Lecture 5

- **Force and Motion.**
- **Mass and Weight,**
- **Free Body Diagrams**

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Physics 105; Fall 2009

Last Lecture: Projectile Motion

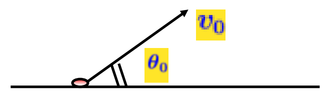
Horizontal motion	Vertical motion
$a_x = 0$	$a_y = -g$

In both directions the acceleration is constant

$v_x = v_{0x} \equiv \text{constant}$

$x = x_0 + v_{0x}t$

$$x - x_0 = v_{0x}t = (v_0 \cos\theta_0)t$$



$v_y = v_{0y} - gt$

$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$

$$y - y_0 = v_{0y}t - \frac{1}{2}gt^2 = (v_0 \sin\theta_0)t - \frac{1}{2}gt^2$$

$$v_y = v_0 \sin\theta_0 - gt$$

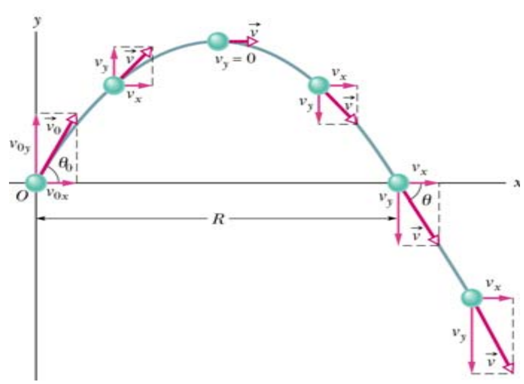
$$v_y^2 = (v_0 \sin\theta_0)^2 - 2g(y - y_0)$$

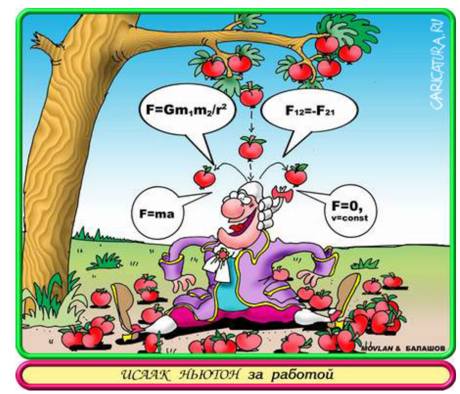
Projectile Motion; General Case

Trajectory and horizontal range

$$y = (\tan\theta_0)x - \frac{gx^2}{2(v_0\cos\theta_0)^2}$$

$$R = \frac{v_0^2}{g}\sin 2\theta_0$$





Newton's Laws

I. If no net force acts on a body, then the body's velocity cannot change.

II. The net force on a body is equal to the product of the body's mass and acceleration.

III. When two bodies interact, the force on the bodies from each other are always equal in magnitude and opposite in direction.

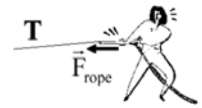
Objectives

- By the end of Week we should be able to
  - Formulate Newton's laws in our own words
  - Draw free-body-diagrams (FBDs) for a given problem
  - Explain the difference between static and kinetic frictional force
  - List a few reference frames where Newton's laws do not apply

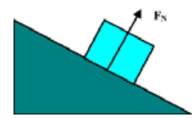
Forces:

- Gravitational Force: $F = mg$
- Archimedes Force

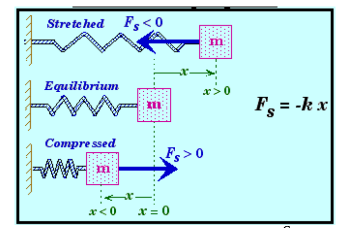
- Friction Force:



