

Chapter 3 – Forces and Motion Along a Line

A force can:

- ▶ Make something start to move
- ▶ Speed something up that was already moving
- ▶ Slow something down
- ▶ Bring something to a stop
- ▶ Keep something from moving

Need two interacting objects for a force to exist:

- ▶ We call these objects “interaction pairs”
- ▶ We say, “there is a force between two objects A and B”
- ▶ Or we can say, “there is a force on A due to B” or vice versa

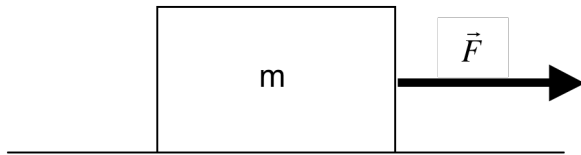
→ A force causes a change in velocity

Newton’s First Law:

- ▶ If an object is at rest ($\vec{v} = 0$) it will stay that way until some other object interacts with it. If a net force is applied, the object will move ($\vec{v} \neq 0$).
- ▶ If an object is moving at a constant velocity, it will continue moving at that speed and in that direction until some other object interacts with it. If a net force is applied, the object will speed up, slow down, or change direction.

1. Explain the need for automobile seatbelts in terms of Newton's first law.

→ A net force causes a change in velocity.



A constant force is applied to cart:

→ cart accelerates at a constant rate

What happens if the same force is applied to a heavier cart?

→ still accelerates, but at a slower constant rate

What happens if a larger force is applied?

→ greater acceleration, but still a constant acceleration.

So we see that the acceleration is proportional to the net force and inversely proportional to the mass → this is Newton's 2nd law:

$$\vec{a} = \frac{\vec{F}}{m}$$

which is usually written as: $\vec{F} = m\vec{a}$

2. The engine on a fighter airplane can exert a force of 105,840 N (24,000 pounds). The take-off mass of the plane is 16,875 kg. (It weighs 37,500 pounds.) If you mounted this aircraft engine on your car, what acceleration would you get? (Please use metric units. The data in pounds are given for comparison. Use a reasonable estimate for the mass of your car. A kilogram mass weighs 2.2 pounds.)

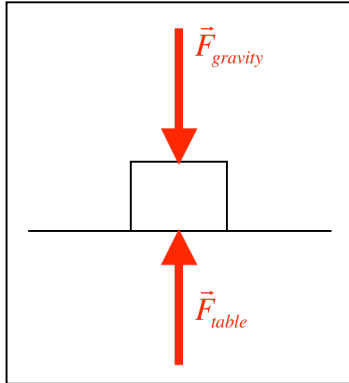
Units for force: N (Newtons) → $1N = 1kg \cdot m/s^2$

$$\text{Acceleration of airplane: } a = \frac{F}{m} = \frac{105840N}{16875kg} = 6.3m/s^2$$

$$\text{Mass of car: } 1000lb \approx 450kg \quad a = \frac{F}{m} = \frac{105840N}{450kg} = 235m/s^2$$

Combining forces along a line:

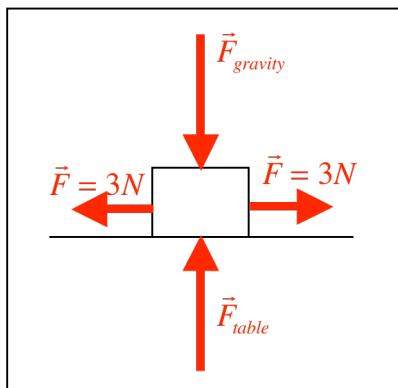
Free-body Diagram – technique used to predict motion due to multiple forces acting on an object.



$$\vec{F}_{table} = (+5N)\hat{j} \text{ and } \vec{F}_{gravity} = (-5N)\hat{j}$$

$$\vec{F}_{net} = \vec{F}_{table} + \vec{F}_{gravity} = (+5N)\hat{j} + (-5N)\hat{j} = 0N$$

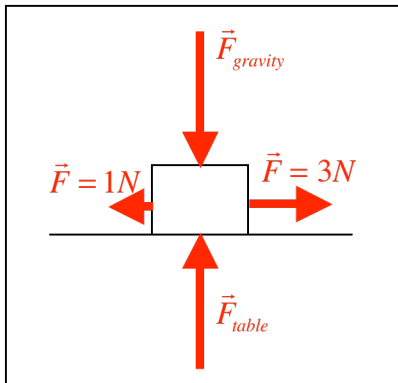
$$\text{So } \vec{F}_{net} = 0 \rightarrow \vec{a}_{net} = 0$$



From above, we can say: $\vec{F}_{net,y} = 0$

$$\vec{F}_{net,x} = (3N)\hat{i} + (-3N)\hat{i} = 0N$$

$$\rightarrow \vec{a}_{net,x} = 0 \text{ and } \vec{a}_{net,y} = 0$$



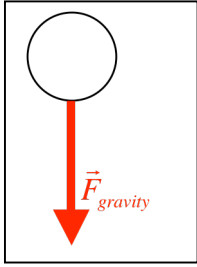
$$\vec{F}_{net,x} = (3N)\hat{i} + (-1N)\hat{i} = (2N)\hat{i}$$

Let's say the mass of the block is 0.5 kg, then using Newton's 2nd Law, we can determine the acceleration of the block:

$$\vec{a}_{net,x} = \frac{\vec{F}_{net,x}}{m} = \frac{2N}{0.5kg} = 4 \text{ m/s}^2$$

Then we can use this acceleration in a kinematic equation to find out something else about the motion...

Object in free-fall:



Newton's 2nd Law: $\vec{F}_{net} = m\vec{a}$

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

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

$$m\vec{g} = m\vec{a} \quad \rightarrow \quad \vec{a} = \vec{g} = (-9.8 \text{ m/s}^2)\hat{j}$$