Wisdom Education Academy

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Motion

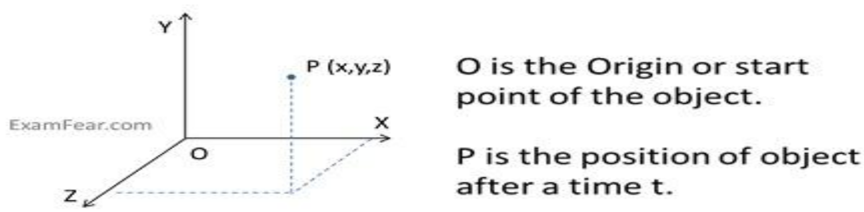
Motion is change in position of an object with time.Motion of object along a straight line is called **rectilinear motion**. Examples include flying kite, moving train, earth's rotation etc.

Objects in some kind of motion

Frame of Reference

In order to know the change in position of an object, a reference point is required. Point O in the figure is the **reference point or Origin** and together with three axes, this system is called the **coordinate system**. A coordinate system with time frame is called **frame of reference**.

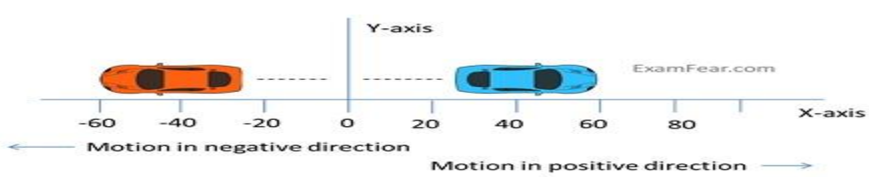
- Objects changing positions with time with respect to the frame of reference are in motion while those which do not change position are at rest.
- For a moving car, for the frame of reference outside the car, it appears moving. While for the frame of reference inside the car, the car appears stationary.



3-dimesional coordinate system

Motion along a straight line

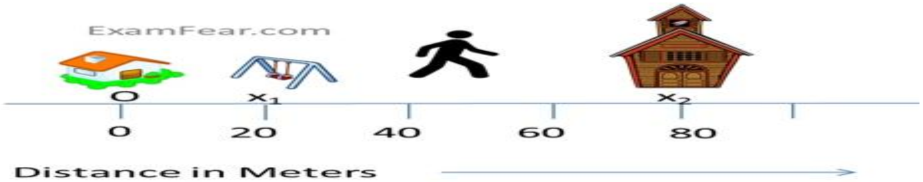
Motion along a straight line is described using only X-axis of the coordinate system.



Path Length (Distance) Vs. Displacement

Path Length: It is the distance between two points along a straight line. It is **scalar** quantity.

Displacement: It is the change in position in a particular time interval. It is **vector** quantity. Change is position is usually denoted by Δx (x_2-x_1) and change in time is denoted by Δt (t_2-t_1).



For the above example, if a person goes from home (O) to school (x_2) and comes back from school to Park (x_1), then

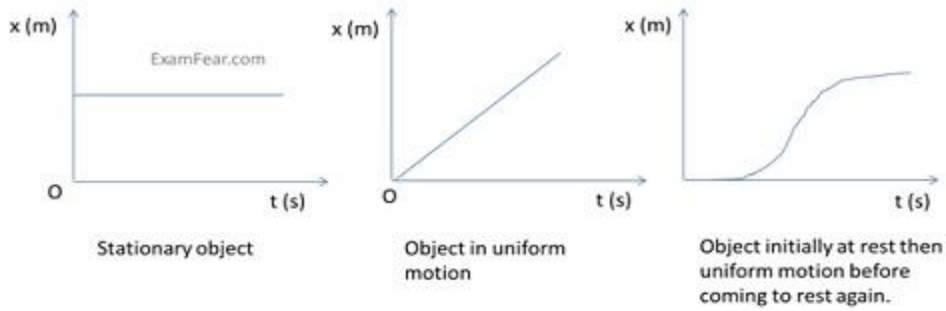
Path length(Home to School and School to Park) = $Ox_2 + x_2x_1$ = (+80) + (+60) = +140m. This is always positive.

Displacement(Home to Park) = $Ox_2 - x_2x_1$ = +80 – (+60) = +20m. This can be positive as well as negative. The negative sign indicates the direction.

