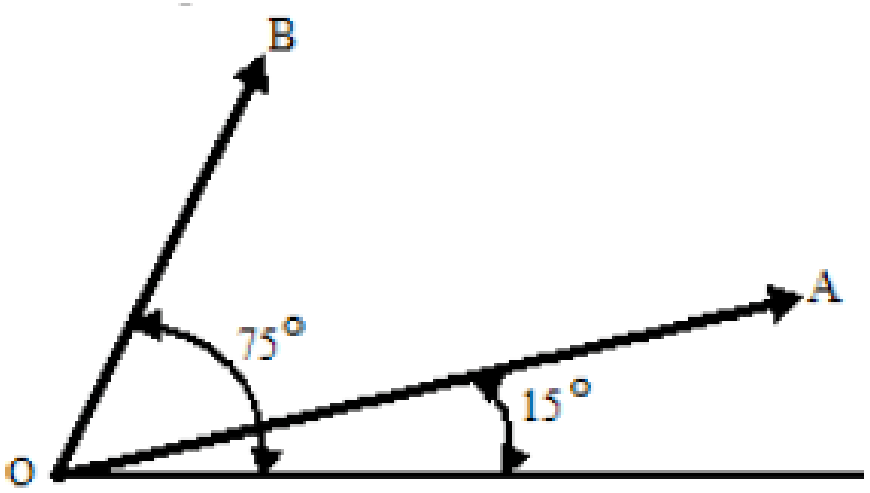
Section 6 – Composition of Forces / Equilibrium



Characteristics of Forces

Force

A push or pull on an object

1. **Net forces (unbalanced forces) change the motion of an object.**

   Net force = Vector sum of all forces.

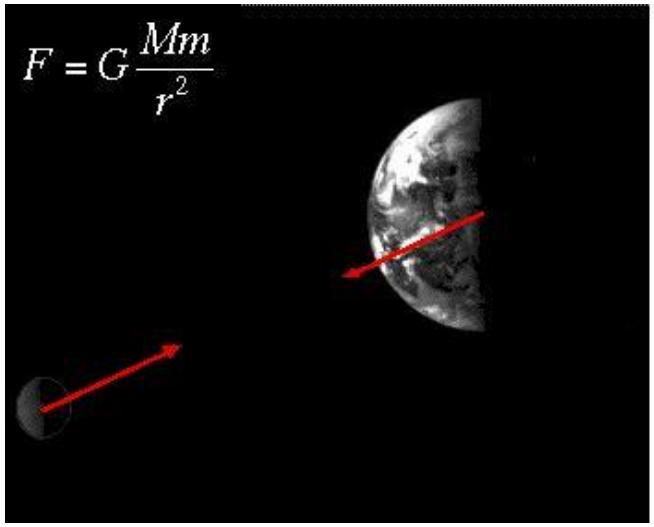
   What does this mean:

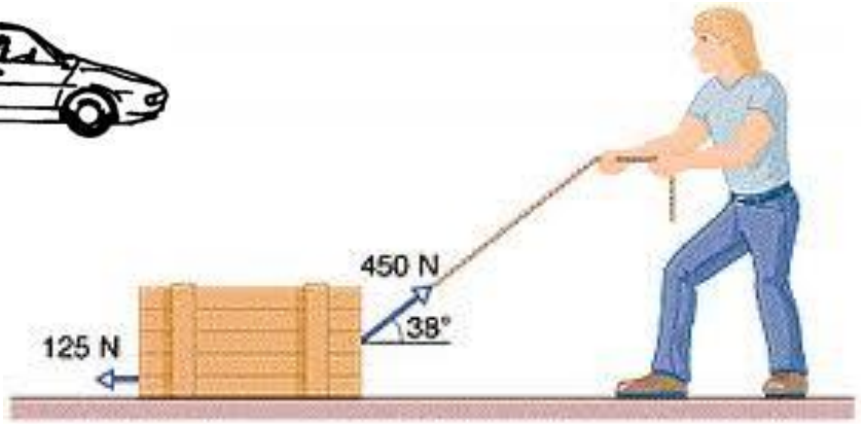
   - **The application of a net force to an object always produces acceleration**

Characteristics of Forces

2. **Forces can be exerted through distance or physical contact.**

   - **Distance:** Gravitational Pull, Magnetic
   - **Physical Contact:** Pushing a car or pulling a box





Characteristics of Forces

3. **Forces always occur in pairs which act in opposite directions.**

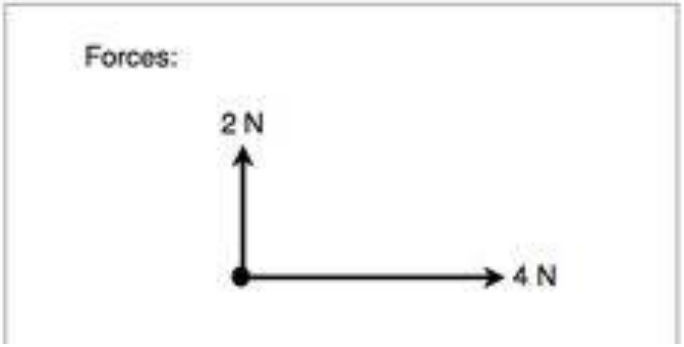
Examples:

- **You on your chair (Force down); Chair on you (Force Up)**
- **Boat on water (Force forward); Water on Boat (Force Back)**

Characteristics of Forces

4. Forces are vectors. They have both magnitude and direction. Forces are represented by arrows.

5. a. The magnitude is represented by the length of the arrow.
   b. The direction is resolved by the physical situation.



