Spring 2014

PHYS-2010

Lecture 33

Announcements

- Read Giancoli **Chapter 8 on Rotational Motion**.
- Next CAPA # 11 due tomorrow at 11 pm.
- No written Homework due this week.
- **Study Session** by Prof. Pollock: tomorrow, 5-6pm, G125.
- **Midterm Exam 3** on Thursday, April 10, 7:30 pm.
- **Practice exam** is posted on D2L.
- Material covered on exam: Giancoli Chapters 5-7

(Gravity, Kepler's laws, Work, Energy, Power, Momentum, Collisions)

- **Exam seating:**
  - if your TA is Rosemary Wulf or Andrew Hess, your exam is here, G1B30.
  - if your TA is Jake Fish or Clarissa Briner, your exam is next door, G1B20.
- More details about the exam are on the course website:

http://www.colorado.edu/physics/phys2010/phys2010_sp14/exams.html

Rotational Dynamics

Translation	↔	Rotation	
x	↔	θ	angle of rotation (rads)
$v = \frac{\Delta x}{\Delta t}$	↔	$\omega = \frac{\Delta\theta}{\Delta t} = \frac{v}{r} = \frac{2\pi}{\tau} = 2\pi f$	angular velocity (rad/s)
$a = \frac{\Delta v}{\Delta t}$	↔	$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_{tan}}{r}$	angular acceleration (rad/s^2)
F	↔	$\tau = r\,F_{\perp}$	torque (N m)
M	↔	$I = \sum m\,r^2$	moment of inertia (kg m^2)
$F_{net} = M\,a$	↔	$\tau_{net} = I\,\alpha$	Newton's 2nd Law

Torque and Moment of Inertia

$$\tau \equiv rF_{\perp}$$

Rotational Analog to Newton's Second Law (*F = ma*):

$$\tau = I\alpha$$

Units of τ: Nm
Units of I: kg m^2
Units of α: rad/s^2

Torque = (moment of inertia) x (rotational acceleration)

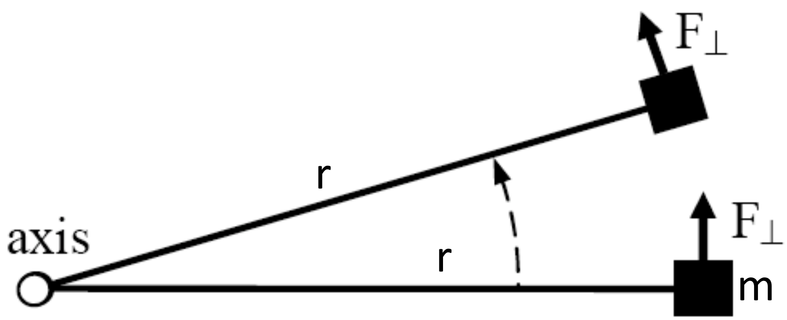
Moment of inertia *I* depends on the distribution of mass and, therefore, on the shape of an object.

$$I_{\text{point}} = mr^2$$

Moment of inertia for a point mass is the mass times the square of the distance of the mass from the axis of rotation.

Torque and Moment of Inertia

$$\tau \equiv rF_{\perp} = I\alpha$$



Consider a point mass *m* to which we apply a constant tangential force $F_{\perp}$.

