LECTURE 6

The Laws of Motion

1. Newton’s First Law

In the absence of external forces, an object at rest remains at rest and an object in motion continues in motion with a constant velocity (that is,with a constant speed in a straight line).

The tendency of an object to resist any attempt to change its velocity is called ***inertia***.

Definition of force:

from the first law, we can define force as that which causes a change in motion of an object.

Mass is that property of an object that specifies how much resistance an object exhibits to changes in its velocity, the SI unit of mass is the kilogram. Experiments show that the greater the mass of an object, the less that object accelerates under the action of a given applied force.

a force acting on an object of mass m1 produces a change in motion of the object that we can quantify with the object's acceleration a_1, and the same force acting on an object of mass m2 produces an acceleration a_2. The ratio of the two masses is defined as the inverse ratio of the magnitudes of the accelerations produced by the force:

$$\frac{m_1}{m_2} \equiv \frac{a_2}{a_1}$$

For example, if a given force acting on a 3-kg object produces an acceleration of 4 m/ s^2, the same force applied to an object with twice the mass, 6 kg, produces an acceleration with half the magnitude, 2 m/s^2.

Mass and weight are two different quantities. The weight of an object is equal to the magnitude of the gravitational force exerted on the object and varies with location. For example, a person weighing 180 lb on the Earth weighs only about 30 lb on the Moon.

2. Newton's Second Law

the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass:

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

Newton's second law: component form

In a vector expression and hence is equivalent to three component equations:

$$\sum F_x = ma_x \qquad \sum F_y = ma_y \qquad \sum F_z = ma_z$$

The SI unit of force is the Newton (N).

Definition of the Newton

1 N = 1 kg . m/s2

In the U.S. customary system, the unit of force is the **pound** (lb). A force of 1 lb is the force that, when acting on a 1-slug mass,[2] produces an acceleration of 1 ft/s^2:

$$1 \text{ lb} \equiv 1 \text{ slug} \cdot \text{ft/s}^2$$

A convenient approximation is $1 \text{ N} \approx \frac{1}{4} \text{ lb}$.

1 kg = 9.8 N

1 slug = 32.174 lb

Force is the cause of changes in Motion

An object can have motion in the absence of forces as described in Newton's first law. Therefore, don't interpret force as the cause of motion. Force is the cause of changes in motion.

Example

A hockey puck having a mass of 0.30 kg slides on the frictionless, horizontal surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in Figure 5.4. The force $\vec{F}_1$ has a magnitude of 5.0 N, and is directed at $\theta = 20°$ below the x axis. The force $\vec{F}_2$ has a magnitude of 8.0 N and its direction is $\phi = 60°$ above the x axis. Determine both the magnitude and the direction of the puck's acceleration.

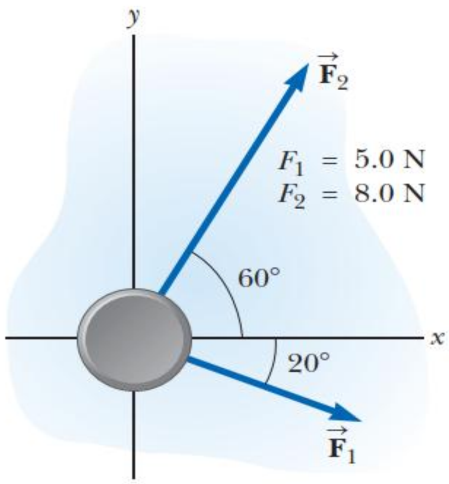

Figure 5.4 (Example 5.1) A hockey puck moving on a frictionless surface is subject to two forces $\vec{F}_1$ and $\vec{F}_2$.

Solution

$$\sum F_y = F_{1y} + F_{2y} = F_1 \sin\theta + F_2 \sin\phi$$

$$a_x = \frac{\sum F_x}{m} = \frac{F_1 \cos\theta + F_2 \cos\phi}{m}$$

$$a_y = \frac{\sum F_y}{m} = \frac{F_1 \sin\theta + F_2 \sin\phi}{m}$$

$$a_x = \frac{(5.0\ \text{N})\cos(-20^\circ) + (8.0\ \text{N})\cos(60^\circ)}{0.30\ \text{kg}} = 29\ \text{m/s}^2$$

$$a_y = \frac{(5.0\ \text{N})\sin(-20^\circ) + (8.0\ \text{N})\sin(60^\circ)}{0.30\ \text{kg}} = 17\ \text{m/s}^2$$

$$a = \sqrt{(29\ \text{m/s}^2)^2 + (17\ \text{m/s}^2)^2} = \boxed{34\ \text{m/s}^2}$$

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{17}{29}\right) = \boxed{31^\circ}$$