

P2211K

9 / 21 / 2010

These lead us to the discussion of interactions that “cause” acceleration, or **Forces**.

- For our working purposes, we need to know that
 - **Force** “causes” an object to accelerate;
 - The amount of acceleration is inversely proportional to the object’s mass;
 - Mass is proportional to weight, but is not the same thing as weight;
 - Forces are vectors;
 - The object’s acceleration is the **vector** result of **ALL** forces acting it.
- Also, from the nature of **Forces**, we can conclude that
 - If an object accelerates, the **net force** on it is non-zero;
 - If the **net force** on an object is non-zero, it will accelerate.
- Newton’s 1st and 2nd laws describe the quantitative nature of **Forces**:

General Principles

Newton’s First Law

An object at rest will remain at rest, or an object that is moving will continue to move in a straight line with constant velocity, if and only if the net force on the object is zero.



The first law tells us that no “cause” is needed for motion. Uniform motion is the “natural state” of an object.

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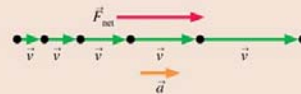
Newton’s laws are valid only in inertial reference frames.

Newton’s Second Law

An object with mass m will undergo acceleration

$$\vec{a} = \frac{1}{m} \vec{F}_{\text{net}}$$

where $\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \dots$ is the vector sum of all the individual forces acting on the object.



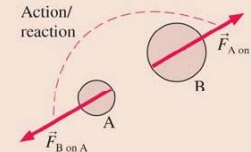
The second law tells us that a net force causes an object to accelerate. This is the connection between force and motion that we are seeking.

Newton’s Third Law

Every force occurs as one member of an **action/reaction pair** of forces. The two members of an action/reaction pair:

- Act on two *different* objects.
- Are equal in magnitude but opposite in direction:

$$\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A}$$



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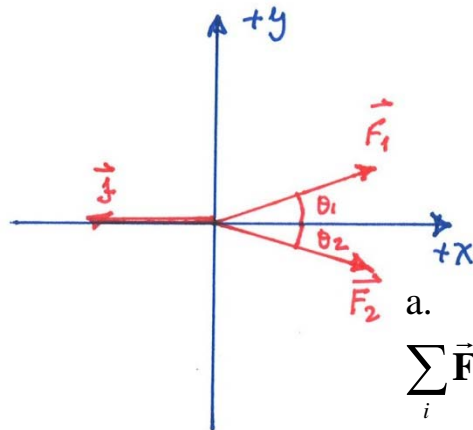
Focus on Newton's 2nd Law: (**Chapter 6**)

- Equilibrium—a special case when $\vec{F}_{\text{net}} = 0$:
- Action by constant forces leading to constant accelerations: $\vec{F}_{\text{net}} = m\vec{a} \neq 0$
- Another special case: weight & elevators
- Models, approximations, & variable forces
 - Gravity: $F_g = G \frac{m_1 m_2}{r^2} = m \left(G \frac{m_E}{R_E^2} \right) = mg$
 - Friction: $\left\{ \begin{array}{l} \mathfrak{F}_s < \mu_s N, \text{ static friction} \\ \mathfrak{F}_k = \mu_k N, \text{ kinetic friction} \end{array} \right\}$, opposite to \vec{v}
 - Air resistance---"drag": $\left\{ \begin{array}{l} D_A = kv^2, \text{ Air resistance; opposite to } \vec{v} \\ D_W = kv, \text{ Water resistance; opposite to } \vec{v} \end{array} \right.$

Focus on Newton's 2nd Law: (**Chapter 6**)

$$\vec{F}_{\text{net}} = 0$$

Problem 6.4: A football coach (125 kg) sits on a sled (50 kg) while two of his players build their strength by dragging the sled across the field with ropes. The friction force on the sled is 1000 N and the angle between the two ropes is 20°.



- a. How hard must each player pull to drag the coach at a steady 2.50 m/s?

a.

