Announcements – Thurs, 22 Oct 2009

1. **CAUTION**: Starting with HW 14 (due Tuesday), some of your HW answers will need to be written in **scientific notation**. Do this with "e" notation, not with "x" signs. For example, if the answer range says
   5.00×10^{33}, 9.00×10^{33} kg·m^2/s

   and you get 6.57×10^{33} kg·m^2/s as your answer…

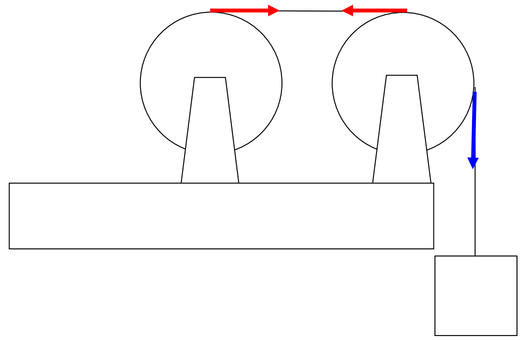
   …then you should type in the answer as **6.57E33**

   No spaces, no "x"s!

   If you put any spaces or x's in your answer, the computer will mark it wrong.

2. **TA-led Exam Review session—results of doodle.com voting**
   a. Day/Time: ___________________
   b. Place?

(From last time)



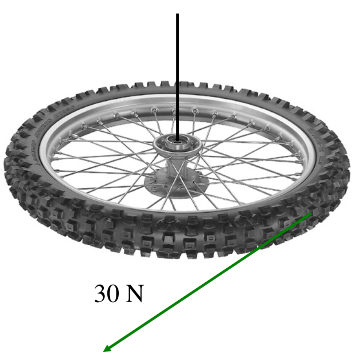
The left disk has a rope wrapped around its edge and the rope passes over a second disk. The two disks are identical and their **mass is significant**. As the system accelerates there is no slipping of the rope on either wheel and both wheels accelerate the same. The tension in the rope is

a. Largest between the disks
b. Largest above the mass
c. The same in both places.

Hint: apply N2 for torques to the right-hand disk

What's different with our old "massless pulleys"?

Another review problem: A bicycle tire ($r = 0.4$ m, $I = 0.8$ kg·m^2) is hanging from a string from the ceiling, not moving. You push on the edge with a 30 N force for 0.3 seconds. What is ω_f? (*Hint*: because time is given, do it with N2, not energy.)



Answer: 4.5 rad/s

Angular Correspondences Review

Kinematics

Distance: x	Angle: θ
Velocity: v	Angular velocity: ω
Acceleration: a	Angular acceleration: α
$x = x_0 + v_0 t + \frac{1}{2}at^2$	$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
$v = v_0 + at$	$\omega = \omega_0 + \alpha t$
$v^2 = v_0{}^2 + 2a(x - x_0)$	$\omega^2 = \omega_0{}^2 + 2\alpha(\theta - \theta_0)$

Mass

Mass: m	Moment of inertia: I

Force/Newton's 2nd Law

Force: F	Torque: τ
$\sum \vec{F} = m\vec{a}$	$\sum \tau = I\alpha$

Energy

$KE_{trans} = \frac{1}{2}mv^2$	$KE_{rot} = \frac{1}{2}I\omega^2$

Momentum…

Momentum: p $(= mv)$	Angular momentum??

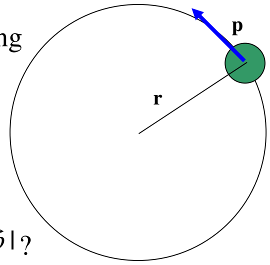
Angular momentum

Imagine a mass *m* on a thin rod moving in a circle, with constant speed v. It has linear momentum $\vec{p}$ =________.

Is $\vec{p}$ constant?________

Is $|\vec{p}|$ constant?________
(magnitude)

What do we need in order to affect $|\vec{p}|$?



<u>Force-momentum relationship</u>
Start with Newton 2:

$\sum \vec{F} = m\vec{a}$

<u>Torque-ang. mom. relationship</u>

$\sum \tau = I\alpha$

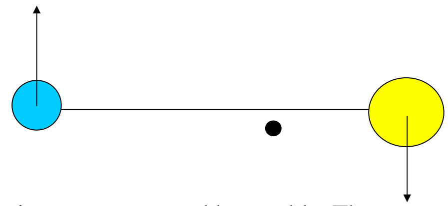
Define $\boxed{L = I\omega}$

If no net external force, no change in momentum

If no net external *torque*, no change in *angular* momentum

Conservation of Angular momentum

$\boxed{\Sigma L_{bef} = \Sigma L_{aft}}$ → if and only if *no net external torques*



Two space stations are connected by a cable. They are rotating about their center of mass. Someone in the blue station pulls the cable in so they are each closer to the center of rotation. What happens?

Demo: Hoberman sphere

Clicker quiz: Is rotational kinetic energy conserved? The total energy afterwards is:
a. more
b. less
c. the same
Hint: is there any non-conservative work done?

