Chapter 3:
LINEAR MOTION

Objectives of this lecture:

- Motion Is Relative
- Speed : Average and Instantaneous
- Velocity: Constant and Changing
- Acceleration
- Free Fall
- Hang Time

Motion Is Relative

Motion of objects is always described as *relative* to something else. For example:

- You walk on the road relative to Earth, but Earth is moving relative to the Sun.
- So your motion relative to the Sun is different from your motion relative to Earth.

Speed

- Defined as the distance covered per amount of travel time.
- Units are meters per second.
- In equation form:

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

Example: A man runs 3 meters in 2 sec. His speed is 1.5 m/s.

Average Speed

- The <u>entire distance</u> covered divided by the <u>total travel time</u>
  - Does not indicate various instantaneous speeds along the way.
- In equation form:

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

Example: When you drive a distance of 200 km in 2 h, your average speed is 100 km/h.

The average speed of driving 30 km in 1 hour is the same as the average speed of driving

A. 30 km in 1/2 hour.

B. 30 km in 2 hours.

C. 60 km in 1/2 hour.

D. 60 km in 2 hours.

The average speed of driving 30 km in 1 hour is the same as the average speed of driving

A. 30 km in 1/2 hour.

B. 30 km in 2 hours.

C. 60 km in 1/2 hour.

D. **60 km in 2 hours**.

Explanation:

Average speed = total distance / time

So, average speed = 30 km / 1 h = 30 km/h.

Same

Now, if we drive 60 km in 2 hours:

Average speed = 60 km / 2 h = 30 km/h

Instantaneous Speed

Instantaneous speed is the speed at any instant.

Example:

- When you ride in your car, you may speed up and slow down.
- Your instantaneous speed is given by your speedometer.

Figure 3.2

20
40
60
80
100
120
140
20
40
60
80
100
120
140
160
180
200
220
MPH
km/h

TABLE 3.1
Approximate Speeds in Different Units

12 mi/h =	20 km/h =	6 m/s
25 mi/h =	40 km/h =	11 m/s
37 mi/h =	60 km/h =	17 m/s
50 mi/h =	80 km/h =	22 m/s
62 mi/h =	100 km/h =	28 m/s
75 mi/h =	120 km/h =	33 m/s
100 mi/h =	160 km/h =	44 m/s

Velocity

- A description of
  - the instantaneous speed of the object AND
  - what <u>direction</u> the object is moving
- Velocity is a <u>vector</u> quantity. It has
  - magnitude: instantaneous speed
  - direction: direction of object's motion

Speed and Velocity

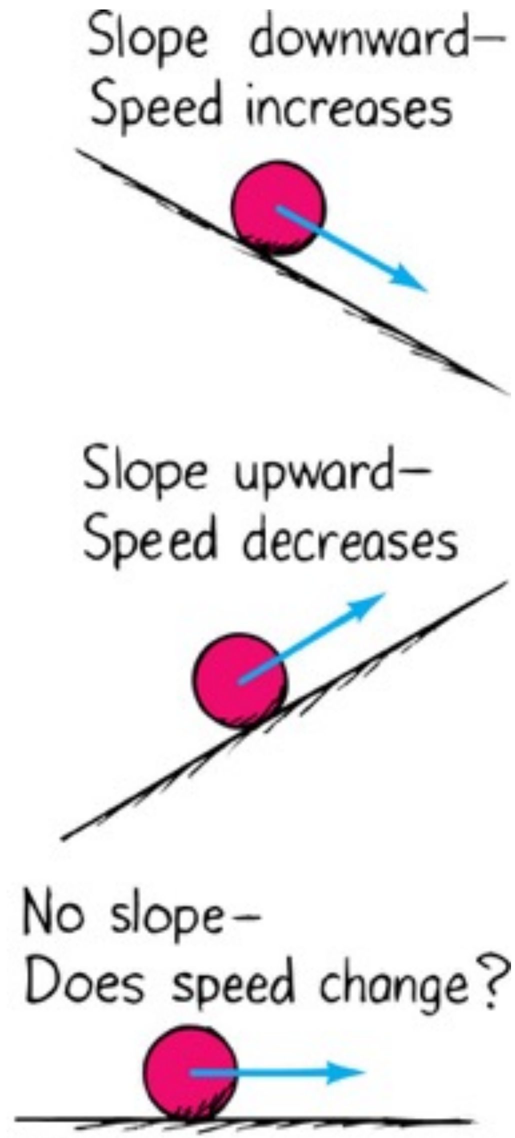
- Constant speed is steady speed, neither speeding up nor slowing down.
- Constant velocity is
  - <u>constant speed</u> and
  - <u>constant direction</u> (straight-line path with no acceleration).

