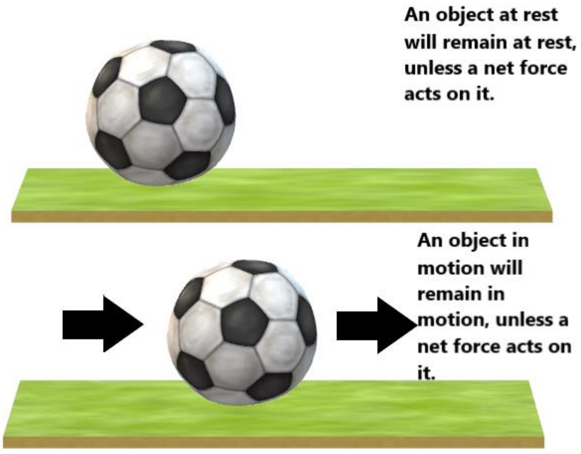
Force

Force: loosely defined as "pushing" or "pulling".

- Net force = sum. of forces, measured in newton (N).
- 1 N = 1 Kg.m/s^2

Newton's First Law: it states that an object will remain at rest or, maintains a constant velocity unless a net external force acts upon it.



Mass: a property of an object that determines how much it will resist a change in velocity.

- Measures an object's resistance to change in velocity.
- Measured in kilograms (Kg).

Gravitational Force (Weight): force of gravity on an object.

- Direction: down.

$$W = mg$$

Where

W: weight.

m: mass.

g: free fall acceleration.

Units: newton (N).

<u>Example:</u> what is this box's weight on earth?

Sol.:

W = mg

= (80 kg) (9.8 m/s^2)

= 784 N.

Newton's Second Law: net force equals mass times acceleration.

ΣF = ma

Where

ΣF: net force.

m: mass.

a: acceleration.

Units: N (Kg.m/s^2)

<u>Example:</u> what is the bag acceleration if it mass equals 15 Kg?

Sol.:

ΣF = ma

F + (-w) = ma

F + (-mg) = ma

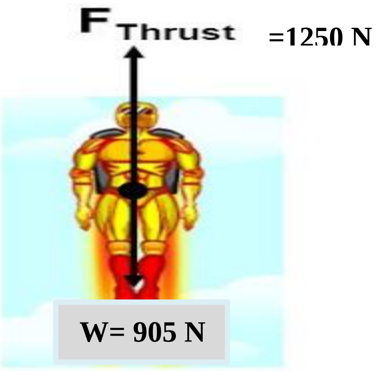
$$a = \frac{F+(-mg)}{m}$$

$$a = \frac{158+(-15x9.8)}{15}$$

a = 0.73 m/s^2 (upward).

Example: rocket guy weighs 905 N and his jet pack provides 1250 N of thrust, straight up. What is his acceleration?

Sol.: the jet pack provides an upward force, while the guy's weight points downward.



$\Sigma F = ma$

$F_T + (-W) = ma$

$1250 + (-905) = ma$

$345 = ma$ … (1)

Since

$W = mg$

$905 = m * 9.81$

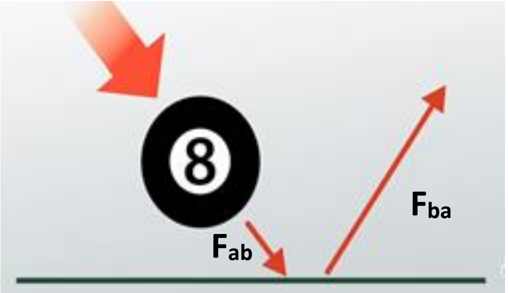
$m = 92.3$ Kg sub. In (1)

$345 = 92.3 * a$

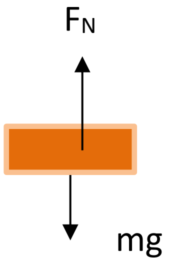
$a = 3.74$ m/s^2 (upward).

