Lecture Notes

(Position & Velocity Time Graphs)

Intro:

- in day-to-day usage, the terms speed and velocity are interchangeable; in physics, however, there's a clear distinction between them

- speed is a scalar quantity, having only magnitude, while velocity is a vector, having both magnitude and direction

Speed:

- one of the most obvious characteristics of an object in motion is how fast it is moving; this is an object's speed, v

$$\text{speed, } v = \frac{\text{distance (m)}}{\text{time (s)}}$$

- speed is the rate at which distance is covered and is always measured in terms of a unit of distance by a unit of time

- because objects do not always move at the same speed we often use the average speed, $\bar{v}$, of an object

- the average speed is the total distance traveled, divided by the time required to cover the distance Ex. if a car travels 200 m in 10 seconds, we say its average speed is 20 m/s

$$\text{avg. speed, } \bar{v} = \frac{\text{total distance covered (m)}}{\text{time (s)}}, \quad \bar{v} = \frac{\Delta d}{\Delta t}$$

- note that the symbol for average speed has a bar above it; do not confuse this with the arrow over a symbol which stands for a vector quantity

- because total distance and total time are always positive, the average speed will be positive, also

- the unit of speed is m/s

<u>Velocity</u>:

- most people use the words speed and velocity interchangeably; strictly speaking, however, there is a distinction between the two

- when we say that something is traveling 60 km/hr we are specifying its speed; however, when we say an object is traveling 60 km/hr due north we are specifying its velocity

- when we describe speed and the direction of motion, we are specifying <u>velocity</u>, $\boldsymbol{v}$ or $\vec{v}$; the first symbol is bold faced showing that this the vector quantity velocity and not the scalar quantity speed

- <u>average velocity</u> is a vector quantity that points in the same direction as the displacement of the object being studied; it is the change in displacement divided by the time

- because displacement and velocity are both vector quantities, they can be related in the same way that speed and distance are related; time is a scalar quantity

$$\text{avg. velocity,} \quad \bar{\boldsymbol{v}} = \frac{\text{displacement (m)}}{\text{time (s)}}, \quad \bar{\boldsymbol{v}} = \frac{\Delta \boldsymbol{d}}{\Delta t}$$

- remember that the velocity can change during the time interval
  Ex. in driving your car to Dallas, you may average 50 mph, but that does not mean you are actually driving that speed the entire time

- avg. velocity does not reveal the velocity for any one moment of time; the speed and direction of an object at a particular instant in time is called the instantaneous velocity

- instantaneous velocity is represented by the symbol v, with no bar on top

- when we say that something is moving at constant velocity or constant speed, the we are saying that the object is covering equal distances in equal intervals of time

- constant velocity and constant speed can mean different things

- constant velocity means constant speed with no change in direction; Ex. a car that rounds a curve at a constant speed does not have a constant velocity, its velocity changes as its direction changes

Fig.1.4 Why doesn't the sign say "Velocity Limit"?

Acceleration:

- going from place to place in your car, you rarely travel long distances at constant velocity; the velocity of the car increases when you step harder on the gas pedal and decreases when you apply the brakes

- the velocity also changes when you round a curve, altering your direction of motion

- the changing of an object's velocity with time is called acceleration

- acceleration is a two part concept that arises due to a change in the direction of the velocity or because of a change in the magnitude of the velocity (speed) or both

- Ex. 1 a racehorse running faster and faster on a straightaway is accelerating because its speed is changing

- Ex. 2 a merry-go-round horse revolving at constant speed is also accelerating, because the direction of its motion is forever changing

- whenever an object moves along a curved path, its velocity vector changes direction and its acceleration will not be parallel to the direction of motion

- in our study of acceleration in this chapter, however, we will study the simpler situation of rectilinear motion; motion where velocities and accelerations occur along the same straight line Ex. a falling rock

- for the case of motion in a straight line, the direction of the velocity of an object and the direction of its acceleration are related as follows:
    1. When the object's velocity and acceleration are in the same direction, the speed of the object increases with time.