$$a_{\tan} = r\alpha$$

$$F_{\perp} = ma_{\tan} = mr\alpha$$

$$\tau \equiv rF_{\perp} = mr^2\alpha = I\alpha$$

$$I = mr^2$$

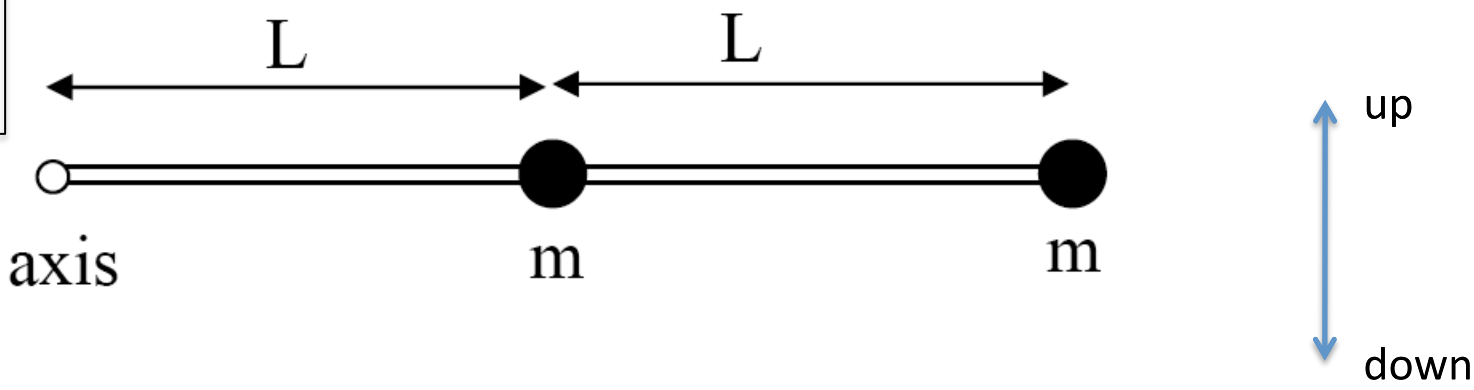
Thus, the moment of inertia for a point mass is equal to mr^2.

Clicker Question

Room Frequency BA

$$\tau \equiv rF_{\perp} = I\alpha$$

$$I_{\text{point}} = mr^2$$



A light rod of length 2*L* has two heavy masses (each with mass *m*) attached at the end and middle. The axis of rotation is at one end. What is the moment of inertia about the axis?

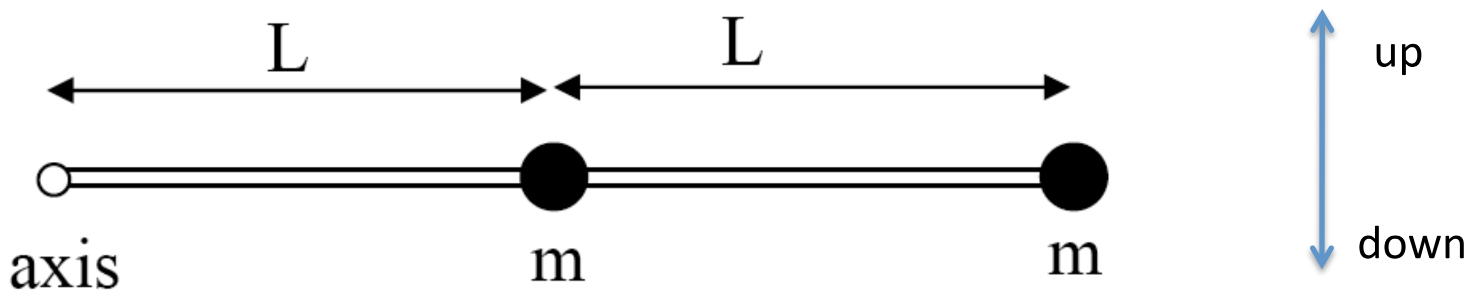
A) mL^2 B) $2mL^2$ C) $4mL^2$ **D) $5mL^2$** E) $9mL^2$

$$I = \Sigma\, m_i r_i^2 = mL^2 + m(2L)^2 = 5mL^2$$

Clicker Question

Room Frequency BA

$$\tau \equiv rF_{\perp} = I\alpha$$
$$I_{\text{point}} = mr^2$$



A light rod of length 2*L* has two heavy masses (each with mass *m*) attached at the end and middle. The axis of rotation is at one end.

1) What is the moment of inertia about the axis? $I = 5mL^2$

2) What is the net torque due to gravity when it's released?

