Announcements

1. Updated web page – http://www.wfu.edu/~natalie/f02phy113

   HW assignments through #18

   New practice exams

2. I will have to miss my office hours today
3. Alternative final exam time? (Official time is 2 PM Saturday, Dec. 14th.)
4. Correction to Wednesday's lecture –
5. Chapter 10 – rotational motion

Notion of impulse:

$$\mathbf{F} = \frac{d\mathbf{p}}{dt}$$

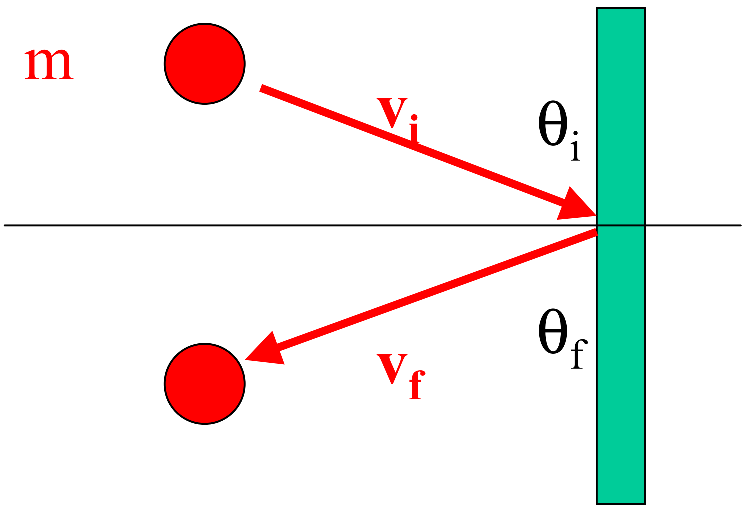
cause ⟷ **effect**

$$\Delta\mathbf{p} = m\mathbf{v}_\mathbf{f} - m\mathbf{v}_\mathbf{i}$$

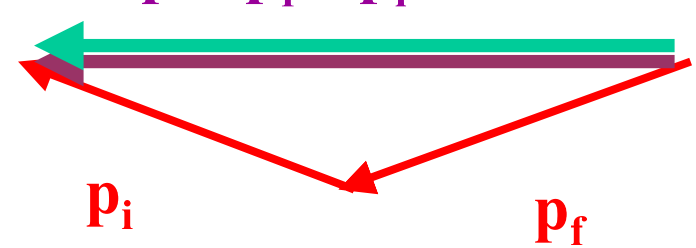
Example:

$$\Delta\mathbf{p} = (mv_f \sin\theta_f + mv_f \sin\theta_f)\ \mathbf{i}$$

$$+(-mv_f \cos\theta_f + mv_f \cos\theta_f)\ \mathbf{j}$$



$$\Delta\mathbf{p} = \mathbf{p}_\mathbf{f} - \mathbf{p}_\mathbf{i} = \mathbf{F}\,\Delta\mathbf{t}$$



Peer instruction question: (from Wednesday)

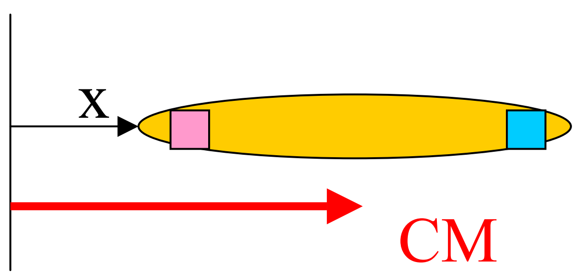
Romeo (60 kg) entertains Juliet (40 kg) by playing his guitar from the rear of their boat (100 kg) which is at rest in still water. Romeo is 2m away from Juliet who is in the front of the boat. After the serenade, Juliet carefully moves to the rear of the boat (away from shore) to plant a kiss on Romeo’s cheek. How does the boat move relative to the shore in this process? (Initially Juliet is closest to the shore.)

