Flipping Physics Lecture Notes:
AP Physics 1 Review of *Rotational Dynamics*
https://www.flippingphysics.com/ap1-rotational-dynamics-review.html

- Torque, the ability to cause an angular acceleration of an object: $\vec{\tau} = \vec{r}_{\perp}\vec{F} = \vec{r}\vec{F}\sin\theta$
  - The moment arm or lever arm is: $\vec{r}_{\perp} = \vec{r}\sin\theta$
  - A larger moment arm will cause a larger torque.
    - Maximize torque by maximizing r, the distance from axis of rotation to the force.
    - Maximize torque by using an angle of 90° because $\left(\sin\theta\right)_{\max} = \sin\left(90°\right) = 1$
  - Dimensions for Torque are Newtons meters, N·m, not to be confused with Joules for energy:
  - Torque is a vector.
    - For direction use clockwise and counterclockwise. (sadly, not the right hand rule)
- Rotational form of Newton's Second Law: $\sum \vec{\tau} = I\vec{\alpha}$
- Moment of Inertia or Rotational Mass:
  - For a system of particles: $I = \sum_i m_i r_i^2$
  - Dimensions for Moment of Inertia: $I = \sum_i m_i r_i^2 \Rightarrow kg \cdot m^2$
  - For a rigid object with shape the value or the equation will be given to you. For example: $I_{solid\ cylinder} = \frac{1}{2}MR^2$; $I_{thin\ hoop} = MR^2$; $I_{solid\ sphere} = \frac{2}{5}MR^2$; $I_{thin\ spherical\ shell} = \frac{2}{3}MR^2$; $I_{rod} = \frac{1}{12}ML^2$; $I_{rod\ about\ end} = \frac{1}{3}ML^2$
    - With the exception of $I_{rod\ about\ end}$, these are all about the center of mass of the object.
- Rotational Kinetic Energy: $KE_{rot} = \frac{1}{2}I\omega^2$
  - KE_{rot}, like translational energy, is in Joules, J.
  - Rolling without slipping: When an object rolls down a hill, it will gain not only translational kinetic energy but also rotational kinetic energy. Which means, the higher the moment of inertia, the higher the rotational kinetic energy of the object and therefore the lower amount of energy that will be left over for translational kinetic energy and therefore a lower final linear velocity.
    - Using Conservation of Mechanical Energy: $ME_i = ME_f \Rightarrow PE_{gi} = KE_{rot\ f} + KE_{t\ f}$
    - Also need the equation for the velocity of the center of mass of a rigid object rolling without slipping: $v_{cm} = R\omega$
- Angular Momentum: $\vec{L} = I\vec{\omega}$
  - Dimensions for Angular Momentum: $\vec{L} = I\vec{\omega} \Rightarrow \left(kg \cdot m^2\right)\left(\frac{rad}{s}\right) = \frac{kg \cdot m^2}{s}$
- Angular Impulse: $\Delta\vec{L} = \vec{\tau}_{impact}\Delta t = Angular\ Impulse$
  - Dimensions for Angular Impulse: $\Delta\vec{L} = \vec{\tau}_{impact}\Delta t \Rightarrow N \cdot m \cdot s$