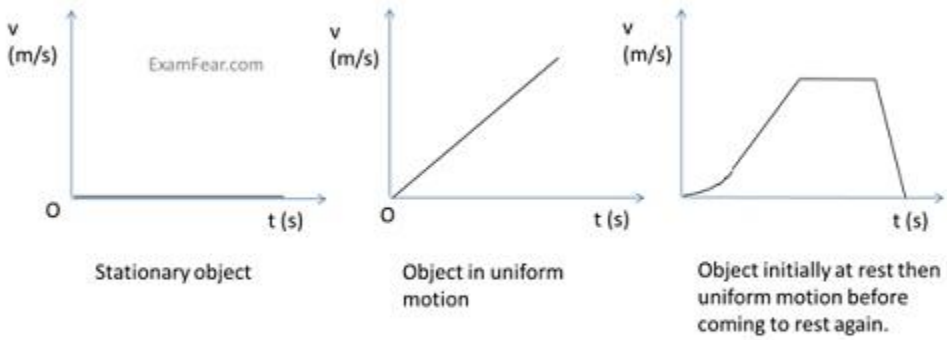
- Magnitude of Displacement may or may not be equal to the path length.
- For a non-zero path length, displacement can be 0 (case where an object returns to origin).

Position-Time, Velocity-Time and Acceleration-Time Graph

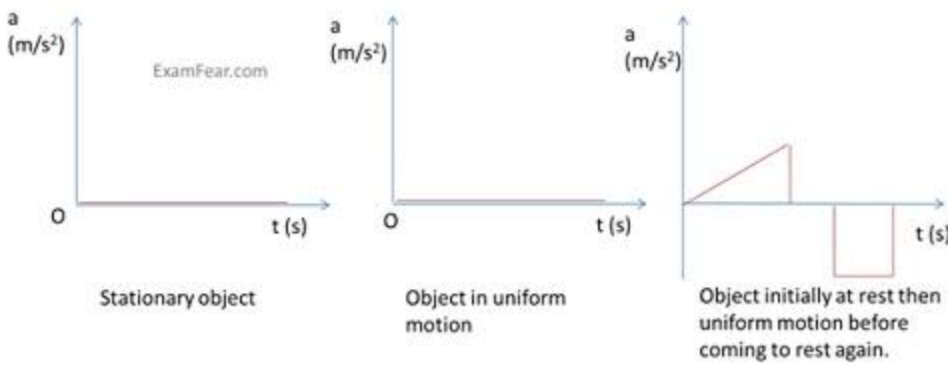
Criteria	**P-T Graph**	**V-T Graph**	**A-T Graph**
X and Y axis	Time and Position	Time and Velocity	Time and Acceleration
Slope	It represents velocity of an object	It represents acceleration of an object.	It represents the jerk or push of a moving object.
Straight slope	Uniform velocity	Uniform acceleration	Uniform jerk
Curvy Slope	Change in velocity	Change in acceleration	Change in the amount of push/jerk



Position-Time (P-T) Graphs for different motions on objects.



Velocity-Time (V-T) Graphs for different motions on objects.

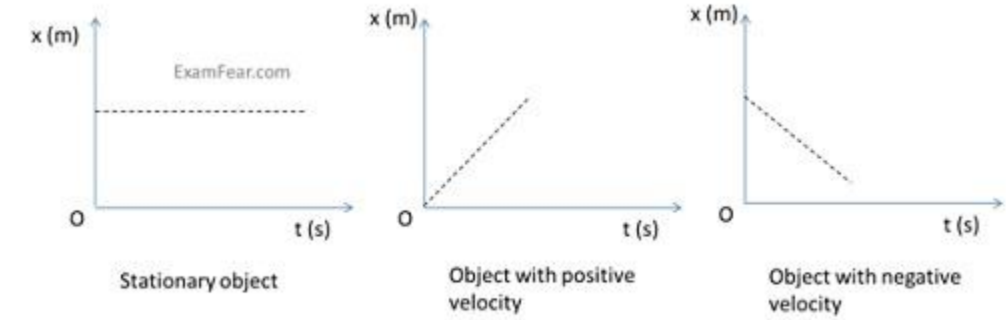


Acceleration-Time (A-T) Graphs for different motions on objects.