Motion is relative to Earth, unless otherwise stated.

Acceleration

Formulated by Galileo based on his experiments with inclined planes.

Acceleration is the rate at which velocity changes over time.



Acceleration

Involves a

- change in speed, or
- change in direction, or
- both.

Example: Car making a turn

Acceleration

In equation form:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

Unit of acceleration is unit of velocity / unit of time.

Example:

- You car's speed right now is 40 km/h.
- Your car's speed 5 s later is 45 km/h.
- Your car's change in speed is 45 – 40 = 5 km/h.
- Your car's acceleration is 5 km/h/5 s = 1 km/hs.

What is the acceleration of a race car that passes you at a constant velocity of 300km/s ?

A. 300 km/s^2
B. zero
C. 150 km/s^2
D. None of the above

What is the acceleration of a race car that passes you at a constant velocity of 300km/s ?

A. 300 km/s^2
B. **zero**
C. 150 km/s^2
D. None of the above

Explanation: because velocity doesn’t change.

Acceleration and velocity are actually

A. the same.

B. rates but for different quantities.

C. the same when direction is not a factor.

D. the same when an object is freely falling.

Acceleration and velocity are actually

A. the same.

B. **rates but for different quantities.**

C. the same when direction is not a factor.

D. the same when an object is freely falling.

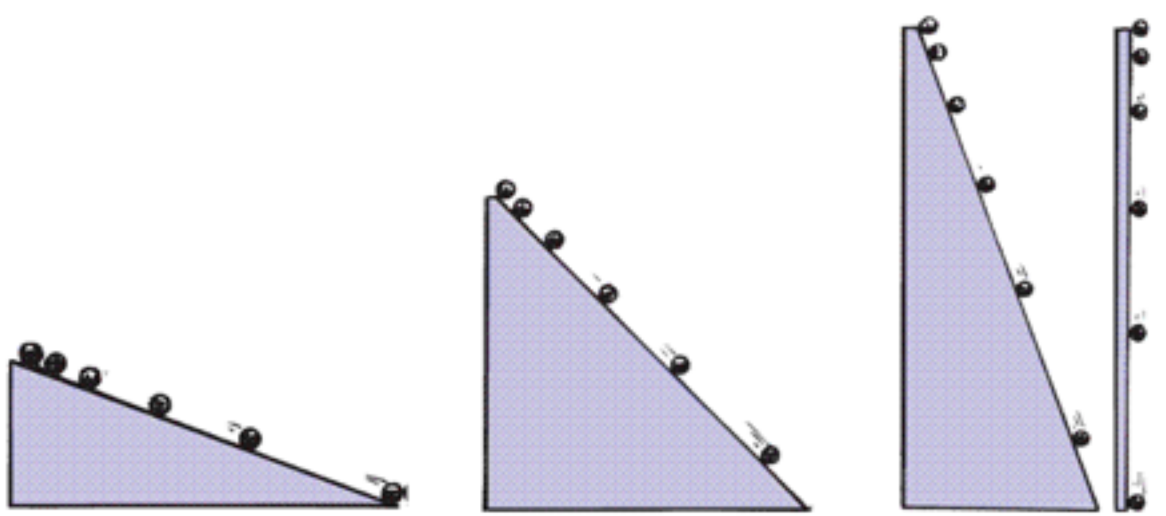
Explanation:

- Velocity is the rate at which distance changes over time,
- Acceleration is the rate at which velocity changes over time.

Acceleration

Galileo increased the inclination of inclined planes.

- Steeper inclines gave greater accelerations.
- When the incline was vertical, acceleration was max, same as that of the falling object.
- When air resistance was negligible, all objects fell with the same unchanging acceleration.



