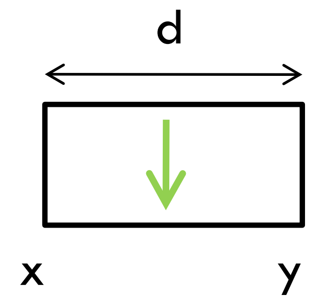
Laboratory measurement

- Determining speed
  - Using one light gate
  - Using two light gates
  - Using ticker timer
- Determining acceleration
  - Using two light gates
  - Using ticker timer

Determining speed

- Using one light gate





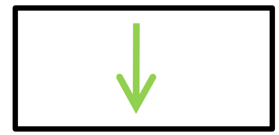
✓ Gate detects the time taken from point X to point Y on the card to pass it= *t*

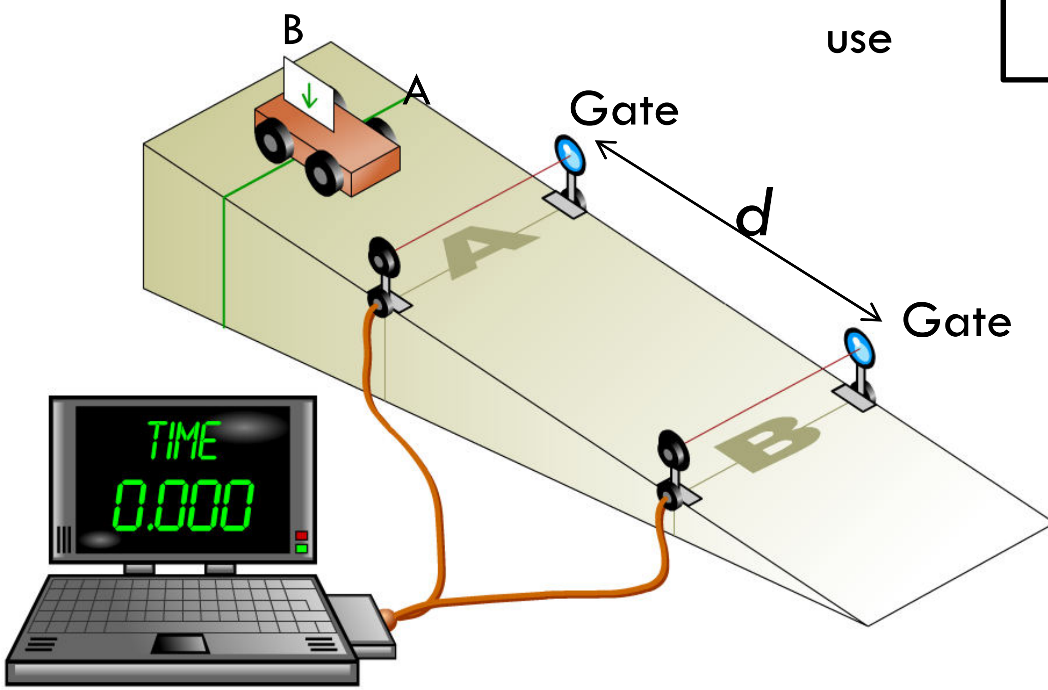
✓ So, speed = *d*/*t*

Determining speed

- Using two light gate

Card
use



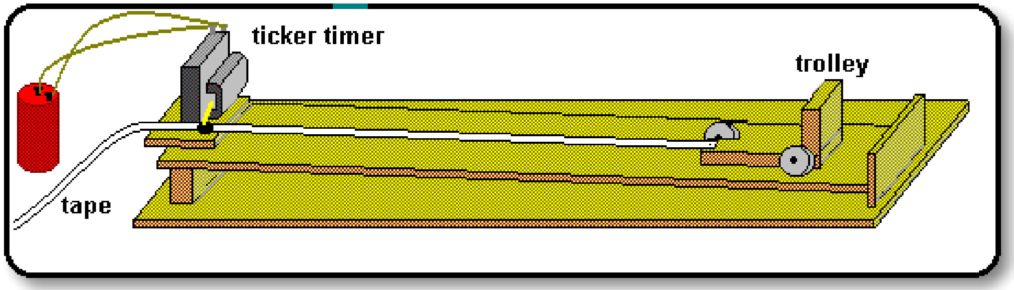


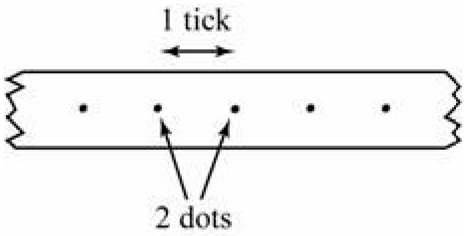
Gate detects the time taken for the card to pass **d** distance = *t*

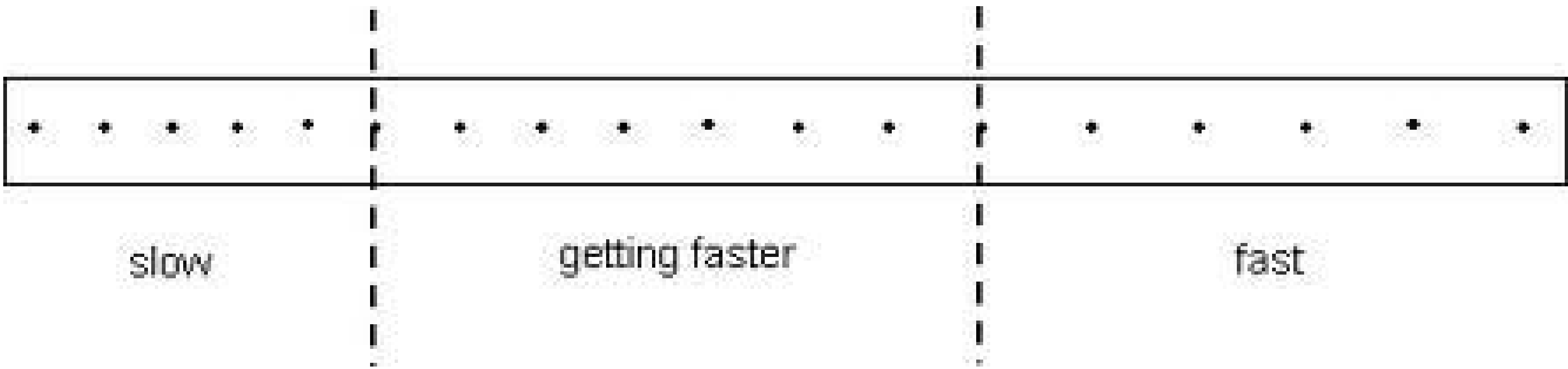
So, speed = *d*/*t*

Determining speed

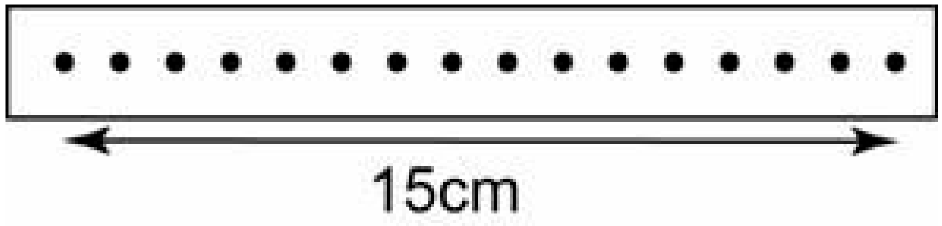
- Using ticker timer with frequency 50 Hz







