Using a Problem-Solving Strategy

(Adapted from Reif 1995; Heller & Heller 1995; Winfrey 2003; Young & Freedman text)

1. Identify the Problem
- A. Draw a sketch or sketches of the situation
- B. Label the known and unknown quantities associated with the problem.
- C. State the problem to be solved, indicating the final target quantity you seek.
- D. Describe a general approach to the problem. Include fundamental physics principles.

2. Set up the Physics
- A. Draw diagrams of the system including a coordinate axis and positions for all objects at any initial and final times.
- B. Draw diagrams of individual components with labels for all variables and forces.
- C. Identify target variables
- D. Identify all the equations that are relevant to the problem.

3. Solve the Problem
- A. Find an equation with your target unknown variable
- B. Count the number of unknown variables, including your target variable
- C. Count the number of equations containing unknown variables. Hopefully you have as many equations as unknown variables. If not, return to Step 2.
- D. Solve the system of equations SYMBOLICALLY for the target variable.

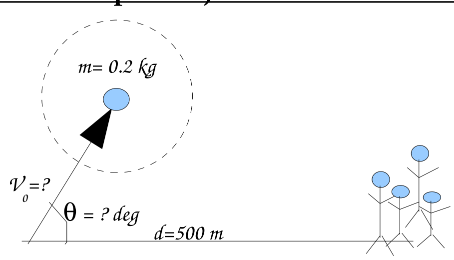
4. Evaluate your Result
- A. Use dimensional analysis to check the units of your solution equation.
- B. Insert numerical values into your equation and evaluate a solution.
- C. Check that the answer contains both a numerical value and correct units (e.g., m/s)
- D. Evaluate whether your answer is reasonable (not too small or large?)

Example problem: The Smith family is at the fireworks and chooses to sit 500 meters away from the launch site. A firework with 9 s fuses are launched directly at the Smiths at an elevation angle of θ degrees from the horizon with an initial velocity of V meters per second. The mass of an individual firework is 0.2 kg. For what combination of launch angles and velocities are the Smiths in danger of a direct hit? (Consider the firework to be in ballistic trajectory and neglect force of air resistance)

Example Solution:

1. Identify the Problem (e.g., 2 of 10 points)

Picture of problem



Given information: *d=500 m* *m=0.2 kg*

V_0 = ? m/s

time until explosion = 9 s

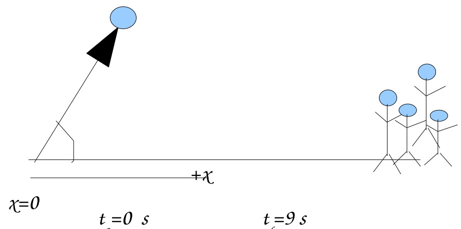
launch angle = ? degrees

Problem to be solved: *What initial velocity and angle puts firework at the Smiths after 9 s.*

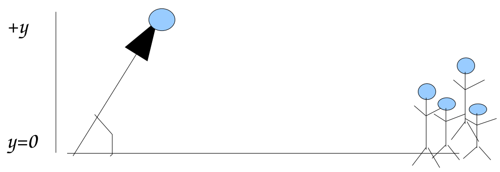
General Approach: *use ballistic trajectories acting under acceleration of gravity to find path of firework as a function of time and see where it lands after 9 s.*

2. Set up the Physics (e.g., 3 of 10 points)

Diagram axes and define variables

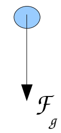


$t_0 = 0$ s	$t_f = 9$ s
$x_0 = 0$ m	$x_f = ?$ m
$v_{0x} = 40\cos(\theta)$ m/s	$v_{fx} = v_{0x}$
$a_{0x} = 0$	$a_{fx} = 0$



$t_0 = 0$ s	$t_f = 9$ s
$y_0 = 0$ m	$y_f = ?$ m
$v_{0y} = v_0\sin(\theta)$ m/s	$v_{fy} = v_{0y}$
$a_{0y} = -9.8$ m/s^2	$a_{fy} = a_{0y}$

firework free-body diagram



Target variables: x_f and y_f

Relevant Equations: $x_f = x_0 + v_0\Delta t + 1/2\, a t^2$

3. Solve the Problem (e.g., 3 of 10 points)

Construct specific equations

two equations with two unknowns: θ *and* v_0

$\Delta t = t_f - t_0$

1) $x_f = x_0 + v_{0x}\Delta t + 1/2\, a_x \Delta t^2$ or $x_f = x_0 + v_0 \cos\theta\, \Delta t + 1/2\, a_x \Delta t^2$

2) $y_f = y_0 + v_{0y}\Delta t + 1/2\, a_y \Delta t^2$ $y_f = y_0 + v_0 \sin\theta\, \Delta t + 1/2\, a_y \Delta t^2$

Outline the Solution

solve 1) for θ *and put into 2)*

solve for v_0*, then put* v_0 *and solve either equation for* θ

Solve for target variables

$\theta = \arccos[(x_f - x_0)/(v_0\, \Delta t)]$ *(solve for* θ*; simplify allowing that acceleration in x direction =0)*

$y_f = y_0 + v_0 \sin(\arccos[(x_f - x_0)/(v_0\, \Delta t)])\Delta t + 1/2\, a_y \Delta t^2$ *(plug in to equation 2)*

$= y_0 + v_0 (1 - \cos(\arccos[(x_f - x_0)/(v_0 \Delta t)]))\Delta t + 1/2\, a_y \Delta t^2$

$= y_0 + v_0\, \Delta t - (x_f - x_0) + 1/2\, a_y \Delta t^2$ *(simplify and solve for* v_0*)*

$v_0 = [(y_f - y_0) + (x_f - x_0) - 1/2\, a_y \Delta t^2]/\Delta t$

4. Evaluate your Solution (e.g., 2 of 10 points)

Units of solution correct?: *yes! units are in distance/time (i.e., m/s)*

Insert numerical values: $v_0 = [(y_f - y_0) + (x_f - x_0) - 1/2\, a_y \Delta t^2]/\Delta t = [(0)+500-1/2(-9.8)9^2]/9 = 99.6$ m/s

$\theta = \arccos[(x_f - x_0)/(v_0\, \Delta t)] = \arccos[500/(99.6 * 9)] = 56$ degrees

Answer reasonable? *yes!* Correct units? *yes! m/s for velocity and degrees for angle*

Name(s) ________________________________

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Problem to be solved:

General Approach:

2. Set Up the Physics

Diagram axes and define variables

Target variables:

Relevant Equations:

3. Solve the Problem

Construct specific equations

Outline the solution

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4. Evaluate your Solution

Units of solution correct?:
Insert numerical values:

Answer reasonable? Correct units?