Free Fall

Falling under the influence of gravity only - with no air resistance

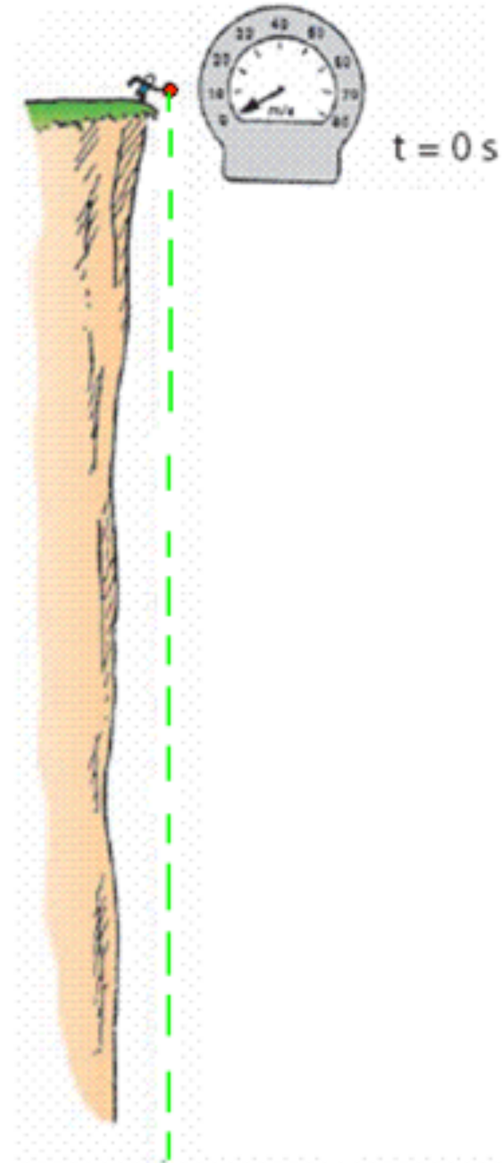
- Freely falling objects on Earth accelerate at the rate of 10 m/s^2 (more precisely, 9.8 m/s^2).

Free Fall—How Fast?

The velocity acquired by an object starting from rest is

Velocity = acceleration x time

$$V = g\,t$$



So, under free fall, when acceleration is 10 m/s^2, the speed is

- 10 m/s after 1 s.
- 20 m/s after 2 s.
- 30 m/s after 3 s.

And so on.

A free-falling object has a speed of 30 m/s at one instant. Exactly 1 s later its speed will be

A. the same.
B. 35 m/s.
C. more than 35 m/s.
D. 60 m/s.

A free-falling object has a speed of 30 m/s at one instant. Exactly 1 s later its speed will be

A. the same.

B. 35 m/s.

C. **more than 35 m/s.**

D. 60 m/s.

Explanation:

One second later its speed will be 40 m/s, because the object gains 10 m/s after every second.

So, at a given instance, if its speed = 30m/s, then a second later, the speed = 30 m/s + 10 m/s = 40 m/s > 35 m/s.

Free Fall—How Far?

The distance covered by an accelerating object starting from rest is

Distance = (1/2) x acceleration x time x time

$$d = (1/2)\, g\, t^2$$

So, under free fall, when acceleration is 10 m/s^2, the distance is

- 5 m after 1 s.
- 20 m after 2 s.
- 45 m after 3 s.

And so on.

What is the distance covered of a freely falling object starting from rest after 4 s?

A. 4 m
B. 16 m
C. 40 m
D. 80 m

What is the distance covered of a freely falling object starting from rest after 4 s?

A. 4 m
B. 16 m
C. 40 m
D. **80 m**

Explanation:

Distance = (1/2) x acceleration x time x time

So: Distance = (1/2) x 10 m/s^2 x 4 s x 4 s

So: Distance = 80m

Hang Time

Vertical height $d = (1/2)\, g\, t^2$

Time $t = \sqrt{\dfrac{2d}{g}}$

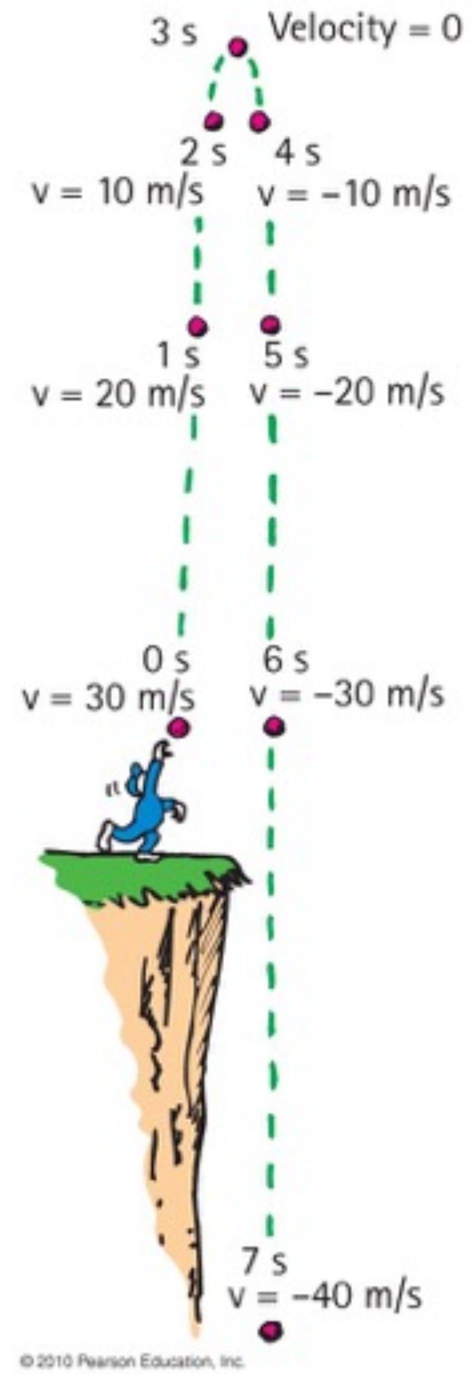
This is time up or time down

Hang time = time up + time down

Chapter 3- Problem (2)

A ball is tossed with enough speed straight up so that it is in the air several seconds.

(a)What is the velocity of the ball when it reaches its highest point?



Chapter 3- Problem (2)

A ball is tossed with enough speed straight up so that it is in the air several seconds.

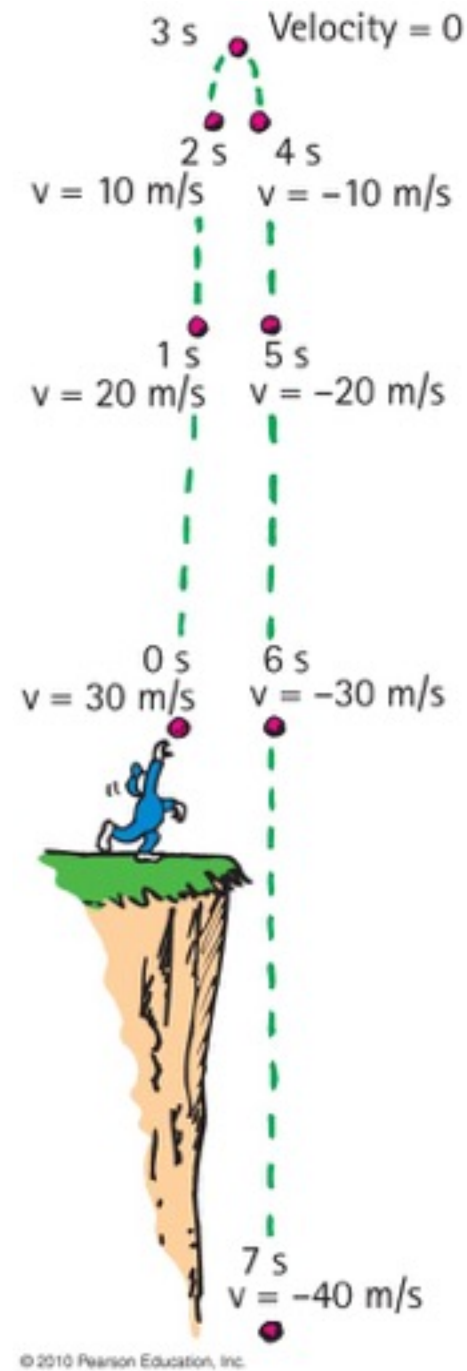
(a)What is the velocity of the ball when it reaches its highest point?

When it reaches its highest point the velocity

$$V = 0$$

(b) What is its velocity 1 s before it reaches its highest point?

(c) What is the change in its velocity during this 1-s interval?



Chapter 3 – Problem(2)