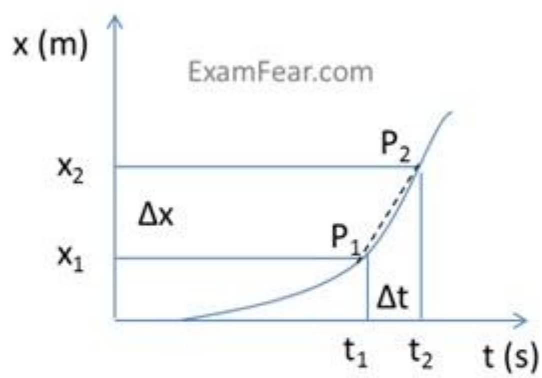
Average Velocity and Average Speed

Criteria	**Average Velocity**	**Average Speed**
Definition	Change in position or displacement divided by time interval.	Total path length travelled divided by total time interval regardless of direction.
Formula		Avg speed = Total path length/Total time interval
Scalar or Vector	Vector	Scalar

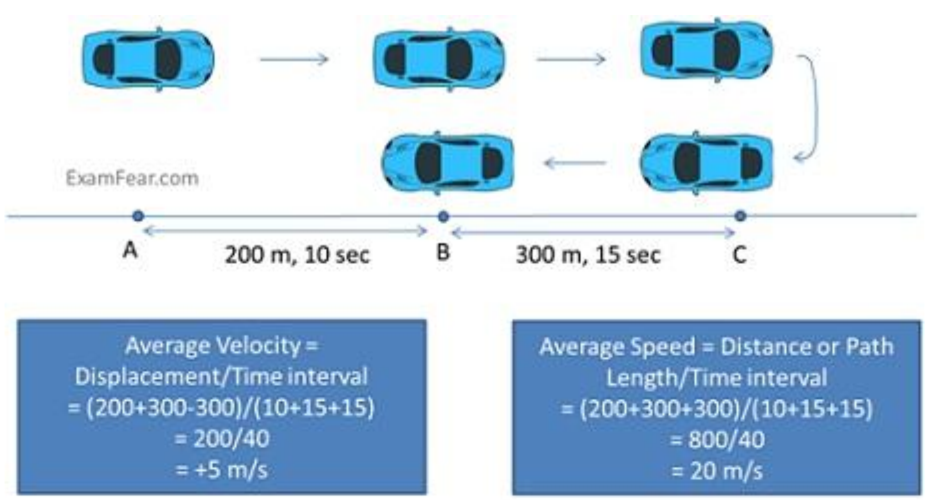
Sign	Can be positive or negative	Always positive
Unit	m/s	m/s



P-T graph of objects with various types of velocities



P-T graph for Average Velocity (slope of line P_1P_2)



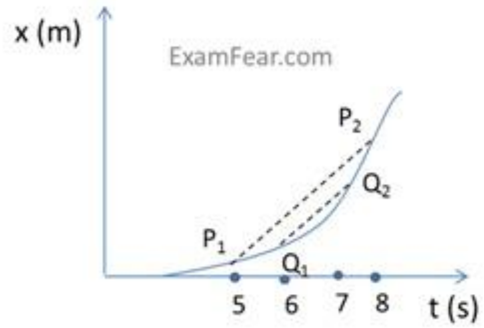
Average velocity and speed example for a car starting from A and coming to stop at B after returning from C.

Instantaneous Velocity and Instantaneous Speed

Instantaneous velocity describes how fast an object is moving at different instants of time in a given time interval. It is also defined as average velocity for an **infinitely small time interval**.

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Here **lim is taking operation of taking limit** with time tending towards 0 or infinitely small. **dx/dt is differential coefficient** – Rate of change of position with respect to time at an instant.



P-T graph for Instantaneous Velocities
Slope P_1P_2 – Velocity at an instant of 3 sec
Slope Q_1Q_2 – Velocity at an instant of 1 sec

Instantaneous speed is the magnitude of velocity. Instantaneous speed at an instant is equal to the magnitude of the instantaneous velocity at that instant.

Acceleration

Acceleration is rate of change of velocity with time. It is denoted by '**a**' and the SI unit is **m/s^2**.

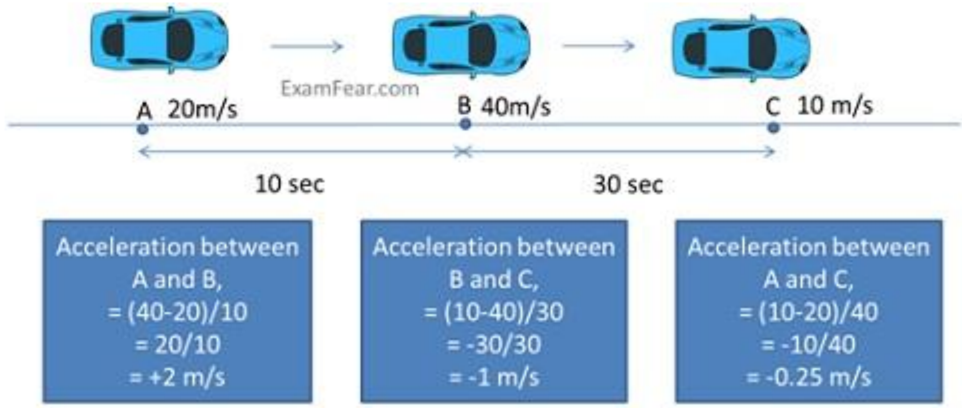
Average acceleration is change of velocity over a time interval.