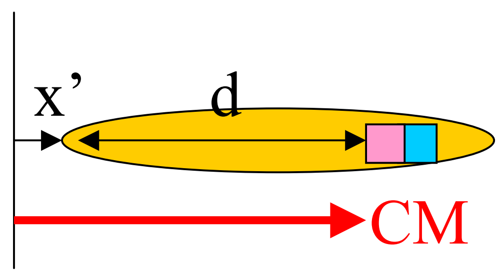
(a) 0.2 m away from shore

(b) 0.4 m away from shore

(c) 0.2 m toward shore

(d) 0.4 m toward shore

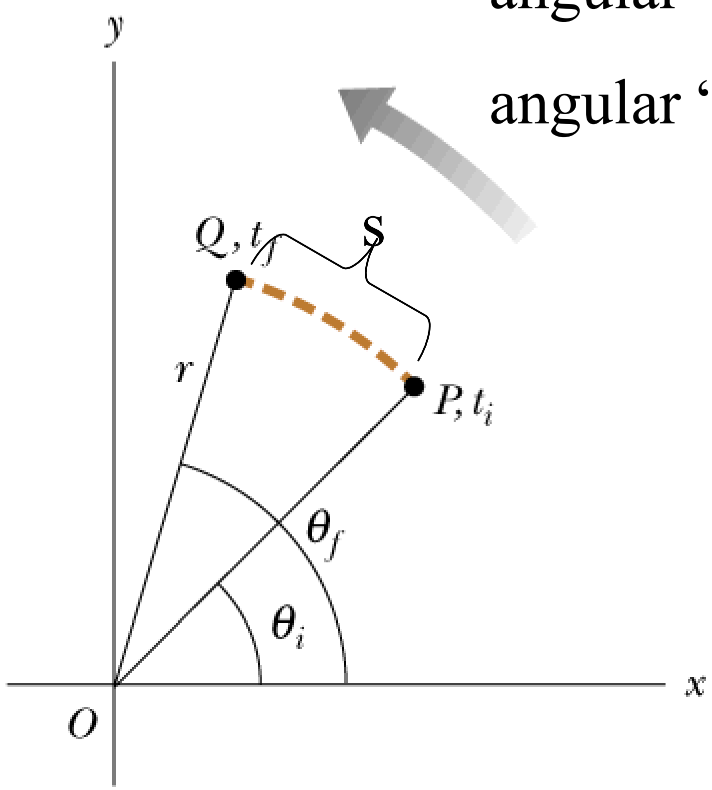




$x-x' = d\, m_J/M_{total} = 0.4\ m_l$

Angular motion

Serway, Physics for Scientists and Engineers, 5/e
Figure 10.2



angular "displacement" ➔ $\theta(t)$

angular "velocity" ➔ $\omega(t) = \dfrac{d\theta}{dt}$

angular "acceleration" ➔ $\alpha(t) = \dfrac{d\omega}{dt}$

"natural" unit == 1 radian

Relation to linear variables:

$$s_\theta = r\,(\theta_f - \theta_i)$$

$$v_\theta = r\,\omega$$

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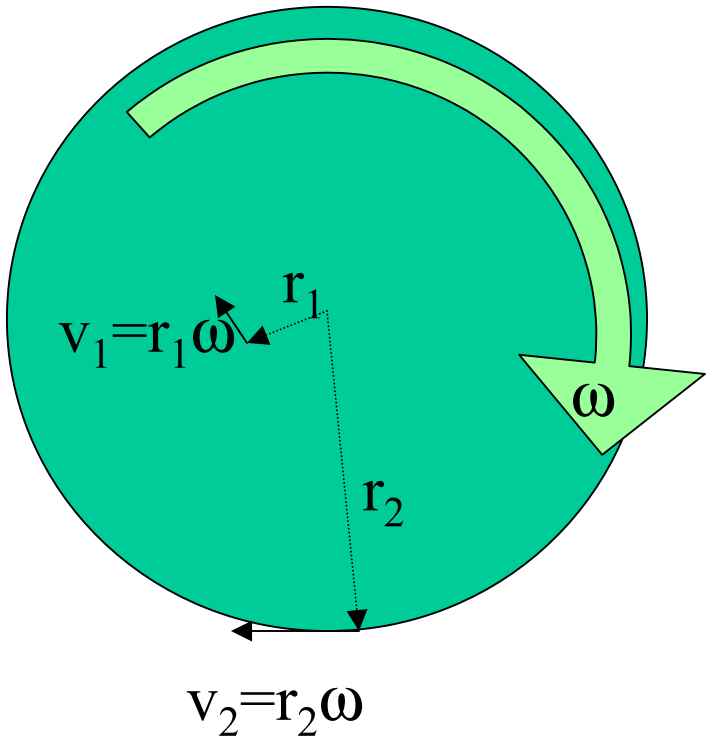
$$a_\theta = r\,\alpha$$



Special case of constant angular acceleration: $\alpha = \alpha_0$:

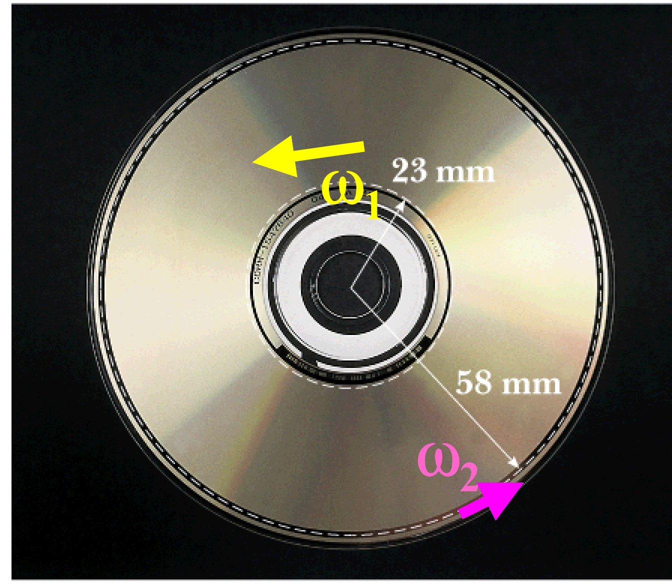
$$\omega(t) = \omega_i + \alpha_0\, t$$

$$\theta(t) = \theta_i + \omega_i\, t + ½\, \alpha_0\, t^2$$

$$(\, \omega(t))^2 = \omega_i^2 + 2\, \alpha_0\, (\theta(t) - \theta_i\,)$$

Serway, Physics for Scientists and Engineers, 5/e
Figure 10.6

Example: Compact disc motion



In a compact disk, each spot on the disk passes the laser-lens system at a constant linear speed of $v_\theta = 1.3$ m/s.

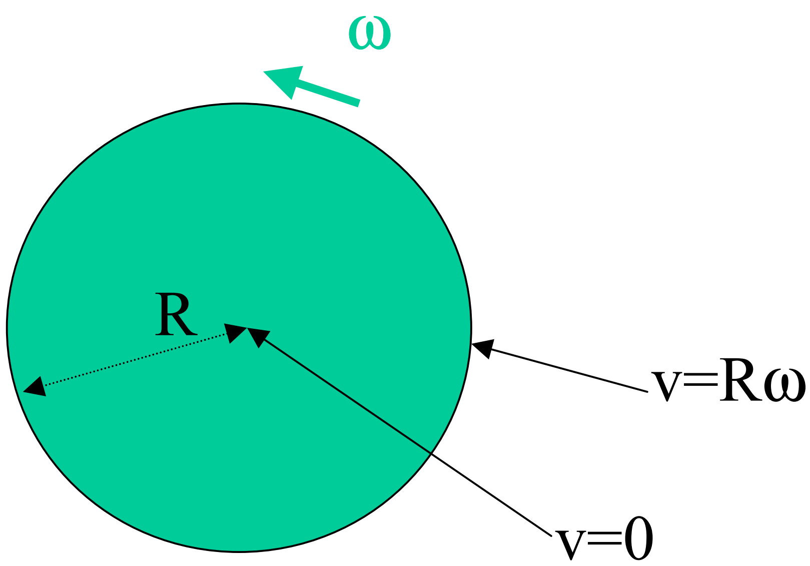
$\omega_1 = v_\theta / r_1 = 56.5$ rad/s

$\omega_2 = v_\theta / r_2 = 22.4$ rad/s

What is the average angular deceleration of the CD over the time interval $\Delta t = 4473$ s?

$\alpha = (\omega_2 - \omega_1)/\Delta t = -0.0076 \text{ rad/s}^2$

Object rotating with constant angular velocity ($\alpha = 0$)



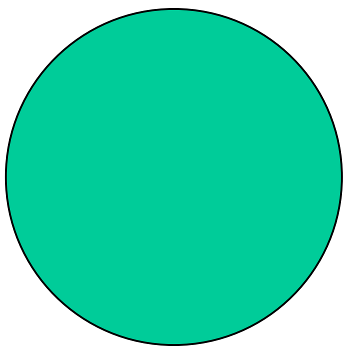
Kinetic energy associated with rotation:

$$K = \sum_i \tfrac{1}{2} m_i v_i^2 = \sum_i \tfrac{1}{2} m_i r_i^2 \omega^2 \equiv \tfrac{1}{2} I \omega^2;$$

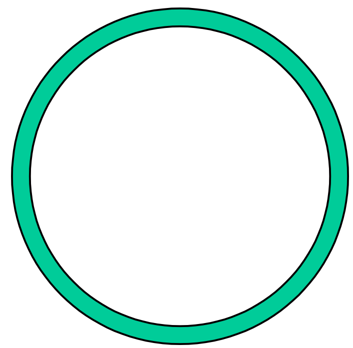
$$\text{where}: I \equiv \sum_i m_i r_i^2$$ "moment of inertia"

Peer instruction question:

Suppose each of the following objects each has the same total mass M and outer radius R and each is rotating counter-clockwise at an constant angular velocity of ω=3 rad/s. Which object has the greater kinetic energy?