    2. When the object's velocity and acceleration are in opposite directions, the speed of the object decreases with time.

- acceleration specifies how rapidly the velocity of an object is changing

- the <u>average acceleration</u> of a body is defined as the ratio of the change in its velocity over the time elapsed in the process

$$\text{avg. acceleration,} \quad \bar{\boldsymbol{a}} = \frac{\text{velocity (m/s)}}{\text{time (s)}}, \quad \bar{\boldsymbol{a}} = \frac{\Delta \boldsymbol{v}}{\Delta t}$$

- acceleration is a vector quantity and is measured in units of (m/s^2)

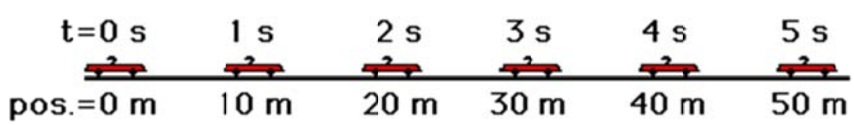
$$\text{units} = \frac{\frac{m}{s}}{s} = \left(\frac{m}{s}\right) \times \frac{1}{s} \text{ or } \frac{m}{s^2}$$

<u>Position-Time Graphs</u>:

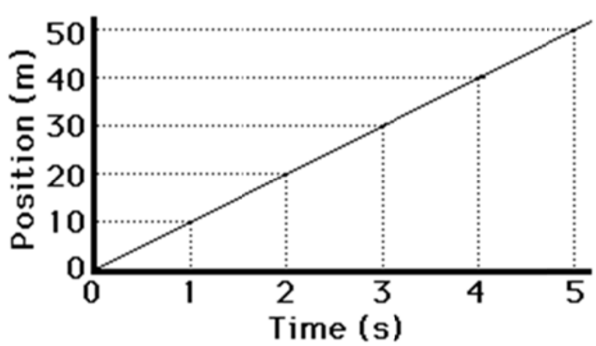
- a position-time graph will allow you to demonstrate motion in one dimension

- the specific features of the motion of objects are demonstrated by the shape and the slope of the lines on a position-time graph

- to begin, consider a car moving with a constant, rightward (+) velocity of 10 m/s

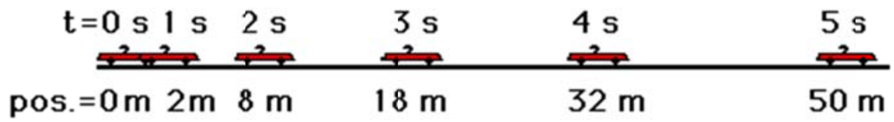


- if the position-time data for such a car were graphed, the resulting graph would look like the graph at the right

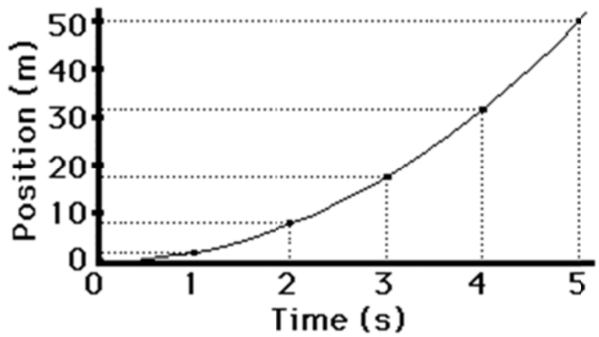


- note that a motion with constant, positive velocity results in a line of constant and positive slope when plotted as a position-time graph

- now consider a car moving with a changing, rightward (+) velocity – that is, a car that is moving rightward and speeding up or accelerating

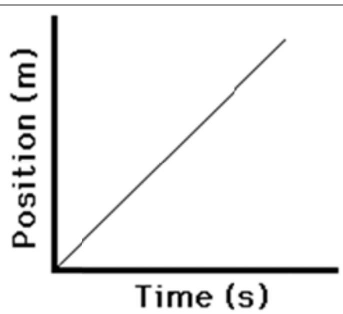
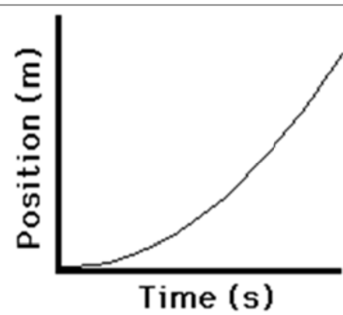


