MOTION IN A STRAIGHT LINE

- Kinematics is the study of motion without going into its causes.
- This chapter deals with motion along a straight line, i.e. rectilinear motion.
- The motion is the change in position of an object with respect to time.

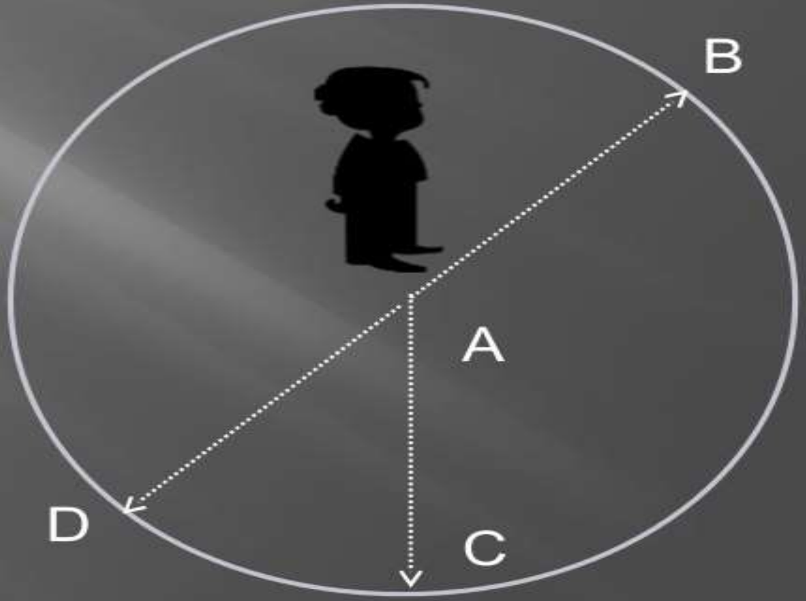
Scalars and Vectors

- The distance an object travels is a scalar quantity, independent of direction.
- The displacement of an object is a vector quantity, equal to the final position minus the initial position.
- An object's speed *v* is scalar quantity, independent of direction.
- Speed is how fast an object is going; it is always positive.
- Velocity is a vector quantity that includes direction.
- In one dimension the direction of velocity is specified by the + or – sign.

DISTANCE AND DISPLACEMENT

- Distance = length of the actual path taken to go from source to destination
- Displacement = length of the straight line joining the source to the destination or in other words the length of the shortest path

Example: If a boy walks from B to D [arc] in a circular path, the distance will be the semicircle of the circle, while the displacement will be the diameter BD.



- Rohit and Seema both start from their house. Rohit walks 2 km to the east while Seema walk 1 km to th west and then turns back and walks 1 km.

Seema is back home and her displacement is 0 m.

This is because direction of motion is different in both cases.

You require both distance and direction to determine displacement.

Distance travelled by them is the same (2 km)

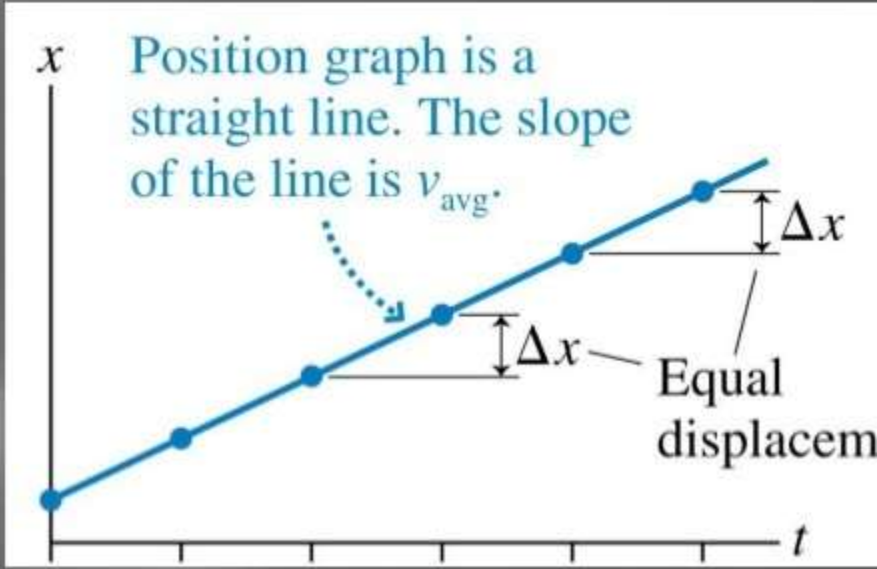
Uniform Motion

- Uniform motion is when equal displacements occur during any successive equal-time intervals.
- Uniform motion is always along a straight line.
- Eg: While driving a car at a perfectly steady 60 kmph, this means there is a

Riding steadily over level ground is a good example of uniform motion.