Characteristics of Forces

6. **Forces can be measured in a lab with a spring scale or a force table.**

Characteristics of Forces

6. Force is measured in Newton's ($kg \cdot m/s^2$)

7. Newton = Force required to accelerate a 1-kg mass at 1-m/s^2

Forces

Composition of Forces

Mathematically this is similar to solving velocity problems

Forces

A. Two or more forces acting on the same point at the same time are called concurrent forces.

B. Resultant Force (F_R) = A single force that produces the same effect as two or more concurrent forces.

C. When two forces act at an angle other than 0° or 180°, the resultant (F_R) can be found using the parallelogram method.

Forces

Example #1

One person pulls on a rope to the left at a force of 100 N (F_1). Another person pulls the other side of the rope to the right at 120 N (F_2). What is the resultant force (F_R)?

20 N Right

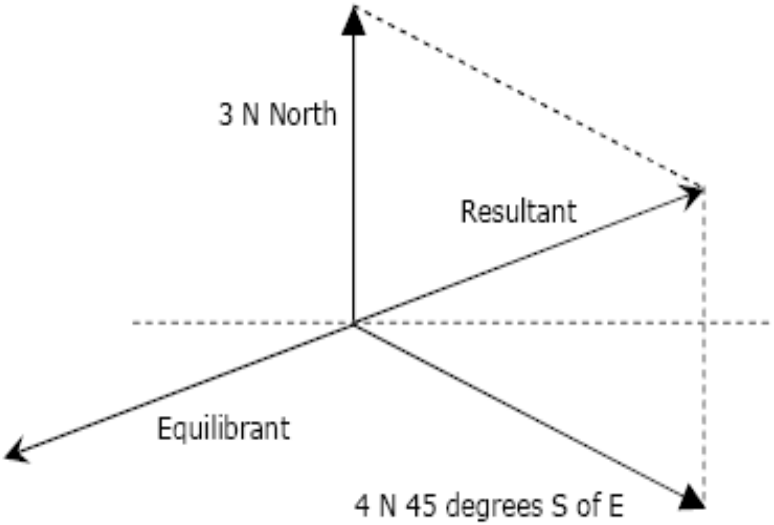
Forces

Example #2

Suppose one force of 10 N (F_E) acts eastward upon an object. Another force of 15 N (F_S) acts southward upon the same point. What is the magnitude and direction of the resultant force?

18.03 N @ 56.31° S of E

Equilibrium



Forces - Equilibrium

An object is in equilibrium when the net force on a body is zero.

When in equilibrium the object is at rest or moves with constant velocity (acceleration = 0).

A body with no net forces acting on it must be in translational equilibrium. This is the state that no net (unbalanced forces) forces are acting on a body.

When there are no unbalanced forces acting on a body, the vector sum of all the forces acting on the body is zero.

Forces - Equilibrium

Translational Equilibrium

Forces up = Forces down

$$\Sigma F_{up} = \Sigma F_{down}$$

Forces to right = Forces to left

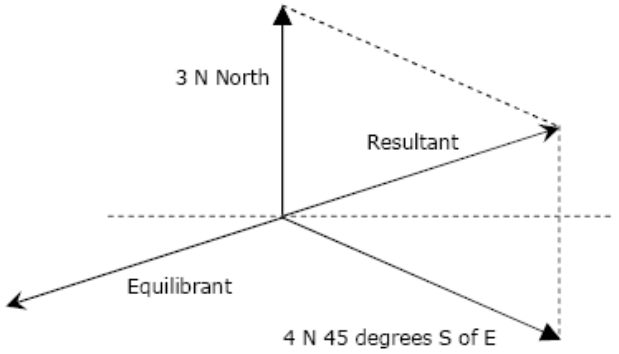
$$\Sigma F_{left} = \Sigma F_{right}$$

Forces - Equilibrium

If two forces are equal in opposite directions, each force is the equilibrant of the other.