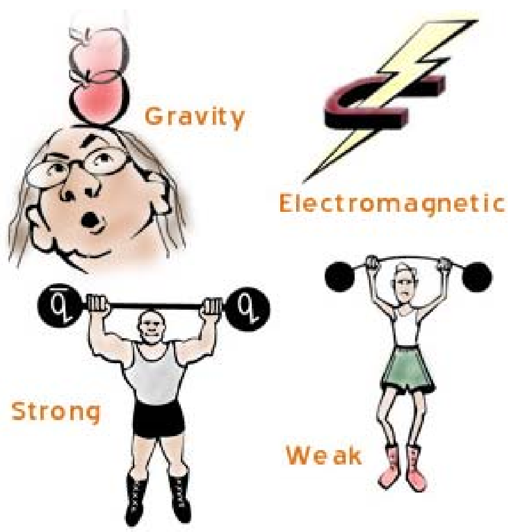
- Tension Force
- Spring Force



- Normal Force



Forces:



Force is a vector. Units: [Newton]

$1\text{ N} = 1\text{ kg} \bullet 1\text{ m/s}^2$

Force has direction and magnitude

Mass connects Force and Acceleration

Mass is a measure of inertia.

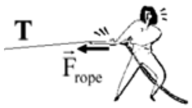
$$\vec{F}_{tot} = 0 \Leftrightarrow \vec{a} = 0 \text{ (constant velocity)}$$

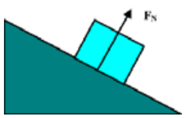
$$\vec{F}_{tot} = m\vec{a} \text{ for any object}$$

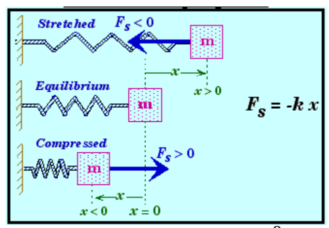
$$F_{tot,x} = ma_x \qquad F_{tot,y} = ma_y \qquad F_{tot,z} = ma_z$$

Forces:

- Gravitational Force: F = mg
- Archimedes Force
- Friction Force:
- Tension Force
- Spring Force
- Normal Force

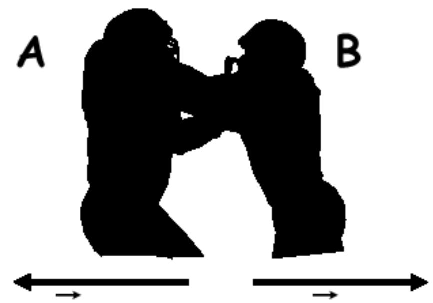






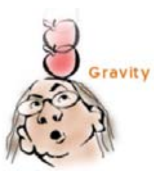
Newton's 3rd Law

When object A exerts a force $\vec{F}$ on object B, then object B exerts force $-\vec{F}$ on object A



$$\vec{F}_{B\ on\ A} = -\vec{F}_{A\ on\ B}$$

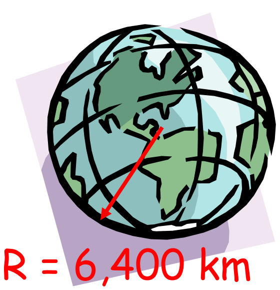
Gravitational Force:



F = mg; g = 9.8 m/s^2

$$\left|\vec{F}\right| = \gamma \frac{M \bullet m}{R^2}$$

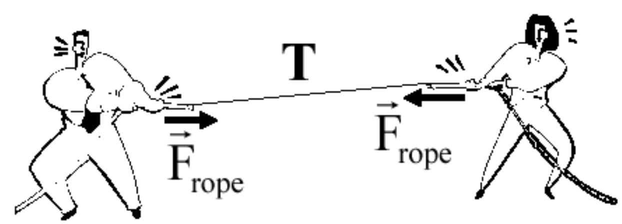
$$\left|\vec{g}\right| = \gamma \frac{M}{R^2} = 9.8 \frac{m}{s^2}$$



