Main Ideas in Class Today

• Wile E. Coyote
• Projectile Motion
• Formulas/Graphs
• X3.5 Relative Velocity (not tested)

Practice: 3.23, 3.25, 3.27, 3.29, 3.31, 3.33, 3.43, 3.47, 3.51, 3.53, 3.55
Upcoming Schedule:

Today-Monday 30: Chapter 3
Wednesday 1: Ch 3 Problem Solving Day (guest)
Friday 3: Ch 4 not on test (guest)
Monday 6: Ch 4 not on test (bonus for 4B)
Wednesday 8: review for Test in class; test in evening
Thursday 9: HW 4B (Monday’s material) due
Friday 10: Ch 4
The Physics of
Wile E. Coyote vs Roadrunner

https://www.youtube.com/watch?v=b5cVYeeMzGI
Ignoring air resistance (very small effect), what would be the path of motion if someone ran off of a cliff?

A. Straight down nearly immediately
B. Straight down after a short time
C. Never completely straight down
The Physics of Wile E. Coyote

• As Mr. Coyote runs off the cliff, he has horizontal velocity.
• A change in velocity is acceleration, in this case horizontal acceleration, which must come from a force in the horizontal direction. \( v_{fx} = v_{ox} + a_x t \)
• If we ignore air resistance (horizontal force = 0), then there is no horizontal force to slow him down horizontally. \( v_{fx} = v_{ox} \)
• Thus, Mr. Coyote will travel *horizontally at the same speed* the whole time until he hits the ground!
The Physics of Wile E. Coyote

• Vertical motion is treated separately.
• As soon as the coyote leaves the cliff he will experience a vertical force due to gravity.
• This force will cause him to start to accelerate in the vertical direction. As he falls he will be going faster and faster in the vertical direction.
• The horizontal and vertical components of the motion of an object going off a cliff are separate from each other, and can not affect each other.

Watch: http://www.youtube.com/watch?v=bp0MuuR5Hqg
Break up what you know in terms of the horizontal and vertical

**Prevents mistakes**

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
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Projectile Motion

- Freely falling objects near surface of earth
- Object can have an initial velocity component parallel to the ground
  - Object will move in two dimensions
- Assumptions:
  - Neglect air resistance because small effect
  - Means that acceleration of gravity $g = 9.8 \text{ m/s}^2$ is the same for all objects ($a_y$)
Motion in Two Dimensions With Constant Acceleration

- Separation of vectors into components allows separation of equations into components:

\[
\begin{align*}
    v_x &= v_{xo} + a_x t \\
    \Delta x &= v_{xo} t + \frac{1}{2} a_x t^2 \\
    v_x^2 &= v_{xo}^2 + 2a_x \Delta x \\
    v_y &= v_{yo} + a_y t \\
    \Delta y &= v_{yo} t + \frac{1}{2} a_y t^2 \\
    v_y^2 &= v_{yo}^2 + 2a_y \Delta y
\end{align*}
\]

- Special case for projectile motion: \( a_x = 0 \) \( a_y = -g = -9.8 \text{ m/s}^2 \)

\[
\begin{align*}
    v_x &= v_{xo} \\
    \Delta x &= v_{xo} t \\
    v_y &= v_{yo} - gt \\
    \Delta y &= v_{yo} t - \frac{1}{2} gt^2 \\
    v_y^2 &= v_{yo}^2 - 2g \Delta y
\end{align*}
\]
After it leaves your hand, before it hits the ground

\begin{align*}
v_x &= v_{xo} \\
x &= x_o + v_{xo}t \\
v_y &= v_{yo} - gt \\
y &= y_o + v_{yo}t - \frac{1}{2} gt^2
\end{align*}

\(v_o\) \equiv \text{initial velocity vector} \\
\(\theta_o\) \equiv \text{initial direction of velocity vector}

- \(v_y = 0\) at top of trajectory
- \(v_x = v_{xo}\) remains the same throughout trajectory because there is no acceleration along the \(x\)-direction
Clicker Question

Ignoring air resistance, an object dropped from a plane flying at constant speed in a straight line will

A. quickly lag behind the plane.
B. remain vertically under the plane.
C. move ahead of the plane.
D. not enough information to determine
Shooting Falling Things

You are a police officer and you’ve been issued an order to shoot a dangerous criminal on sight. If you pull the trigger just as he jumps from a tall building you should aim:

A) Directly at him
B) Below him
C) Above him
D) It is impossible to hit him
Common Strategy for Projectile Motion Problems

The time will be the same for x and y parts of the question.