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

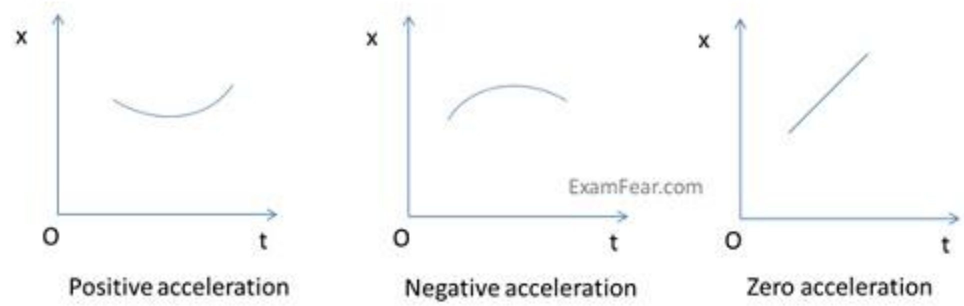
Here v_1 and v_2 are instantaneous velocities at time t_1 and t_2.

- Acceleration can be positive (increasing velocity) or negative (decreasing velocity).
- **Instantaneous acceleration** is acceleration at different instants of time. Acceleration at an instant is slope of tangent to the v-t curve at that instant.

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

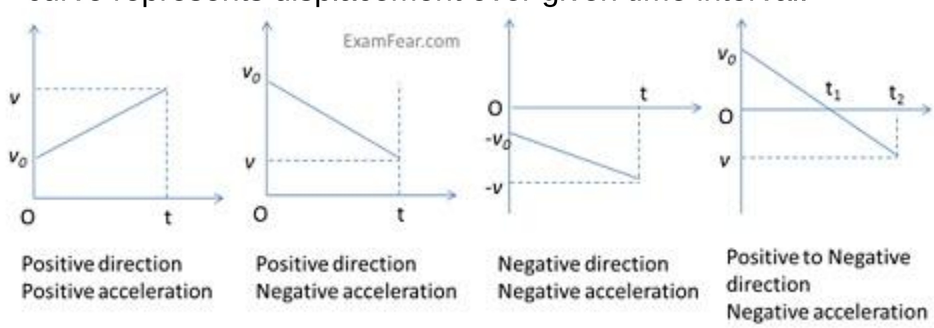


Acceleration at various points for a car moving with different velocities.



Position-Time Graphs depicting acceleration in different types of motion.

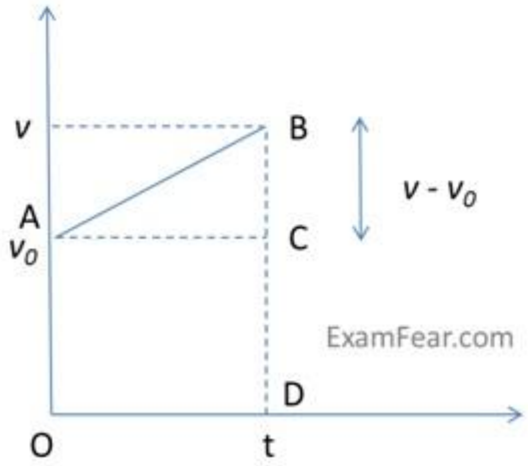
- For a velocity v_0 at time t=0, the velocity v at time t will be, $\boldsymbol{v} = \boldsymbol{v_0} + \boldsymbol{a}$ Area under v-t curve represents displacement over given time interval.



Velocity-Time Graphs for motion with constant acceleration.

- Acceleration and velocity cannot change values abruptly. The changes are continuous.