Uniform Motion

- An object's motion is uniform if and only if its position-versus-time graph is a straight line.
- The **average velocity** is the slope of the position-versus-time graph.
- The SI units of velocity



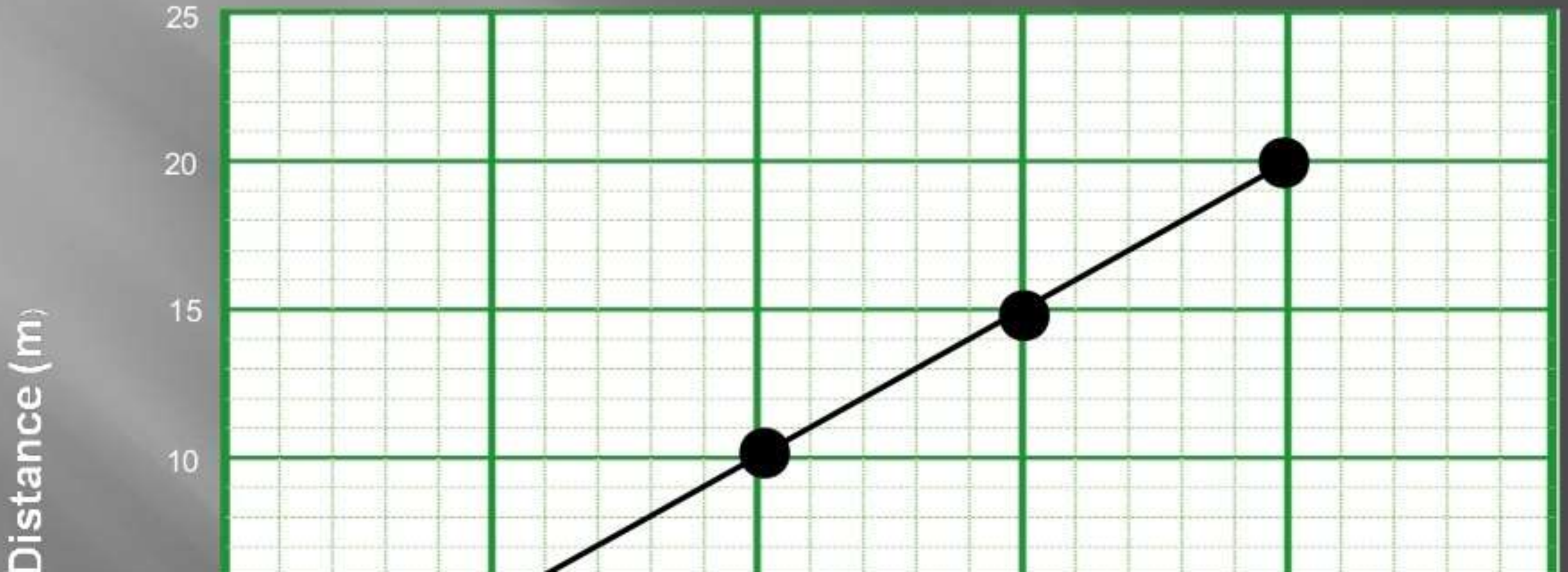
ED AND VELOCITY

led per unit time or the displacement

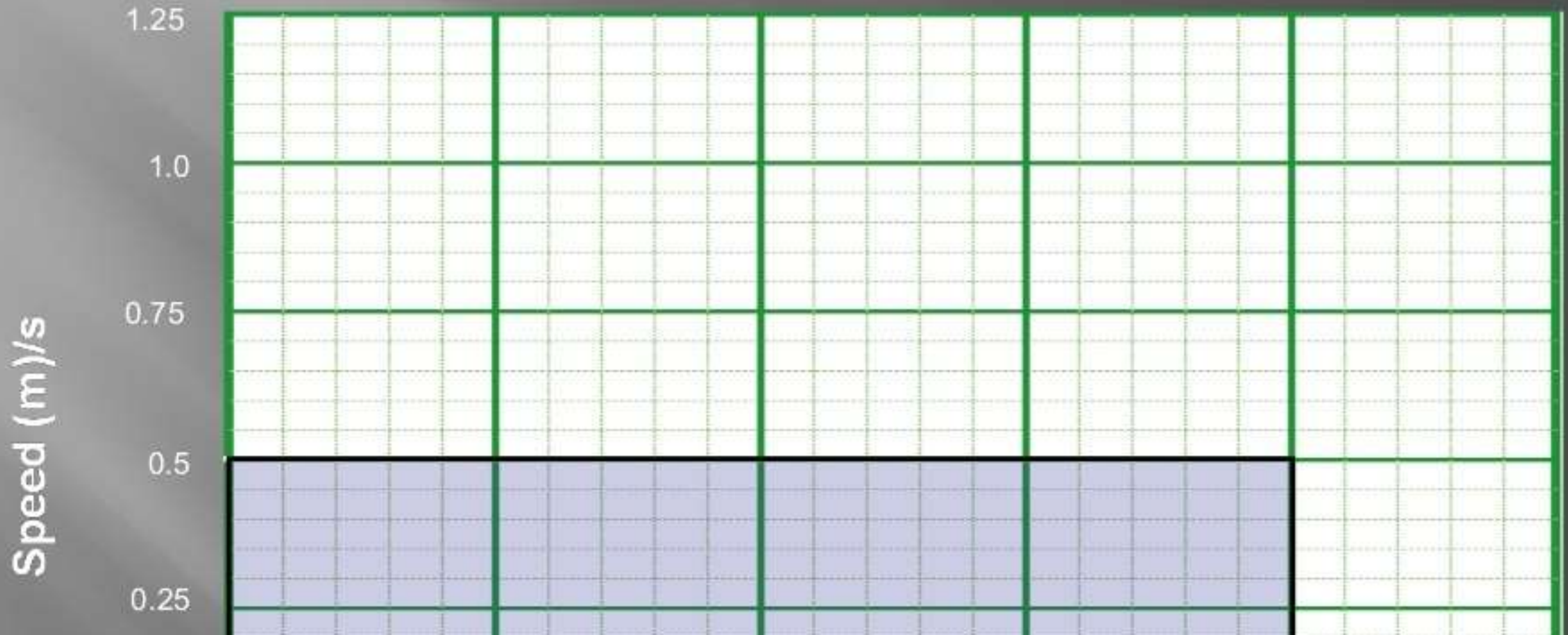
$$d = \frac{distance}{time} meter/second$$

