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 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 needed to prevent 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 $\sum F = ma$. However, it has a maximum value of $|F| \leq \mu_s N$.
- Just about to slip: $|F| = \mu_s N$ where $N$ is the Normal force and $\mu_s$ 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 $\mu_k$ is the coefficient of kinetic friction which is a constant that depends on the surfaces.
- Note: $\mu_s \geq \mu_k$

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 $\sum F = ma$
- 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
    - Sometimes obvious, sometimes requires a calculation

Summary
- $\sum F = ma$  $\sum F = ma$  $\sum F = ma$
- 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