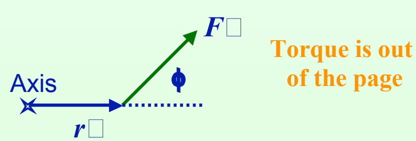
- Last Lecture
  - Statics and dynamics of rotational motion
- Today
  - Everything you need to know about dynamics of rotation
- Important Concepts
  - Equations for angular motion are mostly identical to those for linear motion with the names of the variables changed.
  - Location where forces are applied is now important.
  - Rotational inertia or moment of inertia (rotational equivalent of mass) depends on how the material is distributed relative to the axis.

Important Reminders

- Lectures will be M 11-12, T&W 10-12, F 11-12.
- Check schedule on web for new times and rooms for some recitations (all are still on Thursday).
- Switching of recitations will be permitted if you have a conflict with another IAP activity.
- Contact your tutor about session scheduling
  - Students working with Stephane Essame reassigned.
- Mastering Physics due today at 10pm.
- Pset due this Friday at 11am.

Torque

- How do you make something rotate? Very intuitive!
  - Larger force clearly give more "twist".
  - Force needs to be in the right direction (perpendicular to a line to the axis).
  - The "twist" is bigger if the force is applied farther away from the axis (bigger lever arm).
- In math-speak: $\vec{\tau} = \vec{r} \times \vec{F}$ $\quad |\tau| = |r||F|\sin(\phi)$



More Ways to Think of Torque

- Magnitude of the force times the component of the distance perpendicular to the force (aka lever arm).
- Magnitude of the radial distance times the component of the force perpendicular to the radius.
- Direction from Right-Hand-Rule for cross-products and can also be thought of as clockwise (CW) or counter-clockwise (CCW).
- For torque, gravity acts at the center of mass.

Equations for Dynamics

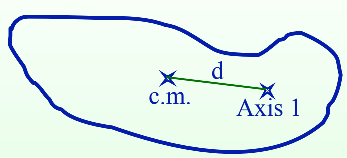
- Same as before: $\Sigma\vec{F} = M\vec{a}$
  - Only the direction and magnitude of the forces matter.
  - This gives one independent equation per dimension.
- Additional condition: $\Sigma\vec{\tau} = I\vec{\alpha}$
  - This is true for ***any fixed*** axis (for example, a pulley).
  - In addition, this equation holds for an axis through the center of mass, even if the object moves or accelerates.
  - As for statics, if all of the forces are in the same plane, you only get ***one*** additional independent equation by considering rotation.

Moment of Inertia

- $I = \Sigma m_i r_i^2 = \int r^2 dm$
  - Hoop (all mass at same radius) I=MR^2
  - Solid cylinder or disk I=$(1/2)MR^2$
  - Rod around end I=$(1/3)ML^2$
  - Rod around center I=$(1/12)ML^2$
  - Sphere I=$(2/5)MR^2$
- The same object could have a different moment of inertia depending on the choice of axis.
- In the equation: $\Sigma\vec{\tau} = I\vec{\alpha}$ all three quantities need to be calculated using the same axis.

Parallel Axis Theorum

- Very simple way to find moment of inertia for a large number of strange axis locations.



- $I_1 = I_{c.m.} + Md^2$ where M is the total mass.

Everything you need to know for Linear & Rotational Dynamics

- $\Sigma\vec{F} = M\vec{a}$
  - This gives one independent equation per dimension.
- $\Sigma\vec{\tau} = I\vec{\alpha}$
  - This is true for ***any fixed*** axis and for an axis through the center of mass, even if the object moves or accelerates.
  - For problems in 8.01, you only get ***one*** additional independent equation by considering rotation.
- Rolling ***without*** slipping: $v = R\omega \quad a = R\alpha \quad f \neq \mu N$
- Rolling ***with*** slipping: $v \neq R\omega \quad a \neq R\alpha \quad f = \mu N$