Determining speed



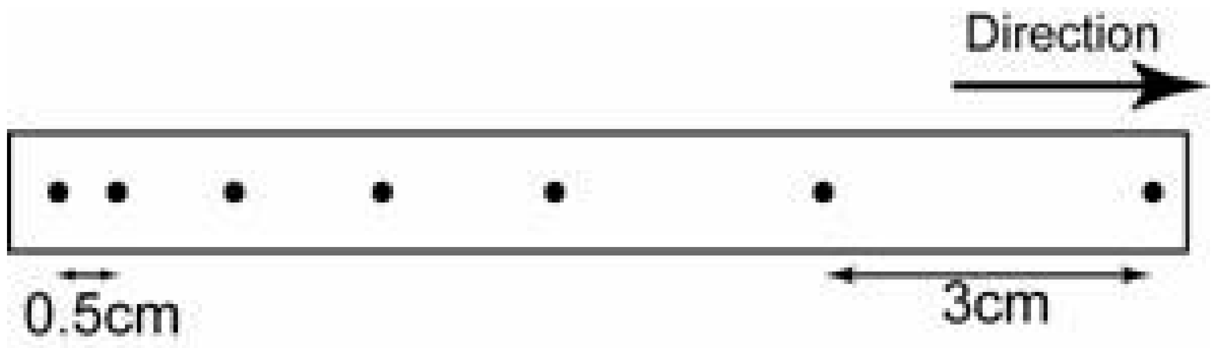
Time between space = 1/50 = 0.02 second

Time taken = 15 spaces x 0.02 s =0.3 s

Distance travel = 15 cm

Speed = 15 cm / 0.3 s = 50 cms^{-1}

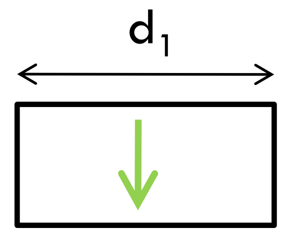
Determine acceleration

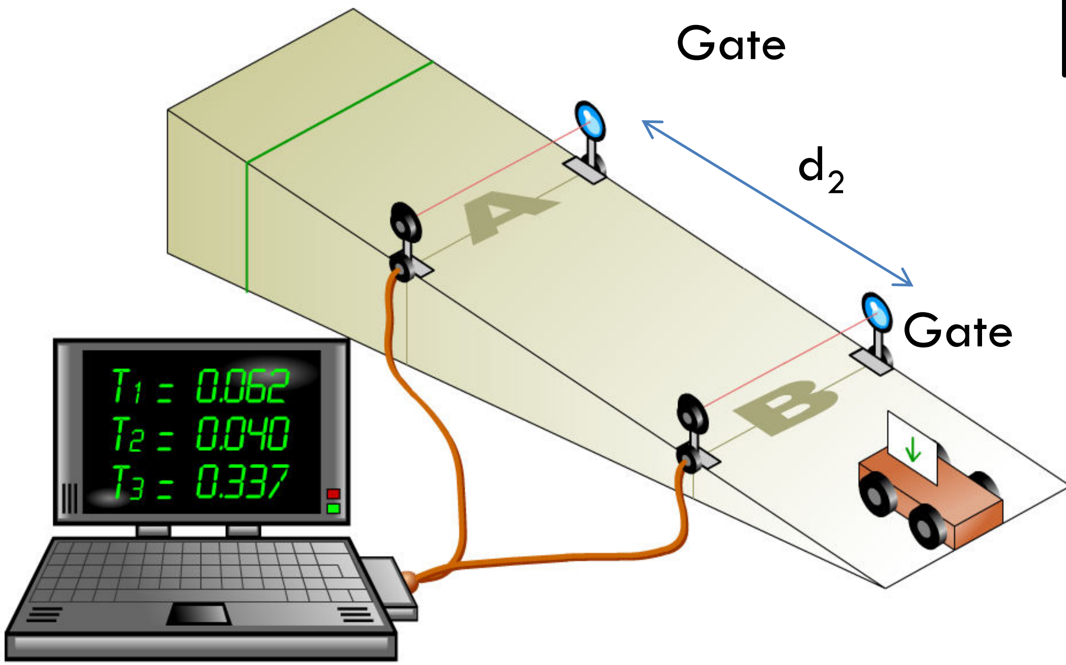


- $a = (v\text{-}u)\ t$
  - ✓ $u = 0.5\ \text{cm} / 0.02\ \text{s} = 25\ \text{cms}^{-1}$
  - ✓ $v = 3.0\ \text{cm} / 0.02\ \text{s} = 150\ \text{cms}^{-1}$
- Time taken for the velocity change
  - ✓ $(0.5 + 4 + 0.5)\ \text{x}0.02\text{s} = 0.1\ \text{s}$
- **$v = (150 - 25) / 0.1 = 1250\ \text{cms}^{-1}$**

Determining acceleration

- Using 2 light gates





T_1 = Time for the card to pass A

T_2 = time for card to pass B

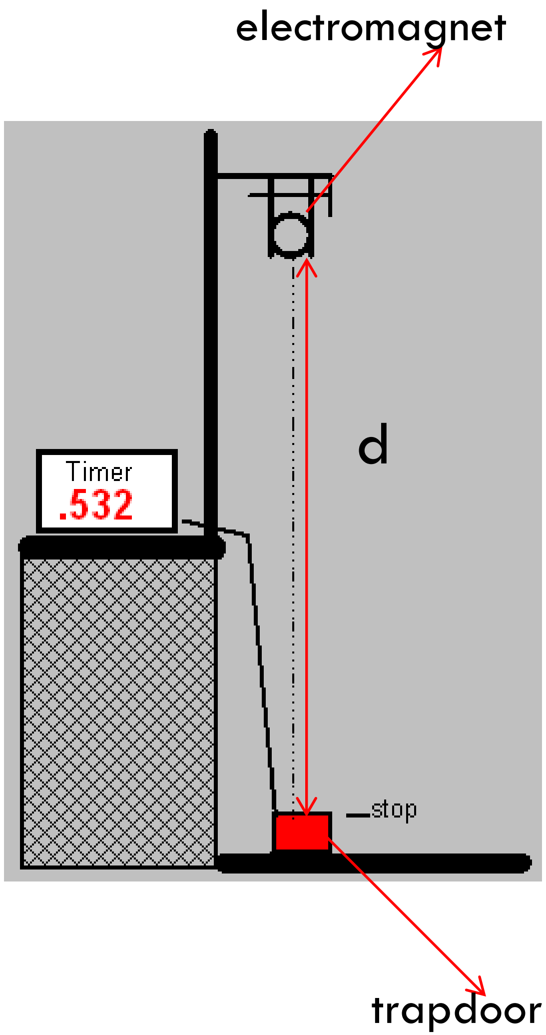
T_3 = time for card to pass distance AB (d_2)

$u = d1/T_1$

$v = d1/T_2$

$a = (v - u)\ T_3$

Determine *g* using a falling body



1. A steel ball bearing is held by an electromagnet.
2. When current to magnet is switched off, the ball begins to fall and an electronic timer starts.
3. The ball falls through a distance d and reach trapdoor.
4. This breaks a circuit to stop the timer.
5. The timer records the time for the ball to fall through the distance d

Determine g using a falling body

- Displacement, s by the ball : d
- Time taken: t
- Initial velocity : $u = 0$
- Acceleration $a = g$
- By using equation $s = ut + (1/2)at^2$, we get

$$d = (1/2)gt^2$$

6. Experiment is repeated with different value of d

Determine g using a falling body

- When plot a graph of ***d*** against ***t***^{2}, The equation of $d = (1/2)gt^2$ is actually a straight line graph through 0 origin;

