Forces

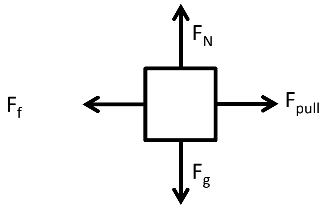
- Push or pull on an object
- Causes acceleration
- Measured in Newtons N = $\frac{Kg\ m}{s^2}$

Contact Forces
Applied Force
Frictional Force
Tensional Force
Normal Force
Drag Force
Spring Force

Field Forces
Gravitational Force
Electrical Force
Magnetic Force

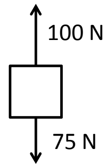
Free Body Diagrams

- Shows all forces as vectors acting on an object
- Vectors always point away from object
- Used to help find net force



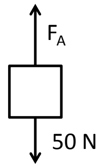
Find the unknown forces!!

Ex. 1



F_{net} = ?

Ex. 2



F_{net} = 10 N Downward

F_{net} = 100N – 75 N

F_{net} = 25 N Upward

$F_{net} = F_A - 50\text{ N} = -10\text{ N}$

F_A = 40 N

Newton's First Law

Law of Inertia – Resistance to change motion

- Objects in motion stay in motion
- Objects at rest stay at rest

Equilibrium – balanced forces, net force = 0

Net force – sum of all forces

Newton's Second Law

A net force will cause acceleration

$$\underset{\text{force}}{F} = \overset{\text{mass}}{m}\underset{\text{acceleration}}{a}$$

Gravity force → $F = mg$

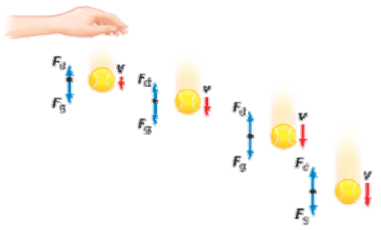
Mass and weight are not the same!!!

Drag Force

- "friction" force from a fluid (gases and liquids)

Terminal Velocity – constant velocity of falling

when $F_{drag} = F_g$



Newton’s Third Law

- Each action has an opposite and equal reaction

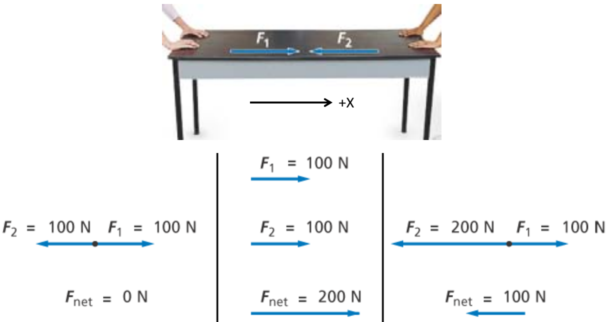
$$F_{A\text{ on }B} = -F_{B\text{ on }A}$$

- Interaction Pair – action / reaction forces

Solving Tips

1. Draw the problem and choose coordinates
2. Determine known and unknown forces.
3. Create a free-body diagram showing the net force.
4. Use Newton’s laws to link acceleration and net force.
5. Solve equations for the unknowns

Combining Forces

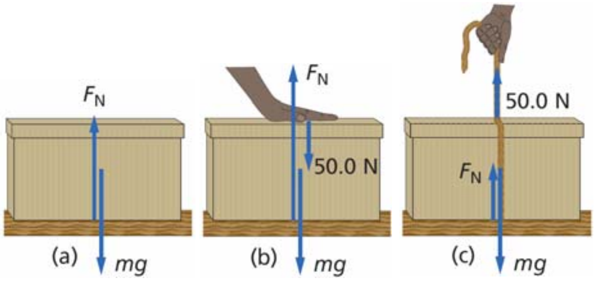


Equal forces
Opposite directions

Equal forces
Same direction

Unequal forces
Opposite directions

Normal Force



$F_N = mg$ $F_N = mg + F_{hand}$ $F_N = mg - F_{string}$

Friction Factor

- Always against motion
- Two branches of friction (3 Types)
  - Kinetic (Moving)
    - Sliding
    - Rolling
  - Static (Stationary)
- Friction of fluids is called viscosity

