Lecture 13 Announcements

1. While you're waiting for class to start, please fill in the "How to use the blueprint equation" steps, in your own words.

2. Exam 2 results:

Momentum Review

Equations

Definition: $\vec{p} = m\vec{v}$

Conservation Law: $\sum \vec{p}_{before} = \sum \vec{p}_{after}$ (if no…)

"Impulse equation": $\vec{F}_{net}\Delta t = \Delta\vec{p}$

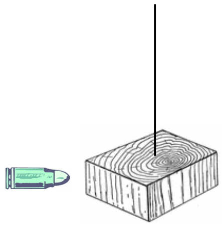
How to use the "Blueprint equation"

1. Draw…
2. Draw in…
3. Choose…
4. Use…
5. Include…
   i. be careful with…
6. Consider…
7. If it's an elastic collision use…

→ how do you know if it's an elastic collision?

Multi-step problems: collision followed by something else

Classic example: "Ballistic pendulum" (very close to HW 11-4)
A bullet of mass m and speed v embeds in a block of wood of mass M hanging from a string. How high does the block rise?



How not to do: $\frac{1}{2}mv^2 = (m+M)gh$

How to do:

1. **Collision part: *p* is conserved** (but KE is not!)
   i. This gets you the combined velocity right after the collision
2. **Motion part: Energy is conserved** (but *p* is not!)
   i. This gets you the height based on the "initial" velocity

Center of Mass

What is the center of mass?

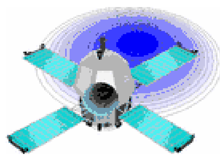
What forces can change the motion of the center of mass?

How does the center of mass move?

Demos: Foam object, CO_2 rocket

Circular Motion

Demo: Bicycle wheel



Complicated motion of rotating body:
Different r, v, a's for different parts

Same _______________

Same _______________

How does circumference (aka 1 revolution) relate to angles?

What are <u>Radians</u>/Why do we use them?

Clicker quiz: Which angle is greatest:

a. 30 revolutions
b. 30°
c. 30 radians

Radians, cont.

Definition:

<u>Questions:</u>
How many radians in one circumference?

How many radians in 360°?

How many radians in an arc of length "s"?

→ I will likely not give you these conversion factors on final!

Clicker quiz: The symbol ω, used for angular velocity, is pronounced:

a. "al-pha"
b. "double-you"
c. "gam-ma"
d. "om-e-ga"
e. "pi"

Angular stuff

displacement $\Delta\theta$ =
average velocity ω_{ave} =
average acceleration α_{ave} =

Angular motion of the whole object vs. motion of a spinning **point**

Angular displacement $\Delta\theta$ vs "distance around circumference", s

Angular velocity ω vs tangential speed v

Angular acceleration α vs tangential acceleration a

Very Important: *Tangential* motion!

Also very important: You must use <u>radians</u> if you want to use those equations

Kinematic equations

(for constant *angular* acceleration)

Substitutions:
$x \to \theta$
$v \to \omega$
$a \to \alpha$

<u>Regular</u>	<u>Angular</u>
Definition: $v_{ave} = \langle v \rangle = \frac{\Delta x}{\Delta t}$	$\omega_{ave} = \langle \omega \rangle = \frac{\Delta\theta}{\Delta t}$
Definition: $a_{ave} = \langle a \rangle = \frac{\Delta v}{\Delta t}$	$\alpha_{ave} = \langle \alpha \rangle = \frac{\Delta\omega}{\Delta t}$
For constant a:	For constant α:
$x = x_0 + v_0 t + \frac{1}{2} a t^2$	$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
$v = v_0 + at$	$\omega = \omega_0 + \alpha t$
$v^2 = v_0^{\ 2} + 2a(x - x_0)$	$\omega^2 = \omega_0^{\ 2} + 2\alpha(\theta - \theta_0)$

Guidance:

1. Pretend a problem involves regular distances & velocities, and figure out how you would solve it
2. Then use the corresponding angular equations

Worked Problem: Friction slows down a 5 cm diameter spinning top with angular deceleration of 2 rad/s^2. It was initially spinning at 50 rad/s.

1. How many revolutions will it turn before stopping?

"Translated problem": Friction slows down a block, a = -2 m/s^2. It was initially travelling at 50 m/s. How far will it go before stopping?