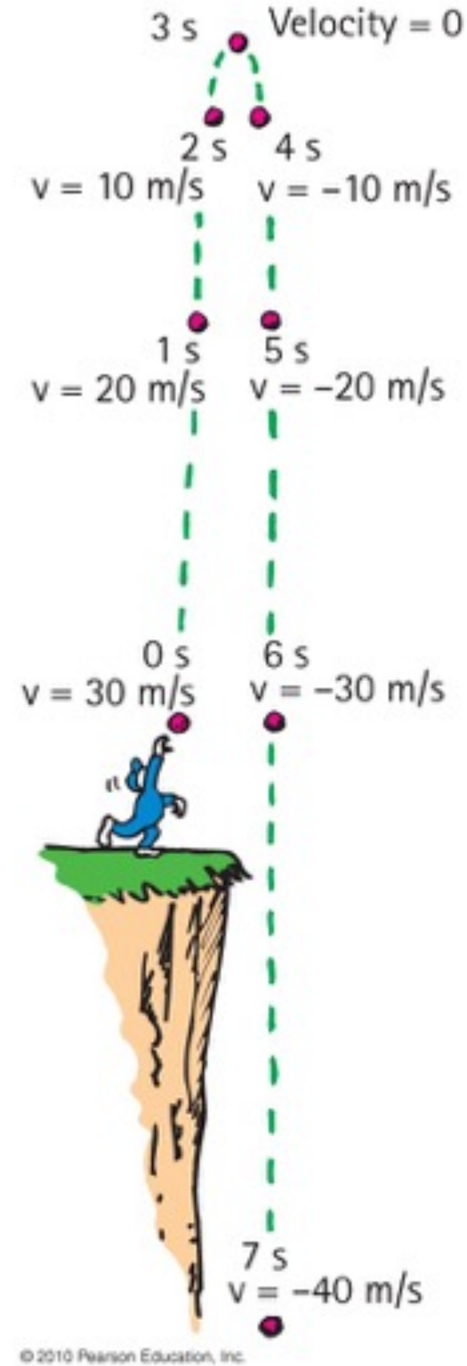
2. A ball is tossed with enough speed straight up so that it is in the air several seconds.

(b) What is its velocity 1 s before it reaches its highest point?

Velocity = acceleration x time

$V = g\,t = 10\ m/s^2 \times 1s = 10\ m/s$ **Up**

(c) What is the change in its velocity during this 1-s interval?



Chapter 3- Problem (2)

A ball is tossed with enough speed straight up so that it is in the air several seconds.

(b) What is its velocity 1 s before it reaches its highest point?

Velocity = acceleration x time

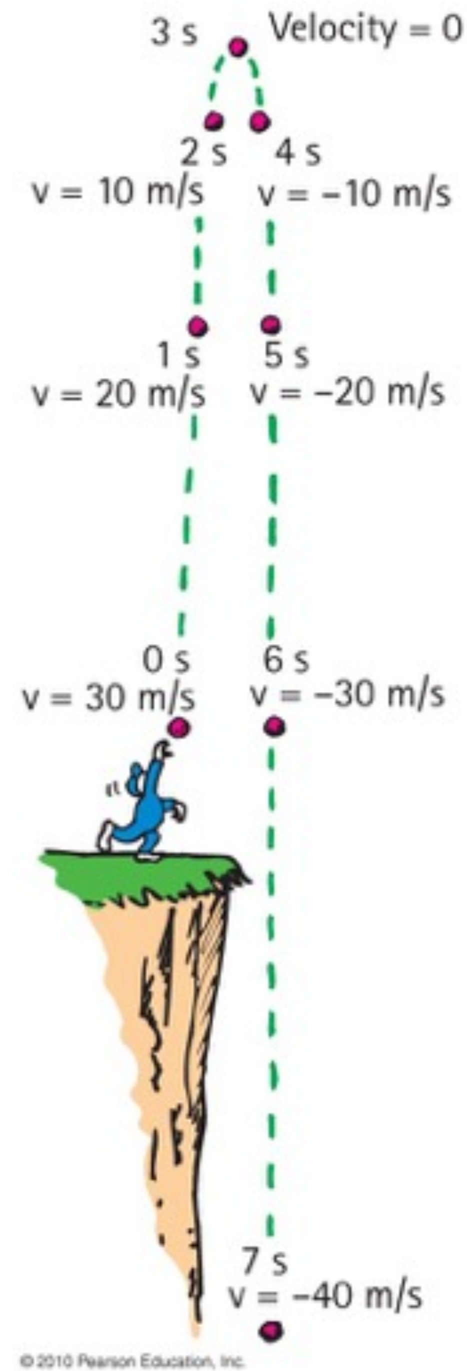
$V = g\,t = 10\ m/s^2 \times 1s = 10\ m/s$ **Up**

(c) What is the change in its velocity during this 1-s interval?

