

Announcements

- ◆ Homework 3 due at end of class Wednesday
- ◆ Note that HW solutions are posted on WebCT
 - » HW 1 already posted
 - » HW 2 will be posted soon
- ◆ Grades are being made available on WebCT
 - » We try to get the bookkeeping done correctly, but we suggest that you check to make sure grades are correctly recorded
 - » If we make a mistake, please let us know so we can fix it

Forces

- ◆ Newton's Laws tell us how an object moves given the forces applied
- ◆ So just what are these forces?
- ◆ We know of 3 distinct and fundamental forces in nature:
- ◆ Gravitational Force
 - » Attractive force between all objects with mass
- ◆ Electro-weak Force
 - » Electromagnetic force acts on all objects with electrical charge
 - » Electromagnetic forces responsible for atomic/material properties
 - » Weak force responsible for radioactivity, fusion (e.g. $p + p \rightarrow d + e + \nu$)
 - » Unified theory of electromagnetic and weak forces developed ~1970
- ◆ Strong Force
 - » Holds protons/neutrons together in the atomic nucleus

Gravitational Force

- ◆ Galileo observed that objects in free-fall near the surface of the earth have a constant acceleration provided air resistance could be neglected
- ◆ What does this tell us about the force due to gravity?

$$\vec{F}_{grav} = m\vec{a}_{grav}$$

$$\vec{a}_{grav} = -g\hat{j}$$

$$\vec{F}_{grav} = -mg\hat{j}$$

- ◆ More on the source of the gravitational force later on
- ◆ From the perspective of Newton's 3rd Law:
 - » Earth exerts a downward force $F = -mg$ on an object
 - » Object exerts an upward force $F = +mg$ on the earth

Mass and Weight

- ◆ Mass is a measure of the force required to accelerate an object

$$\vec{F} = m\vec{a}$$

- ◆ “Weight” is the gravitational force on an object
 - » Near earth, weight is given by mg
 - » Units of weight are Newtons (or pounds)
- ◆ Which of the following devices would measure the wrong value on the moon?



Examples of Electromagnetic Forces

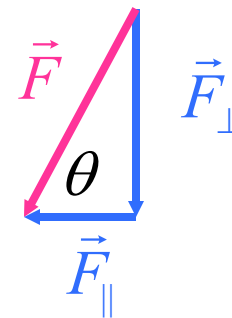
- ◆ Most fundamental of all is the attractive force between positively “charged” protons and negatively charged electrons that produces atoms
 - » Where would we be without atoms???
- ◆ Physics 4/6/47 deal directly with electrical and magnetic forces on charged objects
- ◆ Nevertheless, many common forces due to electrical forces between atoms:
- ◆ Frictional forces
 - » Resists sliding one body over another – will discuss further next lecture
- ◆ Springs
 - » Force increases in proportion to the amount the spring is stretched
- ◆ Tension
 - » Force transmitted along string/wire as it resists being stretched

Normal Force

- ◆ Consider a block resting on a solid surface
- ◆ Force perpendicular to surface will be met by an equal and opposite force (normal force)
- ◆ Example: object on a horizontal table feels a downward force from gravity of mg and an equal upward normal force from the floor
- ◆ If force is not perpendicular, can decompose force into perpendicular and parallel components
- ◆ Example: Floor mop
 - » Parallel force pushes the mop on the floor
 - » Normal force provides “scrubbing” force

$$F_{\perp} = -F \sin \theta$$

$$F_{\parallel} = F \cos \theta$$



Galileo's Incline Revisited

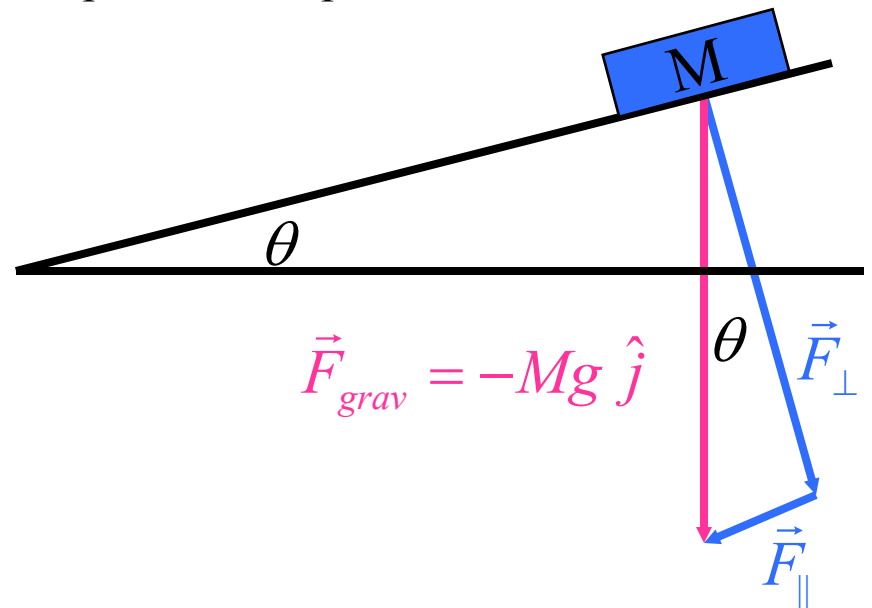
- ◆ Galileo showed that the motion on an inclined plane had constant acceleration, dependent only on the angle and not the mass
- ◆ Galileo then argued, but couldn't rigorously prove, that free-fall motion behaved in an analogous fashion
 - » Using Newton's laws, we can prove Galileo's conjecture
 - » Break force into perpendicular and parallel components

$$F_{\perp} = Mg \cos \theta$$

$$F_{\parallel} = Mg \sin \theta$$

$$= Ma$$

$$a = g \sin \theta$$



Important to Remember

- ◆ Force is a vector!
 - » Example: block on incline
- ◆ Normal force will be as large as required to keep net force perpendicular to a solid surface exactly zero
- ◆ Internal forces do not give rise to net force
 - » Example: Spring inside box
 - » Spring may be compressed, putting large forces on interior walls
 - » Net force is 0 – spring pushes with equal and opposite forces on the walls
 - » Internal forces (one part of an object exerts a force on another part of the object) have no net force
 - » We will be interested in external forces exerted on an object from outside
- ◆ If there is more than one force, it is the net force that determines the object's acceleration

$$\vec{F}_{Net} = m\vec{a}$$

Inertial Reference Frame

- ◆ Newton's laws only apply in inertial reference frames
- ◆ So, what's an inertial reference frame?
 - » HRW: "one in which Newton's laws hold"
- ◆ Example of a slightly non-inertial reference frame: BH 166
 - » Can be seen clearly using a Foucault pendulum
 - » As pendulum swings back and forth, the direction of motion slowly rotates with respect to the floor
 - » Newton's laws would say pendulum should keep swinging in same plane
 - » But, the earth rotates!
 - » What would happen at N pole?
 - » First direct demonstration earth turns



More Non-Inertial Reference Frames

- ◆ Example: try playing catch on a “hurdy-gurdy”
- ◆ Example: motion of objects on dashboard of accelerating car
- ◆ Above examples of non-inertial reference frames were all ones that were undergoing acceleration
- ◆ Inertial reference frames are those that are not being accelerated
 - » Also, need to stay away from black holes and other places where gravity is “warping” space-time (shouldn’t be a problem for Physics 5...)

