- Last Lecture
  - Applications of Newton's Three Laws
- Today
  - Friction
- Important Concepts
  - The magnitude of friction depends on the magnitude of the Normal force
  - The magnitude of friction depends on whether there is motion along the surface ("slipping" or "not slipping")
  - The magnitude of friction has a maximum possible value
  - The coefficient of friction is often less when an object is slipping than when it is not slipping

Important Reminders

- Pset # 3 due here tomorrow at 10am.
- If you want to discuss your exam or general class performance, contact me or your recitation instructor during office hours or by appointment.
  - Students are often hesitant to do this but it is ***strongly*** recommended. Don't be intimidated, we are here to help you and want you to succeed.
- No class next Monday or Tuesday
- Next Mastering Physics due next Wednesday
- Next Pset due next Friday

Properties of Friction - Direction

- Always parallel to the surface
- If there is slipping, friction acts in the direction opposite to the motion
- If there is not slipping, friction acts in the direction needed to prevent motion
  - Note that it's not always immediately obvious what direction this is, problems can get complicated!

Properties of Friction - Magnitude

- Not slipping: The magnitude of the friction force can only be calculated from $\sum \vec{F} = m\vec{a}$. However, it has a maximum value of $|f| \le \mu_s N$
- Just about to slip: $|f| = \mu_s N$ where N is the Normal force and μ_s is the coefficient of static friction which is a constant that depends on the surfaces
- Slipping: $|f| = \mu_k N$ where N is the Normal force and μ_k is the coefficient of kinetic friction which is a constant that depends on the surfaces
- Note: $\mu_s \ge \mu_k$

Checklist for Friction Problems

- Slipping?
  - Direction and magnitude of friction are unambiguous
- Just about to slip?
  - Magnitude of friction is unambiguous
- Not slipping?
  - Magnitude of friction is totally unknown. Use $\sum \vec{F} = m\vec{a}$
- Just about to slip or not slipping?
  - Direction of friction is opposite to direction it will slip
  - Find this direction by determining motion without friction
    - Sometime obvious, sometimes requires a calculation

Summary

- $\sum \vec{F} = m\vec{a}$ $\sum \vec{F} = m\vec{a}$ $\sum \vec{F} = m\vec{a}$
- With friction, pay close attention to whether there is slipping, almost slipping, or no slipping
  - The procedure to solve problems is very different in the three cases
- Think carefully about the direction of friction
- Don't make the careless mistake of blindly substituting $|f| = \mu_s N$ everywhere
- Don't make the careless mistake of assuming you know the Normal force without checking other forces