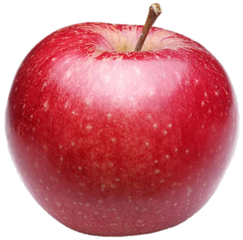
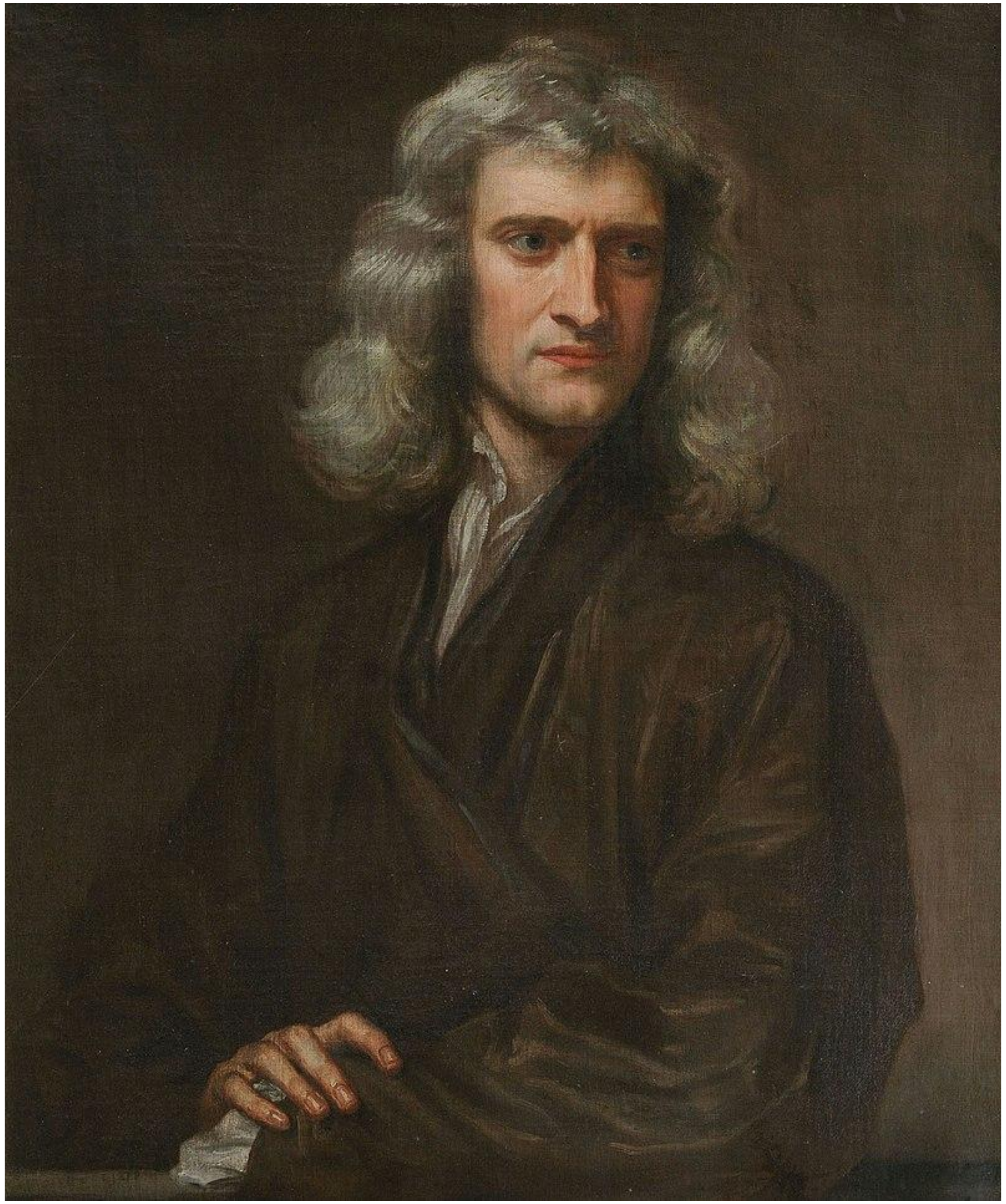


Physics 1 tutorial class

(Cont.)