- if the position-time data for such a car were graphed, the resulting graph would look like the graph at the right



- note that a motion with changing, positive velocity results in a line of changing and positive slope when plotted as a position-time graph

- the position vs. time graphs for the two types of motion – constant velocity and changing velocity (acceleration) – are depicted as follows:

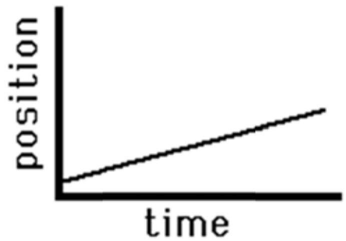
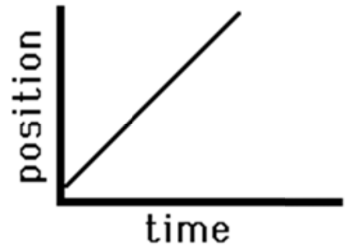
Positive Velocity (Constant Velocity)	Positive Velocity (Acceleration)
	

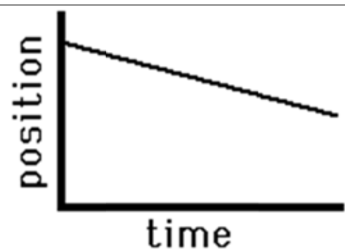
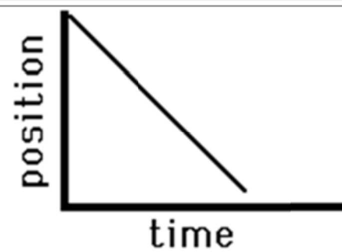
- the slope of the line on a position-time graph reveals useful information about the velocity of the object

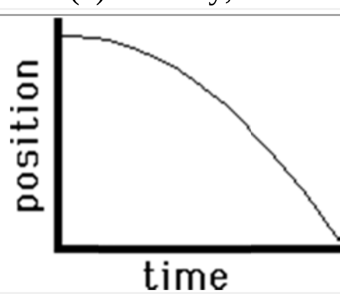
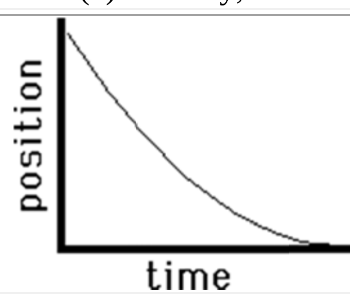
- if the velocity is constant, then the slope is constant (i.e., a straight line)

- if the velocity is changing, then the slope is changing (i.e., a curved line)

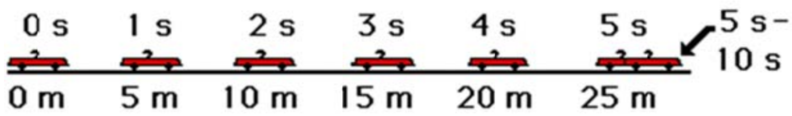
- if the velocity is positive, then the slope is positive (i.e., moving upwards and to the right)

Slow, Rightward (+) Constant Velocity	Fast, Rightward (+) Constant Velocity
	

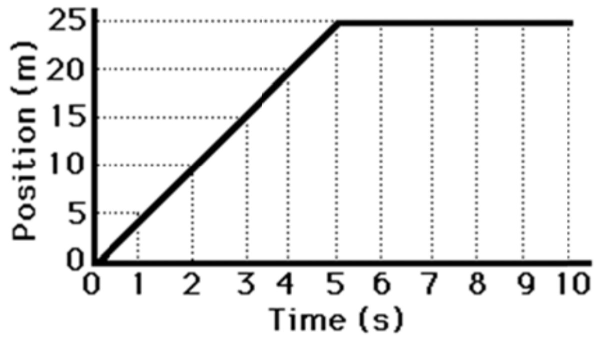
Slow, Leftward (–) Constant Velocity	Fast, Leftward (–) Constant Velocity
	