If you don’t have enough information for x or y components, solve for time.
I throw a ball off the edge of a 15.0m tall cliff. I threw it at 16 m/s at an angle of 60 degrees from the horizontal.

A. **Determine** how much time it takes to fall.

B. **Determine** how far from the base of the cliff it hits the ground. (Need the time first)

C. **Determine** how fast it is moving vertically when it hits the ground. (y component of final velocity)

D. **Determine** what its magnitude of velocity is when it hits the ground.

E. **Determine** the angle that it hits the ground from the horizontal.
(Harder) A battleship simultaneously fires two shells at enemy ships. If the shells follow the parabolic trajectories shown, which ship gets hit first?

A. A  
B. B  
C. Both at the same time  
D. need more information
Clicker Answers

Chapter/Section:  Clicker #:Answer
Ch.3B:3=C, 4=B, 5=A, 6=B
\[ V_0 = 16 \text{ m/s} \quad \theta = 60^\circ \]

\[ V_{ox} = V_0 \cos \theta = 16 \text{ m/s} \cos 60^\circ \]
\[ V_{oy} = V_0 \sin \theta = 16 \text{ m/s} \sin 60^\circ \]
\[ a_x = 0 \quad a_y = -9.8 \text{ m/s}^2 \]
\[ \Delta y = -15.0 \text{ m} \]

\( a) \quad t = ? \quad \Delta y = V_{oy} t + \frac{1}{2} a_y t^2 \)

\[-15.0 \text{ m} = (16 \text{ m/s} \sin 60^\circ) t + \frac{1}{2} (-9.8 \text{ m/s}^2) t^2 \]

\[ \frac{1}{2}(-9.8 \text{ m/s}^2) t^2 - (16 \text{ m/s} \sin 60^\circ) t - 15.0 \text{ m} = 0 \]

\[ t = \frac{13.9 \pm \sqrt{(-13.9)^2 - 4(4.9)(-15.0)}}{2(4.9)} \]

\[ t = \frac{13.9 \pm 22.0}{9.8} = \frac{3.67 \text{ s}}{0.83 \text{ s}} = 3.7 \text{ s} \]

\( b) \quad \Delta x = ? \quad \Delta x = V_{ox} t + \frac{1}{2} a_x t^2 \)

\[ \Delta x = (16 \text{ m/s} \cos 60^\circ) (3.67 \text{ s}) + 0 \]

\[ \Delta x = 29 \text{ m} \]

\( c) \quad V_y = ? \quad V_y = V_{oy} + a_y t \)

\[ V_y = (16 \text{ m/s} \sin 60^\circ) + (-9.8 \text{ m/s}^2) (3.67 \text{ s}) \]

\[ V_y = -22 \text{ m/s} \]

\( d) \quad V = ? \quad V = \sqrt{V_x^2 + V_y^2} \)

\[ V_x = V_{ox} = 16 \text{ m/s} \cos 60^\circ = 8 \text{ m/s} \]

\[ V = \sqrt{(8 \text{ m/s})^2 + (-22 \text{ m/s})^2} = 24 \text{ m/s} \]
e) $\theta = ?$

\[
\tan \theta = \frac{\text{opp}}{\text{adj}} = \frac{V_y}{V_x} = \frac{-22 \text{ m/s}}{8 \text{ m/s}}
\]

\[
\theta = \tan^{-1} \left( \frac{-22 \text{ m/s}}{8 \text{ m/s}} \right)
\]

\[
\theta = -70^\circ
\]