

# PHYS 1441 – Section 001

## Lecture #7

*Thursday, June 18, 2015*

*Dr. Jaehoon Yu*

- Projectile Motion
- Maximum Range and Height
- What is the Force?
- Free Body Diagram
- Newton's Laws

Today's homework is homework #4, due 11pm, Monday, June 22!!

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# Announcements

- Reading Assignment
  - CH4.1 – 4.3
- Mid-term exam
  - In the class coming Tuesday, June 23
  - Comprehensive exam
    - Covers CH1.1 to what we finish Monday, June 22+ Appendix A
  - Bring your calculator but DO NOT input formula into it!
    - Your phones or portable computers are NOT allowed as a replacement!
  - You can prepare a one 8.5x11.5 sheet (front and back) of handwritten formulae and values of constants for the exam → no solutions of any kind, derivations or word definitions!
    - No additional formulae or values of constants will be provided!



# Reminder: Special Project #2 for Extra Credit

- Show that the trajectory of a projectile motion is a parabola and explain your answer.
  - 20 points
  - Due: Monday, June 22
  - You MUST show full details of your OWN computations to obtain any credit
    - Beyond what was covered in this lecture note or in the book!



# Another example for a Projectile Motion

- A stone was thrown upward from the top of a cliff at an angle of  $37^\circ$  to horizontal with initial speed of  $65.0\text{m/s}$ . If the height of the cliff is  $125.0\text{m}$ , how long is it before the stone hits the ground?

$$v_{xi} = v_i \cos \theta_i = 65.0 \times \cos 37^\circ = 51.9\text{m/s}$$

$$v_{yi} = v_i \sin \theta_i = 65.0 \times \sin 37^\circ = 39.1\text{m/s}$$

$$y_f = -125.0 = v_{yi}t - \frac{1}{2}gt^2$$

Becomes

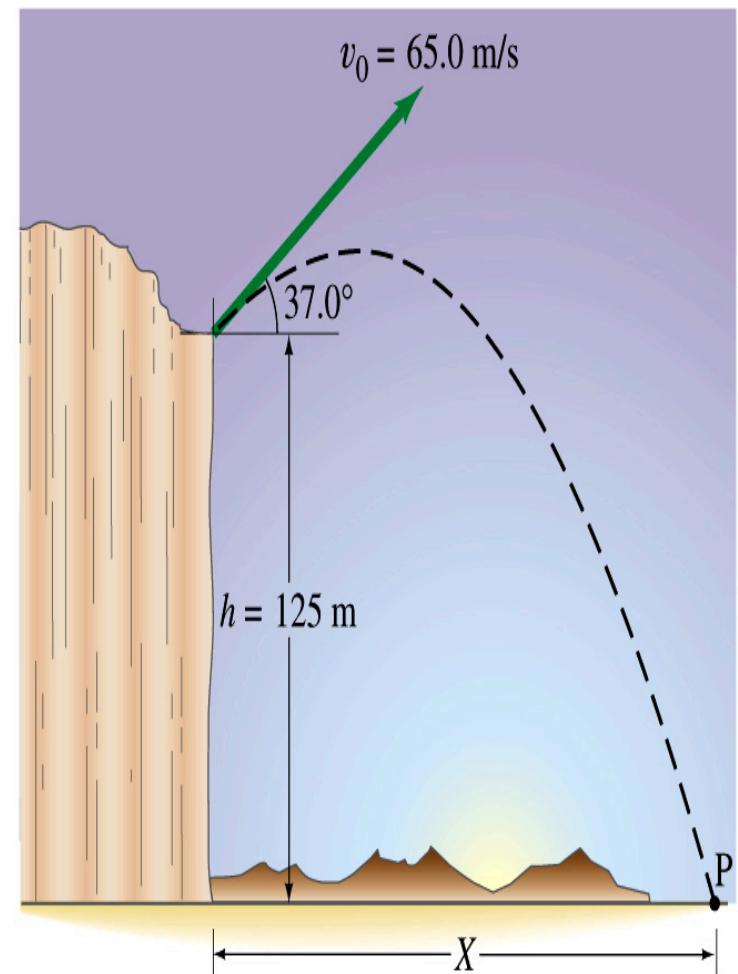
$$gt^2 - 78.2t - 250 = 9.80t^2 - 78.2t - 250 = 0$$

$$t = \frac{78.2 \pm \sqrt{(-78.2)^2 - 4 \times 9.80 \times (-250)}}{2 \times 9.80}$$

$$t = -2.43\text{s} \quad \text{or} \quad t = 10.4\text{s}$$

$$t = 10.4\text{s}$$

Since negative time does not exist.



