PHYS 1443 – Section 002
Lecture #6

Monday, Sept. 22, 2008
Dr. Jaehoon Yu

- Motion in Two Dimensions
  - Maximum ranges and heights
- Reference Frame and Relative Velocity
- Newton's Laws of Motion
  - Force
  - Newton's Law of Inertia & Mass
  - Newton's second law of motion
  - Gravitational Force and Weight
  - Newton's third law of motion

Today's homework is homework #4, due 9pm, Monday, Sept. 29!!

Announcements

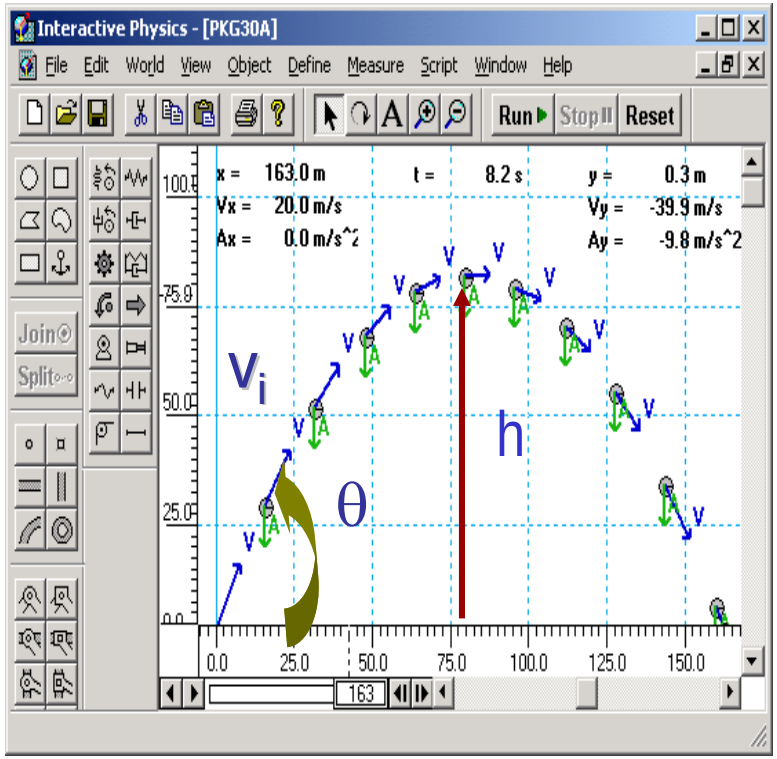
- E-mail distribution list: 60 of you subscribed to the list so far
  - Please come and check with me after the class if you are in doubt!
- Homework site was inaccessible at HW3 due!
  - Many of you communicated to me about the problem! Thanks!
  - I extended the due till 9pm tonight!
  - I strongly urge you to complete homework as early as possible and to submit as you complete problems without waiting till the due
- First term exam is being graded.
  - Will have a discussion on this Wednesday!
- There will be a quiz this Wednesday at the beginning of the class
- LHC News: The first collision event on Sept. 10 was very successful
  - But the accelerator is being warmed up to fix a transformer problem

Horizontal Range and Max Height

- Based on what we have learned in the previous lecture, one can analyze a projectile motion in more detail
  - Maximum height an object can reach
  - Maximum range

What happens at the maximum height?

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



$$v_{yf} = v_{yi} + a_y t$$

$$= v_i \sin\theta_i - g t_A = 0$$

Solve for t_A

$$\therefore t_A = \frac{v_i \sin\theta_i}{g}$$

Horizontal Range and Max Height

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

$$R = v_{xi}t = v_{xi}(2t_A) = 2v_i \cos\theta_i \left(\frac{v_i \sin\theta_i}{g}\right)$$

Range

$$R = \left(\frac{v_i^2 \sin 2\theta_i}{g}\right)$$

$$y_f = h = v_{yi}t + \frac{1}{2}(-g)t^2 = v_i \sin\theta_i \left(\frac{v_i \sin\theta_i}{g}\right) - \frac{1}{2}g\left(\frac{v_i \sin\theta_i}{g}\right)^2$$

