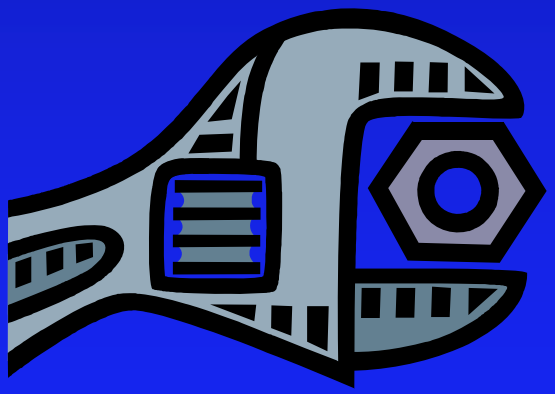
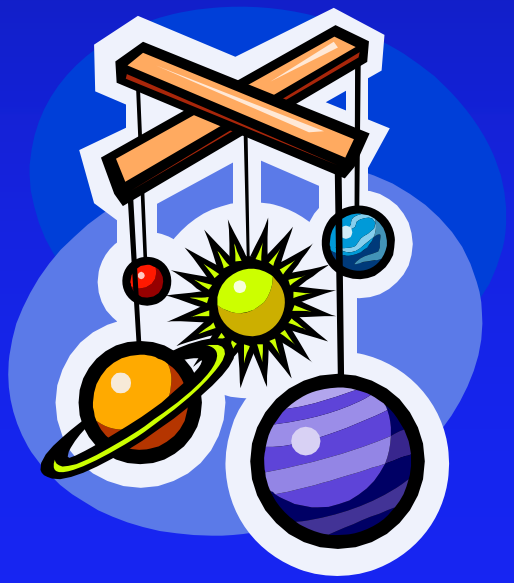
EXAM II

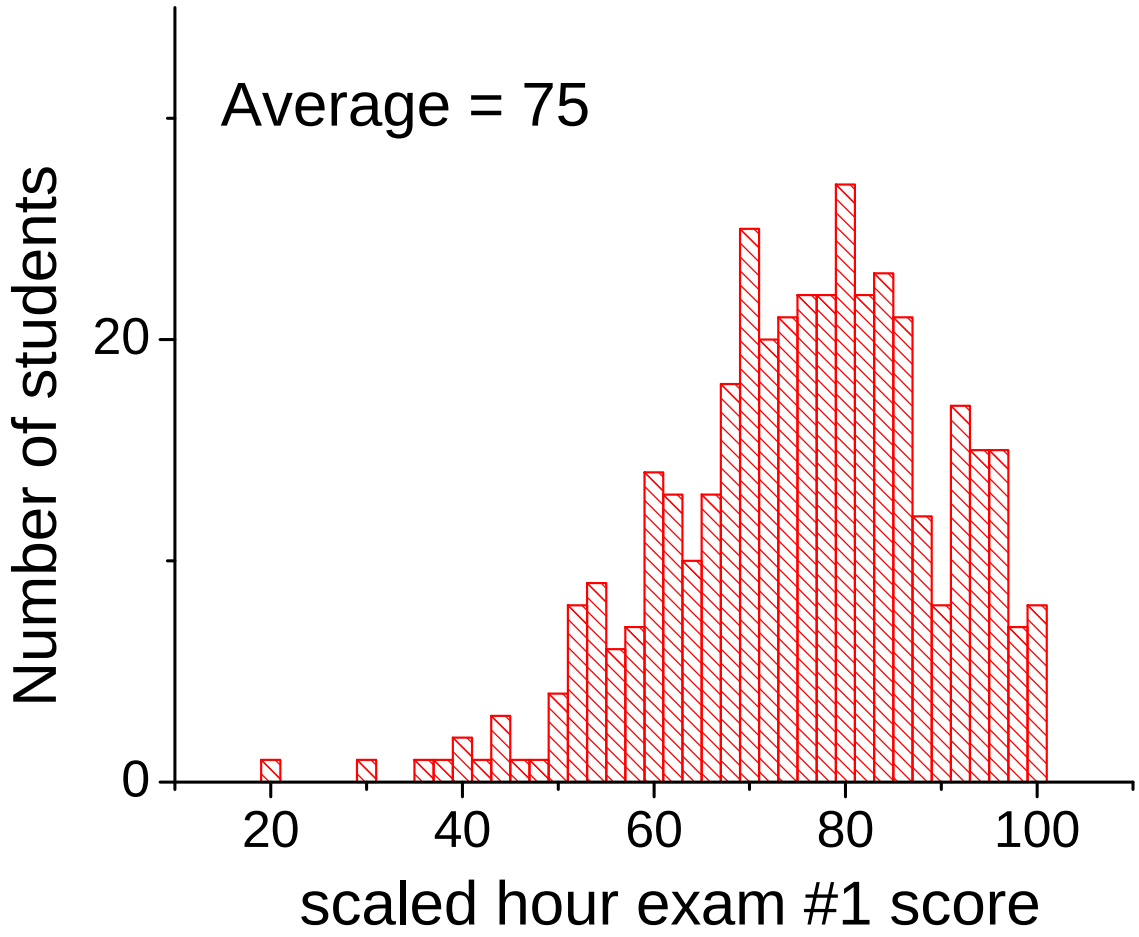
Physics 101: Lecture 14
Torque and Equilibrium

Today's lecture will cover Textbook Chapter 8.2-8.4





Hour Exam 1 Results



How will I do in the course?

Score, max grade, median grade, min grade, # exams
from ONE earlier semester

40- 44	D-,	F,	F	N: 03
45- 49	C,	D-,	D-	N: 02
50- 54	C-,	D-,	F	N: 17
55- 59	B-,	D+,	D-	N: 12
60- 64	B,	C-,	D-	N: 32
65- 69	B+,	C,	F	N: 46
70- 74	A-,	C+,	D	N: 60
75- 79	A,	B,	D-	N: 41
80- 84	A,	B,	D-	N: 51
85- 89	A+,	B+,	C-	N: 55
90- 94	A+,	A,	D-	N: 57
95- 99	A+,	A,	B+	N: 17

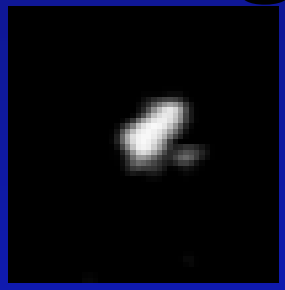
Email me to discuss this.