$$y = mx$$

$$d \qquad (1/2)g \qquad t^2$$

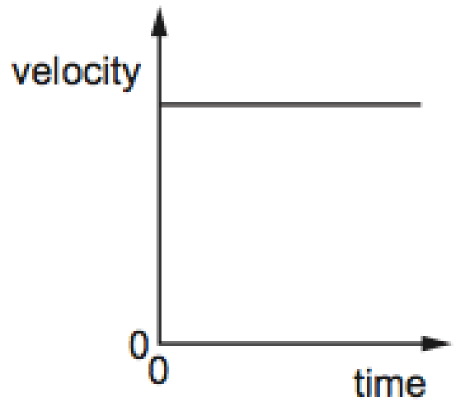
- It means gradient, m = (1/2)g, so, g = 2m
- This means, g = 2 x gradient of graph

Tutorials

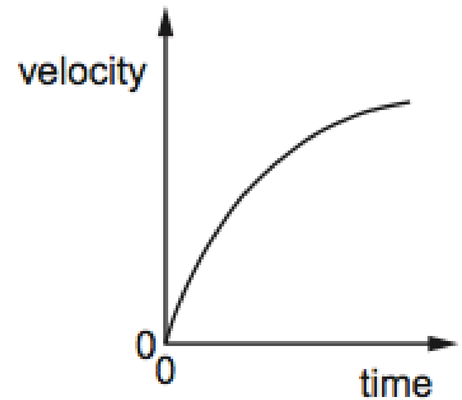
8 A stone is thrown horizontally from the top of a cliff. Air resistance is negligible.

Which graph shows the variation with time of the vertical component of the stone's velocity?

