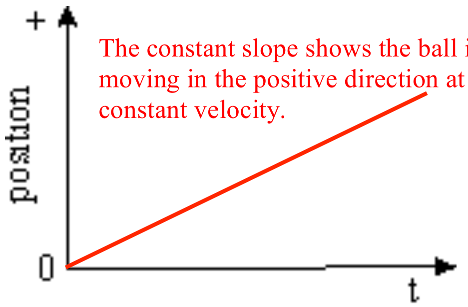
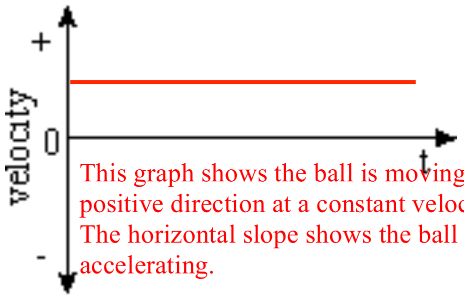
## Particle Models in Two Dimensions:
# Projectile Motion Review

1. A soccer goalie makes a save and then kicks the ball through the air to the middle of the field.

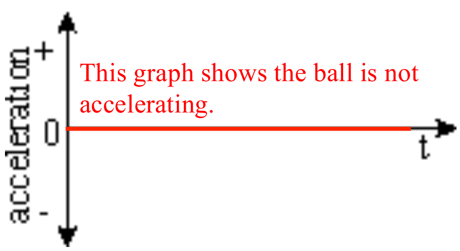
a. Graph the **horizontal** component of the ball's motion while in the air.
b. Explain what each graph shows in words.




The constant slope shows the ball is moving in the positive direction at a constant velocity.



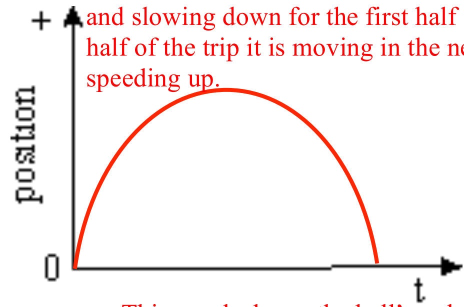

This graph shows the ball is moving in the positive direction at a constant velocity. The horizontal slope shows the ball is not accelerating.



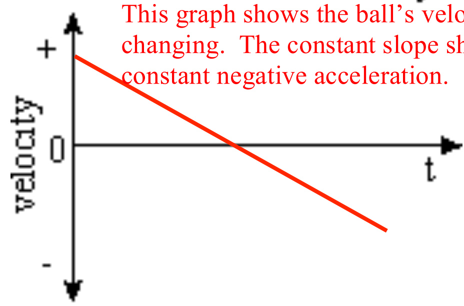

This graph shows the ball is not accelerating.

c. Graph the **vertical** component of the ball's motion while in the air.
d. Explain what each graph shows in words.

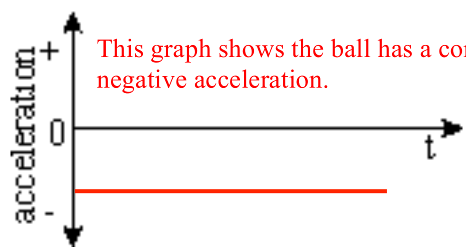
This graph shows the ball is moving in the positive direction and slowing down for the first half of the trip. For the second half of the trip it is moving in the negative direction and speeding up.




This graph shows the ball's velocity is always changing. The constant slope shows the ball has a constant negative acceleration.

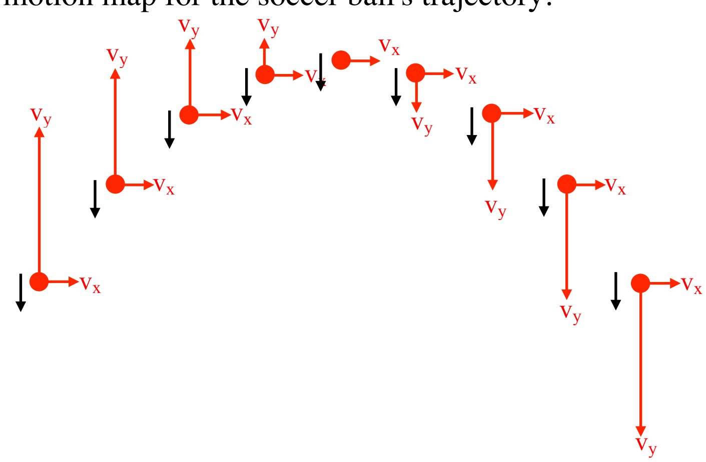



This graph shows the ball has a constant negative acceleration.

