Center of Mass, Torque and Rotational Inertia

Objectives
1. Define center of mass, center of gravity, torque, rotational inertia
2. Give examples of center of gravity
3. Explain how center of mass affects rotation and toppling
4. Write the equations for torque and rotational inertia
5. Explain how to change torque and rotational inertia
Center of Mass/Gravity

• COM – point which is at the center of the objects mass
  – Middle of meter stick
  – Center of a ball
  – Middle of a donut
    • Donuts are yummy

• COG – center of object’s weight distribution
  – Usually the same point as center of mass
Rotation and Center of Mass

• Objects rotate around their center of mass
  – Wobbling baseball bat tossed through the air
• They also balance there
  – Balancing a broom on your finger
• Things topple over when their center of gravity is not above the base
  – Leaning Tower of Pisa
Torque

- Force that causes rotation
- Equation

\[ \tau = \text{torque (in Nm)} \]
\[ F = \text{force (in N)} \]
\[ r = \text{arm radius (in m)} \]

- How do you increase torque
  - More force
  - Longer radius
Rotational Inertia

- Resistance of an object to a change in its rotational motion
- Controlled by mass distribution and location of axis
- Equation

\[ I = \text{rotational inertia (in kgm}^2\text{)} \]
\[ m = \text{mass (in kg)} \]
\[ r = \text{radius (in m)} \]

- How do you increase rotational inertia?
  - Even out mass distribution over larger radius
Angular Momentum

• Measure how difficult it is to start or stop a rotating object

• Equations

\[ L = I \omega = mv_r \]

• It is easier to balance on a moving bicycle

• Precession
  – Torque applied to a spinning wheel changes the direction of its angular momentum
  – The wheel rotates about the axis instead of toppling over
Satellite Motion

- Satellites “fall around” the object they orbit
- The tangential speed must be exact to match the curvature of the surface of the planet
  - On earth things fall 4.9 m in one second
  - Earth “falls” 4.9 m every 8000 m horizontally
  - Therefore a satellite must have a tangential speed of 8000 m/s to keep from hitting the ground
  - Rockets are launched vertically and rolled to horizontal during their flights
  - Satellites are in high orbit to be out of the atmosphere