Announcements – Oct 17, 2013

1. No announcements!
Real satellites:
http://science.nasa.gov/RealTime/JTrack/3d/JTrack3d.html

<table>
<thead>
<tr>
<th>Satellite Type</th>
<th>Altitude</th>
<th>Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>International space station, 340.5 km above surface of Earth (Re = 6,371 km)</td>
<td>7.707 km/s</td>
<td></td>
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<tr>
<td>Geostationary orbit, 35,786 km above surface</td>
<td>3.075 km/s</td>
<td></td>
</tr>
<tr>
<td>Moon, r = 381,715 km</td>
<td>1.022 km/s</td>
<td></td>
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</tbody>
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**Worked Problem:** How long does it take ISS to orbit?

Answer: 91.2 min
Satellite game
http://www.science-animations.com/support-files/satellite.swf
From warmup (last time)
If the Earth attracts the moon with gravitational force, why doesn't the moon fall into the Earth? Give an explanation that a friend in junior high school could follow.

“Pair share”—I am now ready to share my neighbor’s answer if called on.
  a. Yes
Clicker quiz
You are on planet Xarthon, which has a mass of $2\times$ that of the earth and a radius $2\times$ as big. If you throw a ball at the surface, and you will find that $g_{Xarthon}$ is ____ $g_{earth}$
   a. larger than
   b. smaller than
   c. the same as
Clicker quiz
Satellites in higher orbits are travelling slower, so to “shoot” a satellite from the surface of the earth into a high orbit (i.e. with a cannon), you would provide it with ________ initial kinetic energy than for a satellite in a low orbit
  a. more
  b. less
  c. same
Gravitational PE

Need new $\text{PE}_{\text{gravity}}$  
\[ \text{PE} = mgy \] just won’t work…
Force isn’t “mg” any more!

Using calculus to calculate work done against (non-constant) gravitational force…

\[ PE_G = -\frac{GMm}{r} \]

Here the negative sign is critically important!!
(not a vector direction)

Before: PE = 0 when ________________

With new equation: PE = 0 when ________________
From warmup

Ralph noticed the negative sign in the general equation for gravitation potential energy, $PE=-\frac{GMm}{r}$, and he read the book's statement that "this expression reduces to $PE=mg\text{h}$ close to the surface of Earth". He is very confused, because among other things one equation has a negative sign and the other one doesn't! How can they possibly be equivalent? What can you tell Ralph to help him out?

“Pair share”–I am now ready to share my neighbor’s answer if called on.

a. Yes
Worked problem
How much energy would you have to provide in order to “shoot” a 100 kg satellite into a near orbit like the ISS, 6712 km from center of earth? (E.g. via initial KE)

…into a much farther geostationary orbit? (42,157 km)

…to an orbit at the moon’s distance (381,715 km)

Answers: 3.29E9 J, 5.79E9 J, 6.21E9 J
Escape velocity
Same question: …into an orbit very, very far away from the Earth?? (ignore the sun’s gravitational pull)

Hints: What is its orbital velocity?
What is its final kinetic energy?
Final potential energy?

Robert Heinlein:
“If you can get into orbit, then you're halfway to anywhere”

Answers: 6.26E9 J
From warmup
The "escape velocity" of a planet is the speed needed for a rocket to go from the surface of the planet into orbit.
   a. true
   b. false
Worked Problem
What is the escape velocity of the earth?
($R_{\text{earth}} = 6371 \text{ km}; M_{\text{earth}} = 5.974 \times 10^{24} \text{ kg}$)

Answer: 11.2 km/s
Torque and equilibrium

A force supplies a **torque** on an object when it is applied in such a way that could cause the object to __________

**Definition:** \( \tau = r \perp F \)

**Note:** where do you measure the distance \( r \) from?

- If the object is rotating:
- If the object is standing still:

Above all, be ____________
Positive vs. negative torques:

Is torque a vector?
From warmup

In order to apply the most torque to a bolt, you should:

a. use a wrench with a long handle
b. use a wrench with a short handle
c. there would be no difference
Clicker quiz

In order to apply the most torque, you should:

(a) apply the force perpendicular to \( r \)
(b) apply the force at a 45° angle from \( r \)
(c) no difference
“Lever Arm”

View 1:

- Some force $F$
- Pivot point
- Perpendicular distance $r_{\perp}$ = the “lever arm” of the force

View 2:

$\tau = r_{\perp}F = rF_{\perp} = rF \sin \theta$
Demo: T-handle torque

Torque tug-of-war
Torque Summary

\[ \tau = r \perp F = r F \perp = r F \sin \theta \]

→ but be careful about which angle you call \( \theta \)!