$$= \frac{displacement}{time} meter/second$$

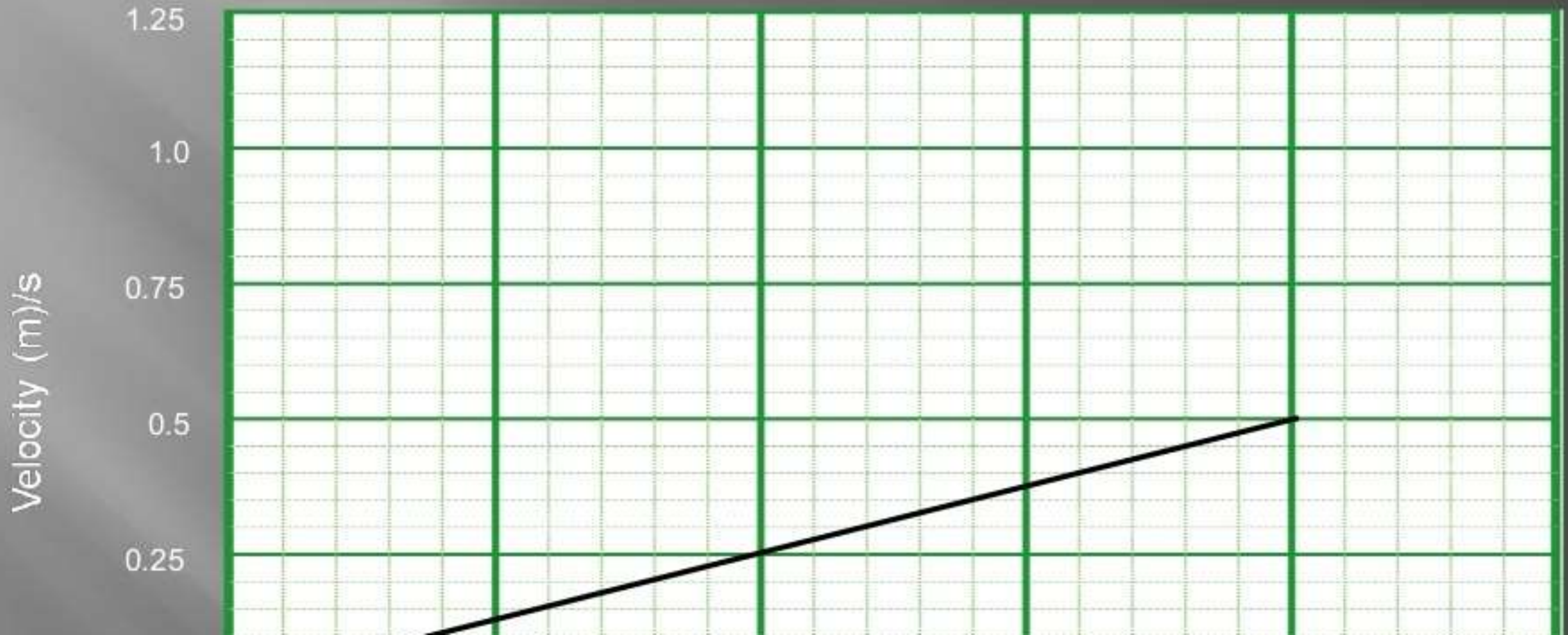
DISTANCE – TIME GRAPH



VELOCITY- TIME GRAPH



NON – UNIFORM MOTION

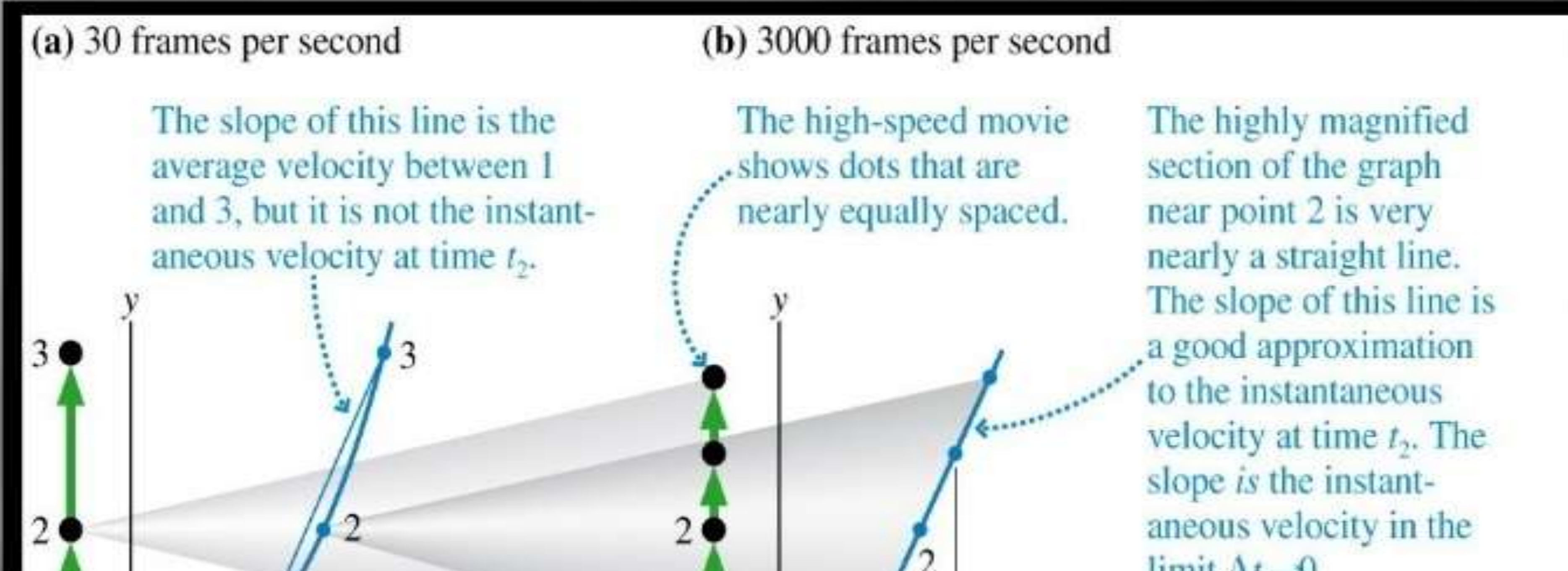


- An object that is speeding up or slowing down is *not* in uniform motion.
- In this case, the position-versus-time graph is *not* a straight line.

yellow

- We can determine the average speed V_{av} between any two times separated by time interval Δt by finding the slope of the straight-line connection between the two points.
- The **instantaneous velocity** is the object's velocity at a single *instant* of time t.
- The average velocity $V_{av} = \Delta s/\Delta t$ becomes a better and better approximation to the instantaneous velocity as Δt gets smaller and smaller.

Motion diagrams and position graphs of rocket.



As Δt continues to get smaller, the average vel
$v_{avg} = \Delta s / \Delta t$ reaches a constant or *limiting* value

The instantaneous velocity at time t is the aver
velocity during a time interval Δt centered on
approaches zero.

In calculus, this is called *the derivative of s with*

Graphically, $\Delta s / \Delta t$ is the slope of a straight lin