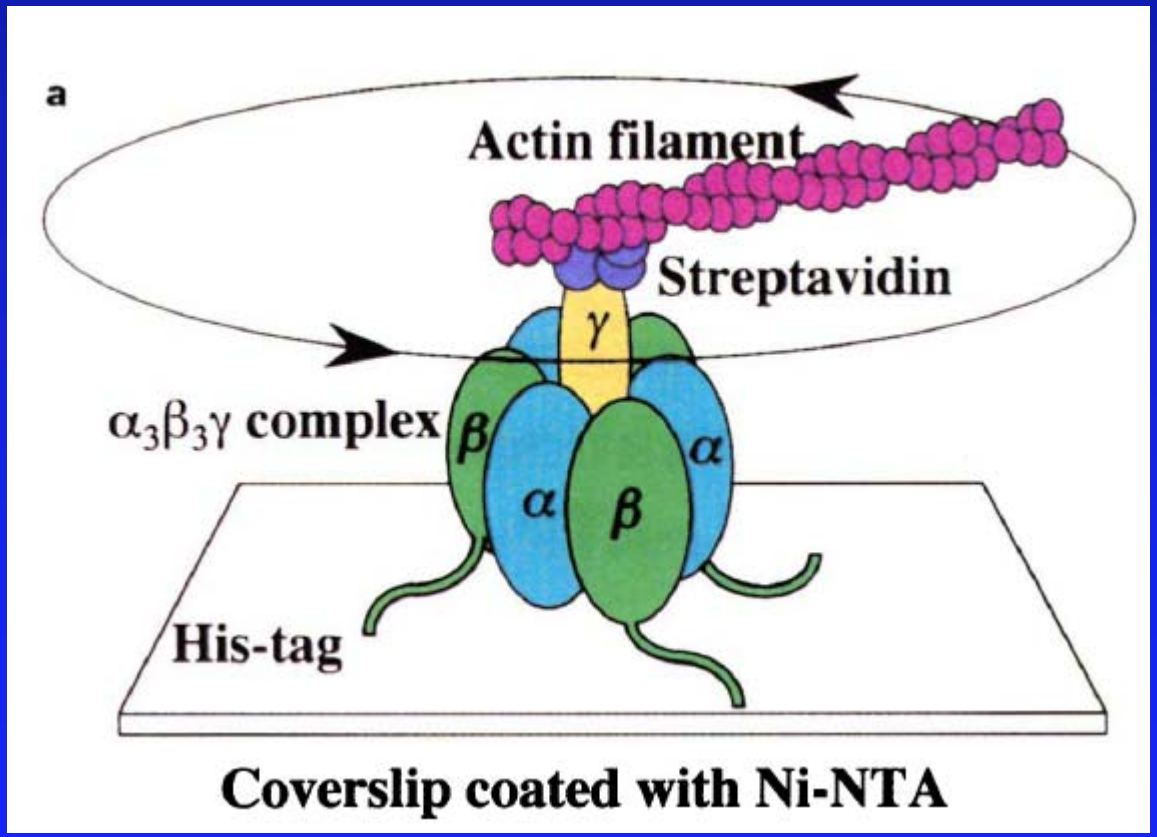
You can also come to my office today

133 Loomis between 3 pm and 5 pm.

Rotary motor in biology #1



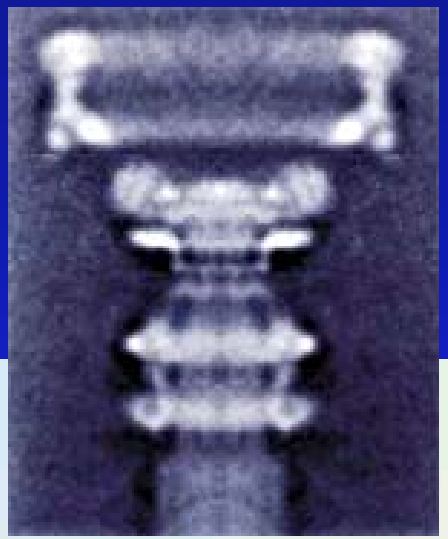


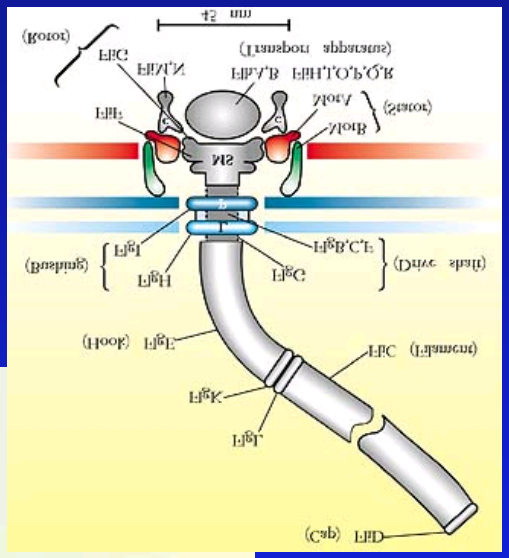


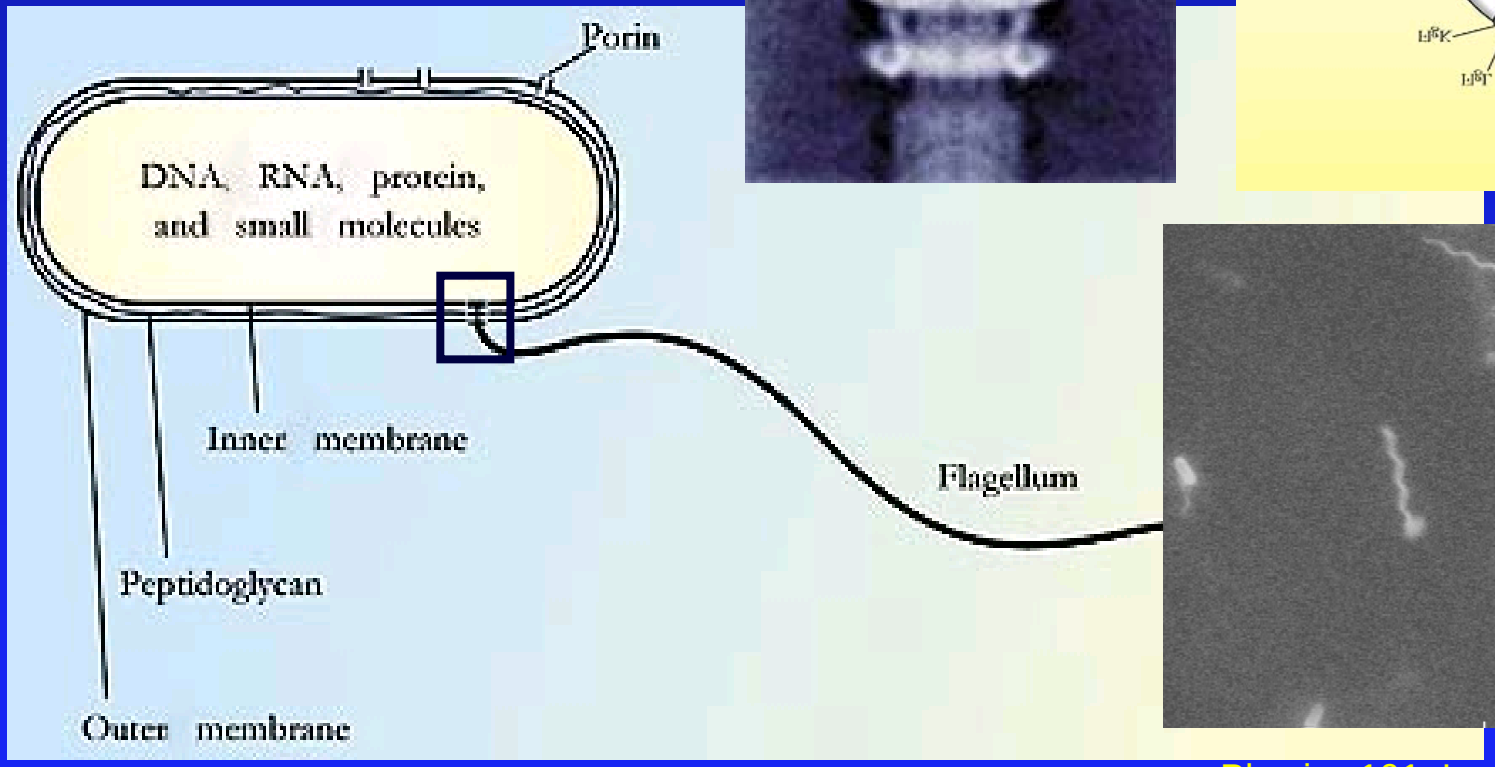
F1-ATPase

Rotary motor in biology #2

Bacterial flagellum







Review

- Rotational Kinetic Energy $K_{rot} = \frac{1}{2} I \omega^2$
- Rotational Inertia $I = \Sigma m_i r_i^2$
- Energy Still Conserved!