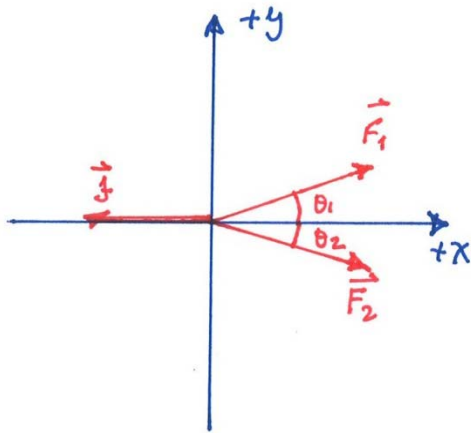
$$\sum_i \vec{F}_i = 0 \quad (\text{constant velocity} \Rightarrow \vec{a} = 0)$$

Assume each player pulls equally and set the coordinate system as shown with $\theta_1 = \theta_2$.

$$\sum_i F_{xi} = 0 = F_1 \cos \theta_1 + F_2 \cos \theta_2 - \mathfrak{F} = 2F \cos 10^\circ - 1000 \text{ N}$$

$$\therefore F = \frac{1000 \text{ N}}{2 \cos 10^\circ} = 507.7 \text{ N}$$

$$\left\{ \text{Note that } \sum_i F_{yi} = 0 = F_1 \sin \theta_1 - F_2 \sin \theta_2 = F \sin \theta - F \sin \theta \right\}$$



- b. How hard must they pull to accelerate the coach from rest to 2.50 m/s over the distance 5.0 m?

b. Like a. except that there's non-zero acceleration and a non-zero net force

$$\sum_i \vec{F}_i = \vec{F}_{\text{net}} = m\vec{a}$$

Get a from v_0 , v_f , and d: $a = \frac{(v_f^2 - v_0^2)}{2d} = 0.625 \text{ m/s}^2$

Assume each player pulls equally and set the coordinate system as shown with $\theta_1 = \theta_2$.

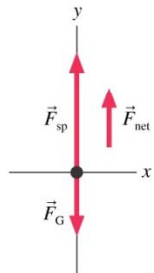
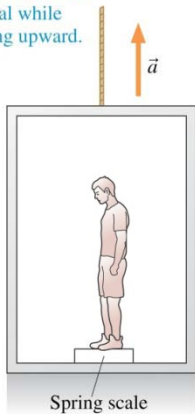
$$\sum_i F_{xi} = ma_x = F_1 \cos \theta_1 + F_2 \cos \theta_2 - \mathfrak{T} = 2F \cos 10^\circ - 1000 \text{ N} = (m_{\text{coach}} + m_{\text{sled}}) 0.625 \text{ m/s}^2 = 109.375 \text{ N}$$

$$\therefore F = \frac{1109.375 \text{ N}}{2 \cos 10^\circ} = 563.2 \text{ N}$$

$$\left\{ \text{Note that } \sum_i F_{yi} = 0 = F_1 \sin \theta_1 - F_2 \sin \theta_2 = F \sin \theta - F \sin \theta \right\}$$

Weight & elevators:

The man feels heavier than normal while accelerating upward.



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- The “heavier” or “lighter” effect in elevators and “free-fall” is a result of the way scales measure weight. They measure the force of contact and indicate that as weight.

- For the case indicated on the side,

$$\vec{F}_{net} = m\vec{a} = \vec{F}_{sp} + \vec{F}_g$$

- If $a = 0$, then $F_{sp} = F_g$ and F_g is W . However, if $a \neq 0$, then

$$\vec{F}_{sp} = m\vec{a} - \vec{F}_g = m\vec{a} - m\vec{g} = m(\vec{a} - \vec{g})$$

Since \vec{g} is down, when component values are entered this becomes:

$$F_{sp} = m(a + g) = m\left(1 + \frac{a}{g}\right)$$

Example: a 75 kg person (about 150 lb.) is in an elevator accelerating upwards at 2.0 m/s². (Use $g = 10 \text{ m/s}^2$)

- What is their apparent weight? (900 N)
- What is it if the acceleration is downwards at the same rate? (600 N)

Assignment: Read and work on Chapter 6