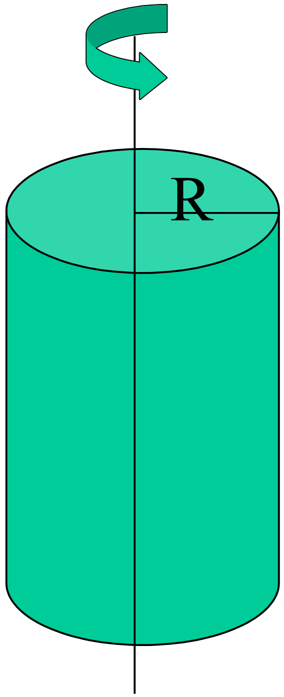


(a) (Solid disk)



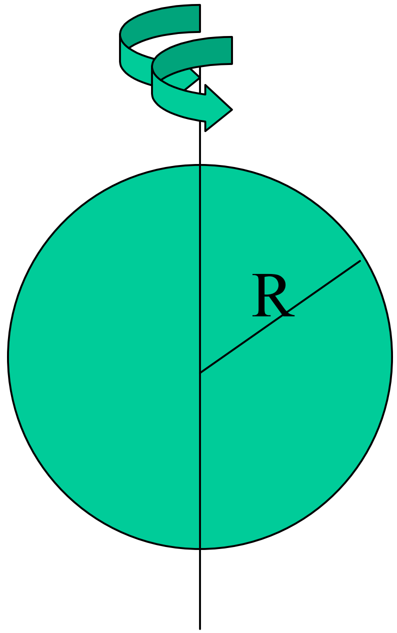
(b) (circular ring)

Various moments of inertia:



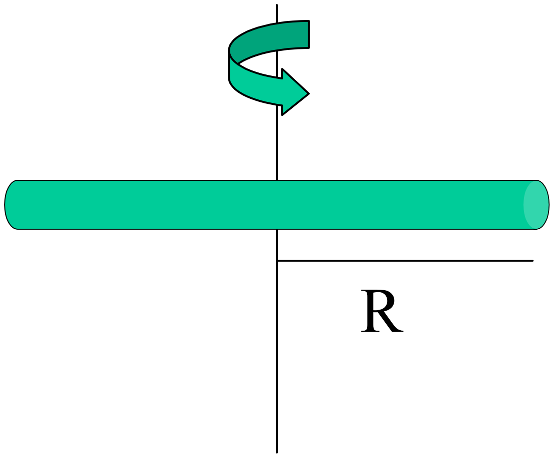
solid cylinder:

$I = 1/2\ MR^2$



solid sphere:

$I = 2/5\ MR^2$

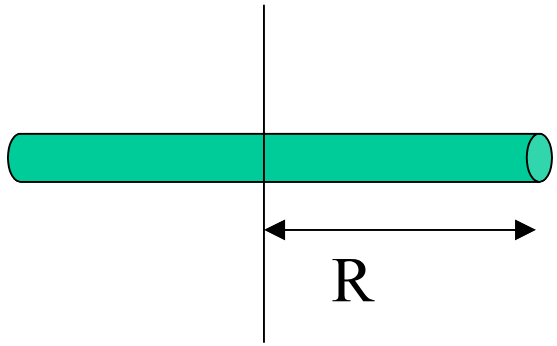


solid rod:

$I = 1/3\ MR^2$

Calculation of moment of inertia:

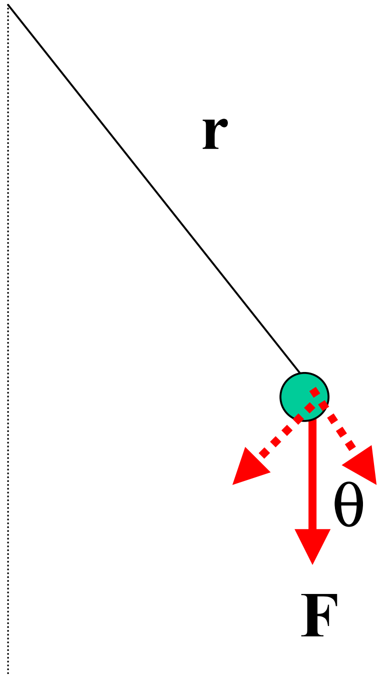
Example -- moment of inertia of solid rod through an axis perpendicular rod and passing through center:



$$I = \sum_i m_i r_i^2 = \int_{-R}^{R} \left(\frac{M}{2R}\right) dr\, r^2 = \left(\frac{M}{2R}\right) \int_{-R}^{R} r^2 dr = \frac{1}{3} MR^2$$

Extra credit: Write out the evaluation of *I* for another shape.

How to make objects rotate.



Define torque:

$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$

$\tau = rF \sin \theta$

$$\mathbf{F} = m\mathbf{a}$$

$$\mathbf{r} \times \mathbf{F} \equiv \boldsymbol{\tau} = \mathbf{r} \times m\mathbf{a} = I\boldsymbol{\alpha}$$