Today

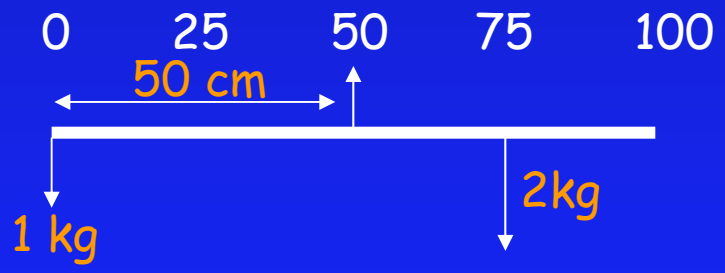
- Torque

You Know Torque!

- A meter stick is suspended at the center. If a 1 kg weight is placed at x=0. Where do you need to place a 2 kg weight to balance it?

A) x = 25 B) x=50 C) x=75 D) x=100

E) 1 kg can't balance a 2 kg weight.



Balance Demo

Torque

- Rotational effect of force. Tells how effective force is at twisting or rotating an object.

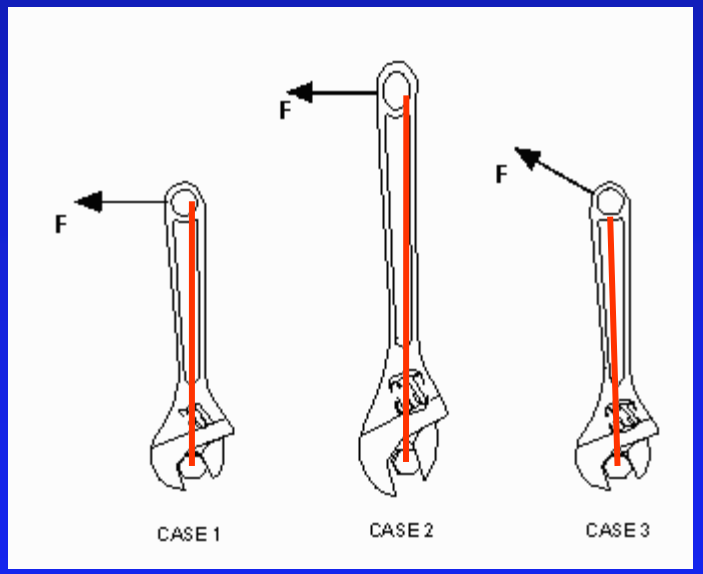
- $\tau = +\text{-}\ r\ F_{perpendicular} = r\ F \sin\theta$
  - Units N m
  - Sign: CCW rotation is positive

ACT

The picture below shows three different ways of using a wrench to loosen a stuck nut. Assume the applied force F is the same in each case.

In which of the cases is the torque on the nut the biggest?

A. Case 1
B. Case 2 ← CORRECT
C. Case 3

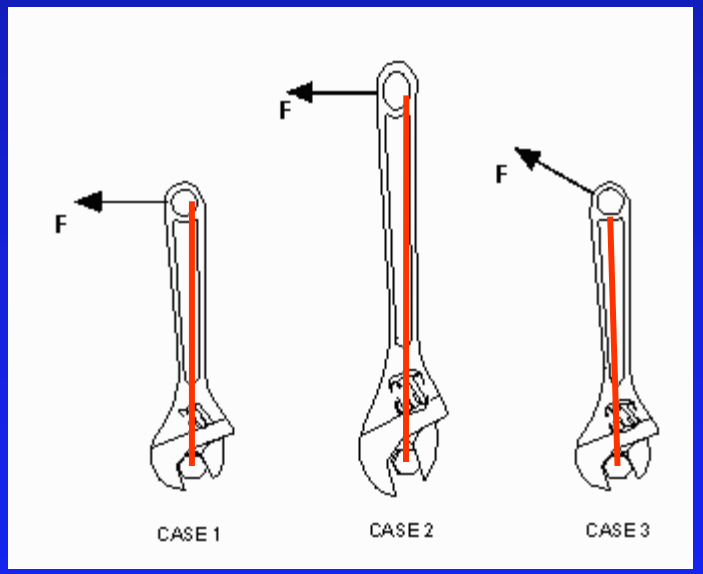


ACT 2

The picture below shows three different ways of using a wrench to loosen a stuck nut. Assume the applied force F is the same in each case.

In which of the cases is the torque on the nut the smallest?

A. Case 1
B. Case 2
C. Case 3 ← CORRECT



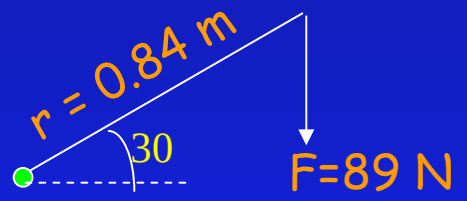
Torque Example and ACT

A person raises one leg to an angle of 30 degrees. An ankle weight (89 N) attached a distance of 0.84 m from her hip. What is the torque due to this weight?

1) Draw Diagram

2) $\tau = F\ r \sin\theta$

$= F\ r \sin(90 - 30)$ $= 65$ N m

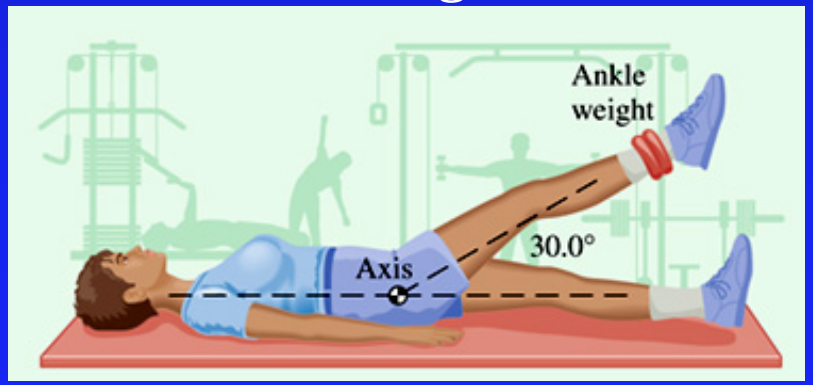


If she raises her leg higher, the torque due to the weight will

A) Increase

B) Same

C) Decrease



Equilibrium Acts

- A rod is lying on a table and has two equal but opposite forces acting on it. What is the net force on the rod?

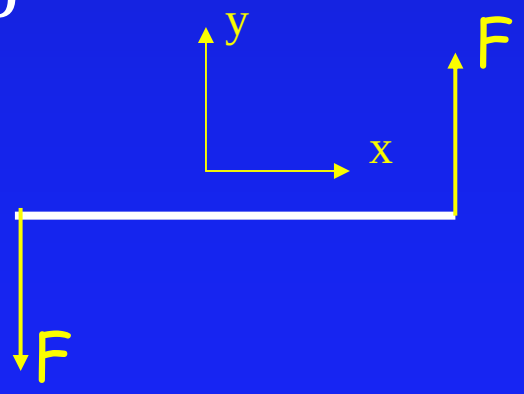
A) Up B) Down C) Zero

Y direction: $\Sigma F_y = ma_y$

$+F - F = 0$

- Will the rod move? A) Yes B) No

Yes, it rotates!