R = 6,400 km

Tension: T

A taut rope exerts forces on whatever holds its ends



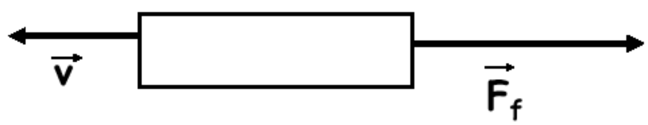
Tension in rope = Force on ends

$$\left|\vec{F}_{on\ A}\right| = T = \left|\vec{F}_{on\ B}\right|$$

Frictional Forces: $\vec{F}_f$

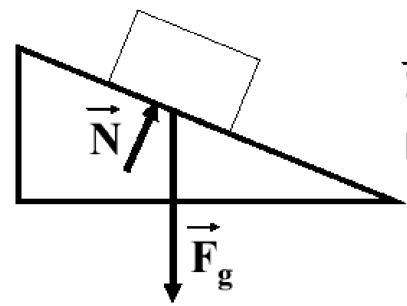
Force from surface or from surrounding fluid which oppose motion

- In direction opposite velocity if moving
- In direction opposite vector sum of other forces if stationary



Normal Force: $\vec{N}$

Force from a solid surface which keeps objects from falling through



$\vec{N} \perp$ surface

Force on surface = $-\vec{N}$

Net Force

A free body diagram is used to calculate the net force on <u>one object</u>.

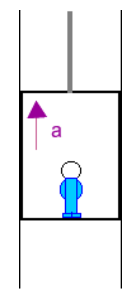
$$\vec{F}_{net} = m\vec{a}$$

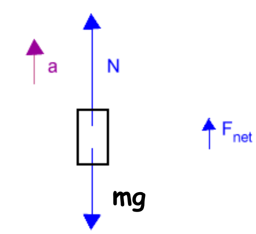
The two equal forces in Newton's Third Law are on *different objects.*

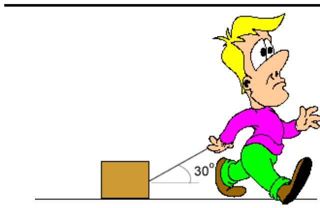
They don't appear on the same free body diagram.

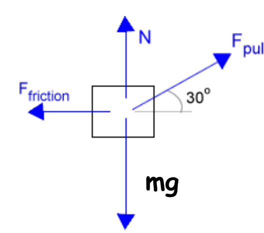
<u>EXAMPLES of Free Body Diagrams</u>

<u>Picture of Situation</u> **<u>FBD</u>**







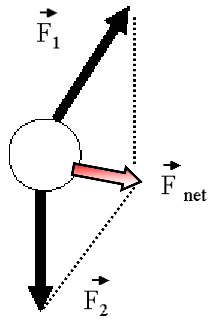


Dealing with Multiple Forces

If multiple forces are acting on the same object, the net force determines the acceleration.

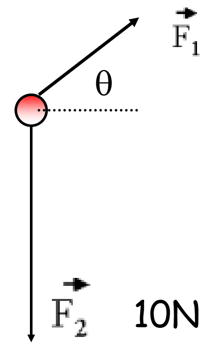
$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$$

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



Use a free body diagram to keep track of the forces on *one object*.

EXAMPLE



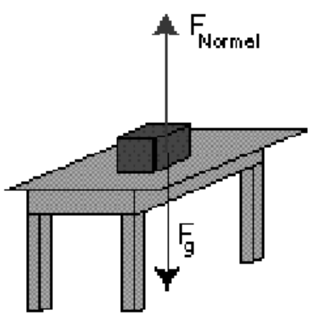
$\theta = 30°$

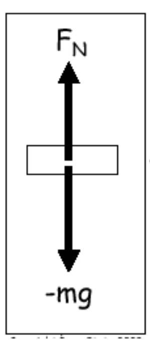
Find F_3 so that $a = 0$

Normal Force

We don't fall through the floor

This is a constraint → Normal Force (F_N)





