Lecture 2

Chapter (2)

Definition of Motion

- Motion represents a continuous change in the position of an object.

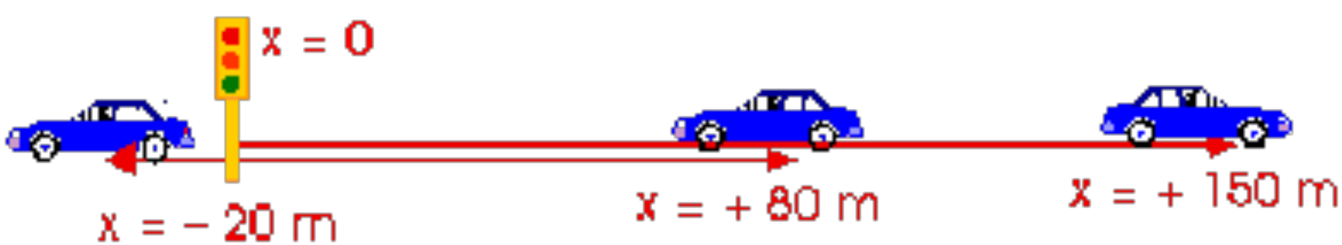
- Example of motion:

  A car moving down a highway.

Particle's Position

- <u>Particle's Position</u> is *the location of the particle with respect to a chosen reference point* that we can consider to be the origin of a coordinate system.

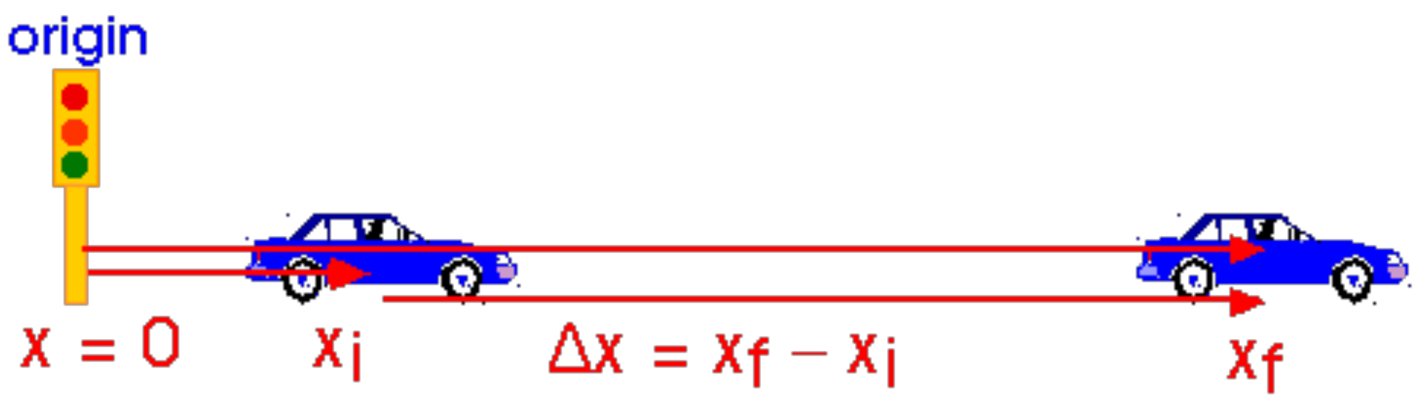
- **Positions to the right of the origin are positive.**
- **Positions to the left of the origin are negative.**



Displacement

- Displacement of a particle Δx is defined as its *change in position* in some time interval.
- **In other word; it is the difference between the final position x_f , and the initial position x_i .**