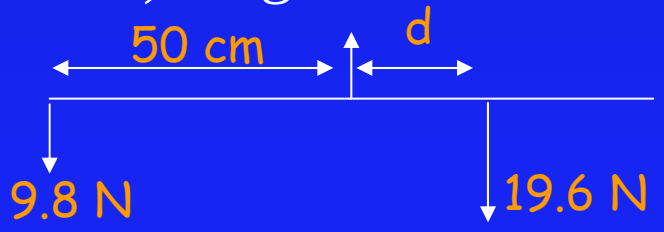
Equilibrium

- Conditions for Equilibrium
  - $\Sigma F = 0$ Translational EQ (Center of Mass)
  - $\Sigma \tau = 0$ Rotational EQ (True for any axis!)
    - » Choose axis of rotation wisely!

- A meter stick is suspended at the center. If a 1 kg weight is placed at x=0. Where do you need to place a 2 kg weight to balance it?

A) x = 25 B) x=50 C) x=75 D) x=100

E) 1 kg can't balance a 2 kg weight.



$\Sigma \tau = 0$

$9.8\,(0.5) - (19.6)d = 0$

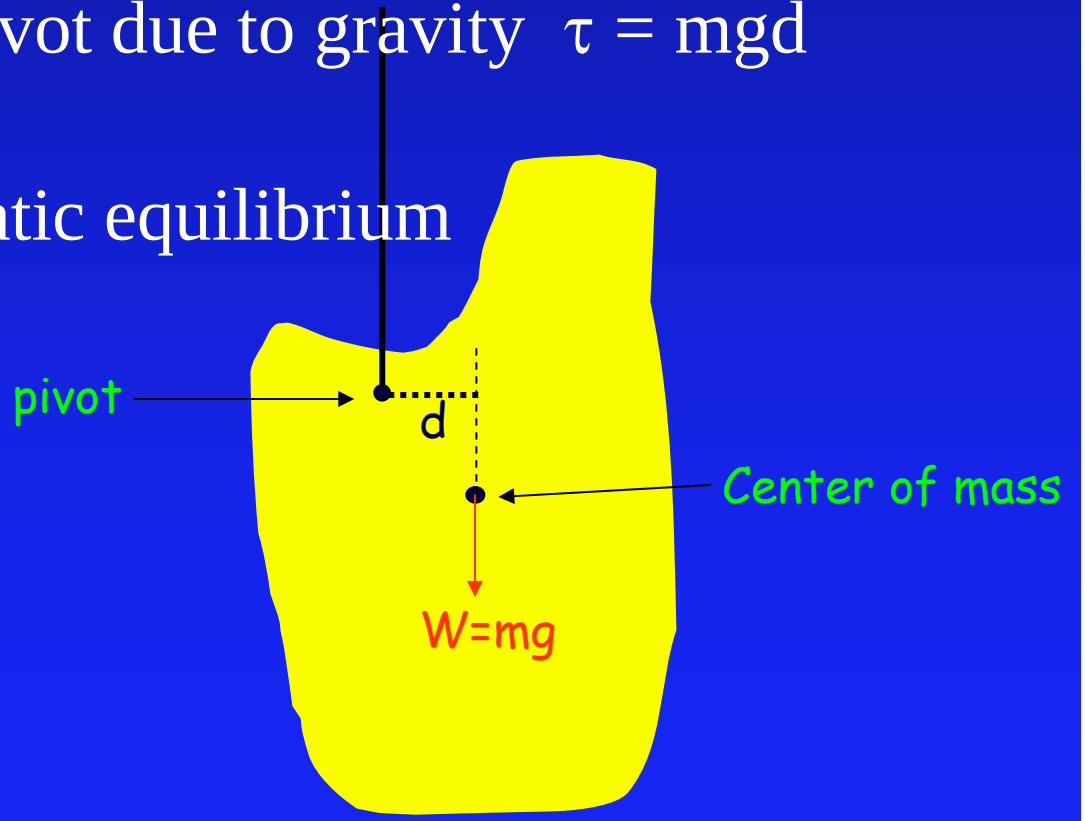
$d = 25$

Balance Demo

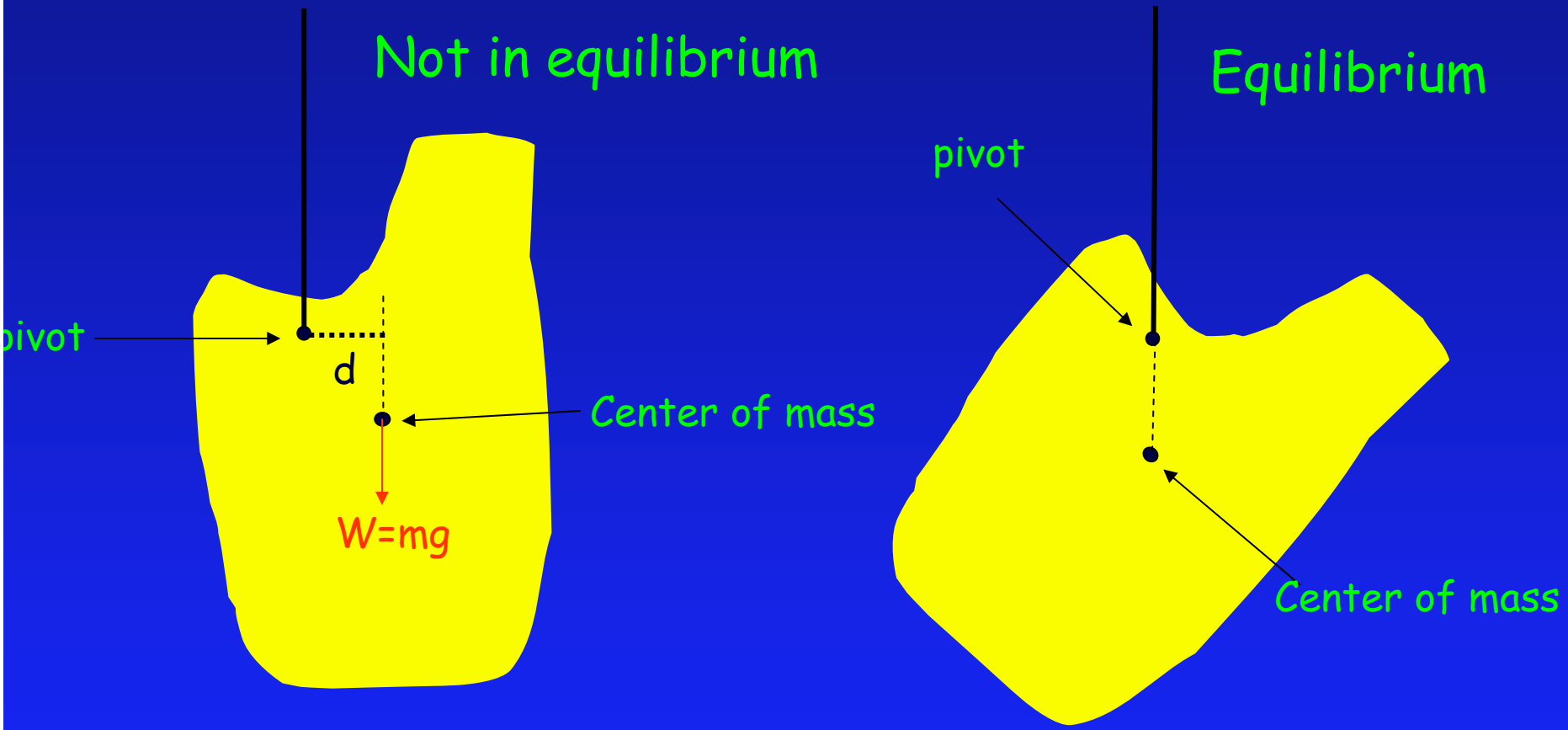
Static Equilibrium and Center of Mass

- Gravitational Force Weight = mg
  - Acts as force at center of mass
  - Torque about pivot due to gravity $\tau = mgd$ (non-zero!)
  - Object not in static equilibrium

