Applications of Newton’s Laws

- Newton’s first law
- Newton’s second law
- Newton’s third law
- Frictional forces
- Applications of Newton’s laws

Isaac Newton’s

Force is a vector

Unit of force in S.I.:

$$1N = 1\frac{kg \bullet m}{s^2}$$

Newton's Laws

I. If a net force is not applied to a body, the speed of the body can not change.
II. The net force on a body equals the body mass and acceleration.
III. When two bodies interact, the forces on the bodies are always equal in magnitude and vice versa.

Forces of Friction: f

- When an object is in motion on a surface or through a viscous medium, there will be a resistance to the motion. This resistance is called the *friction force*
- This depends on the interaction between the object and its surroundings
  - Force of static friction: f_s
  - Force of kinetic friction: f_k
- Direction of friction force: The opposite of the desired direction of movement along the surface

Forces of Friction: *Magnitude*

- Magnitude: Friction is proportional to the normal force
  - Static friction: $F_f = F \leq \mu_s N$
  - Kinetic friction: $F_f = \mu_k N$
  - μ is the coefficient of friction
- Coefficient of friction is almost independent from contact area

Static Friction

- Static friction acts to keep the object from moving
- If $\vec{\mathbf{F}}$ increases, so does $\vec{f}_s$
- If $\vec{\mathbf{F}}$ decreases, so does $\vec{f}_s$
- $f_s \leq \mu_s N$

Figure 5.16
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Kinetic Friction

- The kinetic friction force acts when the object is in motion
- Although μ_k can vary with speed, we will neglect such variations
- $f_k = \mu_k N$

Figure 5.16
Physics for Scientists and Engineers 6th Edition, Thomson Brooks/Cole © 2004; Chapter 5

Explore Forces of Friction

- Vary the applied force
- Note what happens when the box starts to move

Objects in Equilibrium

- Objects that are either at rest or moving with constant velocity are said to be in balance
- Acceleration of an object is zero:

$$\vec{a} = 0$$

- the net force acting on the object is zero

$$\sum \vec{F} = 0$$

- Therefore, set of component equations given by

$$\sum F_x = 0 \qquad \sum F_y = 0$$

Accelerating Objects

- If an object that has an acceleration, there must be a nonzero net force acting on it
- Apply Newton's Second Law in component form

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

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

Inclined Plane

- Suppose a block with a mass of 2.50 kg is resting on a ramp. If the coefficient of static friction between the block and ramp is 0.350, what maximum angle can the ramp make with the horizontal before the block starts to slip down?

Figure 5.19
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Inclined Plane

- Newton 2nd law:

$$\sum F_x = mg\sin\theta - \mu_s N = 0$$

$$\sum F_y = N - mg\cos\theta = 0$$

- Then $N = mg\cos\theta$

$$\sum F_y = mg\sin\theta - \mu_s mg\cos\theta = 0$$

- So $\tan\theta = \mu_s = 0.350$

$$\theta = \tan^{-1}(0.350) = 19.3^\circ$$

Figure 5.19 Physics for Scientists and Engineers 6th Edition, Thomson Brooks/Cole © 2004; Chapter 5

Multiple Objects

Figure 5.21
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- A block of mass m1 on a rough, horizontal surface is connected to a ball of mass m2 by a lightweight cord over a lightweight, frictionless pulley as shown in figure. A force of magnitude F at an angle θ with the horizontal is applied to the block as shown and the block slides to the right. The coefficient of kinetic friction between the block and surface is μ_k. Find the magnitude of acceleration of the two objects.

Multiple Objects

- m1: $\sum F_x = F\cos\theta - f_k - T = m_1 a_x = m_1 a$

  $\sum F_y = N + F\sin\theta - m_1 g = 0$

- m2: $\sum F_y = T - m_2 g = m_2 a_y = m_2 a$

$$T = m_2(a+g)$$

$$N = m_1 g - F\sin\theta$$

$$f_k = \mu_k N = \mu_k(m_1 g - F\sin\theta)$$

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$$F\cos\theta - \mu_k(m_1 g - F\sin\theta) - m_2(a+g) = m_1 a$$

$$a = \frac{F(\cos\theta + \mu_k \sin\theta) - (m_2 + \mu_k m_1)g}{m_1 + m_2}$$