$$\Delta x = x_f - x_i$$

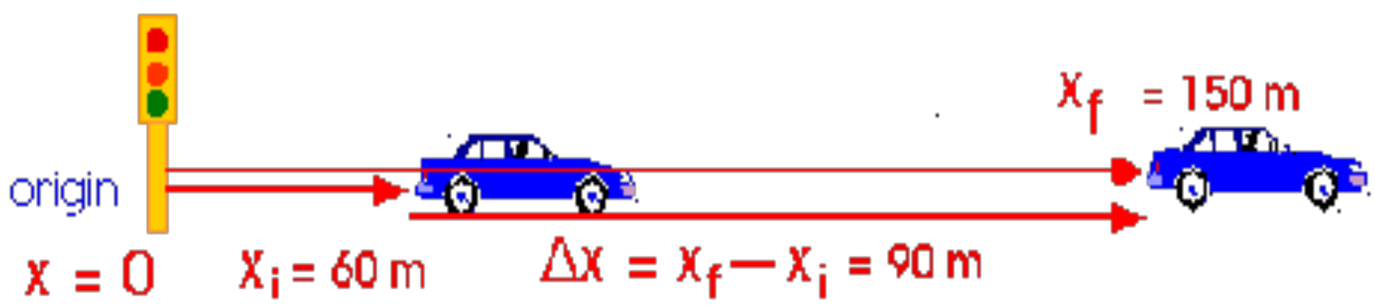


Displacement

- **A displacement to the right will be a positive displacement.**

For example, starting with x_i = 60 m and ending at x_f = 150 m, the displacement is :

$$\Delta x = x_f - x_i = 150\ \text{m} - 60\ \text{m} = 90\ \text{m}$$

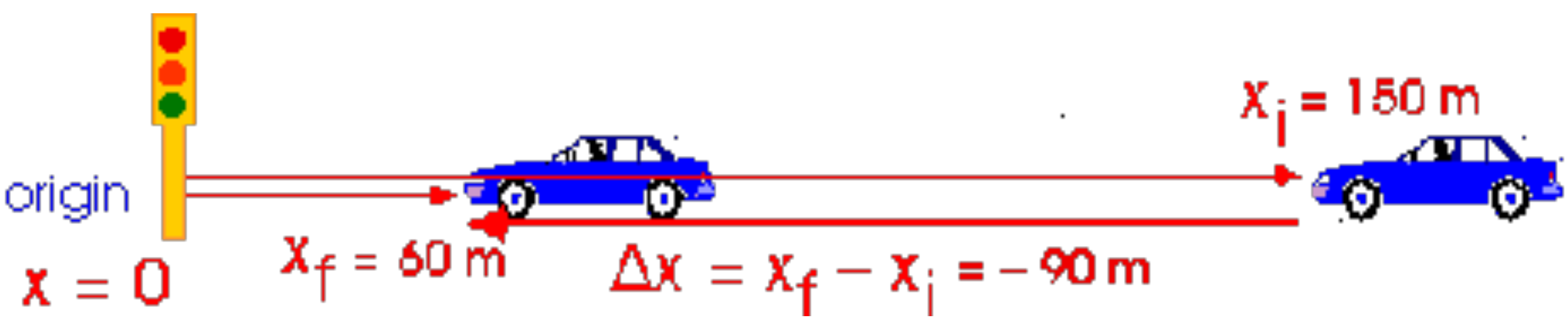


Displacement

- **A displacement to the left will be a negative displacement.**

For example, starting with x_i = 150 m and ending at x_f = 60 m, the displacement is :