$$r_{cm} = \frac{\sum r_i m_i}{\sum m_i}$$



Static Equilibrium



Torque about pivot ≠ 0

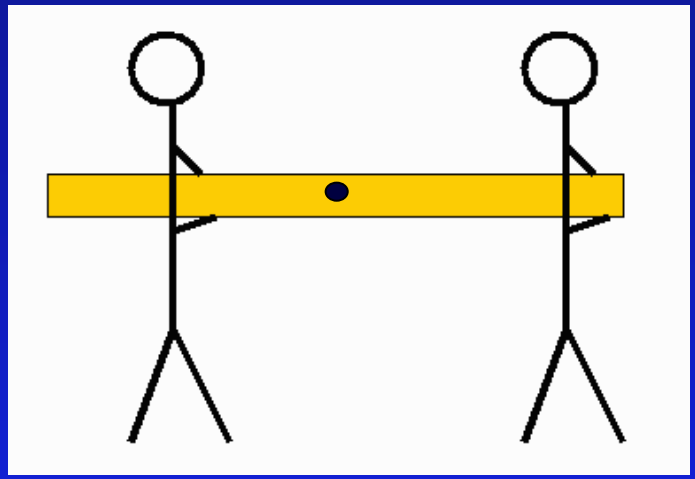
Torque about pivot = 0

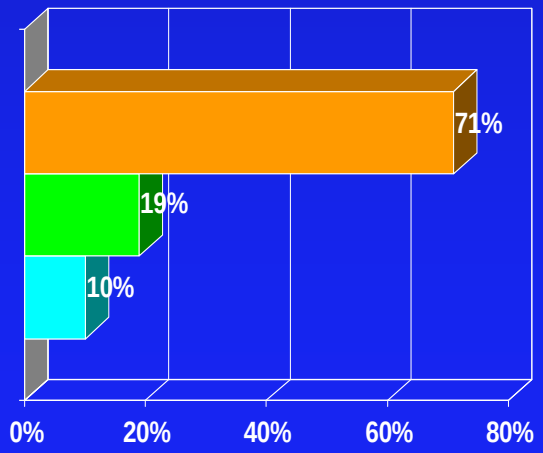
A method to find center of mass of an irregular object

Preflight

The picture below shows two people lifting a heavy log. Which of the two people is supporting the greatest weight?

1. The person on the left is supporting the greatest weight ← CORRECT
2. The person on the right is supporting the greatest weight
3. They are supporting the same weight





"assume r for F1(person on the left to the log) is 1/4R, then after calculation i get F1=2F2"

"The guy on the left has to support more weight because he is further in and has to support more of the board. "

Preflight

The picture below shows two people lifting a heavy log. Which of the two people is supporting the greatest weight?

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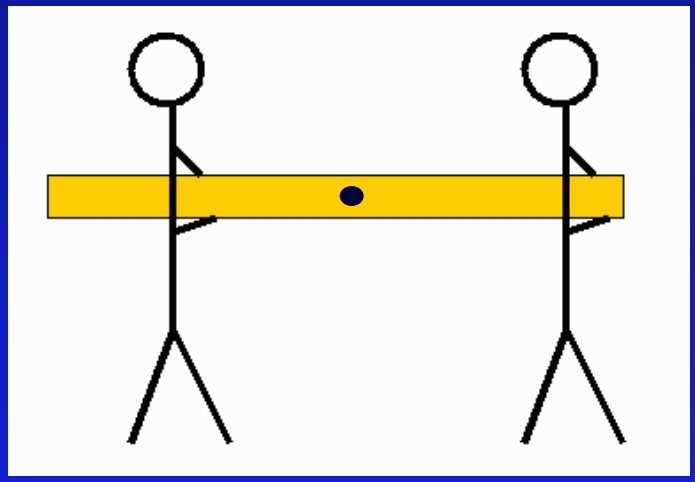
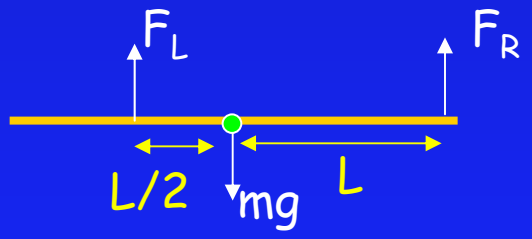


Look at torque about center:

$+F_R\,L - F_L\,L/2 = 0$

$F_R = \frac{1}{2}\,F_L$



Preflight

Most difficult concepts:

"deciding where to make your point of origin or axis"

"difference between…force and torque" [demo]

"How the Illini did so well on defense against Penn State." [33-13]

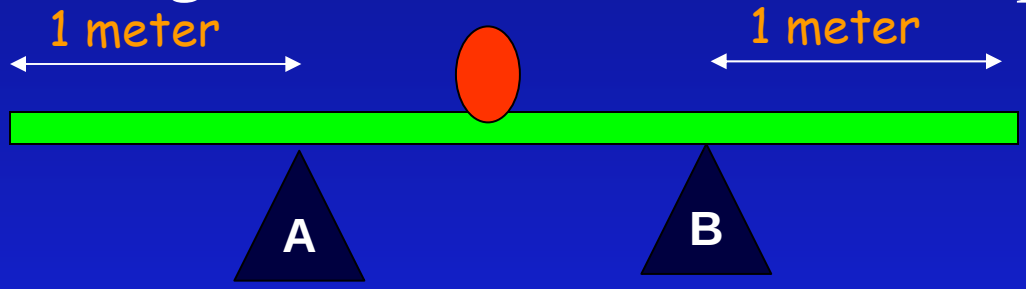
"how to find the signs when putting into the equation"

"studying biochem while completing these physics assignments"

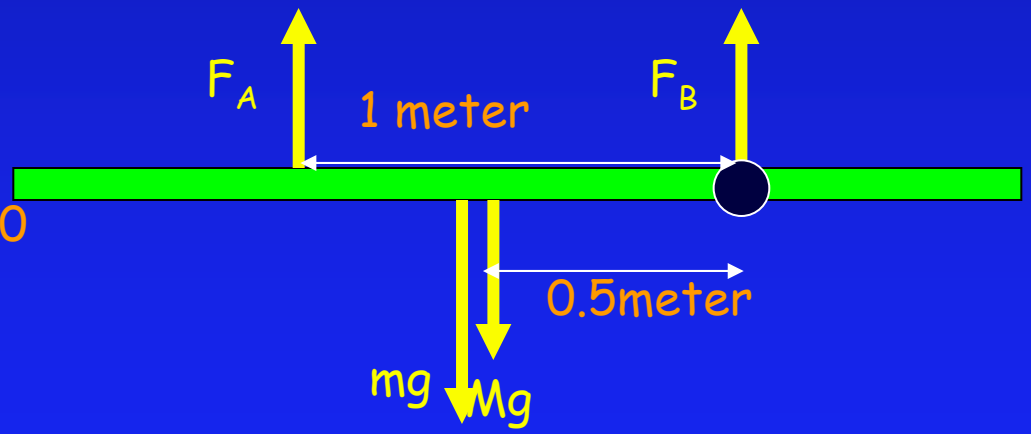
"torque" "Torque sounds so ominous" "all the equations"

Homework 8 Hints

A 75 kg painter stands at the center of a 50 kg, 3 meter plank. The supports are 1 meter in from each edge. Calculate the force on support A.