6. Rotational variables

Angular position, displacement, velocity (average and instantaneous), acceleration…

$$\omega = \omega_0 + \alpha t$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega^2 - \omega_0^2 = 2\alpha(\theta - \theta_0)$$

Just remember: **Linear = Angular times radius**

6. Kinetic Energy of Rotation

- - Mass is replaced by **moment of inertia I** (Unit: kgm^2)

- Rotational kinetic energy:

$$K = \frac{1}{2} I\omega^2$$

- Calculating I:

$I = \sum m_i r_i^2$ (system of particles)

$I = \int r^2 dm$ (continuous bodies, like a cylinder or sphere)

$I = I_{com} + Mh^2$ (Calculate I about any axis, if given I_{com})

6. Kinetic Energy of Rotation

- Example problem #?: A rigid body is initially at rest. At time t=0, the body is given a constant angular acceleration of 0.05 rad/s^2. Find the magnitude of the tangential acceleration and the centripetal acceleration of a point that is a distance of 1.5 m from the rotational axis at t = 6.0 s.

$$a_\perp = \alpha r$$

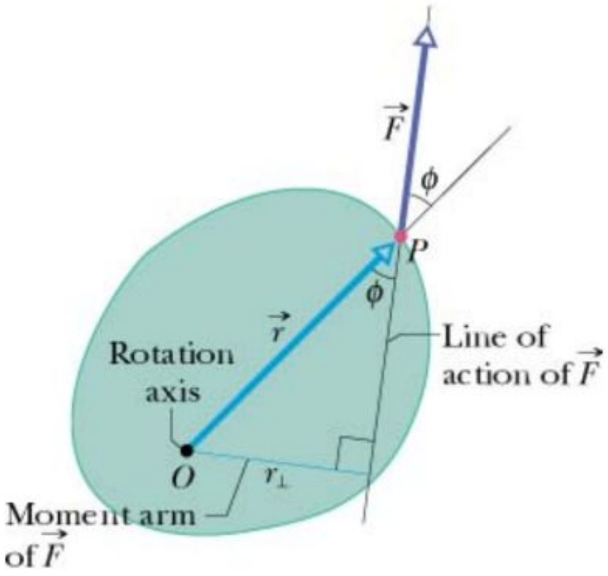
$$a_r = \frac{v^2}{r} = \omega^2 r$$

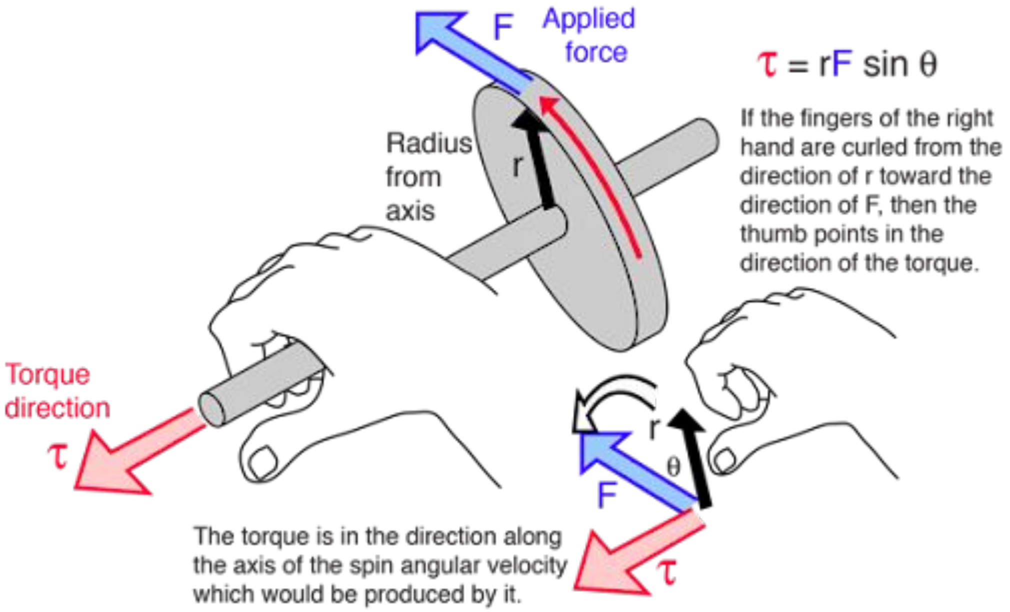
→ Find ω after 6 seconds

7. Torque

- Torque is the ability of a force to rotate a rigid body, it's a VECTOR.

$$\vec{\tau} = \vec{r} \times \vec{F}$$
$$\tau = r_{\perp} F$$





Directions: Use the right-hand rule to determine the direction of the torque. Indicate or draw the direction in the diagrams or figures.