2. How long will that take?

3. How fast was a point on the rim initially going?

Answers: 99.47 revs, 25 s, 2.5 m/s

Centripetal vs. Tangential

Ball on string: Demo

Why does it move in a circle?

Whenever there is a **net force** there is ______________

Turns out…

Centripetal (turning) acceleration: $a_c = \frac{v^2}{r}$ (derived in book)

direction:

(advice: call this positive)

Bottom line:
If circular motion, then there is centripetal acceleration produced by the net inward/outward forces.

This acceleration goes on the **right hand side** of N2

Worked Problem:

You swing a ball (mass m) in a vertical circle with a string; its speed is constant (v) through the whole circle. (a) What is the tension at the lowest point? (b) At the highest point?

(a) Picture:

Equation:

(b) Picture:

Equation:

→ What about "centrifugal" forces?

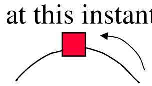
Answers: $mg + mv^2/r$, $mg - mv^2/r$

Combined Centripetal and Tangential

Example: going around a corner while slowing down

Clicker quiz: The centripetal acceleration at this instant is

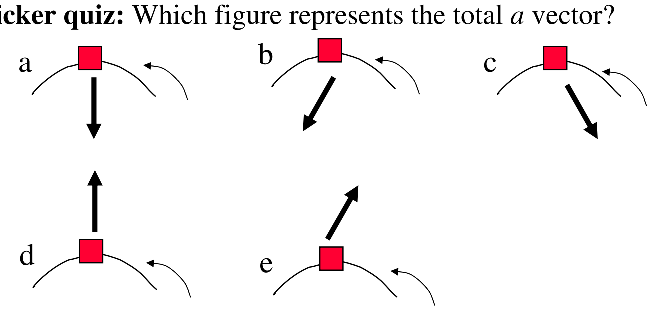
a. up
b. down
c. left
d. right
e. zero



Clicker quiz: The tangential acceleration at that instant is

a. up
b. down
c. left
d. right
e. zero

Clicker quiz: Which figure represents the total a vector?



Applet: pendulum animation
http://stokes.byu.edu/pendulum_flash.html

Space stations and artificial gravity

You are standing on a 50 m diameter space station that rotates at just the right speed so that the **normal force** is

$N = m \times 9.8\ m/s^2$.

This feels "normal"! ☺

What direction do your feet face?

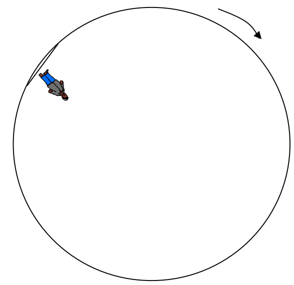
How fast are you traveling? (m/s)

How fast is the station rotating? (revolutions per minute)

Answers: 22.14 m/s, 4.23 rpm

Clicker quiz: Now a large trapdoor opens under you to the outside. What happens, from the point of view of an astronaut outside the space station?

a. You hang motionless above the opening
b. You move through the opening and proceed in a radial direction
c. You move through the opening and proceed in a tangential direction

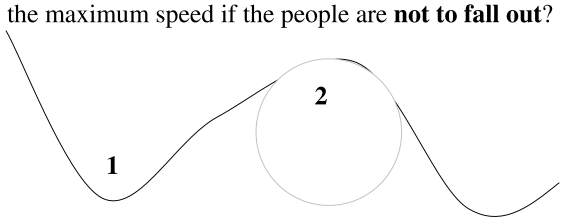


Clicker quiz: The spaceship is rotating clockwise. If it's a hollow cylinder as shown, what can you do to "float" to the other edge, right through the *center* of the cylinder?

a. Jump pushing straight "up"
b. Run clockwise just right and push straight "up"
c. Run counterclockwise just right and push straight "up"
d. Can't be done.

Unsafe roller coasters (no seatbelts)

For the top of an *outside* curve (pt 2), radius of curvature = 8 m, what is the maximum speed if the people are **not to fall out**?



What's the difference between pt 1 and pt 2?

The free-body diagram:

The "secret": When the people are just about to fall out, the normal force is ______________.

Question: Angular velocity of **earth** (1 rev/24 hours, convert to rad/s) gives speed at Provo = 792 mph! Why don't we fly off?

Answer: 8.854 m/s

Floor-dropping ride

If the coefficient of friction is μ, what minimum speed v must you be going before the floor is removed?

Answer: $\sqrt{\frac{rg}{\mu}}$