The equilibrant force is labeled as F_Q

F_Q is equal in magnitude but opposite in direction to the resultant vector. ($F_Q = -F_R$)

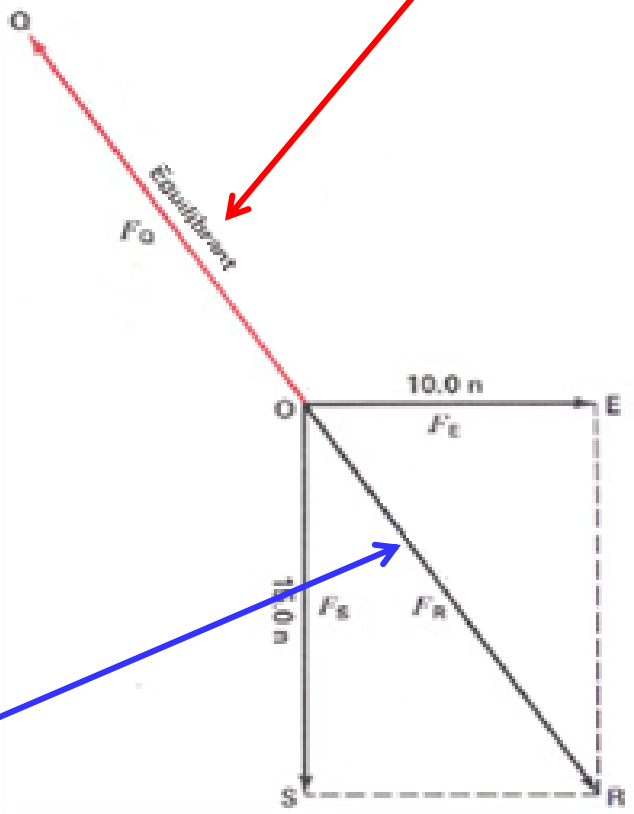


Forces - Equilibrium

Equilibrant Force (F_Q)

F_Q = 18 N @ 56.3° N of W

The equilibrant force is the single force that if applied at the same point (equal in magnitude and opposite on direction) that produces equilibrium.



F_R = 18 N @ 56.3° S of E

Forces - Equilibrium

Example #1:

A person is pulling a box North at 500 N (F_1) and a second person is pulling the same box with a force of 300 N South (F_2)

a. **What is the Resultant force?**
b. **What is the Equilibrant force?**

a. **F_R = 200 N North**
b. **F_Q = 200 N South**

Forces - Equilibrium

Example #2

A force acts north at 50 N (F_1) and a second force acts to the east at 30 N (F_2) on the same object.

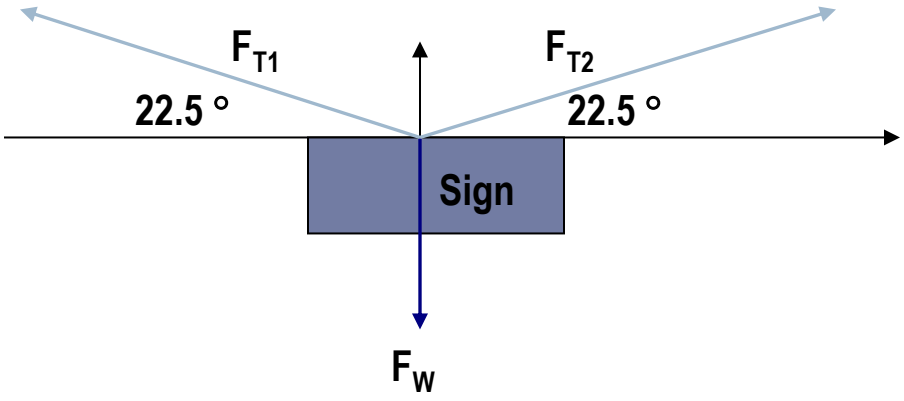
a. **What is the Resultant force?**
b. **What is the Equilibrant force?**

a. $F_R = 58.31$ N @ 59.04º N of E
b. $F_Q = 58.31$ N @ 59.04º S of W

Forces - Equilibrium

Example #3 (Creating Equilibrium)

A 168 N sign is supported in a motionless position by two ropes that each make 22.5° angles with the horizontal. What is the tension in the ropes?

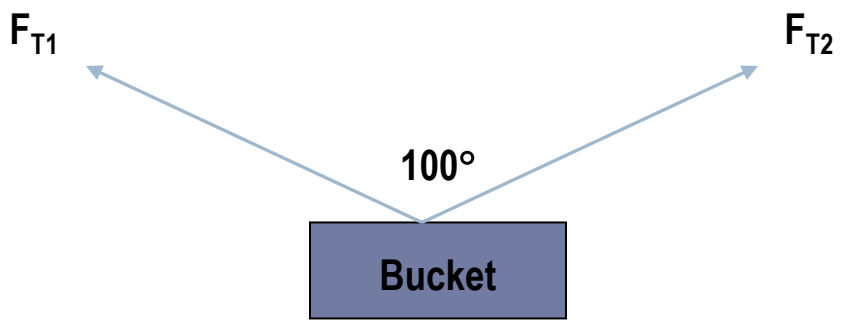


$F_{T1} = F_{T2} = 219.50$ N

Forces - Equilibrium

Example #4

A boy and girl carry a 12 kg bucket of water by holding the ends of a rope with a bucket attached at the middle. If there is an angle of 100° between the two segments of the rope, what is the tension in each part?



$F_{T1} = F_{T2} = 91.57$ N