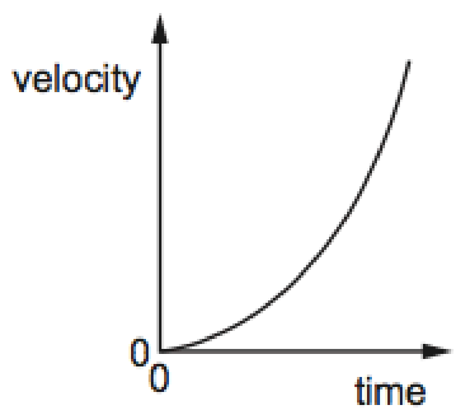
A



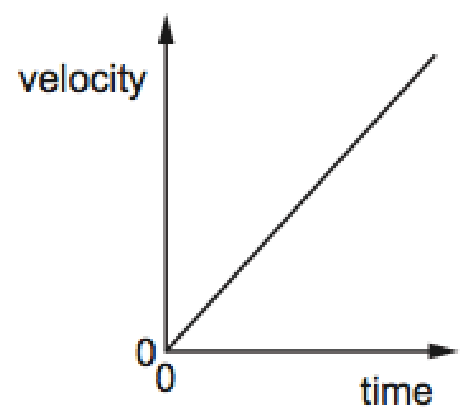
B



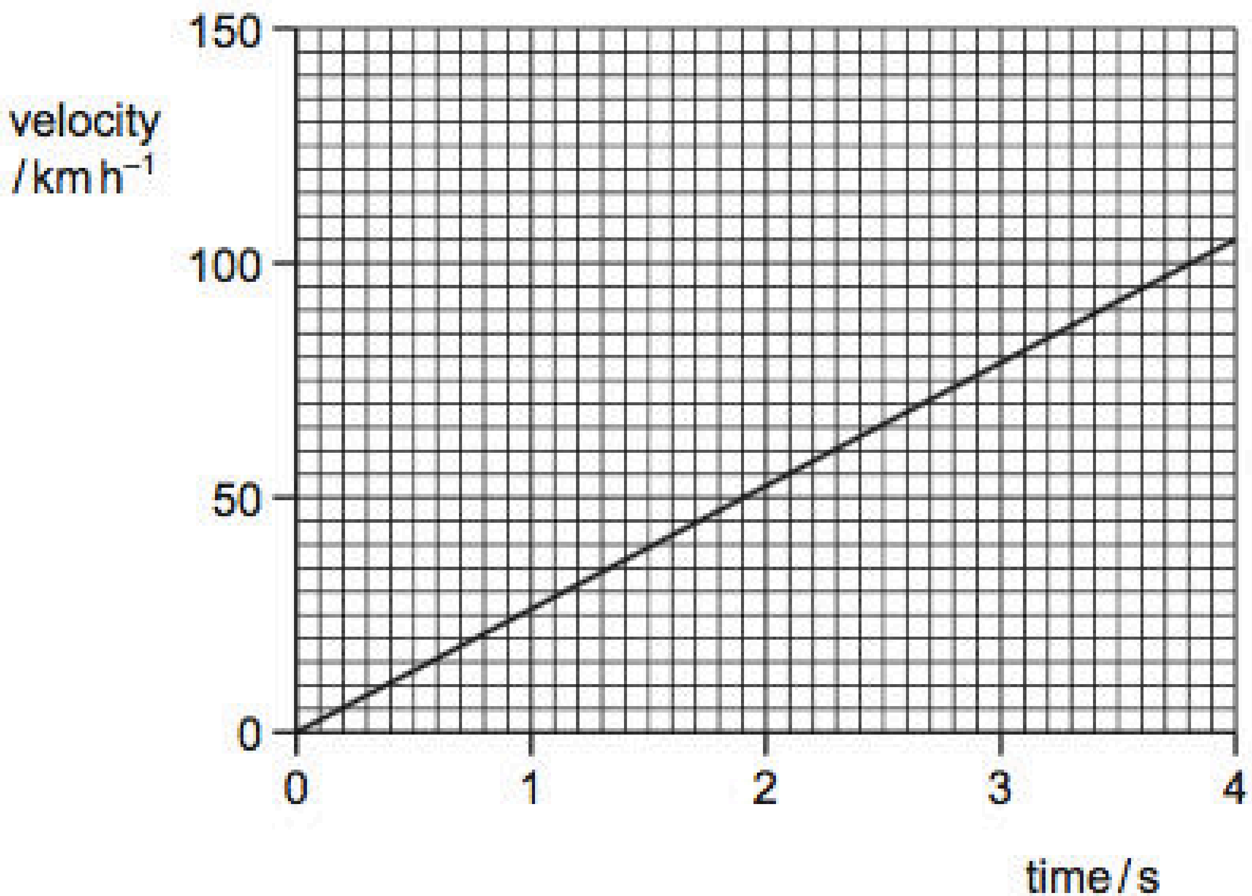
C



D



8 The velocity of an electric car changes as shown.



What is the acceleration of the car?

A $210\,\mathrm{m\,s^{-2}}$ **B** $58\,\mathrm{m\,s^{-2}}$ **C** $26\,\mathrm{m\,s^{-2}}$ **D** $7.3\,\mathrm{m\,s^{-2}}$

6 A tennis ball is thrown horizontally in air from the top of a tall building.

If the effect of air resistance is **not** negligible, what happens to the horizontal and vertical components of the ball's velocity?

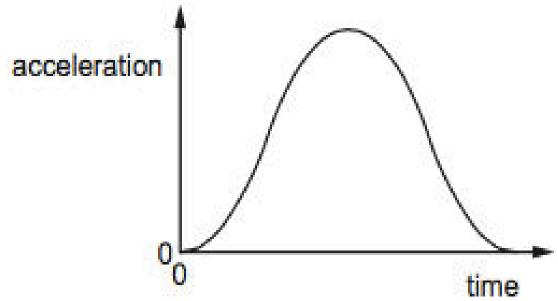
	horizontal component of velocity	vertical component of velocity
A	constant	constant
B	constant	increases at a constant rate
C	decreases to zero	increases at a constant rate
D	decreases to zero	increases to a maximum value

7 An object is thrown with velocity $5.2\,\text{m}\,\text{s}^{-1}$ vertically upwards on the Moon. The acceleration due to gravity on the Moon is $1.62\,\text{m}\,\text{s}^{-2}$.