**Note:** If you are familiar with vector cross products, you can write it like this: \( \tau = \vec{r} \times \vec{F} \)

(direction of \( \tau \)?)
Two people sit on a seesaw. They sit in positions such that the seesaw is balanced in a horizontal position. The two people must weigh the same amount.

a. true
b. false
Clicker quiz

Where should the large elephant stand in order to balance the seesaw? (mass = 4 times the little elephant)

a.  $d$

b.  $d/2$

c.  $d/4$

d.  $d/6$

e.  $d/8$
Clicker quiz

When the see-saw is balanced, what is the upwards force from the pivot point? (Or, equivalently, the downward force on the pivot point.)

a. $mg$
b. $4mg$
c. $5mg$
d. $6mg$
e. $8mg$
Demos: Center of mass
Equilibrium

What concepts are involved?

1. If an object is not moving (“translational equilibrium”), then…

2. If an object is not rotating (“rotational equilibrium”), then…

A new blueprint equation!
From Warmup

If an object is in equilibrium:
   a. the net force on it must be zero
   b. the net torque on it must be zero
   c. both of the above
   d. neither of the above

General advice

Think carefully about the p_______ p_______

and the s_______ of the t________
Worked problem
A 1500 N man, 1 meter from the right end, is standing on a board supported by a wall and a rope. The board weighs 800 N and is 4 meters long. What is the tension in the rope?

1. Draw all of the forces present.
   Note: gravity acts at the center of mass

1b. Divide forces into components

2. Use $\sum \mathbf{F}$ blueprint equation(s)

3. Use $\sum \tau$ blueprint equation
   $\rightarrow$ which pivot point to use?
4. Use the filled-in blueprints to solve for what you’re looking for.

Answer: $T = 3050\ N$
Additional question
What are the horizontal and vertical forces of the wall on the board?

Answers: \( F_x = 2641 \text{ N to right}, F_y = 775 \text{ N up} \)
From warmup
Ralph noticed that both torque and work are obtained by multiplying a force times a distance. He wants to know: how are they different? Do they have the same units? What can you tell Ralph to help him out?

“Pair share”–I am now ready to share my neighbor’s answer if called on.

b. Yes
Problem:
(Like HW 14-4)

A ladder leans against a frictionless wall. The ground has static coefficient of friction $\mu$. What’s the smallest angle $\theta$ such that the ladder doesn’t slip? Length of ladder is $d$, mass of ladder is $m$.

Draw a FBD of ladder:

Clicker quiz: I have done so
a. yes
Clicker quiz

The ground’s frictional force is ________ compared to the wall’s normal force.

a. more than
b. less than
c. the same
d. can’t tell
The ground’s normal force pushing upward is ________ compared to the weight.

a. more than
b. less than
c. the same
d. can’t tell
To solve the problem, we need to use $\sum \tau = 0$ … but about which point should we compute the torques?

a. A  
b. B  
c. C
Solved problem

If \( \mu = 0.5 \rightarrow \theta = 45^\circ; \quad \mu = 0.7 \rightarrow \theta = 35.5^\circ; \quad \mu = 0.9 \rightarrow \theta = 29.1^\circ \)

Answer: \( \theta = \tan^{-1}\left(\frac{1}{2\mu}\right) \)
Modification

Suppose the wall \textit{also} has friction, \( \mu \). What’s the angle \( \theta \) now? (Think: bigger or smaller?)

New FBD:

Equations:
Solved problem

If $\mu = 0.5 \rightarrow \theta = 36.9^\circ$; \hspace{1cm} \mu = 0.7 \rightarrow \theta = 20.0^\circ$; \hspace{1cm} \mu = 0.9 \rightarrow \theta = 6.0^\circ$

Answer: $\theta = \tan^{-1}\left(\frac{1}{2\mu} - \frac{\mu}{2}\right)$
A 0.4 kg meterstick is suspended from support pillars (not shown) via two strings at $\theta_1 = 41.4^\circ$ and $\theta_2 = 60^\circ$, with tensions of 2N and 3N. The strings are attached at 10 cm and 5 cm from the two ends of the meterstick. The stick is not in equilibrium until an additional mass is hung from a point in the middle. Find the unknown $x$ and $m$. 
Answers: 0.171 kg, 38.2 cm