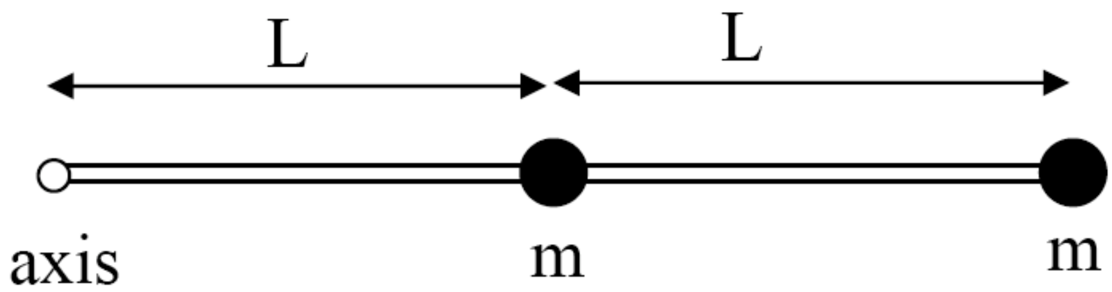
A) 2mgL B) -2mgL C) 3mgL D) - 3mgL E) 4mgL

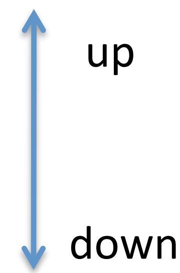
$$\tau = \tau_1 + \tau_2 = -r_1F_{\perp} - r_2F_{\perp} = -L(mg) - 2L(mg) = -3Lmg$$

$\tau = -|\tau| = -3mgL$ because all torques are CW.

$\tau \equiv rF_{\perp} = I\alpha$

$I_{\text{point}} = mr^2$





A light rod of length 2*L* has two heavy masses (each with mass *m*) attached at the end and middle. The axis of rotation is at one end.

1) What is the moment of inertia about the axis? $I = 5mL^2$

2) What is the net torque due to gravity when it's released? $\tau = -3mgL$

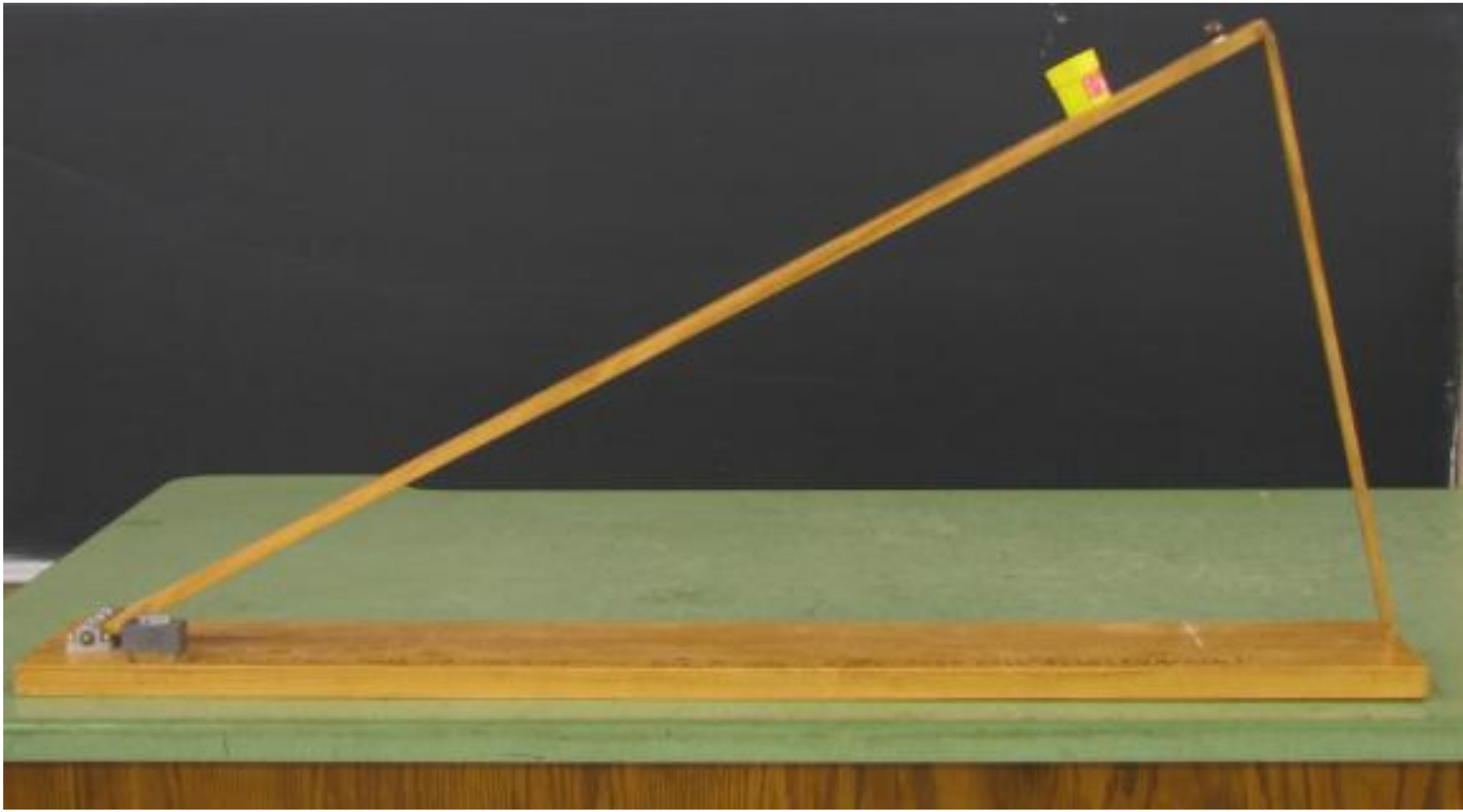
3) If the bar's released from rest, what's the magnitude of its angular acceleration?