Leftward (–) Velocity; Slow to Fast	Leftward (–) Velocity; Fast to Slow
	

- consider a car moving with a constant velocity of +5 m/s for 5 seconds, stopping abruptly, and then remaining at rest (***v*** = 0 m/s) for 5 seconds



- for the first five seconds, the line on the graph goes up 5 meters along the vertical (position) axis for every 1 second along the horizontal (time) axis; that is, the line on the position vs. time graph has a slope of +5 meters/1 second for the first five seconds



- during the last 5 seconds (5 to 10 seconds), the line goes up 0 meters

- the slope of the line on a position-time graph is equal to the velocity of the object

- if the object is moving with a velocity of +4 m/s, then the slope of the line will be +4 m/s; if the object is moving with a velocity of -8 m/s, then the slope of the line will be -8 m/s

Calculating the Slope:

- the slope of a line is found by dividing the amount of rise of the line between any two points by the amount of run of the line between the same two points

Slope: $m = \frac{rise}{run} = \frac{\Delta y}{\Delta x} = \frac{y_f - y_i}{x_f - x_i}$

Uniform Motion Equation:

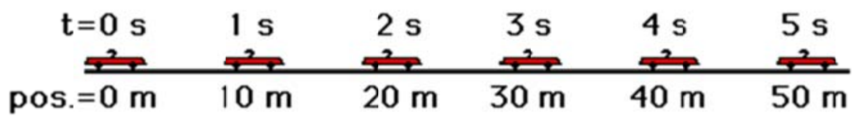
- if we rearrange the average velocity equation $\bar{\boldsymbol{v}} = \frac{\Delta \boldsymbol{d}}{\Delta t}$, we can solve for the position of an object with constant velocity

- we can rewrite the equation as: $\boldsymbol{d}_f = \boldsymbol{d}_i + \boldsymbol{v}t$

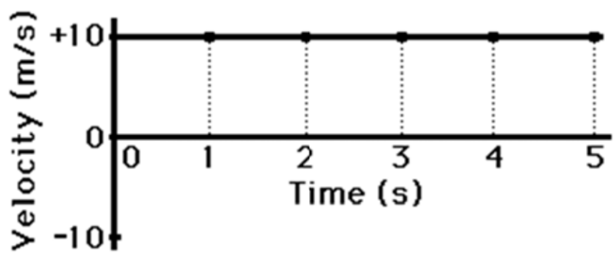
  $\boldsymbol{d}_i$ = initial position
  $\boldsymbol{v}$ = constant velocity
  t = time
  $\boldsymbol{d}_f$ = position at that time

Velocity-Time Graphs:

- consider a car moving with a constant, rightward (+) velocity of +10 m/s.; in the last lecture, we learned that a car moving with a constant velocity is a car moving with zero acceleration



- if the velocity-time data for such a car were graphed, the resulting graph would look like the graph at the right

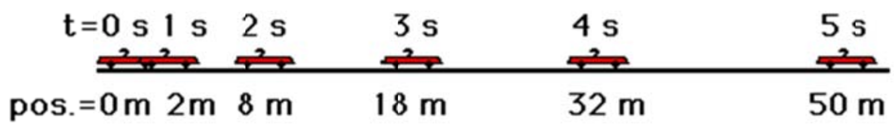


- note that a motion with constant, positive velocity results in a line of zero slope

- a horizontal line has zero slope when plotted as a velocity-time graph; furthermore, only positive velocity values are plotted, corresponding to a motion with positive velocity