1) Draw FBD



2) $\Sigma F = 0$ $F_A + F_B - mg - Mg = 0$

3) Choose pivot

4) $\Sigma\tau = 0$

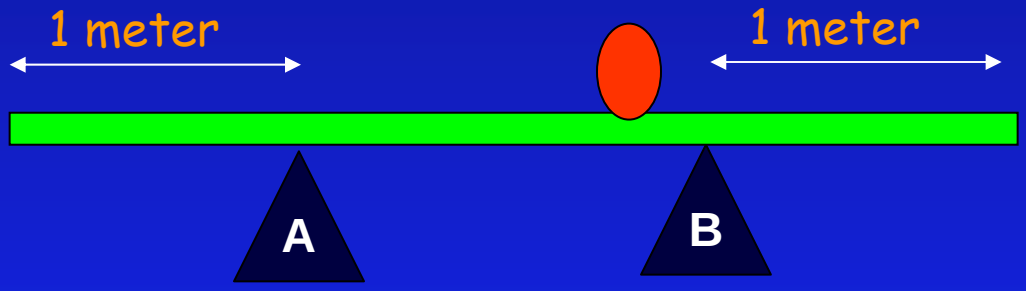
$-F_A * 1 + F_B * 0 * + mg*0.5 + Mg*0.5 = 0$

$F_A = 0.5\ mg + 0.5\ Mg = 612.5$ Newtons

Homework 8 Hints

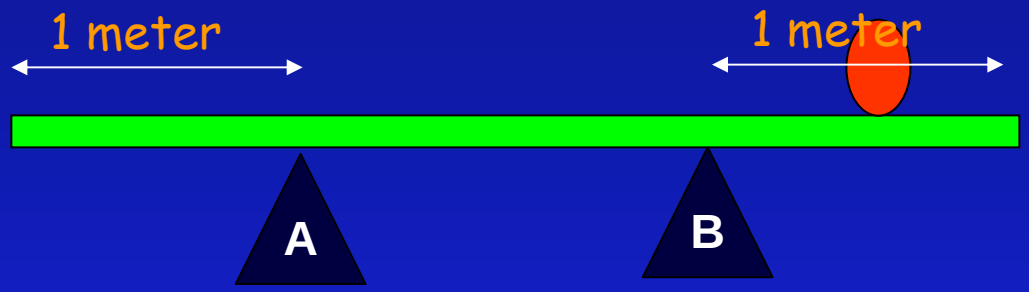
If the painter moves to the right, the force exerted by support A

A) Increases B) Unchanged C) Decreases



Homework 8 Hints

How far to the right of support B can the painter stand before the plank tips?



Just before board tips, force from A becomes zero

1) Draw FBD

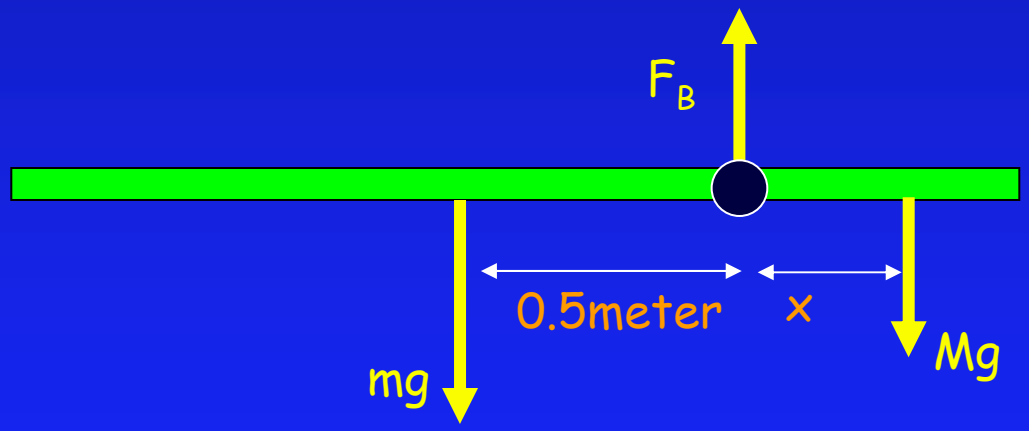
2) $\Sigma F = 0$ $F_B - mg - Mg = 0$

3) Choose pivot

4) $\Sigma\tau = 0$

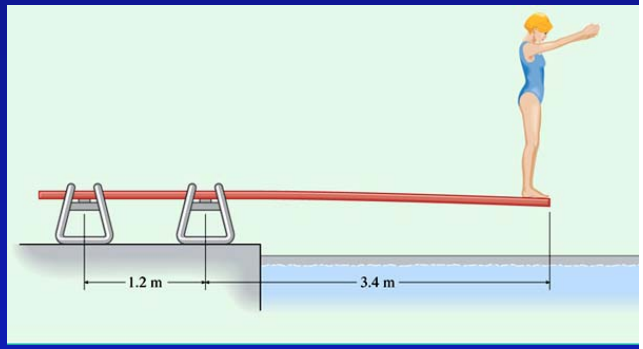
$F_B*0 + mg*0.5 - Mg*x = 0$

$0.5\ m = x\ M$

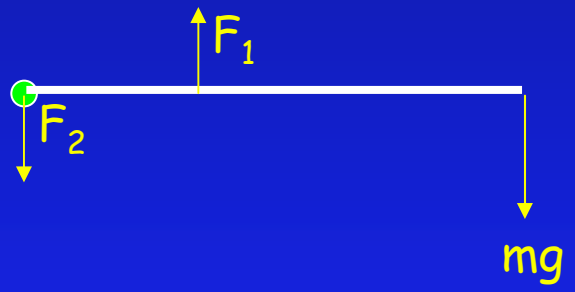


Equilibrium Example

A 50 kg diver stands at the end of a 4.6 m diving board. Neglecting the weight of the board, what is the force on the pivot 1.2 meters from the end?



1) Draw FBD



2) Choose Axis of rotation

3) $\Sigma \tau = 0$ Rotational EQ

$F_1 (1.2) - mg (4.6) = 0$

$F_1 = 4.6 (50 * 9.8) / 1.2$

$F_1 = 1880$ N

4) $\Sigma F = 0$ Translational EQ

$F_1 - F_2 - mg = 0$

$F_2 = F_1 - mg = 1390$ N

Power (Rate of Work)

- $P = W / \Delta t$
  - Units: Joules/Second = Watt

- How much power does it take for a (70 kg) student to run up the stairs in 141 Loomis (5 meters) in 7 sec?