Friction Force

Kinetic Friction

$$F_f = \mu_k F_n$$

μ = friction factor F_n = Normal Force

Static Friction

$$F_{f,static} \leq \mu_s F_n$$

Static Friction

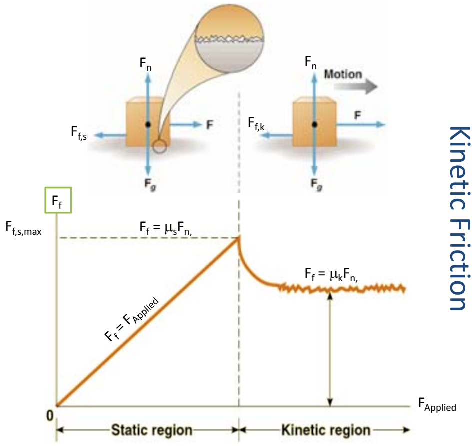
- The force of static friction is not constant!
- Static friction is equal to pulling force until the object begins to move
- The maximum static friction is equal to $\mu_s F_n$

$$F_{f,static,max} \geq F_{applied} \rightarrow \text{stays still}$$

$$F_{f,static,max} = F_{applied} \rightarrow \text{constant speed, a=0}$$

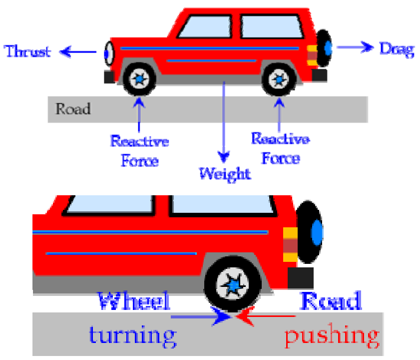
$$F_{f,static,max} \leq F_{applied} \rightarrow \text{accelerates}$$

Static Friction



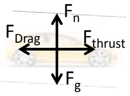
Kinetic Friction

Thrust from Friction



Static Friction and Motion

What is the maximum acceleration a car can achieve if the tires/road friction coefficient is equal to 0.7? (ignore drag)



$$F_{net,x} = F_{thrust} - \cancel{F_{drag}} = ma$$

The maximum thrust cannot exceed road friction

$$F_{thrust} = F_{f,s,max} = \mu_s F_n = \mu_s\, mg$$

From $F_{net,x}$ $\cancel{m}a = \mu_s \cancel{m}g$

$$a = \mu_s\, mg = (0.7)(9.8m/s^2) = 6.9m/s^2$$

Static Equilibrium

The most important rule:

$$\Sigma F = 0$$

This means that:

$$\Sigma F_x = 0 \quad \text{and} \quad \Sigma F_y = 0$$

Static Equilibrium

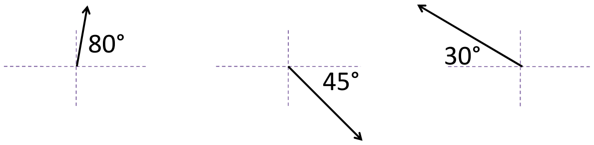
ALWAYS FOLLOW THESE STEPS:

1. Draw a labeled free body diagram
2. Break angled forces into components
3. Write net equations ($F_{net,x}$ = …)
    - Only use the components of angled forces!!
    - $F_{net,x} = 0$ and $F_{net,y} = 0$
4. Solve for unknowns one at a time

Vector Direction (2 Common Ways)

- Labeled degrees north or south of x-axis
- Degrees from east direction (0°).

80° N of East	45° S of East	30° N of West
Or 80°	Or 315°	Or 150°



Working with Forces at an Angle

When a force is at an angle:

- break into x and y components
  - Do not use the original force again!!
- Add x and y components separately
- Find the new resultant force and its angle

$$F = \sqrt{F_x^{\,2}+F_y^{\,2}} \qquad \theta = \mathrm{Tan}^{-1}\frac{O}{A}$$

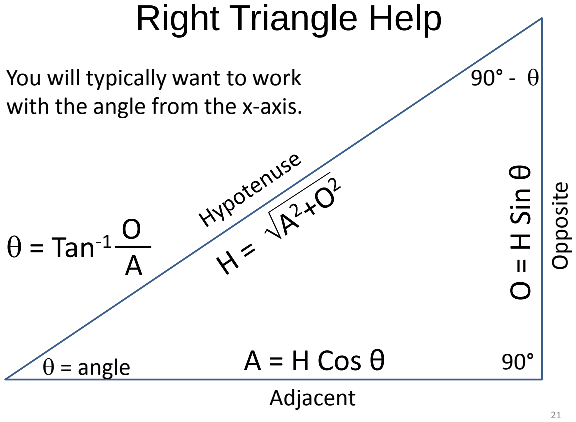
Using the angle from the x-axis:

X-Component	y-Component
$F_x = F\cos\theta$	$F_y = F\sin\theta$

Right Triangle Help

You will typically want to work with the angle from the x-axis.

$$\theta = \mathrm{Tan}^{-1}\frac{O}{A}$$

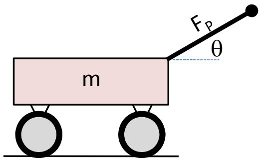


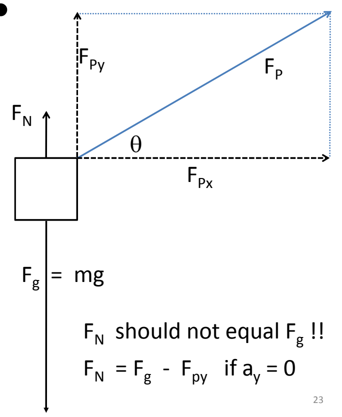
SOH	CAH	TOA
$\mathrm{Sin}\,\theta = \frac{O}{H}$	$\mathrm{Cos}\,\theta = \frac{A}{H}$	$\mathrm{Tan}\,\theta = \frac{O}{A}$

$$\theta = \mathrm{Sin}^{-1}\frac{O}{H} = \mathrm{Cos}^{-1}\frac{A}{H} = \mathrm{Tan}^{-1}\frac{O}{A}$$

Opposite	Adjacent	Hypotenuse
$O = H\,\mathrm{Sin}\,\theta$	$A = H\,\mathrm{Cos}\,\theta$	$H = \frac{O}{\mathrm{Sin}\,\theta}$
$O = A\,\mathrm{Tan}\,\theta$	$A = \frac{O}{\mathrm{Tan}\,\theta}$	$H = \frac{A}{\mathrm{Cos}\,\theta}$
$O = \sqrt{H^2 - A^2}$	$A = \sqrt{H^2 - O^2}$	$H = \sqrt{A^2+O^2}$

Forces at an Angle - Breaking into components





Find F_P Components

$F_{Px} = F_P \,\mathrm{Cos}\,\theta$

$F_{Py} = F_P \,\mathrm{Sin}\,\theta$

Use components for net equations

$F_{netx} = F_{Px}$

$F_{nety} = F_N + F_{Py} - F_g$

F_N should not equal F_g !!

$F_N = F_g - F_{py}$ if $a_y = 0$

Forces on a Ramp - Breaking into components

Find F_g Components

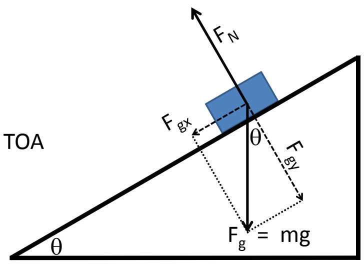
$F_{gx} = F_g \,\mathrm{Cos}\,(90\text{-}\theta)$

$F_{gy} = F_g \,\mathrm{Sin}\,(90\text{-}\theta)$

Or just use SOH CAH TOA

$F_{gx} = F_g \,\mathrm{Sin}\,\theta$

$F_{gy} = F_g \,\mathrm{Cos}\,\theta$



Use components for net equations

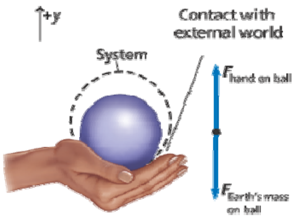
$F_{netx} = -F_{gx}$

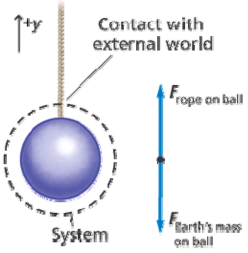
$F_{nety} = F_N - F_{gy}$

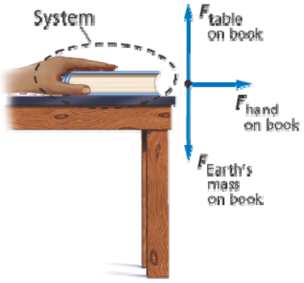
F_N should not equal F_g !!