Kinematic equations for uniformly accelerated motion



Area under v-t curve for an object with uniform acceleration

There are 3 kinematic equations of rectilinear motion for constant acceleration

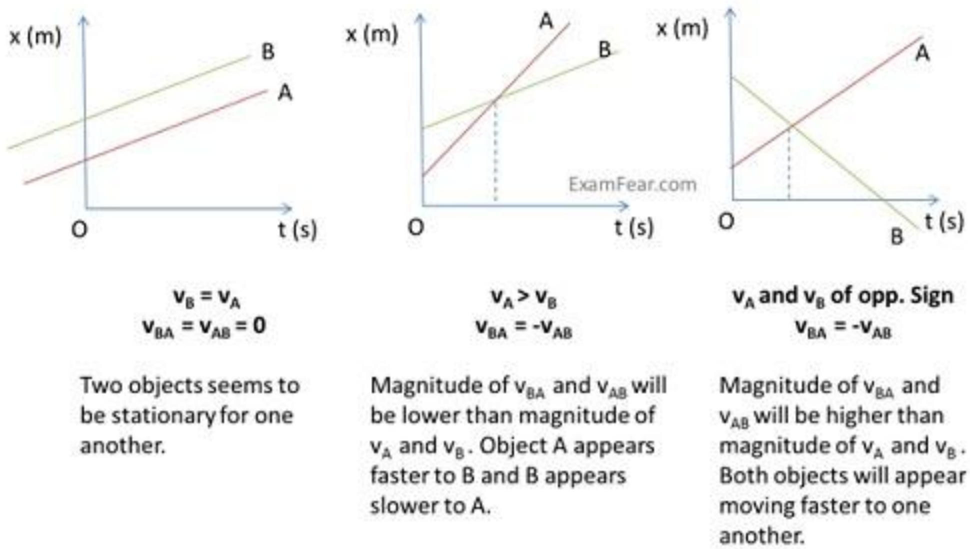
Position of object at time t=0 is 0	Position of object at time t=0 is x_0
$v = v_0 + at$	$v = v_0 + at$
$x = v_0t + ½ at^2$	$x = x_0 + v_0t + ½ at^2$
$v^2 = v_0^2 + 2ax$	$v^2 = v_0^2 + 2a(x-x_0)$

Relative Velocity

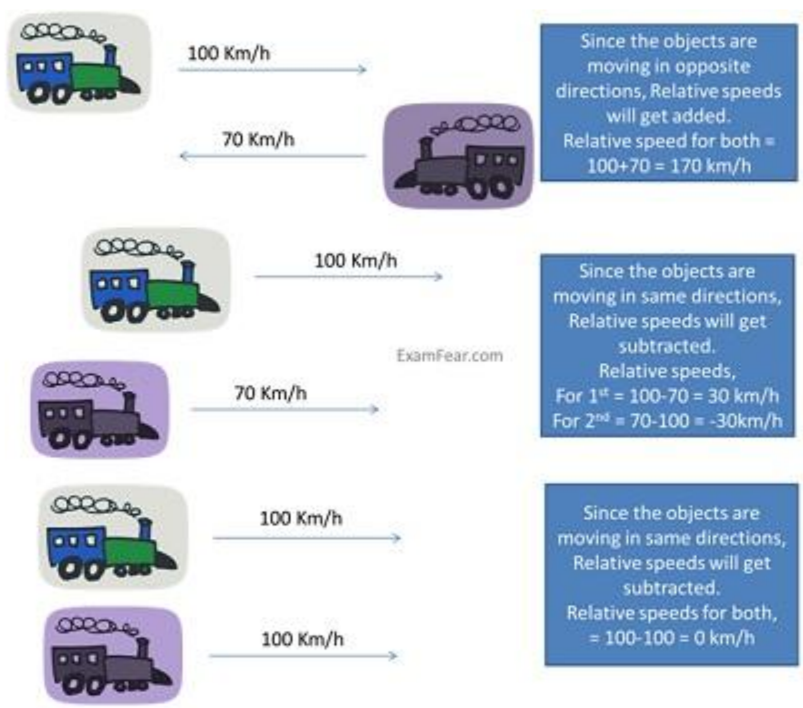
This is the velocity of an object relative to some other object which might be stationary, moving slowly, moving with same velocity, moving with higher velocity or moving in opposite direction.

If initial position of two objects A and B are x_A (0) and x_B (0), the position at time t will be,

- $x_A (t) = x_A (0) + v_A t$
- $x_B (t) = x_B (0) + v_B t$
- Displacement from object A to B, $[x_B (0) - x_A (0)] + (v_B - v_A)t$
- Velocity of B relative to A = $v_{BA} = v_B – v_A$
- Velocity of A relative to B = $v_{AB} = v_A – v_B$



P-T graphs depicting relative velocities



Relative speeds of objects example

Thank You

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Notes provided by

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