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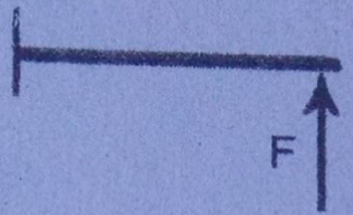

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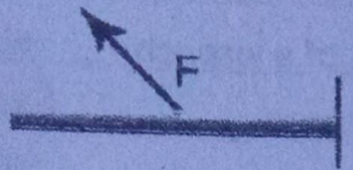

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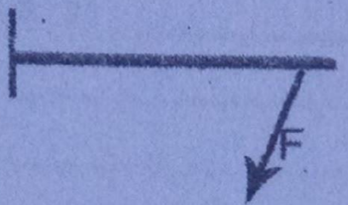

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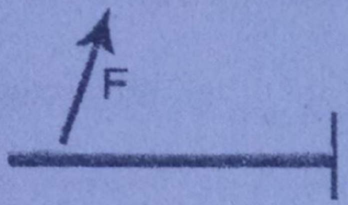

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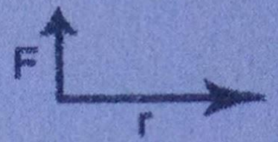

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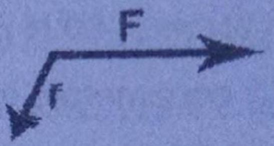

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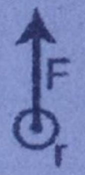

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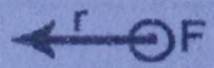

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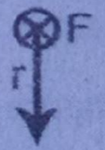


8. Newton’s 2nd law (rotation version)

- From $\boldsymbol{F}_{\boldsymbol{net}} = m\boldsymbol{a}$:

$$\boldsymbol{\tau}_{\boldsymbol{net}} = I\boldsymbol{\alpha}$$

So, you do the same as midterm to solve problems:

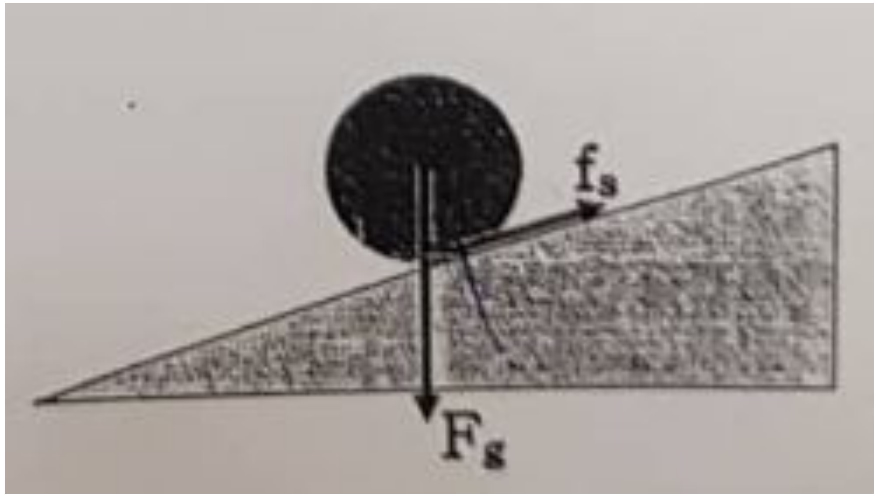
1. Choose a positive direction;
2. Newton’s second law for translational motion;
3. Newton’s second law for rotation
4. Solve the set of equation

9. Rolling motion

- Smooth rolling: Translation of the COM and rotation of the rest of the body.
- SAME formulas for rotational variables.
- Kinetic energy: Sum up!