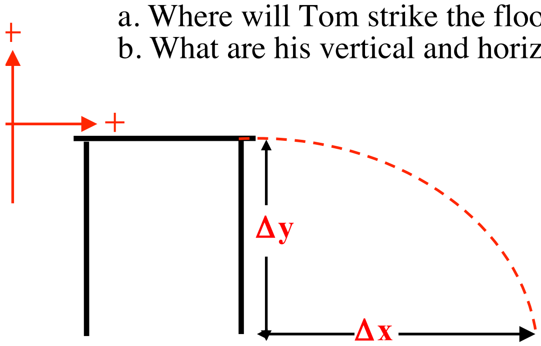



e. Draw a force diagram for the soccer ball while it is in the air.


f. Draw a motion map for the soccer ball's trajectory.



2. Tom the cat is chasing Jerry the mouse across a table surface 1.5 m high. Jerry steps out of the way at the last second, and Tom slides off the edge of the table at a speed of 5 m/s.
   a. Where will Tom strike the floor?
   b. What are his vertical and horizontal velocity components just before he hits the floor?




**$\Delta y$ = -1.5 m**
**$v_{y0}$ = 0 m/s**
**a = g = -10 m/s$^2$**
**$\Delta t$ = ?**
**$\Delta x$ = ?**
**$V_x$ = 5.0 m/s**

A. $\Delta y = v_{y0}t + \frac{1}{2}g\Delta t^2 \Rightarrow t = \sqrt{\frac{2\Delta y}{g}} = \sqrt{\frac{2(-1.5m)}{-10\frac{m}{s^2}}} = 0.55s$

$\Delta x = v_x\Delta t \Rightarrow \Delta x = 5\frac{m}{s}(0.55s) = 2.7m$

B. The horizontal velocity is always **$V_x$ = 5.0 m/s.**

$v_y = v_{y0} + g\Delta t = 0 + (-10\frac{m}{s^2}).55s = -5.5\frac{m}{s}$

**C.**

$$V_R{}^2 = V_X{}^2 + V_Y{}^2$$

$$V_R = \sqrt{\left(5\frac{m}{s}\right)^2 + \left(-5.5\frac{m}{s}\right)^2}$$

$$V_R = \sqrt{55.25\ \frac{m^2}{s^2}}$$

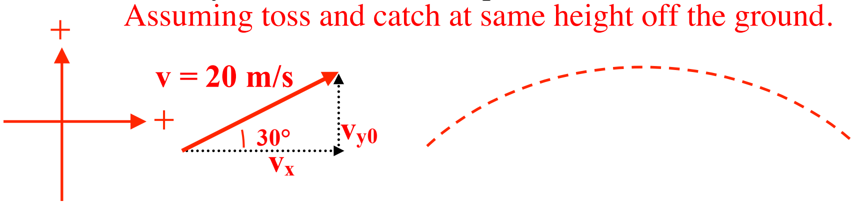
$$V_R = 7.43\frac{m}{s}$$

$$\tan\theta = \frac{V_y}{V_X} \qquad \tan\theta = \frac{-5.5\frac{m}{s}}{5\frac{m}{s}}$$

$$\theta = 47.1^o\ below\ the\ horizontal$$

**$V_R$ = 7.43 m/s @ 47.7$^o$ below the horizontal**

3. A lacrosse player slings the ball at an angle of 30 degrees above the horizontal with a speed of 20 m/s. How far away should a teammate position herself to catch the ball?
 Assuming toss and catch at same height off the ground.

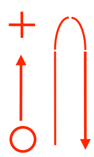



**$\Delta y = 0$ m**
**$v_{y0} = 10$ m/s**
**$v_x = 17.3$ m/s**
**$a = g = -10$ m/s$^2$**
**$\Delta t = ?$**
**$\Delta x = ?$**

$$v_x = \cos 30^\circ (20\,\tfrac{m}{s}) = 17.3\,\tfrac{m}{s}$$
$$v_{y0} = \sin 30^\circ (20\,\tfrac{m}{s}) = 10\,\tfrac{m}{s}$$

$$\Delta y = v_{y0}\Delta t + \tfrac{1}{2} g \Delta t^2 \Rightarrow 0 = (10\,\tfrac{m}{s})\Delta t + \tfrac{1}{2}(-10\,\tfrac{m}{s^2})\Delta t^2$$
$$(5\,\tfrac{m}{s^2})\Delta t = 10\,\tfrac{m}{s} \Rightarrow \Delta t = 2.0s$$
$$\Delta x = v_x \Delta t = (17.3\,\tfrac{m}{s})2.0s = 35m$$