In the limit $\Delta t \to 0$, the straight line is tangent

The instantaneous velocity at time t is the slop
that is tangent to the position-versus-time grap

Calculus: Derivatives

called *the derivative of s with respect to t*.

the slope of the line that is tangent to the

-versus-time graph.

er a function u that depends on time as

vhere c and n are constants:

The derivative of $u = ct^n$ is $\frac{du}{dt} = nct^{n-1}$

ivative of a constant is zero:

$$\frac{du}{dt} = 0 \text{ if } u = c = \text{constant}$$

ing the slope of a graph of the function.

ilarly, evaluating an integral is equivalent to
ing the area under a graph of the function.

sider a function u that depends on time as $u = ct^n$,
ere c and n are constants:

$$\int_{t_i}^{t_f} u\,dt = \int_{t_i}^{t_f} ct^n\,dt = \frac{ct^{n+1}}{n+1}\Bigg|_{t_i}^{t_f} = \frac{ct_f^{\,n+1}}{n+1} - \frac{ct_i^{\,n+1}}{n+1} \qquad (n \neq -1)$$

vertical bar in the third step means the integral
luated at t_f minus the integral evaluated at t_i.

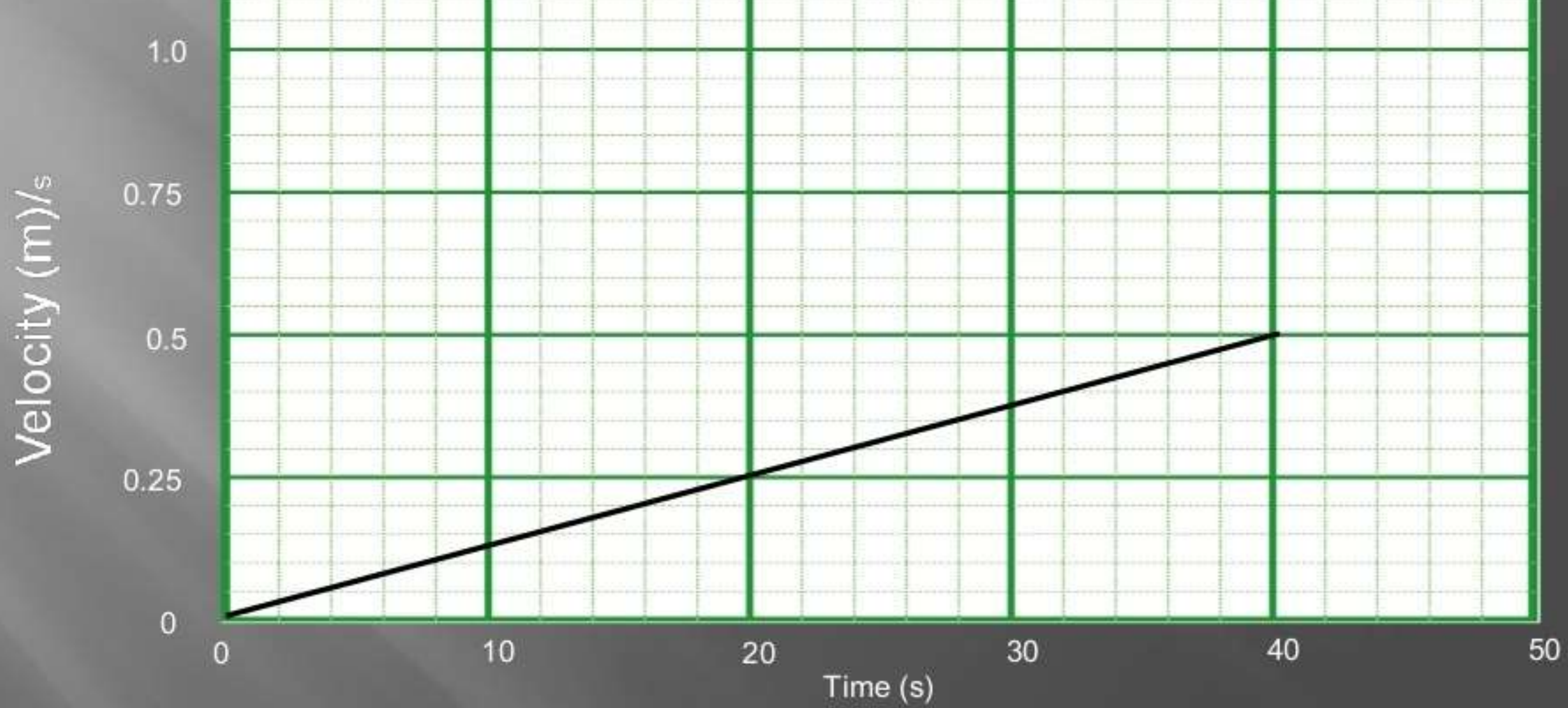
integral of a sum is the sum of the integrals. If u
w are two s… e, then:

$$\int_{t_i}^{t_f} (u + w)\,dt = \int_{t_i}^{t_f} u\,dt + \int_{t_i}^{t_f} w\,dt$$

- The SI units of acceleration are (m/s)/s, or m/s^2.
- It is the rate of change of velocity and measures how quickly or slowly an object's velocity changes.
- The **average acceleration** during a time interval Δt is:

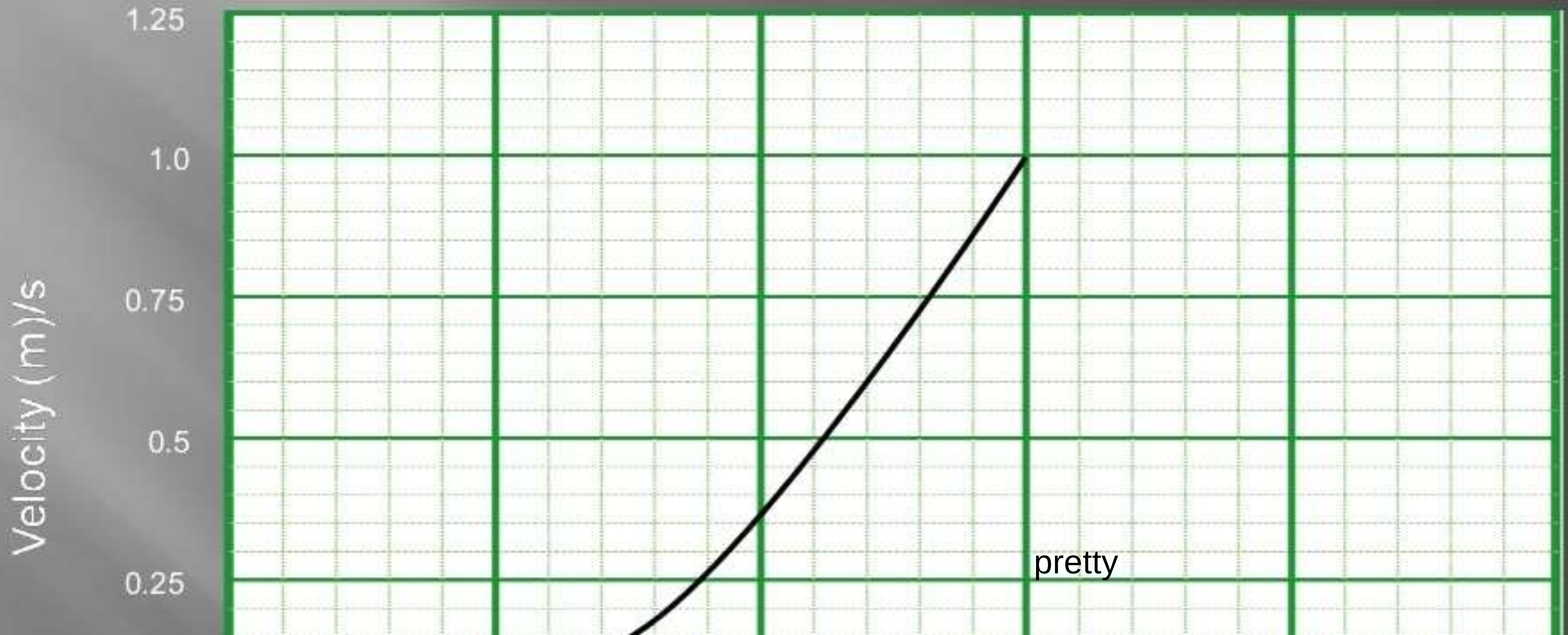
$$a_{\text{avg}} \equiv \frac{\Delta v_s}{\Delta t} \qquad \text{(average acceleration)}$$

- Graphically, a_{avg} is the *slope* of a straight-line velocity-versus-time graph.
- If acceleration is constant, the acceleration a_s is the