What is the time taken for the object to return to its starting point?

A 2.5 s **B** 3.2 s **C** 4.5 s **D** 6.4 s

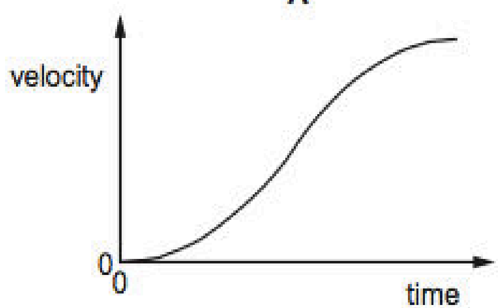
8 The graph shows how the acceleration of an object moving in a straight line varies with time.



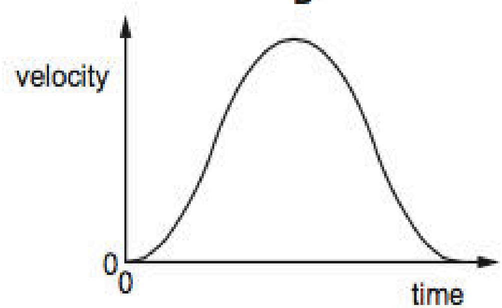
The object starts from rest.

Which graph shows the variation with time of the velocity of the object over the same time interval?

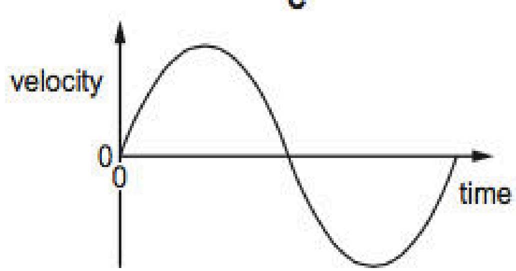
A



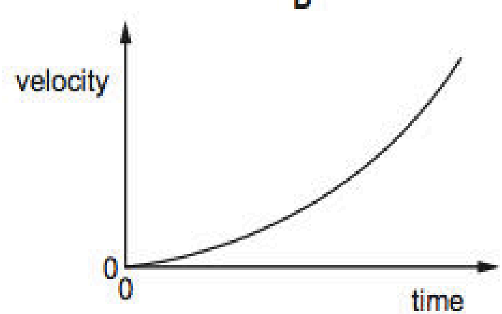
B



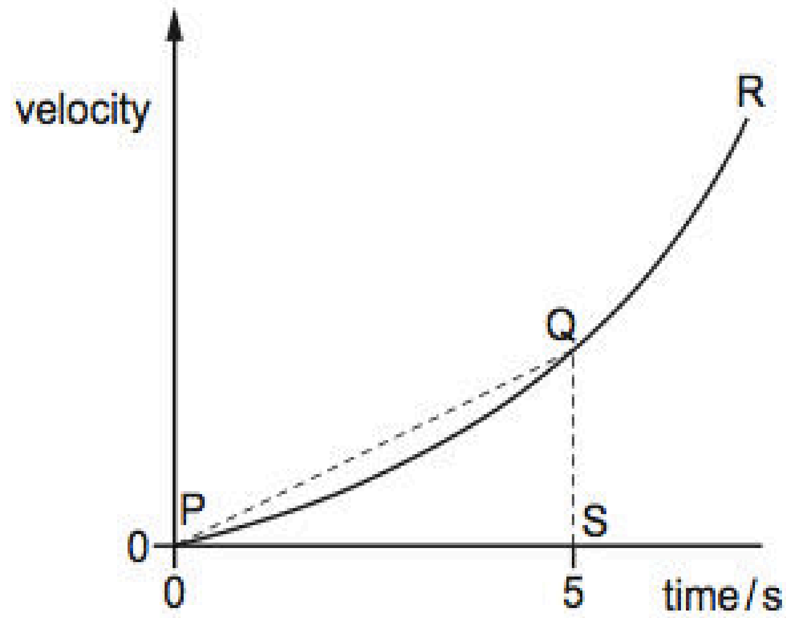
C



D



8 The curved line PQR is the velocity-time graph for a car starting from rest.



What is the average acceleration of the car over the first 5 s?

