Announcements – Oct 15, 2009

1. Don't forget to pick up your exams in the boxes near Tutorial Lab

From last time: 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? (Assume via initial KE)

$KE_{bef} + PE_{bef} = KE_{aft} + PE_{aft}$

$KE_{bef} + (-GmM/R_{earth}) = ½ mv_{orbital}^2 + (-GmM/r_{orbital})$

$KE_{bef} =$ **3.29E9 J**

…into a much farther geostationary orbit? (42,157 km) **5.79E9 J**

…to an orbit at the moon's distance? (381,715 km) **6.21E9 J**

New: …into an orbit <u>very far away</u> from the Earth??

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

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

What is the "escape velocity" of the earth?

→ velocity needed to "escape"…end up very far away

Answers: 6.26E9 J, 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 _____________

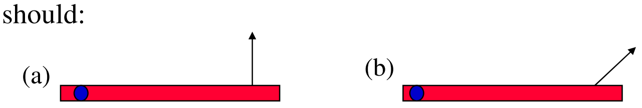
<u>Positive vs. negative torques:</u>

Is torque a vector?

From warmup: in order to apply the most torque to a screw, you should:

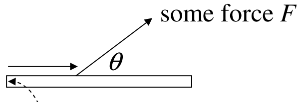
a. use a wrench with a long handle
b. use a wrench with a short handle
c. no difference

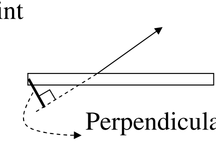
Clicker quiz: In order to apply the most torque, you should:

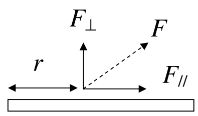


a. apply the force perpendicular to ***r***
b. apply the force at a 45° angle from ***r***
c. no difference

“Lever Arm”



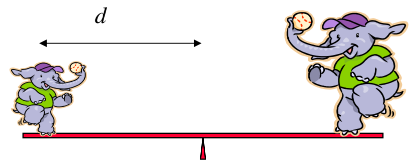




Summary: $$\tau = r_\perp F = rF_\perp = rF\sin\theta$$

→ **be careful about which angle is θ!**

Note: If you are familiar with vector cross products, those equations can be summarized in vector form like this: $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$.



From warmup: 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. $d/8$

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. $mg/4$
b. $mg/2$
c. mg
d. $4mg$
e. $5mg$

Center of mass demos

Equilibrium

What concepts were involved?

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

2. If an object is not ***rotating***, then…

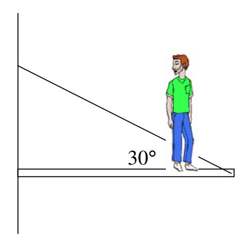
A new blueprint equation!

In that problem:

In general: think carefully about the p______ p_______

and the s______ of 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

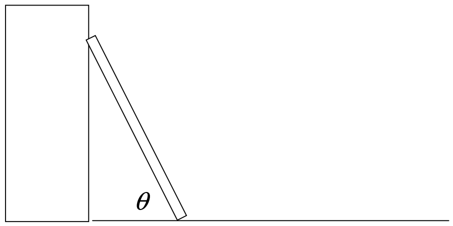
2. Use $\Sigma\mathbf{F}$ blueprint equation(s)

3. Use $\Sigma\tau$ blueprint equation
→ which pivot point to use?

How to do additional question: what are the horizontal and vertical forces of the wall on the board?

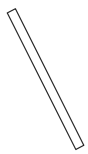
Answers: T = 3050 N, F_x = 2641 N to right, F_y = 775 N up

Problem:



A ladder leans against a **frictionless** wall. The ground has static coefficient of friction μ. What's the smallest angle θ such that the ladder doesn't slip?

Draw FBD of ladder:



Clicker quiz: using the ground contact point as the pivot, the (magnitude of the) *torque* produced by the wall's normal force is ________ compared to the torque produced by the weight.

a. more than
b. less than
c. the same

Clicker quiz: The ground's frictional *force* is ________ compared to the wall's normal force.

a. more than
b. less than
c. the same

Clicker quiz: The ground's normal *force* is ________ compared to the weight.

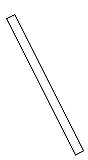
a. more than
b. less than
c. the same

Solved problem: use $\Sigma\tau = 0$… about what point??

Answer: $\theta = \tan^{-1}(1/(2\mu))$ $\mu = 0.5 \rightarrow \theta = 45°$; $\mu = 0.7 \rightarrow \theta = 35.5°$; $\mu = 0.9 \rightarrow \theta = 29.1°$

Modification: Suppose the wall ***also*** has friction, μ. What's the angle θ now? (Think: bigger or smaller?)

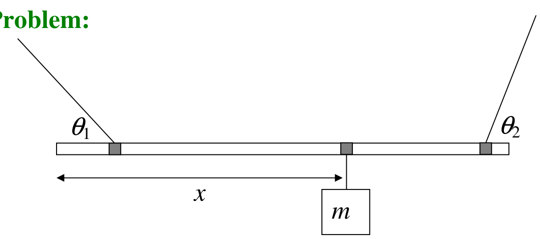
New FBD:



Equations:

Answer: $\theta = \tan^{-1}\left(\frac{1}{2\mu} - \frac{\mu}{2}\right)$ $\mu = 0.5 \rightarrow \theta = 36.9°$; $\mu = 0.7 \rightarrow \theta = 20.0°$; $\mu = 0.9 \rightarrow \theta = 6.0°$

Problem:



A 0.4 kg meterstick is suspended from support pillars (not shown) via two strings at θ_1 =41.4° and θ_2 = 60°, with tensions of 2 N 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