A) $\frac{3g}{5L}$ B) $\frac{5g}{3L}$ C) $\frac{7L}{3g}$ D) $\frac{3L}{5g}$

$$\alpha = \frac{\tau}{I} = \frac{-3mgL}{5mL^2} = -\frac{3g}{5L}$$

$$|\alpha| = \frac{3g}{5L}$$

Falling Chimney Demonstration



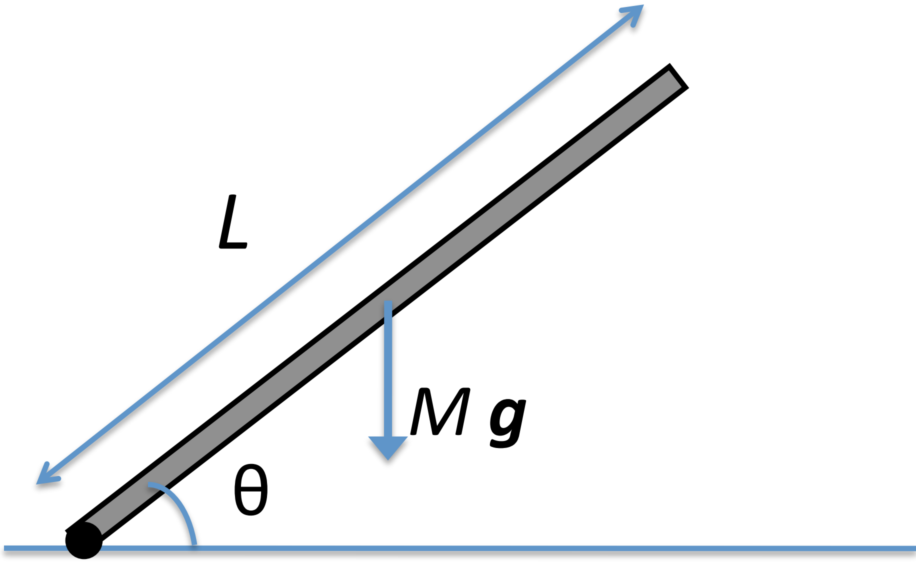
Falling Chimney Demonstration

Falling Chimney Demonstration

Clicker Question

Room Frequency BA

A rod of length *L* and mass *M* makes an angle θ with a horizontal table.



1) What is the magnitude of the torque **τ** exerted on the rod by gravity?

A) ML

B) Mg sin θ

C) MgL

D) 0.5 MgL cos θ

Hint: for a uniform extended rod, the torque due to the force of gravity is applied at the center of mass, i.e., the middle of the rod.

$$\tau = F_{g,\ perp}\,(L/2) = Mg\cos\theta\,(L/2)$$