$ma = F_N + F_G = 0$

$F_N = mg$

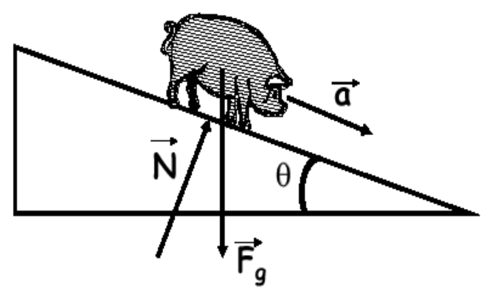
Just balances gravity to keep block on table

Note: normal force is *variable*

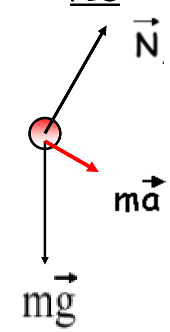
27

EXAMPLE

Pig on Frictionless Inclined Plane



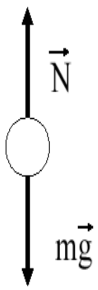
FBD



$$m\vec{a} = m\vec{g} + \vec{N}$$

How do we jump ?

A standing person



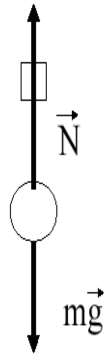
No acceleration

$\Rightarrow$

Net force is zero

$F_{NET}=|N|-mg=0$

A jumping person



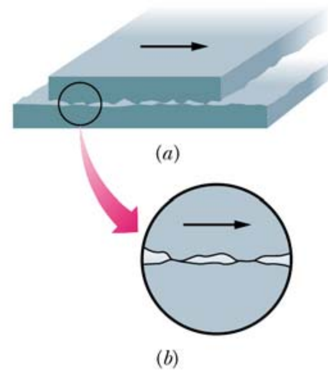
Acceleration

$\Rightarrow$

$F_{NET} = ma$

$|N|-mg=ma > 0$

Static and Kinetic Friction



Static frictional force

$$f_{s,\max} = \mu_s N$$

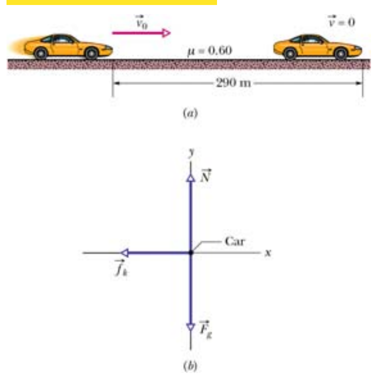
Kinetic frictional force

$$f_{k,\max} = \mu_k N$$

Kinetic Friction

Kinetic frictional force:

$$f_{k,\max} = \mu_k N$$



Skid marks are 290 m long! μ_k = 0.6 and $\boldsymbol{a}$ = const. How fast was the car going when the wheels became locked?

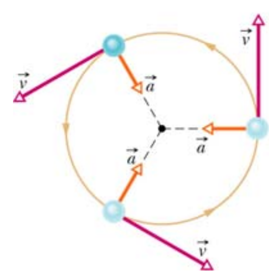
Uniform Circular Motion

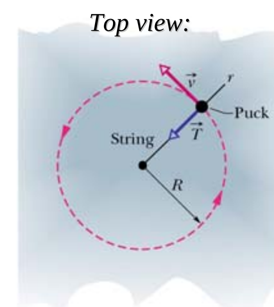
Centripetal acceleration

$$a = \frac{v^2}{r}$$

Period

$$T = \frac{2\pi r}{v}$$





Centripetal force : F = ma

$$F = m\frac{v^2}{r}$$

QZ #5

Name, ID #, Section #

Problem 1:

What is the **acceleration** (in unit vectors notation) of a particle with **m =2 kg** due to a combination of two forces:

$\mathbf{F}_1$= (2N)**i**+(2N)**j**-(3N)**k** and $\mathbf{F}_2$= (-2N)**i**+(2N)**j**+(6N)**k**.

Problem 2:

What is the magnitude of the **acceleration** vector?

Problem 3:

What is the magnitude of the **Net Force** ?