Height

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

Maximum Range and Height

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

$$h = \left(\frac{v_i^2 \sin^2 \theta_i}{2g} \right)$$

This formula tells us that the maximum height can be achieved when θ_i=90^o!!!

$$R = \left(\frac{v_i^2 \sin 2\theta_i}{g} \right)$$

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

Example for a Projectile Motion

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

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

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

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

Becomes

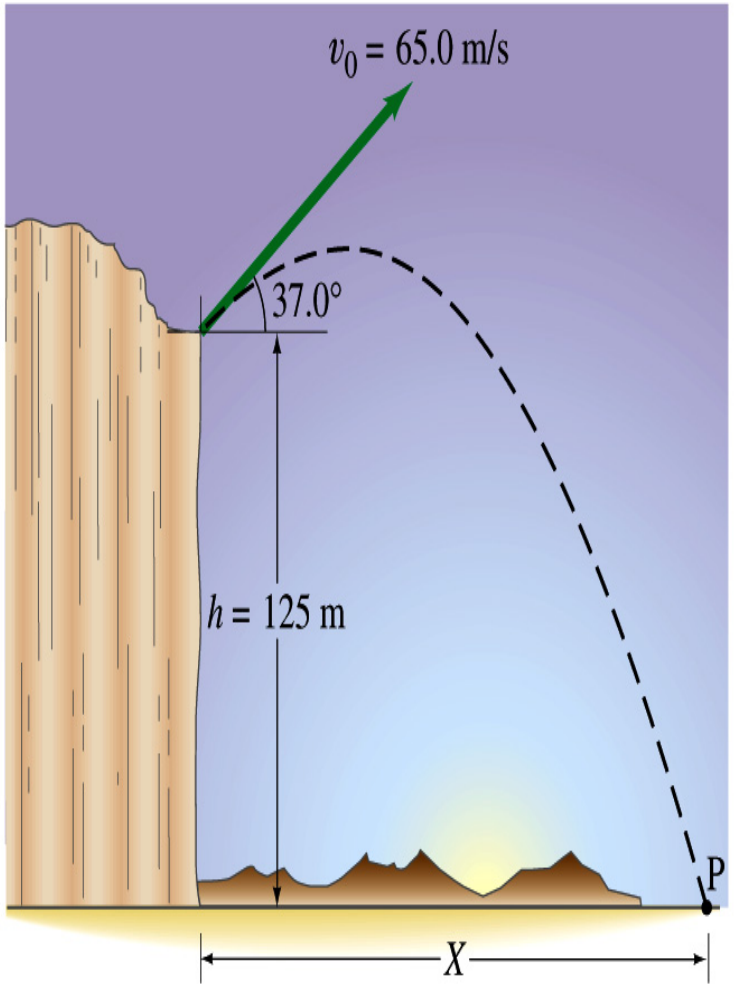
$$g t^2 - 78.2t - 250 = 9.80 t^2 - 78.2t - 250 = 0$$

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

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

$t = 10.4s$

Since negative time does not exist.



Example cont'd

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

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

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

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

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

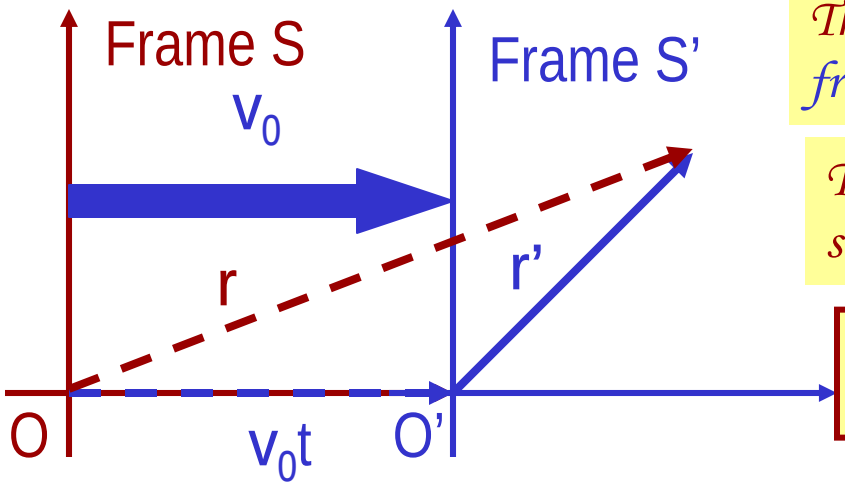
Do these yourselves at home for fun!!!