## Example cont'd

- What is the speed of the stone just before it hits the ground?

$$v_{xf} = v_{xi} = v_i \cos \theta_i = 65.0 \times \cos 37^\circ = 51.9 \text{ m / s}$$

$$v_{yf} = v_{yi} - gt = v_i \sin \theta_i - gt = 39.1 - 9.80 \times 10.4 = -62.8 \text{ m / s}$$

$$|v| = \sqrt{v_{xf}^2 + v_{yf}^2} = \sqrt{51.9^2 + (-62.8)^2} = 81.5 \text{ m / s}$$

- What are the maximum height and the maximum range of the stone?

Do these yourselves at home for fun!!!



# Horizontal Range and Max Height

- Based on what we have learned previously, one can analyze the projectile motion in more detail
  - Maximum height an object can reach
  - Maximum range
- For a projectile fired with an initial speed  $v_0$  at angle  $\theta_0$ , the time for it to reach maximum height can be obtained:

What happens at the maximum height?

At the maximum height the object's vertical motion stops to turn around!!

$$g=9.8\text{m/s}^2$$

$$v_{yf} = v_{0y} + a_y t = v_0 \sin \theta_0 - g t_A = 0$$

Solve for  $t_A$

$$\therefore t_A = \frac{v_0 \sin \theta_0}{g}$$

Time to reach to the maximum height!!



# Horizontal Range and Max Height

Since no acceleration is in x direction, it still flies even if  $v_y=0$ .

$$R = v_{0x} t = v_{0x} (2t_A) = 2v_0 \cos \theta_0 \left( \frac{v_0 \sin \theta_0}{g} \right)$$

Range

$$R = \left( \frac{v_0^2 \sin 2\theta_0}{g} \right)$$

$$y_f = h = v_{0y} t + \frac{1}{2}(-g)t^2 = v_0 \sin \theta_0 \left( \frac{v_0 \sin \theta_0}{g} \right) - \frac{1}{2} g \left( \frac{v_0 \sin \theta_0}{g} \right)^2$$

Height

$$y_f = h = \left( \frac{v_0^2 \sin^2 \theta_0}{2g} \right)$$



# Maximum Range and Height

- What are the conditions that give maximum height and range of a projectile motion?

$$h = \left( \frac{v_0^2 \sin^2 \theta_0}{2g} \right)$$

This formula tells us that the maximum height can be achieved when  $\theta_0 = 90^\circ$ !!!

$$R = \left( \frac{v_0^2 \sin 2\theta_0}{g} \right)$$

This formula tells us that the maximum range can be achieved when  $2\theta_0 = 90^\circ$ , i.e.,  $\theta_0 = 45^\circ$ !!!



# Force

We've been learning kinematics; describing motion without understanding what the cause of the motion is. Now we are going to learn dynamics!!

~~FORCE~~ is what causes an object to move.

Can someone tell me what FORCE is?

The above statement is not entirely correct. Why?

Because when an object is moving with a constant velocity no force is exerted on the object!!!

The FORCE is what cause changes to the velocity of an object!!

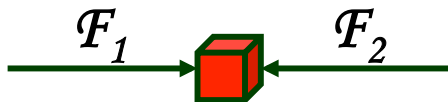
What does this statement mean?

When there is force, there is a change of velocity!!

What does the force cause? An acceleration.!!

What happens if there are several forces being exerted on an object?

Forces are vector quantities, so vector sum of all forces, the NET FORCE, determines the direction of the acceleration of the object.



NET FORCE,  
 $F = F_1 + F_2$

When the net force on an object is 0, it has constant velocity and is at its equilibrium!!

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# More Forces

There are various types of forces

*Contact Forces: Forces exerted by a physical contact of objects*

*Examples of Contact Forces: Baseball hit by a bat, Car collisions*

*Field Forces: Forces exerted without physical contact of objects*

*Examples of Field Forces: Gravitational Force, Electro-magnetic force*

*What are possible ways to measure strength of a force?*

*A calibrated spring whose length changes linearly with the force exerted.*

*Forces are vector quantities, so the addition of multiple forces must be done following the rules of vector additions.*

# Newton's First Law and Inertial Frames

Aristotle (384-322BC): *A natural state of a body is rest. Thus force is required to move an object. To move faster, one needs larger forces.*

Galileo's statement on natural states of matter: *Any velocity once imparted to a moving body will be rigidly maintained as long as the external causes of retardation are removed!!*

Galileo's statement is formulated by Newton into the **1<sup>st</sup> law of motion (Law of Inertia)**: *In the absence of external forces, an object at rest remains at rest and an object in motion continues in motion with a constant velocity.*

What does this statement tell us?

- When no net force is exerted on an object, the acceleration of the object is 0.
- Any isolated object, the object that does not interact with its surroundings, is either at rest or moving at a constant velocity.
- Objects would like to keep its current state of motion, as long as there are no net force that interferes with the motion. This tendency is called the Inertia.

A frame of reference that is moving at a constant velocity is called the *Inertial Frame*

Is a frame of reference with an acceleration an *Inertial Frame*?

**NO!**