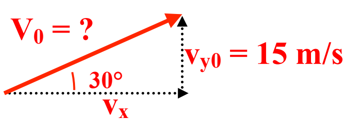
4. A ball is thrown straight upward and returns to the thrower's hand after 3 seconds in the air. A second ball is thrown at an angle of 30 degrees with the horizontal. At what speed must the second ball be thrown so that it reaches the same height as the one thrown vertically?




**$\Delta y = 0$ m**
**$a = g = -10$ m/s$^2$**
**$\Delta t = 3.0$ s**
**$v_{y0} = ??$**

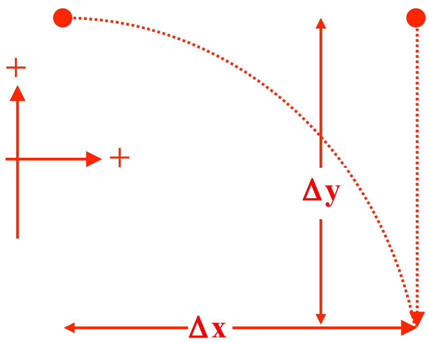
$$\Delta y = v_{y0}\Delta t + \tfrac{1}{2} g \Delta t^2 \Rightarrow 0 = v_{y0}(3.0s) + \tfrac{1}{2}(-10\,\tfrac{m}{s^2})(3.0s)^2$$
$$v_{y0}(3.0s) = (5.0\,\tfrac{m}{s^2})(3.0s)^2 \Rightarrow v_{y0} = (5.0\,\tfrac{m}{s^2})(3.0s) = 15\,\tfrac{m}{s}$$

For a ball thrown at an angle to get to the same height, it must have the same initial vertical velocity.




$$\sin 30^\circ = \frac{15\,\tfrac{m}{s}}{v} \Rightarrow v = \frac{15\,\tfrac{m}{s}}{\sin 30^\circ} = 30\,\tfrac{m}{s}$$

5. Two objects are initially the same height above the ground. Simultaneously, one is released from rest and the other is shot off horizontally with an initial speed of 2.5 m/s. The two objects collide after falling 20 m. How far apart were the objects initially?



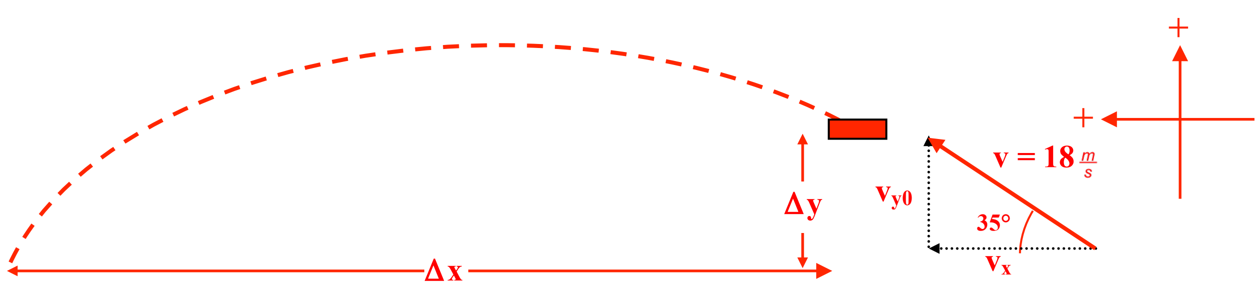

**$\Delta y$ = -20 m**
**$v_{y0}$ = 0**
**$v_x$ = 0**
**a = g = -10 m/s$^2$**
**$\Delta t$ = ?**
**$\Delta x$ = 0**

**$\Delta y$ = -20 m**
**$v_{y0}$ = 0**
**$v_x$ = 2.5 m/s**
**a = g = -10 m/s$^2$**
**$\Delta t$ = ?**
**$\Delta x$ = ?**

$$\Delta y = v_{y0}t + \tfrac{1}{2}g\Delta t^2 \Rightarrow \ t = \sqrt{\frac{2\Delta y}{g}} = \sqrt{\frac{2(\text{-}20m)}{\text{-}10\,\frac{m}{s^2}}} = 2.0s$$

$$\Delta x = v_x \Delta t \Rightarrow \Delta x = 2.5\tfrac{m}{s}(2.0s) = 5.0m$$

6. Frustrated with HISTORY, (you never get frustrated in physics) you open the second story classroom window and (to the horror of your teacher but to the secret delight of your classmates) violently hurl your history book out the window with a velocity of 18 m/s at an angle of 35 degrees above the horizontal. If the launch point is 6 meters above the ground, how far from the building will the book hit the parking lot?