$$\Delta x = x_f - x_i = 60\ \text{m} - 150\ \text{m} = -90\ \text{m}$$



Distance and Displacement

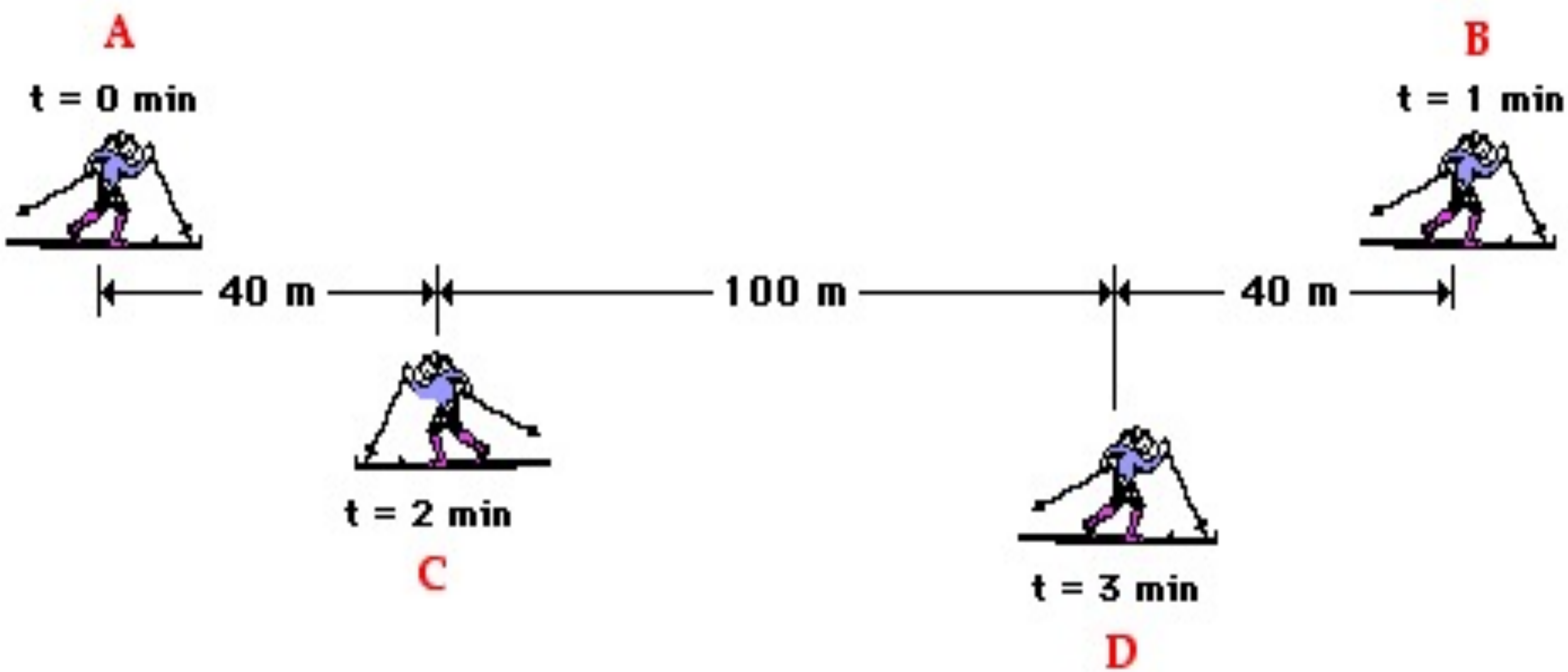
- Distance is the absolute value of the displacement. Distance is always positive and tells how far something is from something else but does not tell us whether it is to the right or to the left.

- Units are important in Physics (and in all of Science). In the lab, we will usually measure distance or displacement in units of meters (m).

- Distance or displacement could also be measured in centimeters (cm) or kilometers (km) or even miles (mi).

Example:

Find the displacement, and the distance between A & D



Ans. :

- Displacement $\Delta x \equiv x_f - x_i$

$$\Delta x = x_D - x_A = 140\text{m} - 0\text{m} = 140\text{m}$$

- Total Distance

$= |\text{Displacement from A to B}| + |\text{Displacement from B to C}|$

$+ |\text{Displacement from C to D}|$

$$= |\Delta x_{A\to B}| + |\Delta x_{B\to C}| + |\Delta x_{C\to D}|$$

Ans. :

- Total Distance $= |x_B - x_A| + |x_C - x_B| + |x_D - x_C|$

$$= |180\text{m} - 0\text{m}| + |40\text{m} - 180\text{m}| + |140\text{m} - 40\text{m}|$$

$$= |180\text{m}| + |-140\text{m}| + |100\text{m}|$$

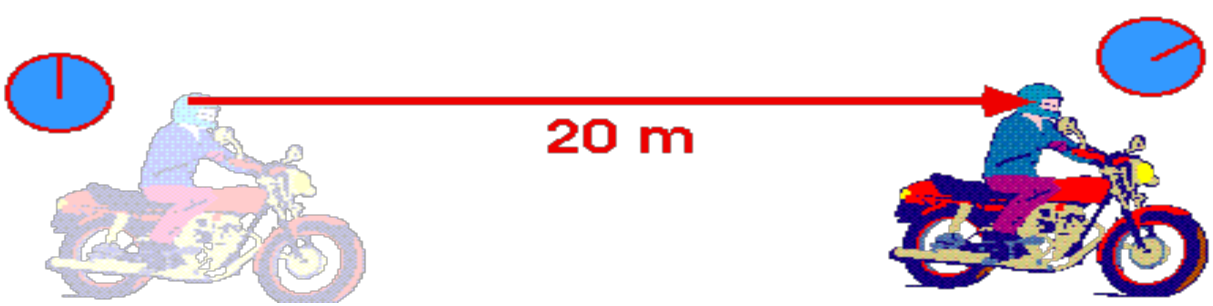
$$= 180\text{m} + 140\text{m} + 100\text{m}$$