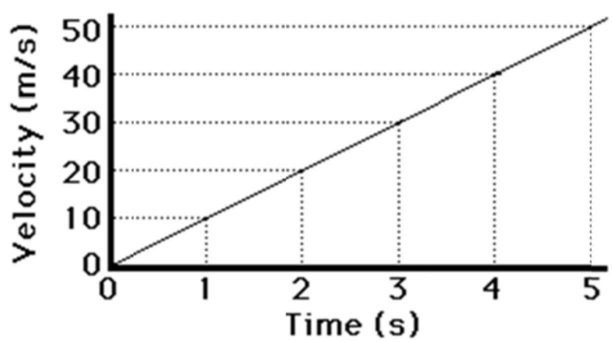
- now consider a car moving with a rightward (+), changing velocity – that is, a car that is moving rightward and speeding up or accelerating

- since the car is moving in the positive direction and speeding up, it is said to have a positive acceleration



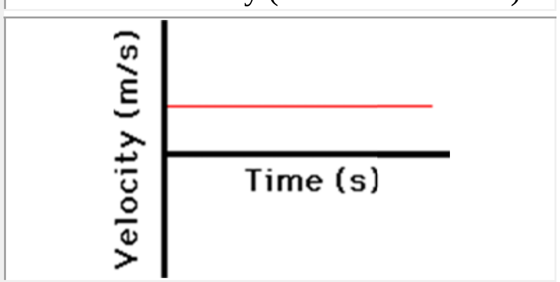
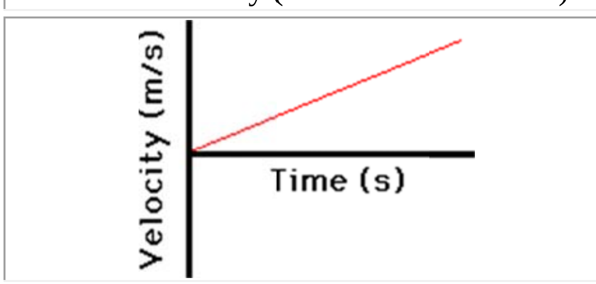
- if the velocity-time data for such a car were graphed, the resulting graph would look like the graph below

- note that a motion with changing, positive velocity results in a diagonal line when plotted as a velocity-time graph



- the slope of this line is positive, corresponding to the positive acceleration; in addition, only positive velocity values are plotted, corresponding to a motion with positive velocity

- the velocity-time graphs for the two types of motion – constant velocity and changing velocity (acceleration) – can be summarized as follows:

Positive Velocity (Zero Acceleration)	Positive Velocity (Positive Acceleration)
	

- the slope of the line on a velocity-time graph reveals the acceleration of an object

- if the acceleration is zero, then the slope is zero (i.e., a horizontal line)

- if the acceleration is positive, then the slope is positive (i.e., an upward sloping line)

- if the acceleration is negative, then the slope is negative (i.e., a downward sloping line)

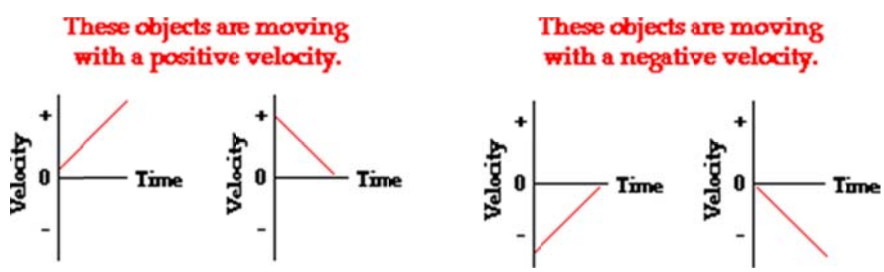
- the velocity is positive whenever the line lies in the positive region (positive y-values, i.e. above the x-axis) of the graph

- the velocity is negative whenever the line lies in the negative region (negative y-values, i.e. below the x-axis) of the graph

- if an object is moving in the positive direction, the line is located in the positive region of the velocity-time graph (regardless if it is sloping up or sloping down)

- if an object is moving in the negative direction if the line is located in the negative region of the velocity-time graph (regardless if it is sloping up or sloping down)

- if a line crosses the x-axis from the positive region to the negative region of the graph (or vice versa), then the object has changed directions



- if the line is moving away from the x-axis (the 0-velocity point), then the object is speeding up

- if the line is moving towards the x-axis, the object is slowing down