Many cases, F_N will equal F_{gy}

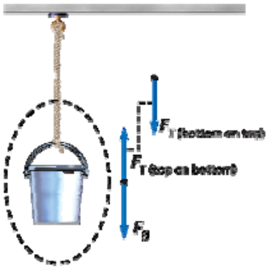
Free Body Diagrams



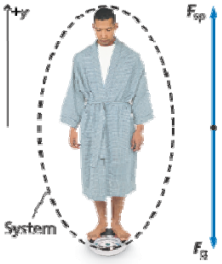




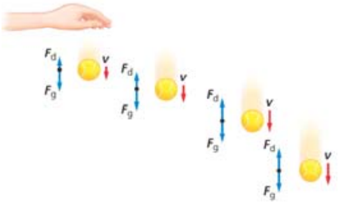
Tension Force

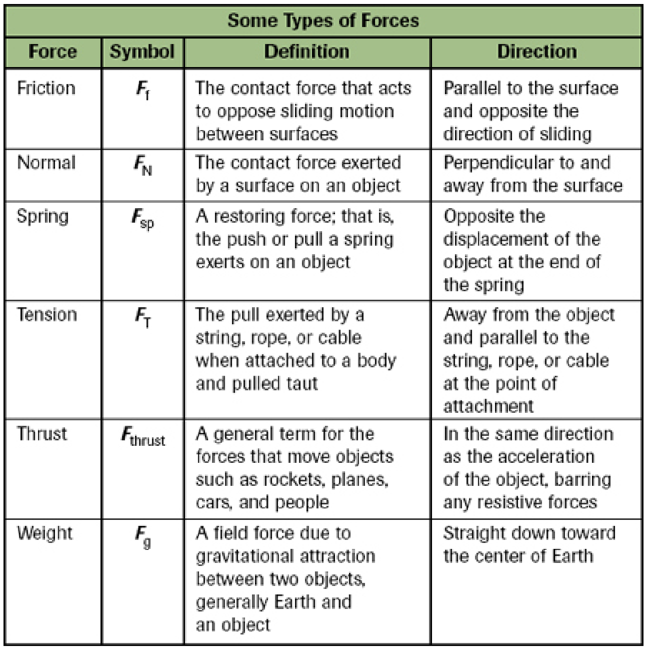


Spring Force

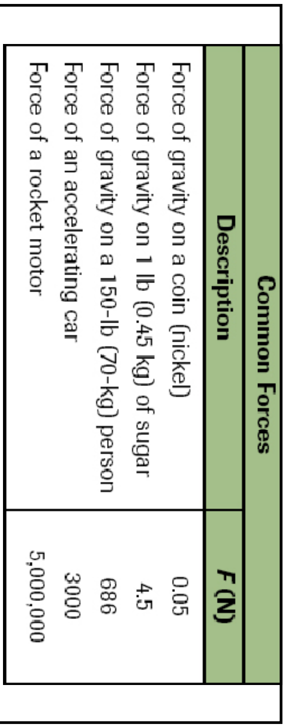


Drag Force





Some Types of Forces			
Force	**Symbol**	**Definition**	**Direction**
Friction	F_f	The contact force that acts to oppose sliding motion between surfaces	Parallel to the surface and opposite the direction of sliding
Normal	F_N	The contact force exerted by a surface on an object	Perpendicular to and away from the surface
Spring	F_{sp}	A restoring force; that is, the push or pull a spring exerts on an object	Opposite the displacement of the object at the end of the spring
Tension	F_T	The pull exerted by a string, rope, or cable when attached to a body and pulled taut	Away from the object and parallel to the string, rope, or cable at the point of attachment
Thrust	F_{thrust}	A general term for the forces that move objects such as rockets, planes, cars, and people	In the same direction as the acceleration of the object, barring any resistive forces
Weight	F_g	A field force due to gravitational attraction between two objects, generally Earth and an object	Straight down toward the center of Earth



Common Forces	
Description	**F (N)**
Force of gravity on a coin (nickel)	0.05
Force of gravity on 1 lb (0.45 kg) of sugar	4.5
Force of gravity on a 150-lb (70-kg) person	686
Force of an accelerating car	3000
Force of a rocket motor	5,000,000