8. Newton's 2nd law (rotation version)

- Example problem #?: A solid cylinder of mass $M = 1.2\,kg$ and radius $R = 10\,cm$ rolls smoothly down a rough incline of 30°. Find the static frictional force acting on the cylinder $\left(I = \frac{1}{2}MR^2\right)$



Smooth rolling?

$$\omega = \frac{v_{com}}{r}$$

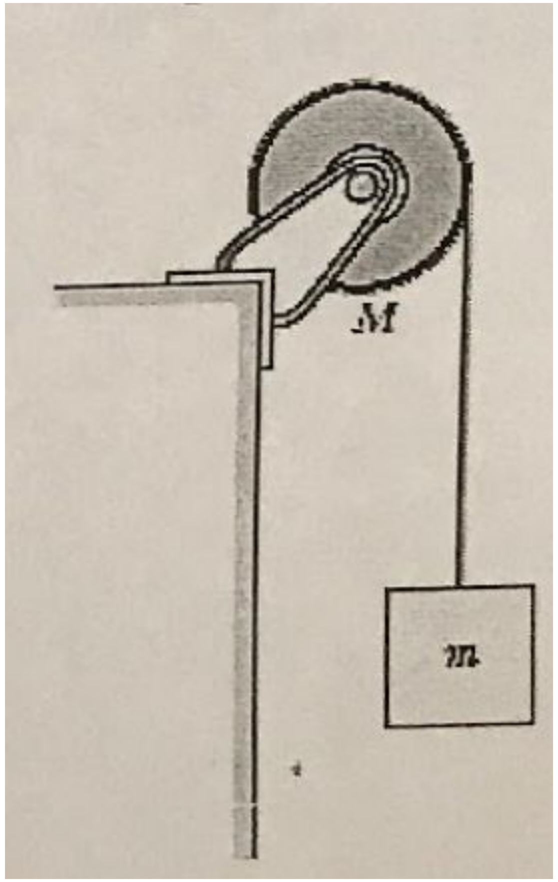
$$\alpha = \frac{a_{com}}{r}$$

8. Newton's 2nd law (rotation version)

- Example problem #?: A box of mass 15kg is suspended by a very light rope wrapped around a solid uniform cylinder with radius R and mass $M = 12kg$. The cylinder pivots on a frictionless axle through its center. The box is released from rest and falls down. The moment of inertia of the cylinder with respect to its axle is $\frac{1}{2}MR^2$.

a) What is the tension in the rope while the box is falling?

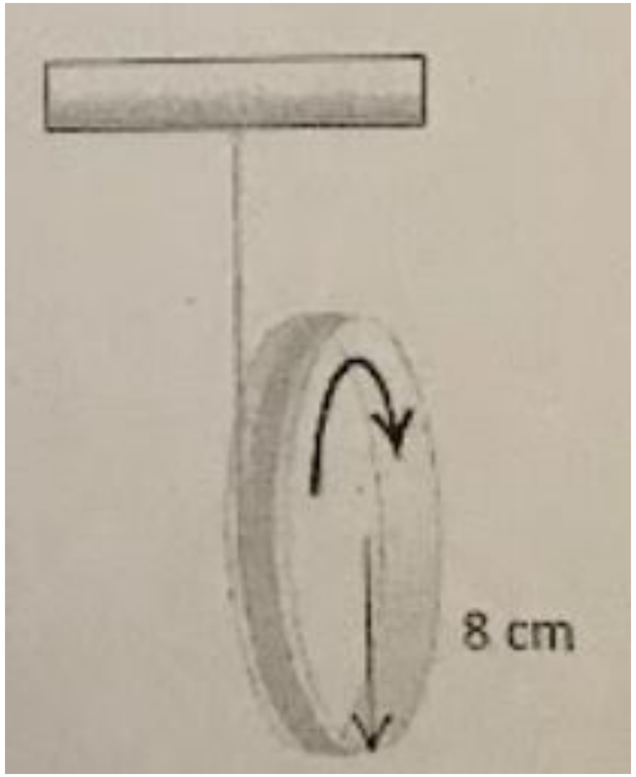
b) Compute the speed of the box when it falls 10m.



8. Newton's 2nd law (rotation version)

- Example problem #?: A string is wrapped several times around the rim of a small hoop with radius 8 cm 0.18 kg. The free end of the string is held in place and the hoop is released from rest.

After the hoop has descended 75 cm, **calculate the angular speed of the rotating hoop and the speed of its center.** Given that the moment of inertia of the hoop is mR^2. (Hint: You may use conservation of energy to solve this).