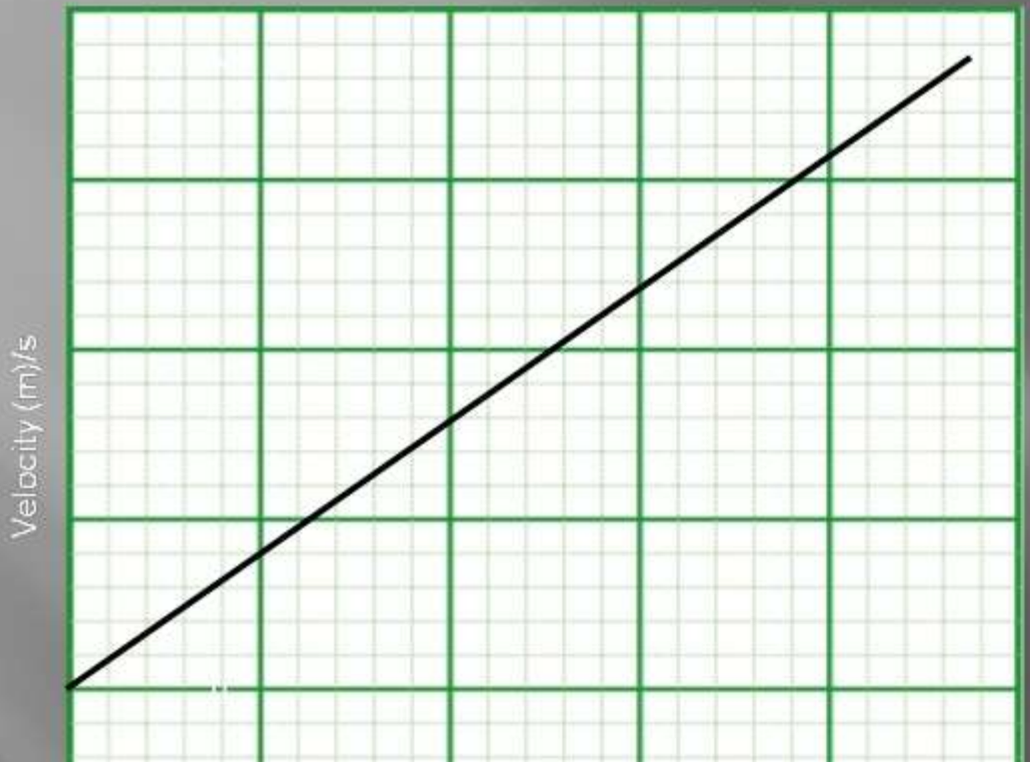


Velocity – Time graph
Uniform Acceleration
Acceleration = 0.125 m/s^2

NON UNIFORM ACCELERATION



1st Equation of Motion

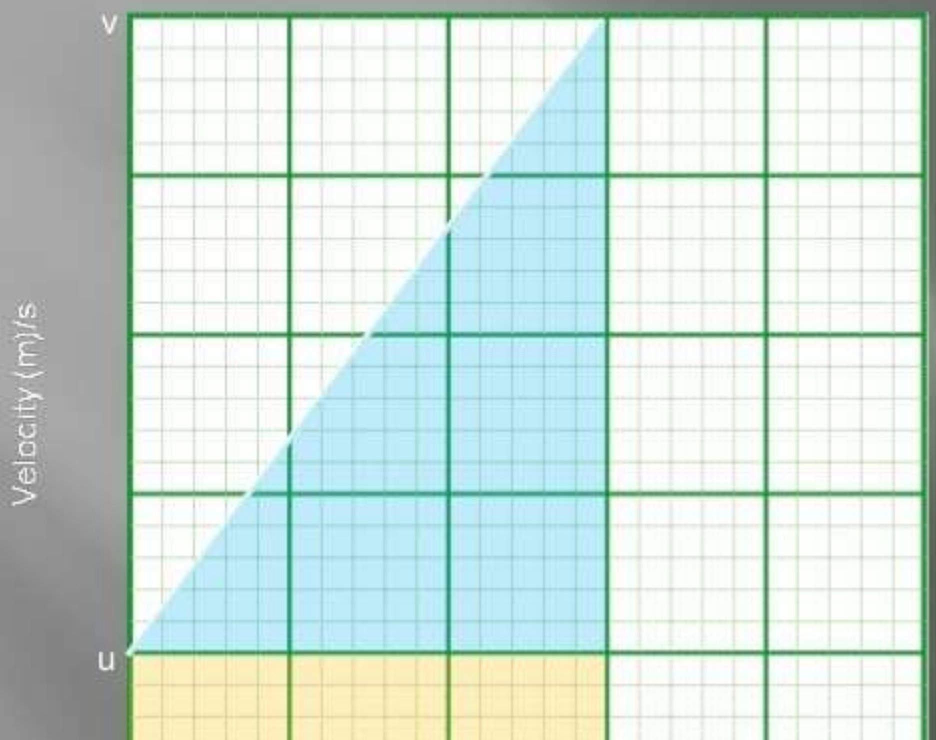


Initial velocity = u
Final velocity = v
Time = t
Acceleration = a
Displacement = s

