NEWTON'S 3RD LAW

- For every action there is an **equal** and **opposite** reaction
  - The astronaut pushes on the rock and the rock pushes on the astronaut

"If object 1 and object 2 interact, the force $\mathbf{F}_{12}$ exerted by object 1 on object 2 is equal in magnitude but opposite in direction to the force $\mathbf{F}_{21}$ exerted by object 2 on object 1."

$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

Forces in nature always exist in pairs, as an interaction between two objects.

We represent this in a system schema with arrows that point both directions.

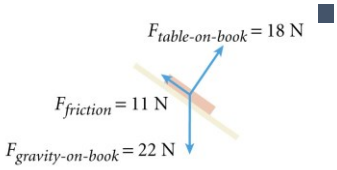
NEWTON'S THIRD LAW (ACTION AND REACTION)

Every force is part of an interaction between two objects.
This interaction makes up an action-reaction pair.
If you can switch the order of objects, you have an action-reaction pair.

Use the phrase: **Force with which A pulls (or pushes) B**
The reaction is: Force with which B pulls(or pushes) A Equal and Opposite
Fn and FG are NOT !

Warning: When drawing an FBD for an object, you will never have an action-reaction pair. Only one of these forces can act on the object.

FRICTION



Friction – is the force that resists the sliding of one object past another.

- In free-body diagrams, the force of friction is always **parallel** to the surface of contact.
- Force of friction (F_f) is proportional to the magnitude of the normal force (F_N)
  - Depends upon
    - Kinds of materials
    - How much they are pressed together

2 TYPES OF FRICTION

Kinetic Friction:

- **Kinetic Friction** describes the contact force resisting the relative motion between two objects when one or both are moving
- The direction of the force of friction is always parallel to the plane of contact between the objects (perpendicular to the normal force) and opposite of the direction of motion

Static Friction:

- **Staic Friction** describes the contact force resisting the relative motion between two objects when neither object is moving (relative to the other)
- The force of static friction can vary depending on the force it's opposing, up to a maximum amount

STATIC FRICTION

The static force of friction opposes the relative motion that would occur if there were no friction.

Another interesting feature is that ***the static force of friction adjusts itself to whatever it needs to be to prevent relative motion between the surfaces in contact.***

Within limits, that is. The static force of friction has a maximum value ,Ffsmax

FORCE OF FRICTION

Calculating Frictional Force:

Both static and kinetic friction depend on two factors:

- The normal force (which measures how strongly the two objects are pushed together)
- The coefficient of friction (which measures the microscopic "roughness" of the surfaces that are in contact with each other)

- The coefficient of friction is a property of the two materials that are in contact with each other and has a different value for static and kinetic friction. It's represented by the Greek letter μ.

Coefficient of static friction: μ_s **Coefficient of kinetic friction: μ_k**

2 TYPES OF FRICTION

1. Object is not moving

- **Static friction (F_{sf})** is a force that resists the start of sliding motion between two surfaces that are in contact and at rest
- As long as object doesn't move $F_s = - F_{applied}$
- Maximum force of F_s is $F_{s,max}$
  - $F_{s,Max}$ – Just before movement starts
  - $F_{s,max} = \mu_s F_N$
  - μ_s = coefficient of static friction
    - μ_s depends upon the two surfaces

2 TYPES OF FRICTION (CONT)

2. Object is moving

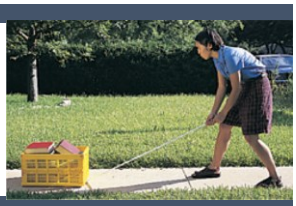
- **Kinetic friction** (F_k) is the force that opposes the movement of two surfaces that are in contact and are sliding over each other.
  - Kinetic friction is always less than the maximum static friction.
  - $F_k = \mu_k F_N$
    - μ_k = coefficient of kinetic friction
- For any pair of surfaces $\mu_k < \mu_s$
  - It's harder to push an object from rest than it is to keep it in motion

COEFFICIENTS OF FRICTION TABLE

Coefficients of Friction

	μ_s	μ_k		μ_s	μ_k
Steel on steel	0.74	0.57	Waxed wood on wet snow	0.14	0.1
Aluminum on steel	0.61	0.47	Waxed wood on dry snow	—	0.04
Rubber on dry concrete	1.0	0.8	Metal on metal (lubricated)	0.15	0.06
Rubber on wet concrete	—	0.5	Ice on ice	0.1	0.03
Wood on wood	0.4	0.2	Teflon on Teflon	0.04	0.04
Glass on glass	0.9	0.4	Synovial joints in humans	0.01	0.003

SAMPLE PROBLEM-FRICTION



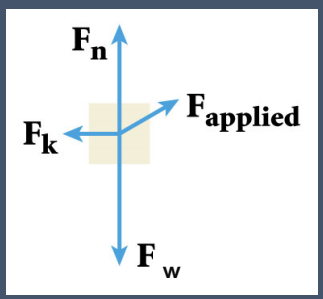
A Student attaches a rope to a 20.0 kg box of books. He pulls with a force of 90.0 N at an angle of 30.0° with the horizontal. The coefficient of kinetic friction between the box and the sidewalk is 0.500. Find the acceleration of the box.

Given:

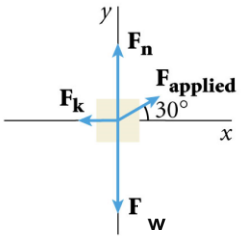
m = 20.0 kg
μ_k = 0.500
$F_{applied}$ = 90.0 N
Angle = 30.0°

Unknown:

a = ?



SAMPLE PROBLEM-FRICTION



- Any vectors not on X & Y axis break it into its components

$F_{ax} = F_a \cos\theta$

$F_{ax} = (90.0\ N)\cos 30.0^o$

$= 77.9\ N$

Sum of Forces in X-Direction

$\Sigma F_x = ma_x$

$F_{ax} - F_k = ma$

$F_k = U_k F_n$ Sub into eqn

$F_{ax} - U_k F_n = ma$

$F_{ay} = Fa \sin\theta$

$F_{ay} = (90.0\ N)\sin 30.0^o$

$= 45.0\ N$

Sum of Forces in Y-Direction

$\Sigma F_y = ma_y$ no motion in y

$F_{ay} - F_w + F_n = 0$

$F_n = F_w - F_{ay}$ $F_w = Mg$

$F_n = Mg - F_{ay}$

$F_n = (20.0\ kg)(9.8\ m/s^2) - 45.0\ N$

$F_n = 151$

SAMPLE PROBLEM-FRICTION

$F_{ax} - U_k F_n = ma_x$

$$a_x = \frac{F_{applied,x} - F_k}{m} = \frac{77.9\ \text{N} - 75.5\ \text{N}}{20.0\ \text{kg}} = \frac{2.4\ \text{N}}{20.0\ \text{kg}} = \frac{2.4\ \text{kg} \bullet \text{m/s}^2}{20.0\ \text{kg}}$$

a = 0.12 m/s^2 to the right