Name: * Solutions *

Collaborator(s): ______________________

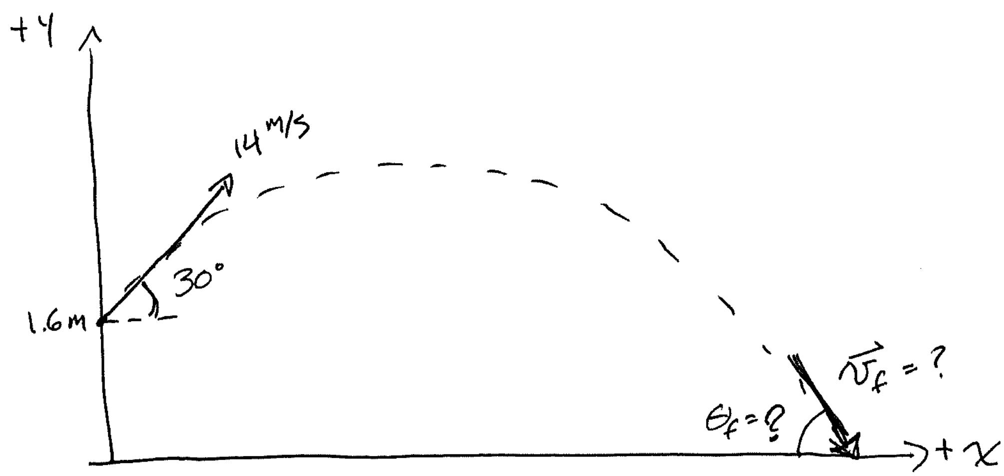
This tutorial will walk you through solving a projectile motion physics problem. Following similar steps will enable you to solve a wide variety of multi-dimensional kinematics problems.

Hercules throws a 7.25 kilograms shot put from a height of 1.6 meters. The release angle of the shot put is 30 degrees from the horizontal and its initial speed is 14.0 m/s. What is the magnitude of the shot put velocity when it strikes the ground and what angle does it hit at?

Read the problem carefully, underlining key words as you go.

Draw a diagram

1. Draw a diagram of the above situation, labeling all known information.



Identify the missing and relevant information

2. List all the relevant variables for which you know a value. List the variable(s) you will be solving for.

Known:

$v_0 = 14$ m/s

$\theta_0 = 30°$

$y_0 = 1.6$ m

$x_0 = 0$ m ← in my chosen coordinate system

Solve for:

v_f

θ_f

when $y(t) = 0$

Identify the necessary equations

3. Write equations for $v_x(t)$ and $v_y(t)$.

$$v_x(t) = v_{0x} = v_0 \cos\theta_0$$

$$v_y(t) = v_{0y} - gt = v_0 \sin\theta_0 - gt$$

4. Write equations for $x(t)$ and $y(t)$.

$$x(t) = \cancel{x_0}^{\to 0} + v_{0x} t = v_0 \cos\theta_0 t$$

$$y(t) = y_0 + v_{0y} t - \tfrac{1}{2} g t^2 = y_0 + v_0 \sin\theta_0 t - \tfrac{1}{2} g t^2$$

Solve for unknowns

5. Solve for the time at which the shot put will strike the ground. i.e. when does $y(t) = 0$?

$$0 = y_0 + v_0 \sin\theta_0 t - \tfrac{1}{2} g t^2$$

$$= 1.6\,\text{m} + (14\,\text{m/s}) \sin(30^\circ)\, t - \tfrac{1}{2}(10\,\text{m/s}^2)\, t^2$$

$$0 = 1.6 + 7t - 5t^2$$

unphysical! Prior to ball launch

quadratic eqn

$$t = \frac{-7 \pm \sqrt{7^2 - 4(1.6)(-5)}}{2(-5)} = \cancel{-0.2\,\text{s}} \text{ or } \boxed{1.6\,\text{s}}$$

6. What are the x and y components of the velocity at the time the shot put strikes the ground?

$$v_x(1.6\text{s}) = v_{0x} = (14\,\text{m/s}) \cos(30^\circ) = \boxed{12.1\,\text{m/s} = v_x}$$

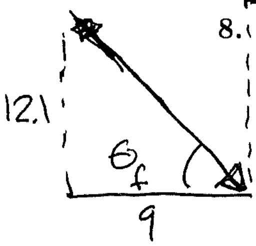
$$v_y(1.6\text{s}) = v_{0y} - gt = (14\,\text{m/s}) \sin 30^\circ - (10\,\text{m/s}^2)(1.6\,\text{s})$$

$$\boxed{v_y = -9\,\text{m/s}}$$

7. Determine the magnitude of the velocity at this point in time.

$$v_f = \sqrt{v_x^2 + v_y^2} = \sqrt{(12.1\,\text{m/s})^2 + (-9\,\text{m/s})^2}$$

$$\boxed{v_f = 15.1\,\text{m/s}}$$



8. Determine the angle at which the shot put is striking.

$$\tan\theta_f = \frac{12.1\,\text{m/s}}{9\,\text{m/s}} \Rightarrow \theta_f = \tan^{-1}\left(\frac{12.1}{9}\right)$$

$$\boxed{\theta_f = 53^\circ}$$

relative to the ground

Check the reasonableness of your answer

9. How does the final velocity compare to the initial velocity? Is this what you would expect and why?

v_f is larger than v_o. This is expected b/c the shotput will re-attain a speed of 14 m/s when it gets back to a height of 1.6 m. It then continues to speed up (in the y-direction) as it travels the extra 1.6 m to the ground.

10. How does the angle the shot put strikes at compare with the angle it was released at? Is this what you would expect and why?

θ_f is larger than θ_o. Because the y-component of the final velocity is larger than the initial y-component (while the x-component stays the same), you would expect a steeper angle upon impacting the ground.