**$\Delta y$ = -6.0 m**
**$v_{y0}$ = 10.3 m/s**
**$v_x$ = 14.7 m/s**
**a = g = -10 m/s$^2$**
**$\Delta t$ = ?**
**$\Delta x$ = ?**

$$v_x = \cos 35^\circ(18\tfrac{m}{s}) = 14.7\tfrac{m}{s}$$

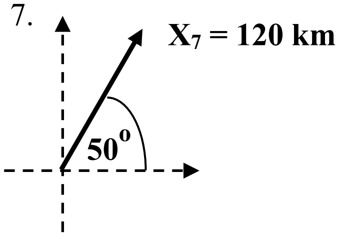
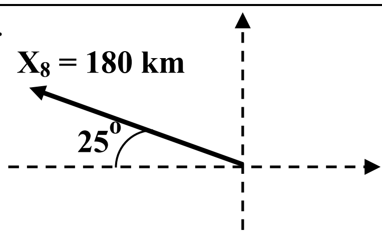
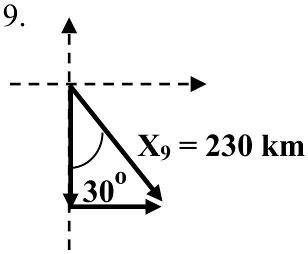
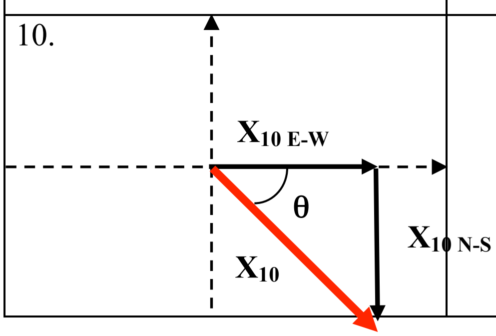
$$v_{y0} = \sin 35^\circ(18\tfrac{m}{s}) = 10.3\tfrac{m}{s}$$

$$\Delta y = v_{y0}t + \tfrac{1}{2}g\Delta t^2 \Rightarrow \ \text{-}6.0m = (10.3\tfrac{m}{s})t + \tfrac{1}{2}(-10\tfrac{m}{s^2})t^2$$

$$(-5\tfrac{m}{s^2})t^2 + (10.3\tfrac{m}{s})t + 6.0m = 0 \ \text{(use solver or quadratic)}\ t = 2.53s$$

$$\Delta x = v_x \Delta t \Rightarrow \Delta x = 14.7\tfrac{m}{s}(2.53s) = 37m$$

Resolve the following Vectors into component parts. For problem #10 find the Resultant Vector from adding together problems #7-9

| | |
|---|---|
| 7.   | **Refer to Unit 4 Worksheet 2 #1-3 & 9 for the Exemplars of how to solve these type of problems.** |
| 8.   | |
| 9.   | |
| 10.   | |

| | E-W | N-S |
|---|---|---|
| **$X_7$** | **77.1 km** | **91.9 km** |
| **$X_8$** | **-163.1 km** | **76.1 km** |
| **$X_9$** | **115 km** | **-199.2 km** |
| **$X_{10}$** | **29 km** | **-31.2 km** |

$$X_{10}{}^2 = X_{10\,E-W}{}^2 + X_{10\,N-s}{}^2$$

$$X_{10} = \sqrt{(X_{10\,E-W})^2 + (X_{10\,N-s})^2}$$

$$X_{10} = \sqrt{(29\,km)^2 + (-31.2\,km)^2}$$

$$X_{10} = \sqrt{1814.44\,km^2}$$

$$X_{10} = 42.6\,km$$

$$\tan\theta = \frac{X_{10\,N-S}}{X_{10\,E-W}} \qquad \tan\theta = \frac{-31.2\,km}{29\,km}$$

$$\theta = 47.1^o south\ of\ east$$

**$X_{10}$ = 42.6 km @ 47.1$^o$ south of east**