A the area below the curve PQ

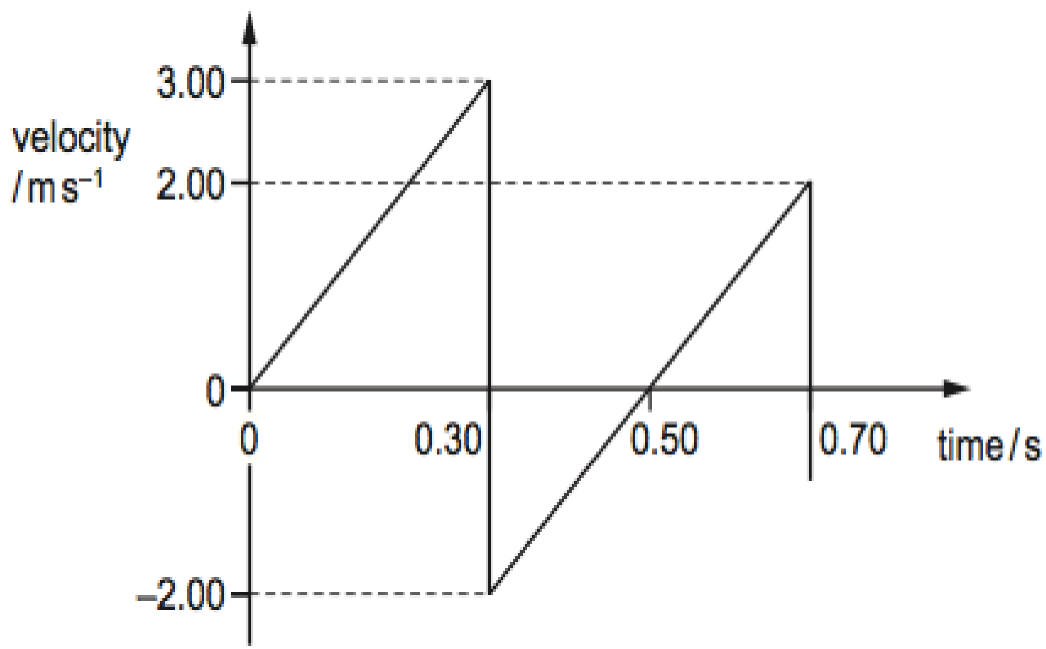
B the area of the triangle PQS

C the gradient of the straight line PQ

D the gradient of the tangent at Q

9 A ball is released from rest above a horizontal surface. It strikes the surface and bounces several times.

The velocity-time graph for the first two bounces is shown.



What is the maximum height of the ball after the first bounce?

A 0.20 m **B** 0.25 m **C** 0.45 m **D** 0.65 m

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

10 A firework rocket is fired vertically upwards. The fuel burns and produces a constant upwards force on the rocket. After 5 seconds there is no fuel left. Air resistance is negligible.

What is the acceleration before and after 5 seconds?

	before 5 seconds	after 5 seconds
A	constant	constant
B	constant	zero
C	increasing	constant
D	increasing	zero

9 The water surface in a deep well is 78.0 m below the top of the well. A person at the top of the well drops a heavy stone down the well.

Air resistance is negligible. The speed of sound in the air is $330\,\mathrm{m\,s^{-1}}$.

What is the time interval between the person dropping the stone and hearing it hitting the water?

A 3.75 s **B** 3.99 s **C** 4.19 s **D** 4.22 s