To reach a velocity of 0 the change must be

-10 m/s or 10 m/s **Down**, or

Change in velocity = $V_{final} - V_{initial} = 0 - 10m/s = 10m/s$



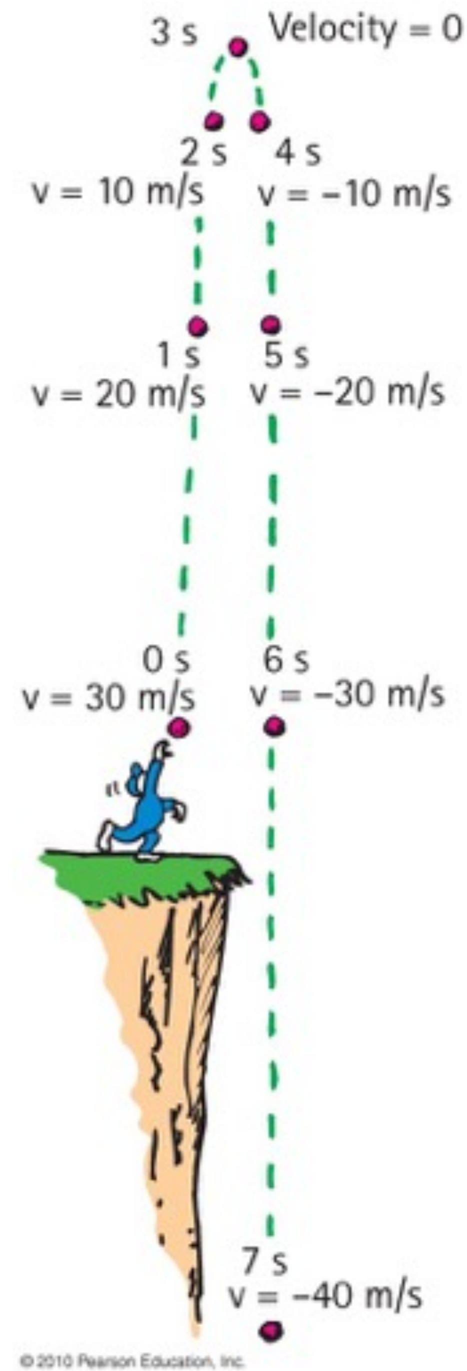
Chapter 3- Problem (2)

(d) What is its velocity 1 s after it reaches its highest point?
The same as if it was dropped from it's highest point
$V = g\,t = 10\ m/s^2 \times 1s = 10\ m/s$ **Down**

(e) What is the change in velocity during this 1-s interval?
Again the change in velocity is = $V_{final} - V_{initial}$
$V(1s) - V(0) = 10\ m/s - 0 = 10\ m/s$ **Down**

(f) What is the change in velocity during the 2-s interval?
$V = g\,t = 10\ m/s^2 \times 2s = 20\ m/s$ **Down**

(g) What is the acceleration of the ball during any of these time intervals and at the moment the ball has zero velocity?
<u>In the case of free fall it's always 10 m/s</u>



Chapter 3- Problem (4)

A car takes 10 s to go from $v = 0$ m/s to $v = 25$ m/s at constant acceleration. Find the distance traveled.
Hint: use the equation $d = 1/2\ at^2$

To determine *d* you must first compute the acceleration.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

$a = (v_{final} - v_{initial})/(t_{final} - t_{initial}) = (25\text{m/s} - 0) / (10\text{s} - 0) = 25/10\ \text{m/s}^2$.

$a = 2.5\ \text{m/s}^2$.

Then $d = ½\ (2.5\text{m/s}^2)\ (10\text{s})^2 = 1.25\ \text{m/s}^2 \times 100\text{s}^2 =$ **125 m**

Chapter 3 – Problem (6)

A dart leaves the barrel of a blowgun at a speed *v.* The length of the blowgun barrel is *L.* Assume that the acceleration of the dart in the barrel is uniform.

a. <u>Show that the dart moves inside the barrel for a time of t = 2L/v</u>

Note that **v = a t** or **a = v/t**.
Since $d = \frac{1}{2} a t^2$, substituting v/t and d = L into the equation for distance we have $L = \frac{1}{2}(v/t)\, t^2$ or $L = \frac{1}{2} v t$.

Solving for time, we have **t = 2L/v**

b. If the dart's exit speed is 15.0 m/s and the length of the blowgun is 1.4 m, <u>show that the time the dart is in the barrel is 0.19 s.</u>

Since t = 2L/v = 2 (1.4 m) / 15 m/s = 2.8 / 15 = 0.19s

Homework

(1) Read Chapter 3 in detail.

(2) Do Ranking # 1

(3) Do Exercises 13 , 32

(3) Do Problems 1, 3

Homework due: May 23