$$= 420\text{m}$$

Speed & Velocity

# The average velocity during a time interval t is the displacement Δx divided by the time t : $\vec{v}_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$ # SI Unit: meter per second (m/s) # Velocity is a vector quantity.	# The average speed of an object over a given time interval is defined as the total distance traveled divided by the total time elapsed: $\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$ SI unit: meter per second (m/s) Speed is a scalar quantity.

Speed & Velocity is also measured in km/h (and even in mi/hr).



Speed & Velocity

- **Q. :** If you run from $x = 0$ m to $x = 25$ m and back to your starting point in a time interval of 5 s,

find the **average velocity** & **average speed .**

Ans. :

$$\vec{v}_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

$$\overrightarrow{v_{avg}} = \frac{0m - 0m}{5s} = 0 \text{ m/s}$$

The average Velocity is zero m/s.

Speed & Velocity

Ans. :

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

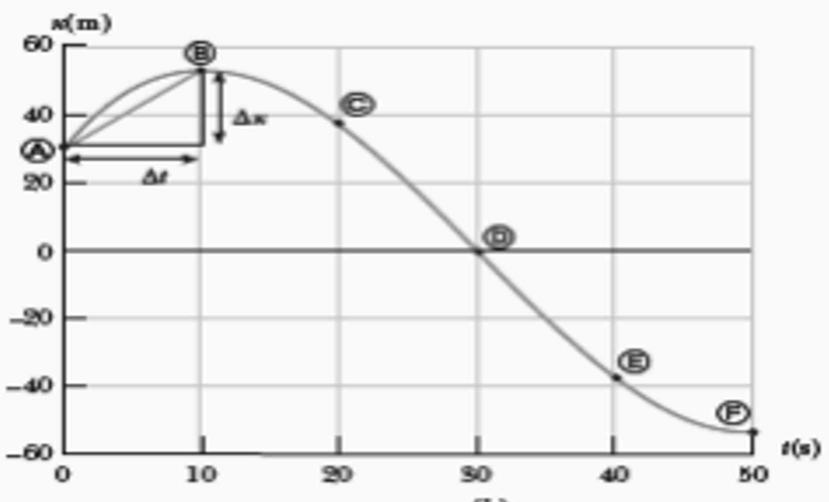
$$\text{Average Speed} = \frac{25\text{m} + 25\text{m}}{5\text{s}} = \frac{50\text{m}}{5\text{s}} = 10\text{m/s}$$

The average Speed is 10 m/s.

Example

Calculating the Average Velocity and Speed

Find the displacement, average velocity, and average speed of the car in the figure between positions A and F.



(b)

TABLE 2.1

Position of the car at various times

Position	t(s)	x(m)
A	0	30
B	10	52
C	20	38
D	30	0
E	40	-37
F	50	-53

Ans. :

$x_A = 30m$ at $t_A = 0s$ and $x_F = -53m$ at $t_F = 50s$

- Displacement:

$$\Delta x = x_F - x_A = -53\text{ m} - 30\text{ m} = \boxed{-83\text{ m}}$$

- Average Velocity:

$$\bar{v}_x = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} = \frac{x_F - x_A}{t_F - t_A}$$

$$= \frac{-53\text{ m} - 30\text{ m}}{50\text{ s} - 0\text{ s}} = \frac{-83\text{ m}}{50\text{ s}}$$

$$= \boxed{-1.7\text{ m/s}}$$

Ans. :

- Applying the Formula to find Total Distance:

$$Total\ Distance = |\Delta x_{A \to B}| + |\Delta x_{B \to C}| + |\Delta x_{C \to D}| + |\Delta x_{D \to E}| + |\Delta x_{E \to F}|$$

$$= |x_B - x_A| + |x_C - x_B| + |x_D - x_C| + |x_E - x_D| + |x_F - x_E|$$

$$= |52m - 30m| + |38m - 52m| + |0m - 38m| + |-37m - 0m|$$

$$+ |-53m - 37m)$$

$$= |22m| + |-14m| + |-38m| + |-37m| + |-16m|$$

$$= 22m + 14m + 38m + 37m + 16m$$

$$= 127m$$

Ans. :

- Total distance traveled:

From the car's position described by the curve, we find that the distance traveled from A to B is 22m plus 105m the distance traveled from B to F for a total of 127m.