Acceleration = Rate of change of velocity

$$a = \frac{v - u}{t} \, m/s^2$$

2^{nd} Equation of Motion



Initial velocity = u

Final velocity = v

Time = t

Acceleration = a

Displacement = s

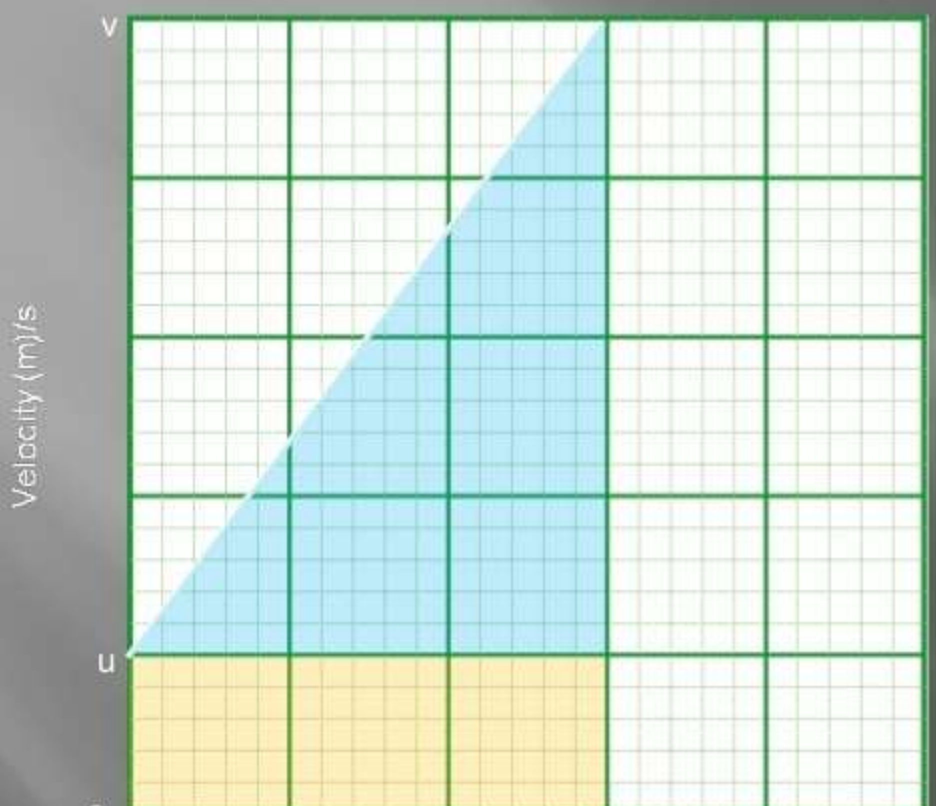
Displacement = Area under the line

$s = area\ of\ rectangle + area\ of\ trian$

$s = ut + \frac{1}{2}\left(t * (v - u)\right) m$

But $\frac{(v-u)}{t} = a$ or $(v - u) = at$

3rd Equation of Motion



Initial velocity = u

Final velocity = v

Time = t

Acceleration = a

Displacement = s

Displacement = Area under the line

$s = area\ trapezium$

$s = \frac{1}{2}\ (u + v)\ * t\ m$

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

$s = \frac{1}{2}\ (u + v)\ * \frac{(v - u)}{a} m$

CALCULUS METHOD

Derivation of equation 1; $v = v_0 + at$

$$a = \frac{dv}{dt}$$

a is constant →

$$dv = a\,dt$$

Integrate both sides with respect to time from 0 to t

$$\int_0^v v\,dt = \int_0^t a\,dt = a\int_0^t dt$$

CALCULUS METHOD

$$a = dv/dt = dv/dx \times dx/dt$$

$$a = v\,dv/dx$$

$$v\,dv = a\,dx$$

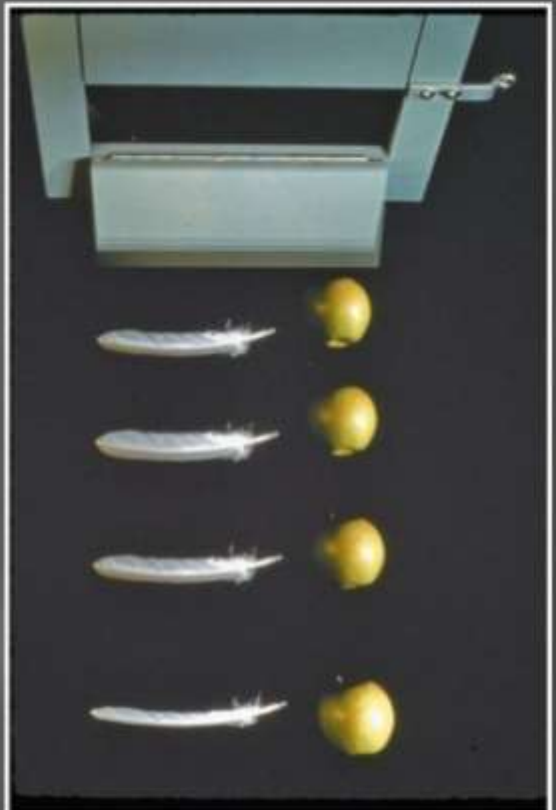
$$\int_u^x v\,dv = \int_x^x a\,dx$$

$$v^2 - u^2 = a(x - x_0) = as$$

2

Free Fall

- The motion of an object moving under the influence of gravity only, and no other forces, is called **free fall**.
- Two objects dropped from the same height will, if air resistance can be neglected, hit the ground at the same time and with the same speed.
- Consequently, any two objects in free fall, regardless of their



CALCULUS METHOD

Derivation of eqs.2 $x = x_o + v_o t + \frac{at^2}{2}$

$v = \frac{dx}{dt} \rightarrow dx = vdt$ $v = v_o + at$ $\rightarrow$ $dx = (v_o + at)dt$ $\rightarrow$

$dx = v_o dt + atdt$ Integrate both sides with respect to time from 0

x x

$\int_0^x \mathrm{dx} = v_o \int_0^t dt + a\int_0^t tdt \rightarrow [x]_0^x = v_o [t]_0^t + a\left[\frac{t^2}{2}\right]_0^t \rightarrow$

