Chapter 5: Applying Newton's Laws

Equilibrium

An object is said to be in equilibrium if the net force on it is zero.

Symbolically, this means:

$$\begin{array}{ccc} \sum \vec{F} = \vec{0} & \Leftrightarrow & \vec{a} = \vec{0} \\ \Updownarrow & & \Updownarrow \\ \left.\begin{array}{l} \sum F_x = 0 \\ \sum F_y = 0 \\ \sum F_z = 0 \end{array}\right\} & \Leftrightarrow & \left\{\begin{array}{l} a_x = 0 \\ a_y = 0 \\ a_z = 0 \end{array}\right. \end{array} \qquad (1)$$

Apparent Weight

The apparent weight of an object is the weight the object “appears” to have when the object is *accelerating*.

- **The apparent weight is the weight a scale would read.**

Frictional Forces

In general, friction forces exist whenever two surfaces are in contact with each other.

Really two kinds:

- force of *static* friction, f_s: two surfaces *not moving* with respect to one another

- force of *kinetic* friction, f_k: two surfaces *are* moving with respect to one another

Force of Static Friction

The force is static friction is a *force of constraint*. For any particular pair of surfaces, f_s can take on *any value* (up to a certain *maximum* value) so that the surfaces *do not slide relative to one another*. This constitutes a constraint on the motion of the two surfaces. No sliding relative to one another means that the two surfaces move with the *same acceleration*.

Notice two things:

1. f_s can be *zero*.

2. For any pair of surfaces, f_s has a *maximum value*.
   - Turns out that this maximum value, $(f_s)_{\max}$ is proportional to the normal force:

$$(f_s)_{\max} = \mu_s N \tag{2}$$

We summarize all of this as follows:

$$f_s \leq \mu_s N \tag{3}$$

Force of Kinetic Friction

- f_k not a force of constraint, as f_s is. Rather, f_k is an example of a *dissipative friction force*. The force of air resistance is another example.

- f_k always opposes the motion. (Note that this is *not* true for f_s!)

- Turns out that f_k also proportional to the normal force, but with a different constant of proportionality:

$$f_k = \mu_k N \tag{4}$$

  - μ_k = "*coefficient of kinetic friction*" (property of the two surfaces in contact)
  - For a given pair of surfaces, $\mu_k < \mu_s$, usually.
    - Easier to *keep* moving, once moving, than to *start* moving in the first place.

Working Problems Involving Friction Between Surfaces

- Just include $\vec{f}_s$ or $\vec{f}_k$ (whichever one is appropriate) in your FBD. Then do the problem like any other problem.

- Use (3) or (4)… (whichever is appropriate)

Air Resistance (Fluid Resistance)

- Another example (like $\vec{f}_k$) of *dissipative friction*.

- Depends on the *speed* of the object relative to the fluid.
  - o As object moves faster through fluid, it makes more frequent collisions with fluid particles $\Rightarrow$ f_{air} increases.

  - o At low speeds, f_{air} proportional to first power of v:

$$f_{air} = bv \quad \text{(\textit{viscous} friction)} \tag{5}$$

  - o At higher speeds, f_{air} proportional to *second* power of v:

$$f_{air} = cv^2 \quad \text{(\textit{drag})} \tag{6}$$

Circular Motion (revisited)

Recall Sec. 3.4. We said that anytime an object moves in a circular path, there must be a radial (centripetal) component of acceleration:

$$a_{rad} = \frac{v^2}{r} \quad (5)$$

If we apply Newton's second law to the radial direction, then, we get:

$$\sum F_{rad} = ma_{rad}$$

$$\sum F_{rad} = m\frac{v^2}{r} \quad (6)$$