Spinning

From warmup. Rotating stool, student with weights. Her arms are extended, holding the weights as far from her body as possible. She then pulls the weights in close to her body, she will rotate faster. What happens to her moment of inertia as she pulls in the weights?
a. increases
b. decreases
c. remains the same

From warmup. What happens to her rotational speed as she pulls in the weights?
a. increases
b. decreases
c. remains the same

Application to skaters? (frictionless ice)

Demo: spinning chair

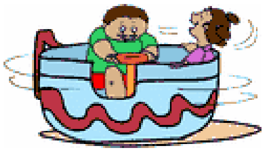
From warmup: What happens to her rotational kinetic energy as she pulls in the weights?
a. increases
b. decreases
c. remains the same

Worked Problem: A skater has an initial ω of 2 rad/s and I = 30 kg·m^2. When she brings in her arms, I = 10 kg·m^2. What is her final ω?

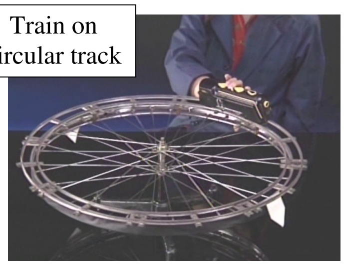
How much work did it take to do this?

Answers: 6 rad/s, 120 J

Is L conserved in these cases?



"Teacups": central post is connected to the platform floor



Train on circular track

Pocket watch with internal spring

Yo-yo

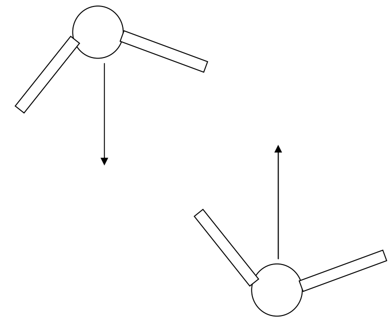
Videos: train on circular track, pocket watch

Food for thought: two skaters joining hands

(frictionless ice)

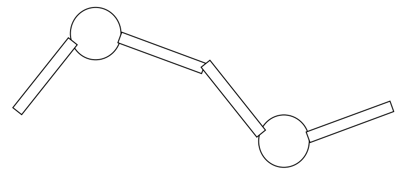
Before

Any L?



After

Any L?



Was angular momentum conserved? (system: both skaters)

→ It must be, if there is no net external torque

Clicker quiz: Is there an external torque here? I.e. was angular momentum conserved?

a. Yes external torque/not conserved
b. No external torque/yes conserved

Another expression for L…

Start with

$\tau = r_\perp F$

Remember

$F_{net} = \Delta p/\Delta t$

$\tau_{net} = \Delta L/\Delta t$

Result: $\boxed{L = r_\perp p}$ $\quad (= r\, p_\perp = r\, p \sin\theta)$

Worked Problem: Skaters on previous page have 0.7 m arms and are each 62 kg. They come together at 3.5 m/s. How fast (rad/s) are they turning afterwards?

Answer: 5 rad/s

Comment on vectors… (aka L has a direction!)

Does ω have a direction? ___________

Therefore ____________________

Thus with **no external torques**…

Demos: gyroscope

With external torque?

Demo: briefcase

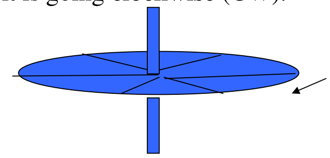
To fully describe what happens to angular momentum with external torque takes more math than we have… just understand that strange things can happen. ☺

From warmup: http://science.howstuffworks.com/gyroscope1.htm
Ralph watched the video with the bicycle wheel, but became very confused. He had learned that angular momentum is conserved, but in this case isn't the angular momentum of the wheel constantly changing in direction as the wheel spins around. What's up?

Answer from the class:

Demo: bicycle wheel

José sits still on frictionless ice, holding a bicycle wheel that's already spinning. View from above it is going **clockwise** (CW).



Clicker quiz: If he grabs on to the wheel edge firmly and stops it from spinning he will:

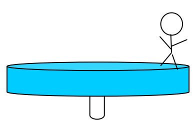
a. Start to turn CW (viewed from the top)
b. Start to turn CCW
c. Remain sitting without turning

Clicker quiz: If, instead of stopping the wheel, he carefully turns it over so it is going CCW (viewed from the top), he will start to:

a. Turn CW, but slower than in the previous problem
b. Turn CCW, but slower than in the previous problem
c. Turn CW, but faster than in the previous problem
d. Turn CCW, but faster than in the previous problem
e. Remain sitting without turning

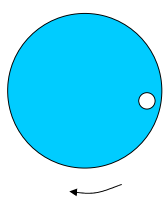
Demos: rotating platform, bicycle wheel
Demo: double bicycle wheels

A girl is on a spinning merry-go round.



What will happen to the rotational speed ω of the merry-go-round if she…

HINT: Sometimes it's easier to think of the **forces (torques)** she put on the merry-go-round to change, rather than conservation of L.



Clicker quiz 1: Walks towards the center?

a. it slows down
b. it stays same speed
c. it speeds up

Clicker quiz 2: Starts running opposite to the spinning so she is at rest vs the ground? (same choices)

Clicker quiz 3: Slips off when she steps on a frictionless icy part? (same choices)

Clicker quiz 4: Throws her shoe off tangentially in the direction she's moving? (same choices)