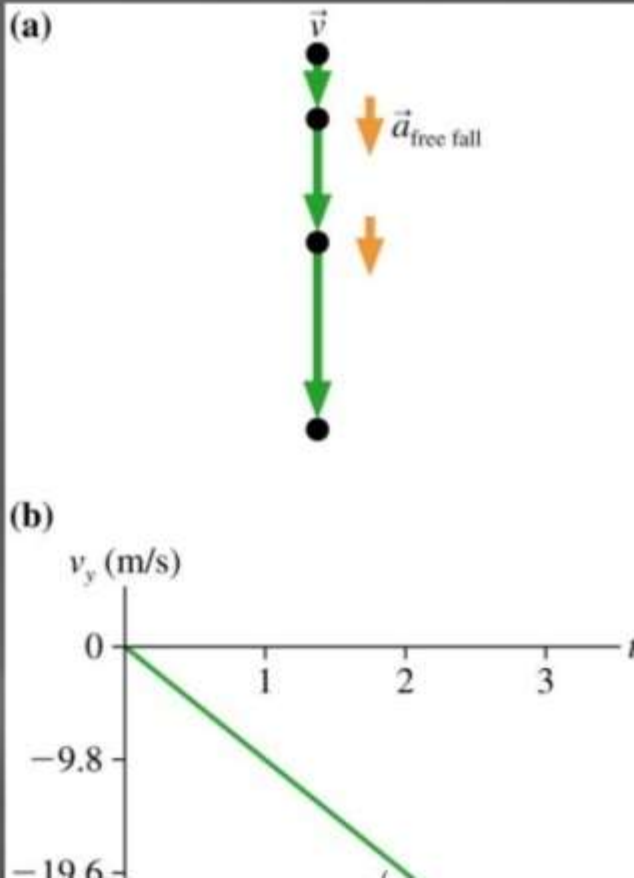
$x - x_o = v_o (t - 0) + a\left(\frac{t^2}{2} - 0\right) = v_o t + a\frac{t^2}{2} \rightarrow$

Free Fall

- Figure (a) shows the motion diagram of an object that was released from rest and falls freely.
- Figure (b) shows the object's velocity graph.
- The velocity graph is a straight line with a slope:

ho!!

$$a_y = a_{\text{free fall}} = -g$$



RELATIVE VELOCITY

- When two bodies are moving in the same direction parallel to each other;

  $v_{ab} = v_a - v_b$

- When two bodies are moving in opposite directions;

  $v_{ab} = v_a + v_b$

- When two bodies make an angle with each other

  $v_{ab} = \sqrt{v_a^2 + v_b^2 + 2v_{ab}\cos\Theta}$

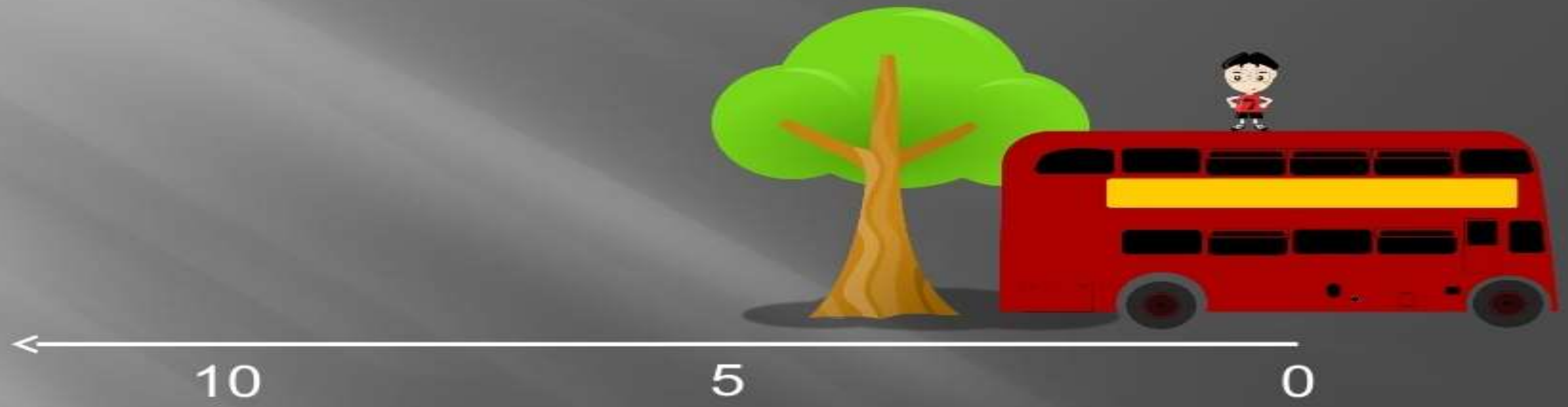
Person outside the bus

The **bus moved** away from the tree

The person is comparing the position of the bus with respect to the position of the tree

Reference (or origin) is position of the tree

Person inside the bus



The **tree moved** away from the bus.

The person is comparing the position of the tree with respect to the position of the bus.

Reference (or origin) is position of the bus.

Motion is relative

Both the observations are correct. The difference is what taken as the origin.

Motion is always relative. When one says that a object i moving, he/she is comparing the position of that object wi another object.

Motion is therefore **change in position** of an object with respect to another object over time.

Kinematics studies motion without delving into what caus the motion.

THANK YOU