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

$$\text{Average speed} = \frac{127\ \text{m}}{50\ \text{s}} = \boxed{2.5\ \text{m/s}}$$

The instantaneous velocity

- The instantaneous velocity v_{inst} *is the velocity right now, at this particular moment.*
- If the velocity is constant :

$$v_{inst} = \overrightarrow{v}_{avg}$$

SI unit : meter per second (m/s)

Acceleration

We are often interested in how fast the velocity is changing. This is the acceleration.

Acceleration is a change of velocity divided by a change of time.

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

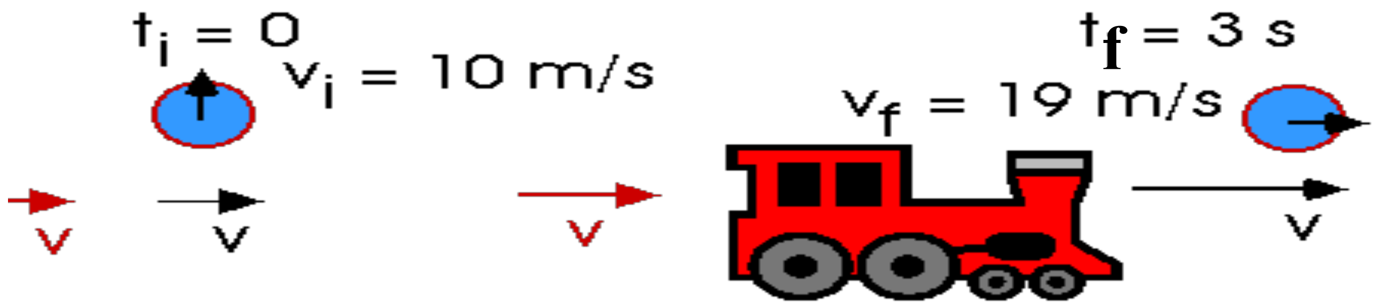
This quantity has units of (meters/second)/second. We will write this as m/s^2 (there are **no** "square seconds")**.**

As with the velocity, we can describe the instantaneous acceleration, the acceleration right now, at this particular moment. If the acceleration is constant :

$$a_{inst} = \vec{a}_{avg}$$

Acceleration

Example: **Find the acceleration from the figure below .**



Ans. :

$$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{(19 - 10)\,m/s}{3\,s} = \frac{9\,m/s}{3\,s} = 3\,\frac{m/s}{s}$$

