## Physics 207, Lecture 17, Nov. 1

- Agenda: Problem Solving and Review for MidTerm II, Ch. 7-12
  - ❖ Work/Energy Theorem, Energy Transfer
  - ❖ Potential Energy, Friction, Power,
  - ❖ Systems (Cons. & Non-Cons.), Hooke's Law springs
  - ❖ Momentum, Collisions, Impuse, Center-of-mass
  - ❖ Angular Momentum, Torque, Rotational Energy, Work
  - ❖ Parallel-axis Theorem, Moment of Inertia, Rolling Motion
  - ❖ Statics, (Note: Elastic properties of matter, not on midterm)

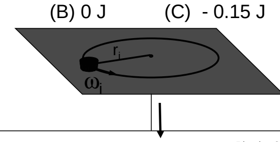
Assignments:
- For Monday Nov. 6, Read Chapter 14 (Fluids)
- WebAssign Problem Set 7 due Nov. 14, Tuesday 11:59 PM
- MidTerm Thurs., Nov. 1, Chapters 7-12, 90 minutes, 7:15-8:45 PM
- NOTE: Assigned Rooms are 105 and 113 Psychology
- McBurney Students: Room 5310 Chamberlin



## Lecture 17, *Exercise 1*

- A mass m=0.10 kg is attached to a cord passing through a small hole in a frictionless, horizontal surface as in the Figure. The mass is initially orbiting with speed $\omega_i$ = 5 rad/s in a circle of radius $r_i$ = 0.20 m. The cord is then slowly pulled from below, and the radius decreases to r = 0.10 m. How much work is done moving the mass from $r_i$ to r ?
- Underlying concept: Conservation of Momentum

(A) 0.15 J (B) 0 J (C) - 0.15 J



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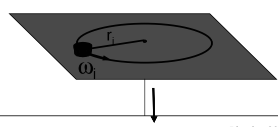
- Principle: No external torque so *L* is constant

$L = I\,\omega = m\,r_i^2\,\omega_i = m\,r^2\,\omega_f \rightarrow \omega_f = r_i^2\,\omega_i / r^2 = 20$ rad/s

$W = K_f - K_i = ½\,m\,r_f^2\,\omega_f^2 - ½\,m\,r_i^2\,\omega_i^2 = 0.05\,(4 - 1)$ J

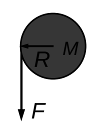
(A) 0.15 J (B) 0 J (C) - 0.15 J






## Example: Disk & String

- A massless string is wrapped 10. times around a solid disk of mass M=3.14 kg and radius R=10. cm. The disk starts at rest and is constrained to rotate without friction about a fixed axis through its center. The string is pulled with a force F=0.5 N until it has unwound. (Assume the string does not slip, and that the disk is initially at rest).
- Recall, $W = \tau\,\theta$, if the applied torque is constant
  - ❖ How fast is the disk spinning after the string has unwound?
  - ❖ Can solve two ways!



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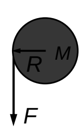
$W = \tau\,\theta = ½\,I\,\omega^2 \rightarrow \omega = (2\,R\,F\,\theta\,/\,½mR^2)^{½}$

$\omega = (4\,F\,\theta\,/\,mR)^{½}$

$\omega = (4 \times 0.5 \times 10 \times 2\pi\,/\,3.14 \times 0.10)^{½}$

$\omega = (400)^{½} = 20$ rad/s



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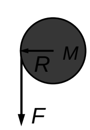
$\tau = I\,\alpha = R\,F \rightarrow \alpha = R\,F\,/\,I = 2\,F\,/\,mR$

$\alpha = 2 \times 0.5 / 3.14 \times 0.10 = 10 / \pi$ rad/s$^2$

$\omega = \alpha\,t \quad \theta = ½\,\alpha t^2 \rightarrow \omega = (2\,\alpha\theta)^{½}$

$\omega = (2 \times (10/\pi) \times 10 \times 2\pi)^{½} = 20$ rad / s

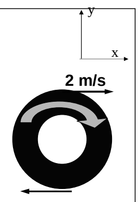


## Rolling

A wheel is spinning clockwise such that the speed of the outer rim is 2 m/s. The center of mass is stationary.

What is the velocity of the top of the wheel relative to the ground?

What is the velocity of the bottom of the wheel relative to the ground?




You now carry the spinning wheel to the right at 2 m/s.

What is the velocity of the top of the wheel relative to the ground?

(A) -4 m/s (B) -2 m/s (C) 0 m/s (D) +2m/s (E) +4 m/s

What is the velocity of the bottom of the wheel relative to the ground?

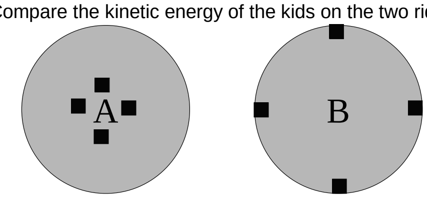
(A) -4 m/s (B) -2 m/s (C) 0 m/s (D) +2m/s (E) +4 m/s



## Merry Go Round

Four kids (mass m) are riding on a merry-go-round rotating with angular velocity $\omega$=3 rad/s. In case A the kids are near the center (r = 1.5 m), in case B they are near the edge (r = 3 m).

Compare the kinetic energy of the kids on the two rides.