Newton's Third Law: to any action is always an opposite and equal reaction; in other words, the actions of two bodies upon each other are always equal and opposite in direction.

$$F_{ab} = -F_{ba}$$



Normal Force:

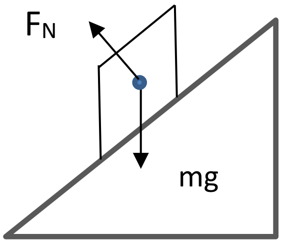


- It occurs with two objects in direct contact.
- It is perpendicular to surface of contact.

<u>Example:</u> what is the direction of the normal force for the following figure?

Sol.:

It is perpendicular to the surface of the ramp.



<u>Example:</u> the string supplies an upward force on the block which is resting on the table as shown in the figure below. What is the normal force of the table on the block?

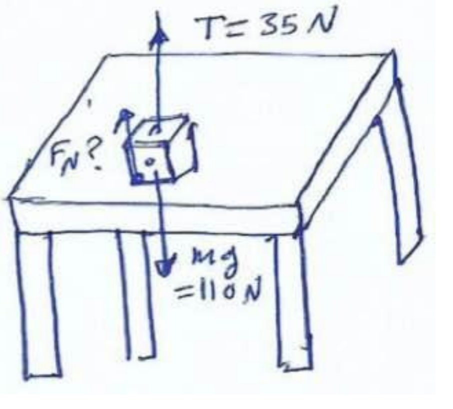
Sol.:

$\Sigma F = ma = 0$ (a=0, resting on the table)

$F_N + T + (-mg) = 0$

$F_N + 35 - 110 = 0$

$F_N = 75$ N (upward).



Tension (T): force exerted by a string, cord, twine, rope, chain, cable, etc.

<u>Example:</u> what is the amount of tension in the rope for the figure below?

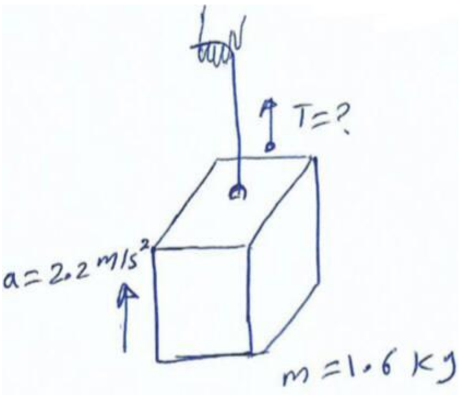
Sol.:

$\Sigma F = ma$

$T + (-mg) = ma$

$T + (-1.6 * 9.81) = 1.6 * 2.2$

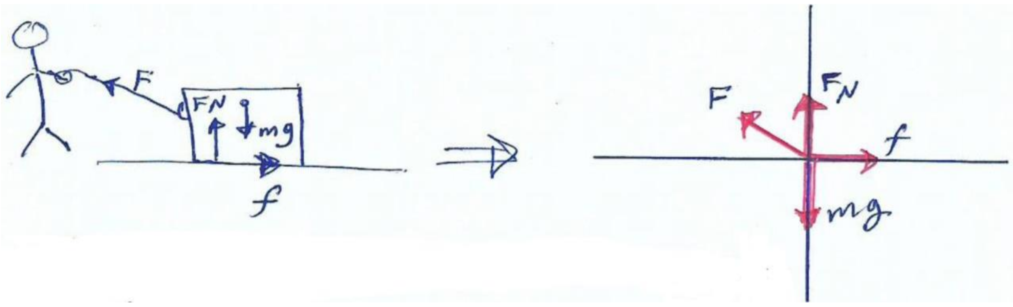
$T = 19$ N (upward).



Free – Body Diagram: a drawing of the external force exerted on an object.