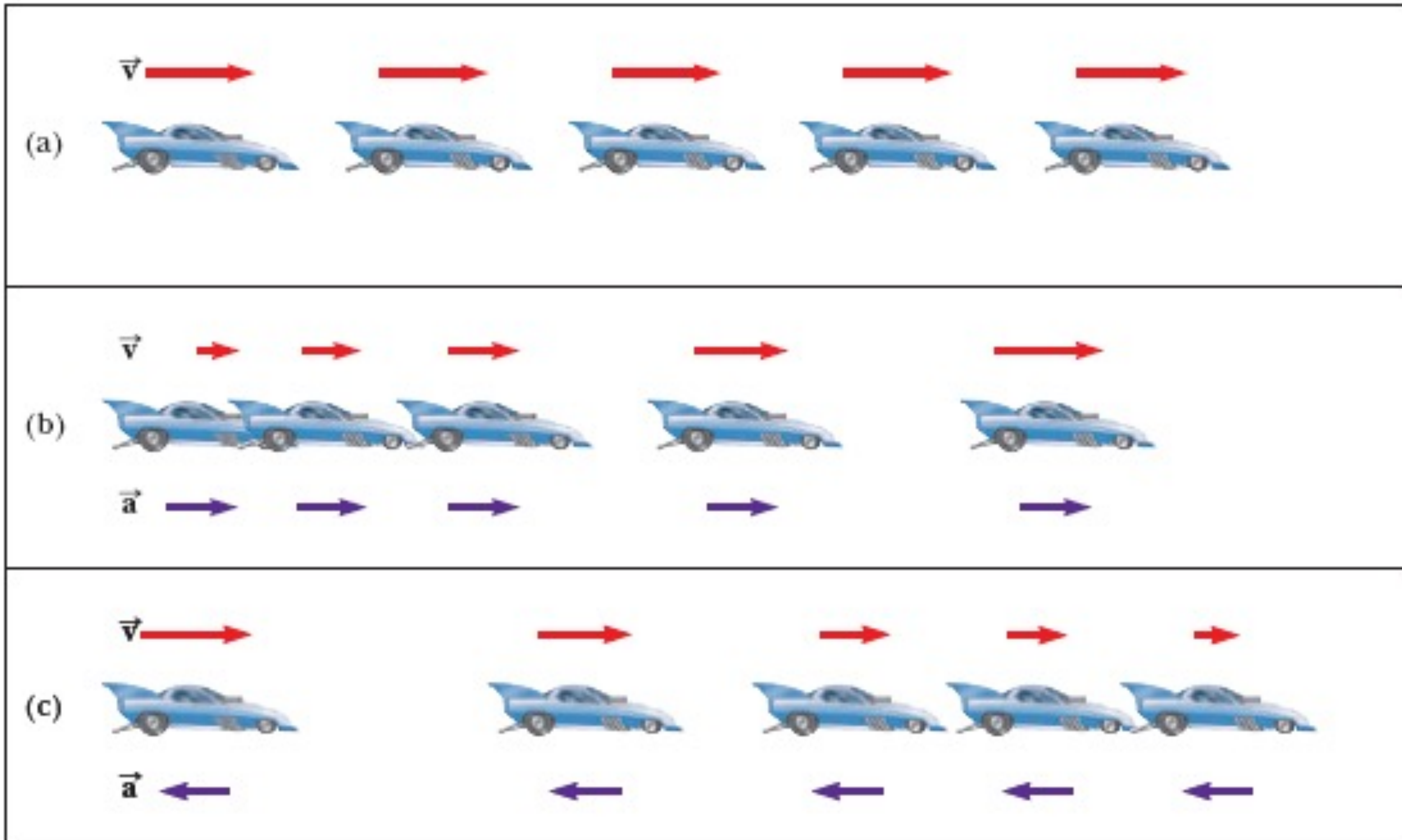
$$a = 3\,m/s/s = 3\,m/s^2$$

Velocity vs Acceleration

- When the object's velocity and acceleration are in the same direction, the object is speeding up.

- On the other hand, when the object's velocity and acceleration are in opposite direction, the object is slowing down.

MOTION DIAGRAMS



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The Four Kinematic Equations

Table 2.2

Kinematic Equations for Motion of a Particle Under Constant Acceleration	
Equation	**Information Given by Equation**
$v_{xf} = v_{xi} + a_x t$	Velocity as a function of time
$x_f = x_i + \frac{1}{2}(v_{xi} + v_{xf})t$	Position as a function of velocity and time
$x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$	Position as a function of time
$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$	Velocity as a function of position

Note: Motion is along the x axis.

<u>Example</u>: **Consider a car that starts at rest and accelerates at 2 m/s² for 3 seconds.**

At that time, t = 3 s, <u>how fast</u> is it going? and <u>how far</u> has it gone?

<u>Ans. :</u>

$$v_{xf} = v_{xi} + a_x t$$

$$v = a\,t$$

$$v = (2\,{}^{m}/_{s^2})(3\ s)$$

$$v = 6\,{}^{m}/_{s}$$

$$x_f = x_i + v_{xi}t + \tfrac{1}{2}a_x t^2$$

$$x = {}^{1}/_{2}\,a\,t^2$$

$$x = {}^{1}/_{2}(2\,{}^{m}/_{s^2})(3\ s)^2$$

$$x = 9\ m$$

Homework

Problem 1:

The velocity of a particle moving along the x-axis varies according to the expression $v_x = (40 - 5t^2)$ m/s, where t is in seconds.

Find the average acceleration in the time interval

$t = 0$ to $t = 2.0$ s.

Homework

Problem 2:

- Carrier Landing

A jet lands on an aircraft carrier at 140 mi /h (≈ 63 m/s).

a) What is its acceleration (assumed constant) if it stops in 2.0 s ?

b) If the plane touches down at position $x_i = 0$, what is the final position of the plane ?