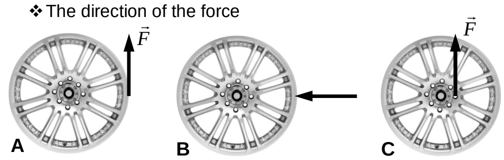



(A) $K_A > K_B$ (B) $K_A = K_B$ (C) $K_A < K_B$



## Forces and rigid body rotation

- To change the angular velocity of a rotating object, a force must be applied
- How effective an applied force is at changing the rotation depends on several factors
  - ❖ The magnitude of the force
  - ❖ Where, relative to the axis of rotation the force is applied
  - ❖ The direction of the force

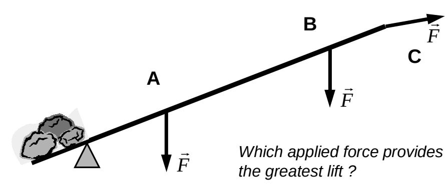



*Which applied force will cause the wheel to spin the fastest?*



## Leverage

- The same concept applies to leverage
  - ❖the lever undergoes rigid body rotation about a pivot point:

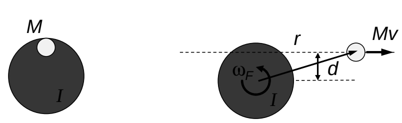



*Which applied force provides the greatest lift ?*



## Example: Throwing ball from stool

- A student sits on a stool, initially at rest, but which is free to rotate. The moment of inertia of the student plus the stool is *I*. They throw a heavy ball of mass *M* with speed *v* such that its velocity vector moves a distance *d* from the axis of rotation.
  - ❖ What is the angular speed $\omega_F$ of the student-stool system after they throw the ball ?




Top view: before after



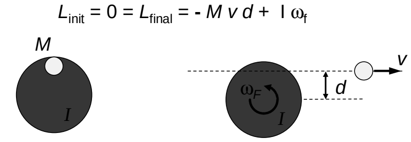
## Example: Throwing ball from stool

- What is the angular speed $\omega_F$ of the student-stool system after they throw the ball ?
- Process: (1) Define system (2) Identify Conditions

(1) System: student, stool and ball (No Ext. torque, L is constant)

(2) Momentum is conserved (check **r** X **p** for sign)

$$L_{init} = 0 = L_{final} = - M\, v\, d + I\, \omega_f$$




Top view: before after

### Approach to Statics:

- In general, we can use the two equations

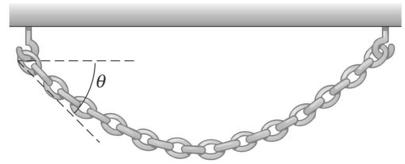
$$\boxed{\sum \boldsymbol{F} = 0} \qquad \boxed{\sum \boldsymbol{\tau} = 0}$$

to solve any statics problems.

- When choosing axes about which to calculate torque, choose one that makes the problem easy....



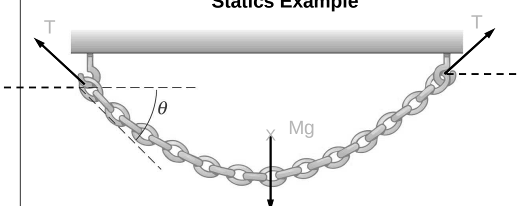
### Lecture 17, Statics Example




A freely suspended, flexible chain weighing Mg hangs between two hooks located at the same height. At each of the two mounting hooks, the tangent to the chain makes an angle θ = 42° with the horizontal. What is the magnitude o f the force each hook exerts on the chain and what is the tension in the chain at its midpoint.



### Statics Example




Here the tension must be directed along the tangent.

$\Sigma \mathbf{F} = 0 \rightarrow 0 = T_2 \cos 42° - T_1 \cos 42°$ let $T_1 = T_2 = T$

So $0 = 2\,T \sin 42° - Mg$

Statics requires that the net force in the x-dir be zero everywhere so $T_x$ is the same everywhere or $T \cos 42°$



### Comparison Kinematics

| Angular | Linear |
|---|---|
| $\alpha = constant$ | $a = \text{constant}$ |
| $\omega = \omega_0 + \alpha t$ | $v = v_0 + at$ |
| $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$ | $x = x_0 + v_0 t + \frac{1}{2} a t^2$ |
| $\omega^2 - \omega_0^2 = 2\alpha\theta$ | $v^2 - v_0^2 = 2ax$ |
| $\omega_{AVE} = \frac{1}{2}(\omega + \omega_0)$ | $v_{AVE} = \frac{1}{2}(v + v_0)$ |



### Comparison: Dynamics

| Angular | Linear |
|---|---|
| $I = \Sigma_i m_i r_i^2$ | m |
| $\tau = \mathbf{r} \times F = \alpha I$ | F = m a |
| $L = \mathbf{r} \times \mathbf{p} = I \omega$ | p = mv |
| $\tau_{EXT} = \frac{d\mathbf{L}}{dt}$ | $F_{EXT} = \frac{d\mathbf{p}}{dt}$ |
| $W = \tau \Delta\theta$ | $W = \boldsymbol{F} \cdot \boldsymbol{\Delta x}$ |
| $K = \frac{1}{2} I\omega^2$ | $K = \frac{1}{2} mv^2$ |
| $\Delta K = W_{NET}$ | $\Delta K = W_{NET}$ |



### Lecture 17, Statics Exercises 4 and 5

1. A hollow cylindrical rod and a solid cylindrical rod are made of the same material. The two rods have the same length and outer radius. If the same compressional force is applied to each rod, which has the greater change in length?
   (A) Solid rod
   (B) Hollow rod
   (C) Both have the same change in length

2. Two identical springs are connected end to end. What is the force constant of the resulting compound spring compared to that of a single spring?
   (A) Less than
   (B) Greater than
   (C) Equal to

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  - ❖ Statics, Elastic properties of matter

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