Lecture 15 Announcements

1. Don't forget to pick up your exams: boxes near Tutorial Lab, same place where you turn in HW
   → Bubble sheets will not be returned this time

2. Survey results:

Escape Velocity, repeated from last time

How much KE must we provide to launch a 100 kg object into an orbit VERY FAR AWAY from the Earth??

Hint: What is final kinetic energy? Final potential energy?

What was **velocity** of that satellite?

Escape velocity in general—velocity needed to "escape" the earth/planet/sun… end up very far away

Answers: 6.26E9 J, 11.2 **km/s (sorry about unit error on last lecture notes)**

Tricky maneuvering in orbit

Higher orbits have more total energy, but less KE!
If you want to have a **faster orbit** (less time/orbit) you have to **throw away** energy with your rockets!

Free Computer Game/Simulator: "Orbiter"
http://orbit.medphys.ucl.ac.uk/orbit.html
→ link to a tutorial also available on our class website

In short: this program looks awesome.

Extra credit available for one person (or maybe a small team): figure out some "cool stuff" you can do with the game, prepare a ~5 minute demo for the class. First come, first served—contact me if you want to do this.

New stuff: **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:

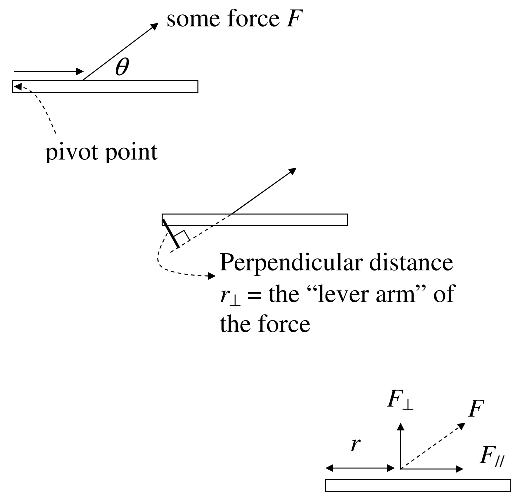
From warmup quiz: in order to apply the most torque to a screw, you should:

- use a wrench with a long handle
- use a wrench with a short handle
- 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

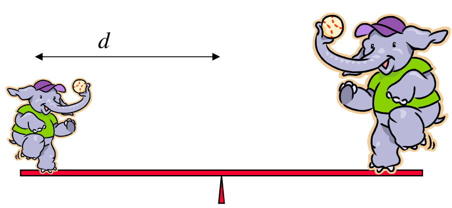
Lever Arm



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: $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$.



Clicker quiz: Where should the large elephant stand in order to balance the seesaw? (mass = 4 times the little elephant) (Like warmup quiz)

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?

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

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!

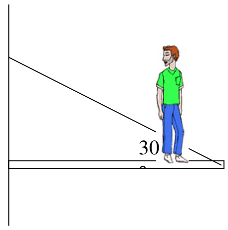
In that problem:

In general: think carefully about the ____________

How does "center of mass" apply?

Harder problems…

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

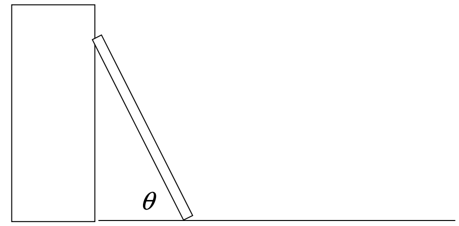
2. Use **ΣF** blueprint equation(s)

3. Use Στ 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?

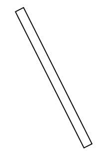
Answers: T = 3050 N, F_x = 2641 N to right, F_y = 775 N up

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.

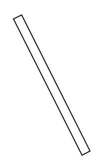
a. more than
b. less than
c. the same

Solved problem: use Στ = 0… about what point??

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

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

New FBD:

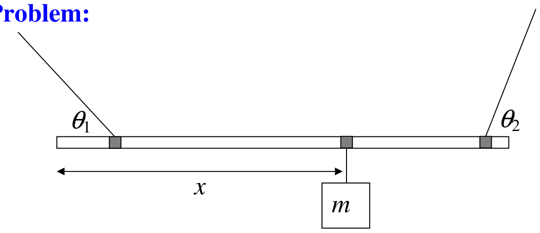


Equations:

Answer: (if I did the algebra correctly…)

$\theta = \tan^{-1}\left(\frac{1}{2\mu} - \frac{\mu}{2}\right)$ μ = 0.5 → θ = 36.9°; μ = 0.7 → θ = 20.0°; μ = 0.9 → θ = 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