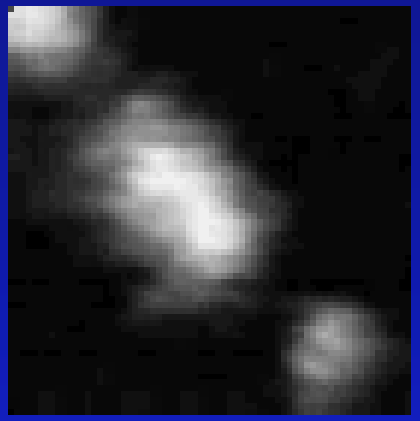
$P = W / t$

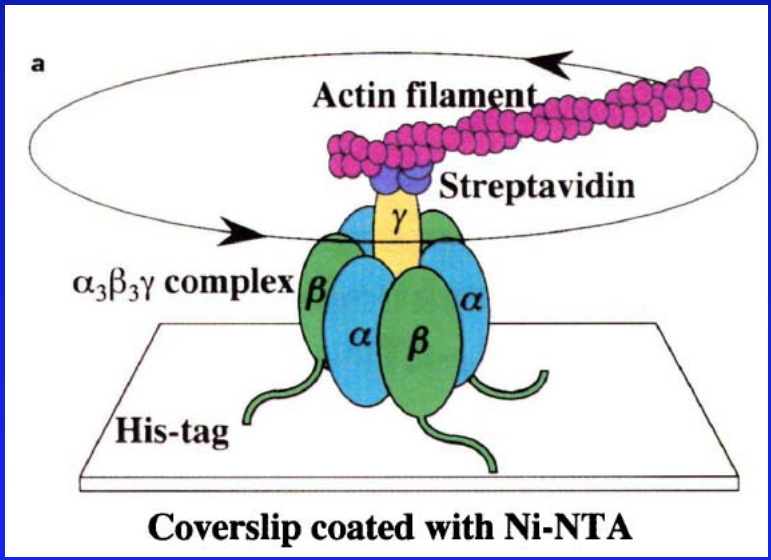
$= m g h / t$

$= (70\ kg)(9.8\ m/s^2)(5\ m) / 7\ s$

$= 490\ J/s$ or 490 Watts

Work done by torque



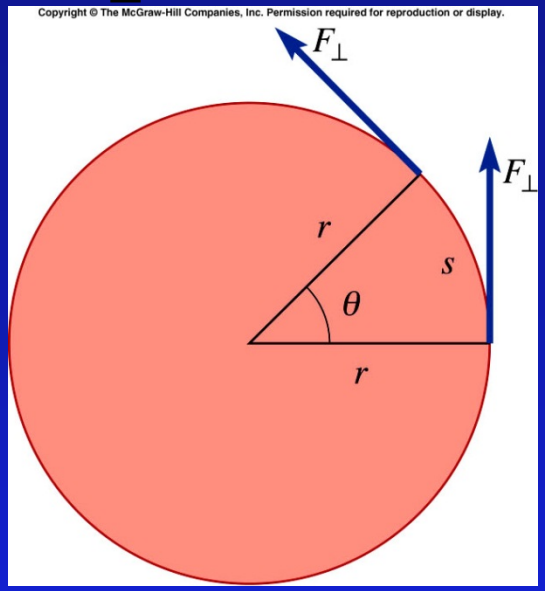


(and 20 μM) ATP, the rotational rates were consistent with a constant frictional torque (the drag coefficient × the rotational rate) of ~40 pN·nm (red line in Figure 2a), indicating that the subcomplex produced this much of torque irrespective of the frictional load. This torque times 2π/3, ~80 pN·nm, is the work done in one-third of a revolution. On the other hand, the free energy of hydrolysis of one ATP, ΔG_{ATP}, is ~80 pN·nm under physiological conditions (Stryer, 1995). Thus, if one ATP is hydrolyzed per 120° revolution as implicated in the Boyer's rotational catalysis model (Boyer and Kohlbrenner, 1981; Boyer, 1997), the efficiency of the $\alpha_3\beta_3\gamma$ subcomplex is ~100%.

pN = 10^{-12} Newton

nm = 10^{-9} meter

Work Done by Torque



- Recall $W = F\ d \cos\theta$

- For a wheel
  - Work: $W = F_{tangential}\ d$

    $= F_{tangential}\ 2\pi r\ [\theta / (2\pi)]$ (θ in radians)

