Today:
Apparent weight.
   How to weigh a fish: PHYS 2A approach.
Applying Newton’s Laws.
   New situations – the same physical principles.
Newton’s Laws in a Messy World:
   Friction.

Use all of Newton’s Laws together effectively:

- Newton’s 1st Law: one object, \(\Sigma F\) predicts motion.
- Newton’s 2nd Law: one object, \(\Sigma F\) predicts motion.
- Newton's 3rd Law: two objects, a pair of forces (one force per object); no prediction of resulting motion.
Horse-and-cart dilemma

A horse exerts a force on the cart, and the cart exerts an equal but opposite force on the horse ... So how can the two start moving?

\[ \Sigma F_{\text{on horse}} = m_{\text{horse}} \vec{a}_{\text{horse}} \]

\[ F_{\text{pull, horse on cart}} \quad F_{\text{pull, cart on horse}} \]

\[ F_{\text{push, road on horse}} \quad F_{\text{push, horse on road}} \]

Motion of an object is not described by the 3rd law, but rather by the 2nd law. The 2nd law instructs us to look at the net force on the object.

Spring force

- Consider a mass hanging from a spring. Force diagram for the mass:

\[ a_y = 0 \]

\[ \Rightarrow \Sigma F_y = 0 \]

- The spring pulls up on the mass so that the mass does not accelerate.

- Add another mass => add \( F_{\text{gravity}} \) => the spring added more force by displacing more from its equil. position.

- Hooke’s Law:
  spring force vs. displacement

\[ F_{\text{spring}} = -k(\Delta \vec{x}) \]

\( k \) = “spring constant”; Units of \( k \): N/m
Example
• You weigh a fish on a spring scale attached to the ceiling of an elevator. If the actual weight of the fish is 40.0 N, what reading does the spring scale give when the elevator accelerates at 2.00 m/s\(^2\) while moving downward?

Solution
• First, define a coordinate system.
• Choose up as positive y.

Solution
• Next, draw a force diagram for the fish:

\[ \Sigma F_y = m_{\text{fish}}a_y \]

\[ \Sigma F_y = F_{\text{spring}} - F_{\text{gravity}} = m_{\text{fish}}a_y \]

\[ F_{\text{spring}} = F_{\text{gravity}} + m_{\text{fish}}a_y \]
Answer

• Don’t know the mass of the fish. Know the weight:

\[ W = F_{\text{gravity}} = m_{\text{fish}} g \quad \Rightarrow \quad m_{\text{fish}} = \frac{F_{\text{gravity}}}{g} \]

• Back to Newton’s Law:

\[ F_{\text{spring}} = F_{\text{gravity}} + m_{\text{fish}} a_y = F_{\text{gravity}} \left( 1 + \frac{a_y}{g} \right) \]

\[ F_{\text{spring}} = 40.0 \text{ N} \left[ 1 + \left( \frac{-2.00 \text{ m/s}^2}{9.80 \text{ m/s}^2} \right) \right] = 31.8 \text{ N} \]

• Reading of the spring scale in an accelerating reference frame is known as the apparent weight. Here, the weight appears to the spring scale to be less than the actual weight (the gravitational force).

Multiple Objects

Example

• Two blocks are in contact on a frictionless table. You apply a horizontal force to the larger block. If \( m_1 = 2.3 \text{ kg}, \ m_2 = 1.2 \text{ kg}, \) and \( F_{\text{applied}} = 3.2 \text{ N}, \) find the magnitude of the force between the two blocks.

Solution

• First, define a coordinate system.

• Choosing up as \( +y \) and the direction of the applied force as \( +x \).
Multiple Objects

Solution (cont’d)

- Draw a force diagram for each block separately:

- No need to break the forces into components.
- Apply Newton’s 2nd Law separately to each object.
- The blocks move together \( \Rightarrow a_{1x} = a_{2x} = a_x \)

Answer

- For \( m_1 \) in the x-direction:
  \[ \Sigma F_x = m_1 a_{1x} \quad F_{appl} - F_{cont, 2 on 1} = m_1 a_{1x} \]
  \[ a_{1x} = \frac{(F_{appl} - F_{cont, 2 on 1})/m_1}{m_2} \]

- For \( m_2 \) in the x-direction:
  \[ \Sigma F_x = m_2 a_{2x} \quad F_{cont, 1 on 2} = m_2 a_{2x} \]
  \[ a_{2x} = \frac{(F_{cont, 1 on 2})/m_2}{m_1} \]
  \[ (F_{appl} - F_{cont})/m_1 = (F_{cont})/m_2 \]

- Solve for \( F_{cont} \):
  \[ F_{cont} = \frac{F_{appl}}{1 + \frac{m_1}{m_2}} = \frac{3.2}{1 + \frac{2.3}{1.2}} = 1.1 \text{ N} \]
Clicker Question

Head-on collision on the freeway.

An SUV with mass 3000 kg has a head-on collision with a mosquito of mass 3 mg on the freeway and exerts a force of magnitude $2.9 \times 10^2$ N on the mosquito. What is the magnitude of the force that the mosquito exerts on the SUV in the collision?

A) zero.
B) the same as that of the SUV, $2.9 \times 10^2$ N.
C) $10^9$ times smaller than that of the SUV.
D) $10^9$ times larger than that of the SUV.
E) depends on the species of the mosquito*.

* There are more than 3,500 species of mosquitoes. About 175 of them are found in the United States, with the Anopheles quadrimaculatus, Culex pipiens, Aedes aegypti and Aedes albopictus among the most common.


- Friction is a force that opposes a slide or an attempted slide of a body over a surface.
- If there is an attempt to slide the body but the body does not slide, the friction force is static friction force, $f_s$.
- Static friction will increase as the applied force increases, until it reaches a maximum given by
  \[ f_{s,\text{max}} = \mu_s F_N \]
  
  \[ \text{coefficient of static friction} \]
  \[ \text{normal force} \]

- In general, static friction is $f_s \leq \mu_s F_N$.
**Static friction**

- Direction of the static friction force?
  - opposite to the direction of the applied force that is attempting the motion.

\[ f_s \leq \mu_s F_N \]

**Kinetic friction**

- Before you can get an object to move you must overcome the maximum static friction.

- Once you have an object moving over a surface, the friction will become kinetic friction, \( f_k \).

- \( f_k < f_{s, \text{max}} \) for a given surface.

- Magnitude of kinetic friction:

\[ f_k = \mu_k F_N \]

(direction independent of the value of any applied force! (unlike static friction))
Static and kinetic friction: summary

**Static region**
- **Applied force** $F$
- **Friction force** $f_s = \mu_s F_N$

**Kinetic region**
- **Applied force** $F$
- **Friction force** $f_k = \mu_k F_N$

$F_{N_{s,max}} = \mu_s F_N$

$\Rightarrow$ when calculating any type of friction, it is helpful to calculate the normal force.

Coefficient of kinetic friction

- Rubber on dry concrete: $\mu_k = 0.8$ ($\mu_s = 1$)
- Typical $\mu_k$ range from 0.01 (smooth/well-lubricated surf.) to 1.5 (very rough surfaces)

With synovial fluid: $\mu_k = 0.003$

Dry bone on bone: $\mu_k = 0.3$
For Next Time:

• Read Chapter 4
• Finish up HW for Chapter 4
• Study HARD for Quiz 3 (Ch.4)
• Attend Problem & Discussion sessions: we hold them exclusively FOR YOU!