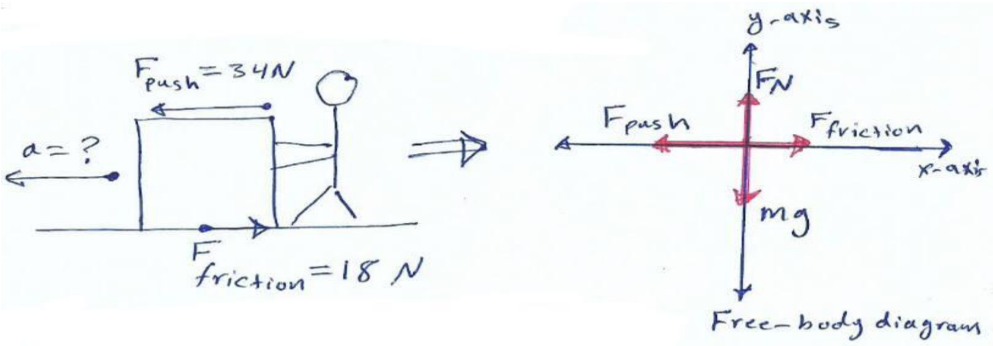
- It shows all external forces acting on the body.
- Often drawn from the origin.

Example: draw a free – body diagram of the forces on the box as shown below?



f: friction acts to oppose motion when two objects are in contact.

Example: pushing a box horizontally, what is the acceleration of 15 Kg box?



Sol.:

- The person shown above is pushing horizontally, causing it to accelerate. The force of friction opposes this movement.
- The free – body diagram shows all the forces acting on the box. In solving the problem, we use only the horizontal forces from the push and friction in our calculations. There is no net vertical force because the downward force of weight is balanced with the upward normal

force. The fact that there is no vertical acceleration confirms that there is no net vertical force.

$\Sigma F_x = ma$

$F_{friction} - F_{push} = ma$

$18 - 34 = 15 * a$

$a = -1.07\ m/s^2$

Friction: a force that resist the motion of one object sliding past another.

- It varies by materials in contact.
- It is proportional to normal force.

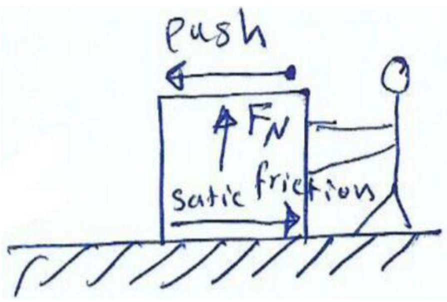
There are two types of friction:

1. Static friction.

2. Kinetic friction.

Static Friction: a force that resists the sliding motion of two objects that are stationary relative to one another.

- Force opposing sliding when there is no motion.
- It balances pushing force until object slides.
- Maximum static friction proportional to:
  - Coefficient of static friction.
  - Normal force.



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

Where

$f_{s,max}$: maximum static friction.

μs: coefficient of static friction.

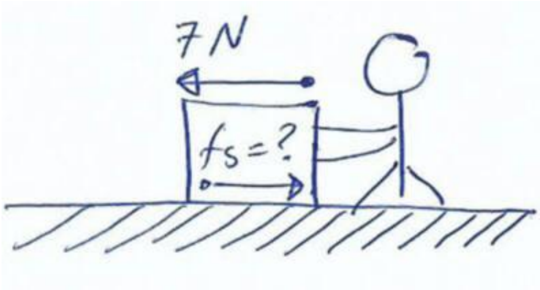
F_N: normal force.

The table below shows some selected values of coefficient of static friction.

Table (1.1) : coefficient of static and kinetic friction.

System	Static friction μ_s	Kinetic friction μ_k
Rubber on dry concrete	1.0	0.7
Rubber on wet concrete	0.7	0.5
Wood on wood	0.5	0.3
Waxed wood on wet snow	0.14	0.1
Metal on wood	0.5	0.3
Steel on steel (dry)	0.6	0.3
Steel on steel (oiled)	0.05	0.03
Teflon on steel	0.04	0.04
Bone lubricated by synovial fluid	0.016	0.015
Shoes on wood	0.9	0.7
Shoes on ice	0.1	0.05
Ice on ice	0.1	0.03
Steel on ice	0.04	0.02

<u>Example:</u> a person is pushing box as shown in the figure below, but the box does not move. What is the force of static friction?