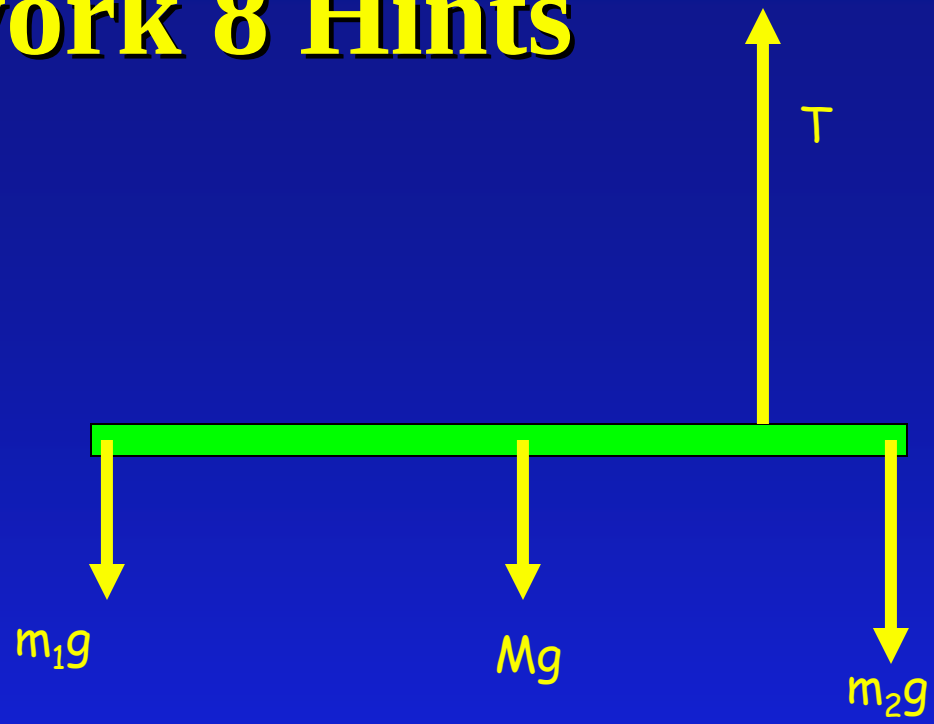
    $= F_{tangential}\ r\ \theta$

    $= \tau\ \theta$
  - Power: $P = W/t = \tau\ \theta/t$

    $= \tau\ \omega$

Homework 8 Hints

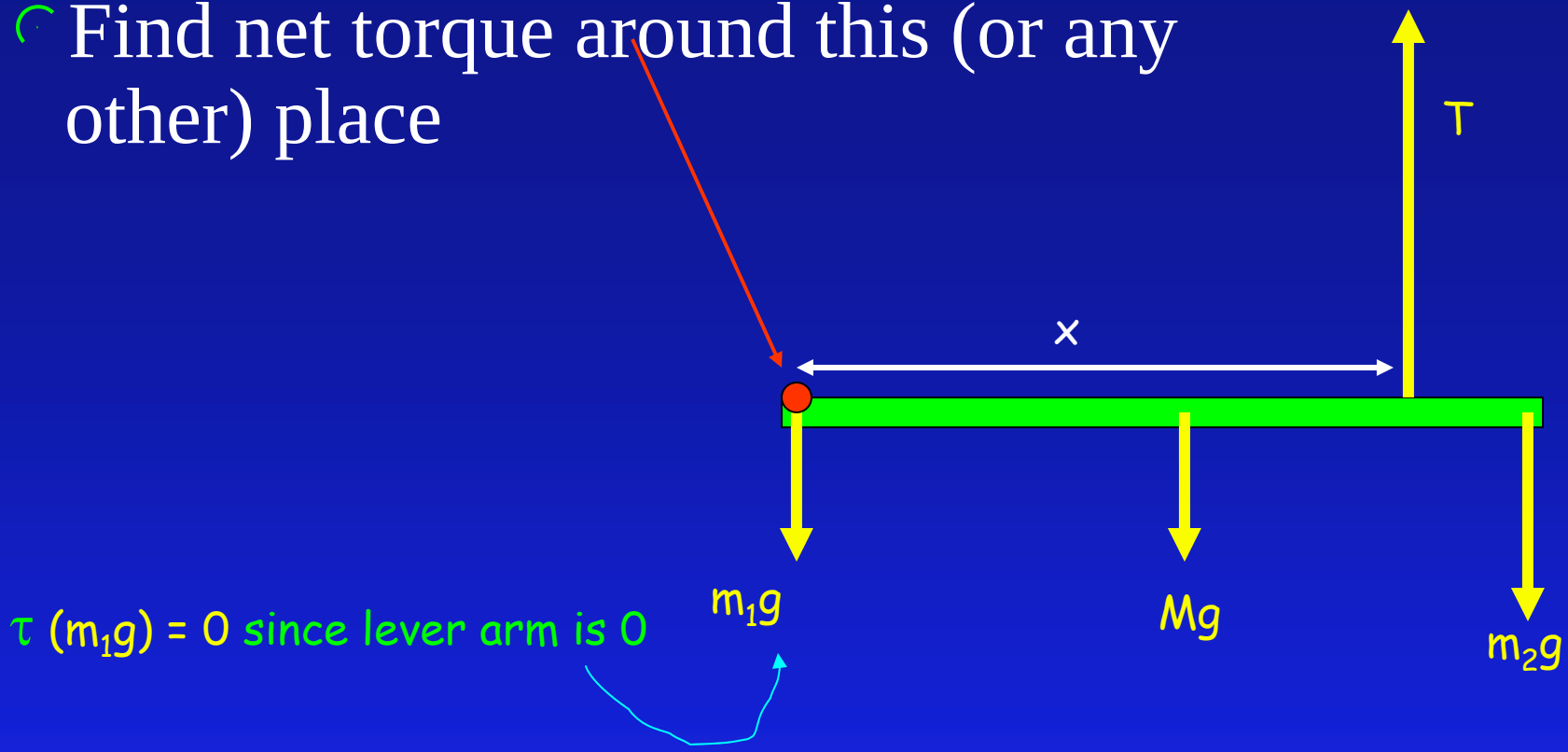
- Bar & Weights



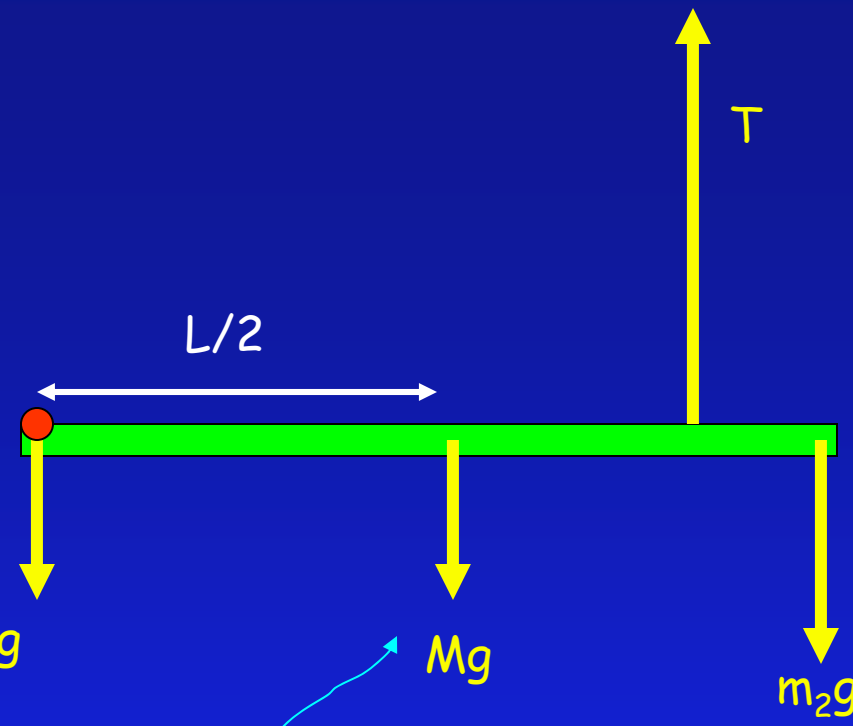
Using $F_{TOT} = 0$: $T = m_1g + m_2g + Mg$

allows you to solve for m_1

- Find net torque around this (or any other) place

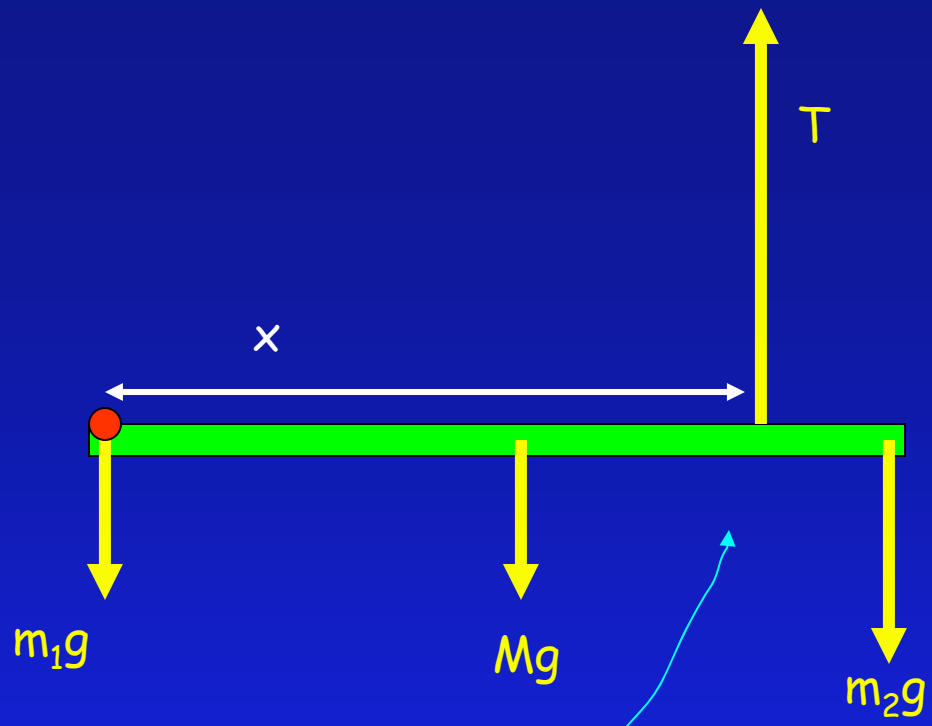


τ (m_1g) = 0 since lever arm is 0



$\tau\ (m_1g) = 0$ since lever arm is 0

$\tau\ (Mg) = -Mg\ L/2$



$\tau\ (m_1 g) = 0$ since lever arm is 0

$\tau\ (Mg) = -Mg\ L/2$

$\tau\ (T) = T\ x$

Summary

- Torque = Force that causes rotation
  - $\tau = F\, r \sin\theta$
  - Work done by torque $W = \tau\, \theta$
- Equilibrium
  - $\Sigma F = 0$
  - $\Sigma \tau = 0$
    - » Can choose any axis.