Observations in Different Reference Frames

Results of physical measurements in different reference frames could be different

Observations of the same motion in a stationary frame would be different than the ones made in the frame moving together with the moving object.

Consider that you are driving a car. To you, the objects in the car do not move while to the person outside the car they are moving in the same speed and direction as your car is.



The position vector r' is still r' in the moving frame S' no matter how much time has passed!!

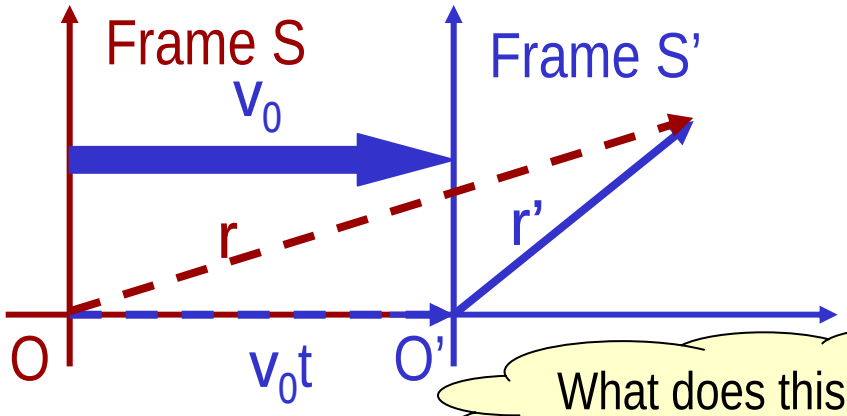
The position vector r is no longer r in the stationary frame S when time t has passed.

How are these position vectors related to each other?

$$\vec{r}(t) = \vec{r}_0 + \vec{v}_0 t$$

Relative Velocity and Acceleration

The velocity and acceleration in two different frames of references can be denoted, using the formula in the previous slide:



Galilean transformation equation

$$\vec{r}\,' = \vec{r} - \vec{v}_0 t$$

$$\frac{d\vec{r}\,'}{dt} = \frac{d\vec{r}}{dt} - \vec{v}_0$$

$$\vec{v}\,' = \vec{v} - \vec{v}_0$$

What does this tell you?

$$\frac{d\vec{v}\,'}{dt} = \frac{d\vec{v}}{dt} - \frac{d\vec{v}_0}{dt}$$

The accelerations measured in two different frames are the same when the frames move at a constant velocity with respect to each other!!!

$\vec{a}\,' = \vec{a}$, when $\vec{v}_0$ is constant

The earth's gravitational acceleration is the same in a frame moving at a constant velocity wrt the earth.

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!!!

FORCEs are what cause any changes to the velocity of an object!!

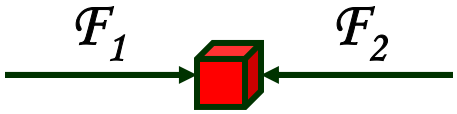
What does this statement mean?

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

What does force cause? It causes 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!!*

More Forces

There are various classes of forces

Contact Forces: Forces exerted by 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 the 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, ones 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 1st 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 force is exerted on an object, the acceleration of the object is 0.
- Any isolated object, the object that do 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 forces that interfere with the motion. This tendency is called the Inertia.

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

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

NO!