Chap 4 Issac Newton and the Laws of Motion

Newton's "Miraculous Year": 1665

Einstein's "Year of Miracles": 1905

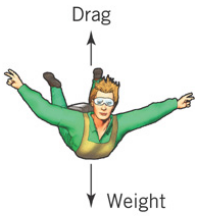
First Law

Newton's First Law of Motion (law of inertia)

If the net force exerted on an object is zero, the object will continue in a state of rest or in a state of motion at a constant speed along a straight line.

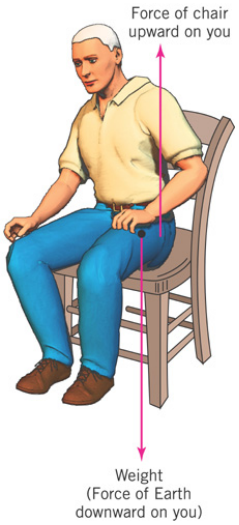
A force is a push or pull, either by contact or from a distance (field force). The net force on an object is the vector sum of all the forces acting on this object.

Balanced and Unbalanced Forces



(*b*) Weight > Drag

(*c*) Weight = Drag



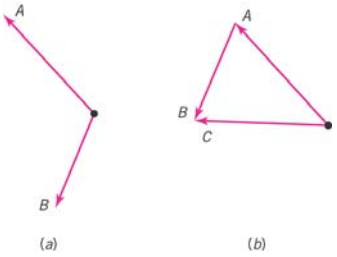
Second Law $F = ma$

Newton's Second Law of Motion

The acceleration of an object as a result of a net external force is proportional to the net force and has a magnitude that is inversely proportional to the mass. The direction of the acceleration is the same as the direction of the net force.

$$\vec{a} = \frac{\sum \vec{F}}{m} \qquad \text{or} \qquad \sum \vec{F} = m\vec{a}$$

Vector Nature of Force and Acceleration



Breaking $\sum \vec{F} = m\vec{a}$ **into its components (in 2D),**

we get $\sum F_X = m a_X$ **and** $\sum F_Y = m a_Y$

The acceleration in x-direction (y-direction) is related only to the x-components (y-components) of the external forces.

The motion along the x-direction can be treated independently of the motion/forces along the y-direction, and vice versa.

Unit of Force: newton (N)

Examples

20. A bicycle rider accelerates from rest up to full speed on a flat, straight road. Compare the frictional force between the road and the tires pushing her forward to the air drag (and other frictional forces) pushing back: a. in the first few seconds of the ride, and b. after she has reached full speed.

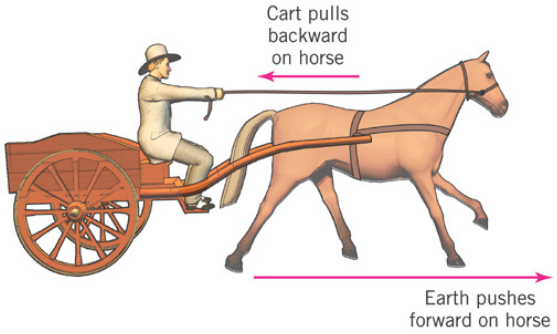
21. When an object is moving in air, the air drag force is in the opposite direction to the velocity. A light foam ball is thrown up into the air. When is the net force on the ball the greatest: When it is moving up, when it is at the top of its trajectory, or when it is moving down? Explain.

22. A car is driving up a straight hill at a constant speed of 50 kilometers per hour. Is the net force on the car zero? A second car is driving over the crest of the hill at a constant speed of 50 miles per hour. Is the net force on the car zero?

Newton's Third Law of Motion

Newton's Third Law of Motion (action-reaction)

Whenever one body exerts a force on a second body, the second body exerts an oppositely directed force of equal magnitude on the first body. For every action, there is an equal and opposite reaction.



Problems

4. John pushes a loaded wheelbarrow, which is initially at rest, with a constant horizontal force of 10 newtons. The mass of the wheelbarrow is 15 kg. Neglect friction forces.

a. What is the constant acceleration of the wheelbarrow?
b. If John pushes the wheelbarrow for 3 seconds, what distance does the wheelbarrow cover during this time?
c. What is the speed of the wheelbarrow after 3 seconds?

Problems

6. Margie (45 kg) and Bill (65 kg), both with brand new roller blades, are at rest facing each other in the parking lot. They push off each other and move in opposite directions, Margie moving at a constant speed of 14 ft/s. At what speed is Bill moving? (*Hint:* Recall from Newton's third law that Margie and Bill experience equal and opposite forces.)

7. Tracy (50 kg) and Tom (75 kg) are standing at rest in the center of the roller rink, facing each other, free to move. Tracy pushes off Tom with her hands and remains in contact with Tom's hands, applying a constant force for 0.75 seconds. Tracy moves 0.5 meters during this time. When she stops pushing off Tom, she moves at a constant speed.

a. What is Tracy's constant acceleration during her time of contact with Tom?
b. What is Tracy's final speed after this contact?
c. What force was applied to Tracy during this time? What is its origin?
d. What happened to Tom? If Tom moved, describe his motion, force, acceleration, and Tom's final velocity.