9. Angular momentum

- It's like momentum, but angular ☺

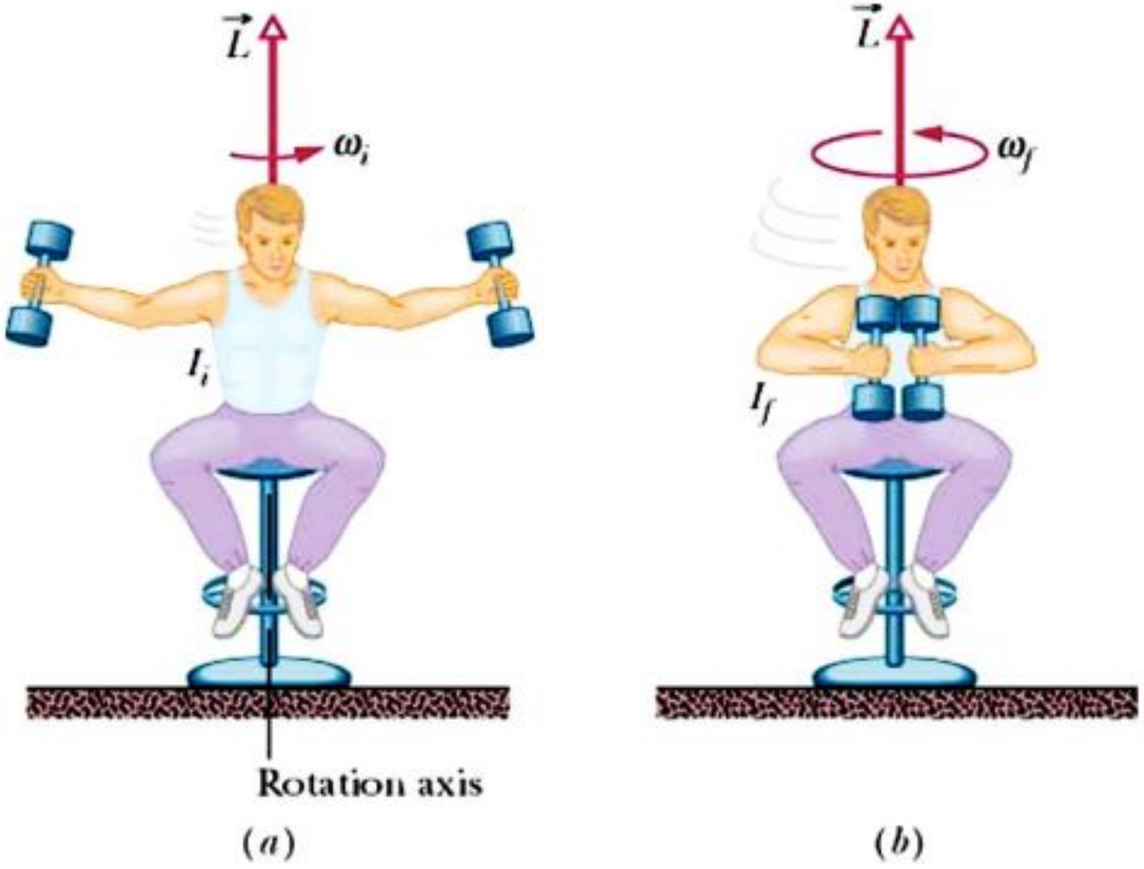
$$L = I\omega$$

And it's conserved:

$$I_i\omega_i = I_f\omega_f$$

Second Law:

$$\tau_{net} = \frac{dL}{dt}$$



9. Angular momentum

- Example problem #?: A thin, uniform metal bar, 2.0 m long and weighting 90 N is hanging vertically from the ceiling by a frictionless pivot. Suddenly it is struck 1.5m below the ceiling by a small 3kg ball, initially travelling horizontally at 10 m/s. The ball rebounds in the opposite direction with a speed of 6 m/s. The moment of inertia of the bar with respect to the pivot is $\frac{1}{3}ML^2$.

a) Find the angular speed of the bar just after the collision.

b) During the collision, why the angular momentum conserved but not the linear momentum?

9. Angular momentum

- Example problem #?: A disk having a radius R = 2m and a mass of M = 120 kg is initially rotating at 3.00 rad/s about a vertical axis through its center. Suddenly, a 70 kg object falls onto the disk at a point near the outer edge and sticks to the disk. The moment of inertia of the disk is $\frac{MR^2}{2}$.

(a) Find the angular speed of the disk after the object sticks to the disk.

(b) Compute the kinetic energy of the system before and after the collision. Why are these kinetic energies not equal?