Sol.:

$\Sigma F_x = ma$

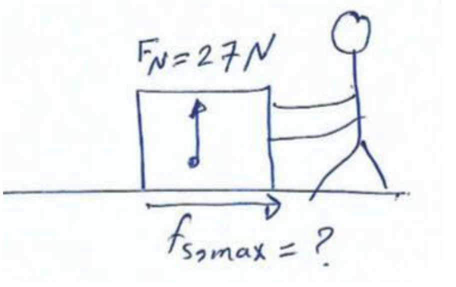
$f_s - F_{push} = ma$

$f_s - F_{push} = 0$ (a=0, the box does not move)

$f_s - 7 = 0$

$f_s = 7$ N (to the right).

Example: what is the maximum static friction force? The coefficient of static friction for these materials is 0.31.



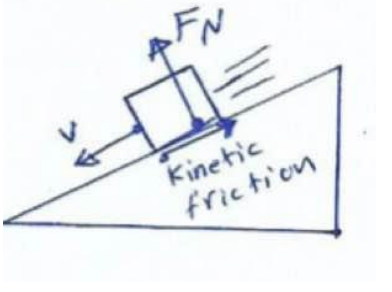
Sol.:

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

$= (0.31)\ (27)$

$= 8.4$ N.

Kinetic Friction: friction when an object slides along another.



- Friction opposing sliding in motion.
- Force is constant as an object slides.
- Kinetic friction is proportional to:
    - Coefficient of kinetic friction.
    - Normal force.

$$\mathbf{f_K = \mu_K F_N}$$

Where

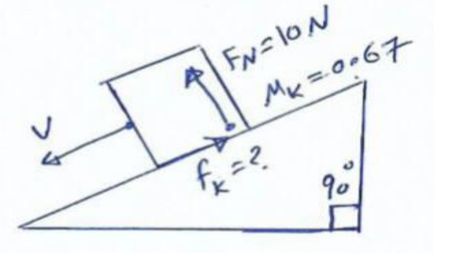
F_K : force of kinetic friction.

μ_K: coefficient of kinetic friction.

F_N: normal force.

The table (1.1) shows some selected values of coefficient of kinetic friction.

Example: what is the force of friction for the figure below?



Sol.:

$f_K = \mu_K F_N$

$f_K = (0.67)\ (10)$

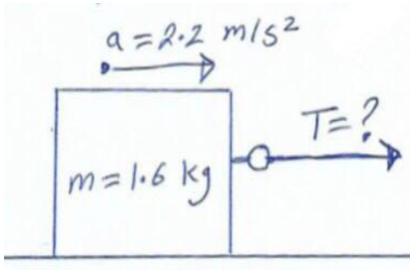
$= 6.7$ N (pointing up the ramp)

<u>Example:</u> The coefficient of kinetic friction is 0.2. What is the magnitude of the tension force in the rope for the figure below?

Sample problem: (friction and tension).

Sol.:

Since the surface is horizontal, the amount of normal force (F_N) equals the weight (W) of the block.



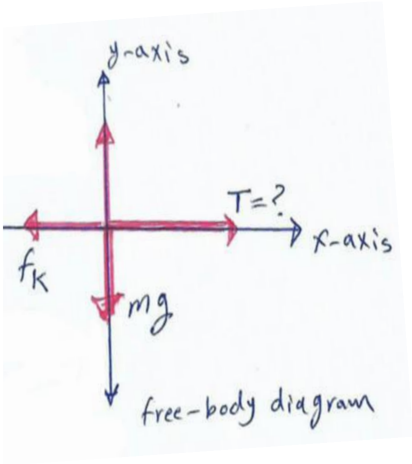
$F_N = W = mg$

$= 1.6 * 9.81 = 15.7$ N

Since

$\Sigma F = ma$ (Newton's 2nd law)

Net horizontal force $= \Sigma F_X = ma$



$\Sigma F_X = T + (-f_K) = ma$

$= T + (- f_K) = 1.6 * 2.2$

$= T + (- f_K) = 3.52$ … (1)

Since

$f_K = \mu_K F_N$

$= 0.2 * 15.7$

$= 3.14$ sub. In (1)

$T + (-3.14) = 3.52$

$T = 6.66$ N.