Announcements 30 Mar 09

- Office hours today
  - Earlier than usual: 2:00 to 3:30 pm
- Homework #7
  - Online homework #7 due on Tuesday by 8 am
  - Written + online homework #8 due on Friday
- Exam 2
  - Tuesday April 7 from 7 to 9 pm
  - Includes material from homeworks #4, #5, #6, #7, #8
  - See full info on course blog (next slides)
  - *Arrange makeup exams this week!*

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Calculating the Center-of-Gravity Position

MP TACTICS BOX 7.1 **Finding the center of gravity** Exercise 12

1. Choose an origin for your coordinate system. You can choose any convenient point as the origin.
2. Determine the coordinates (x_1, y_1), (x_2, y_2), (x_3, y_3), . . . for the particles of mass m_1, m_2, m_3, . . . respectively.
3. The x-coordinate of the center of gravity is

$$x_{cg} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} \quad (7.9)$$

4. Similarly, the y-coordinate of the center of gravity is

$$y_{cg} = \frac{y_1 m_1 + y_2 m_2 + y_3 m_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} \quad (7.10)$$

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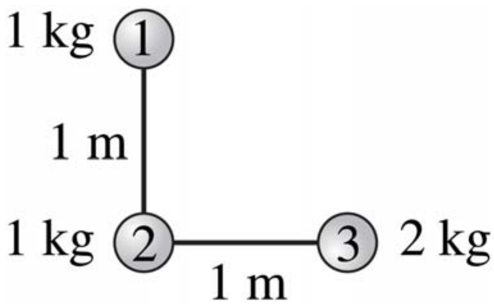
Center of Gravity Sample Problem

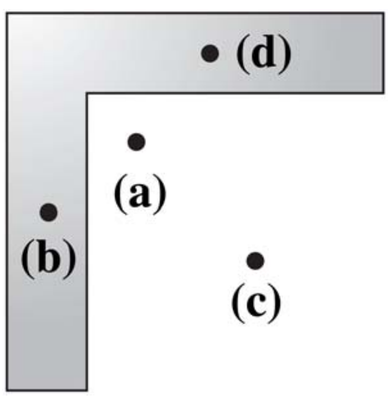
An object consists of the three balls shown, connected by massless rods. Find the *x*- and *y*-positions of the object's center of gravity.



Center of Gravity Question

PRS

Which point could be the center of gravity of this L-shaped piece?



DEMO: **Center of gravity toys**

Chapter 8
Equilibrium and Elasticity

Topics:

- Torque and static equilibrium
- The spring force
- Hooke's law
- Elastic materials
- The elastic limit

Sample question:

How does a dancer balance so gracefully *en pointe*?

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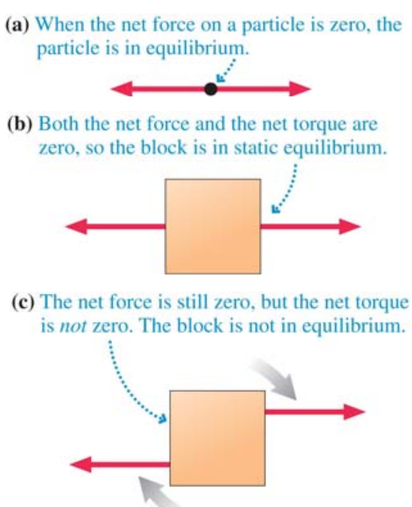
Torque and Static Equilibrium

For an extended object to be in equilibrium, the net force *and* the net torque must be zero.



$$\left.\begin{aligned}\sum F_x &= 0\\ \sum F_y &= 0\end{aligned}\right\}\ \text{No net force}$$

$$\sum \tau = 0 \ \}\ \text{No net torque}$$

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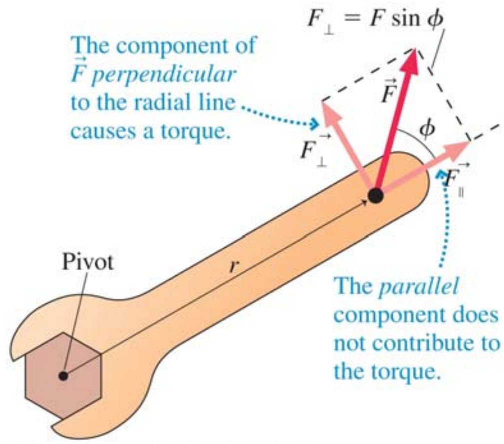
Interpreting Torque

Torque is due to the component of the force *perpendicular* to the radial line.



$$\tau = rF_\perp = rF\sin\phi$$

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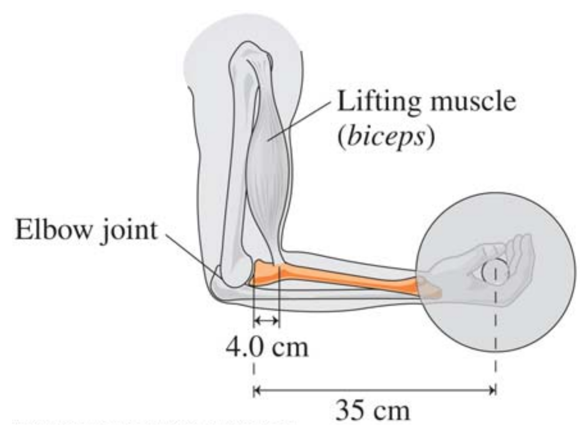
Lifting Weights, How Much Force?

What is the tension in the tendon connecting the biceps muscle to the bone while holding a 900 N barbell stationary?

What is the force exerted by the elbow on the forearm bones?



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Solving Static Equilibrium Problems

MP PROBLEM-SOLVING STRATEGY 8.1 **Static equilibrium problems**

PREPARE Model the object as a simple shape. Draw a visual overview that shows all forces and distances. List known information.

- Pick an axis or pivot about which the torques will be calculated.
- Determine the torque about this pivot point due to each force acting on the object.
- Determine the sign of each torque about this pivot point.

SOLVE The mathematical steps are based on the fact that an object in static equilibrium has no net force and no net torque.

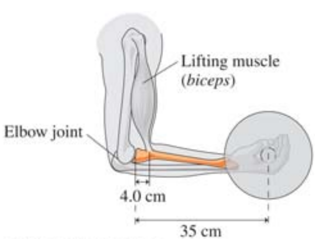
$$\vec{F}_{net} = \vec{0} \quad \text{and} \quad \tau_{net} = 0$$

- Write equations for $\sum F_x = 0$, $\sum F_y = 0$, $\sum \tau = 0$.
- Solve the resulting equations.

Counter clockwise rotation: torque > 0
Clockwise rotation: torque < 0

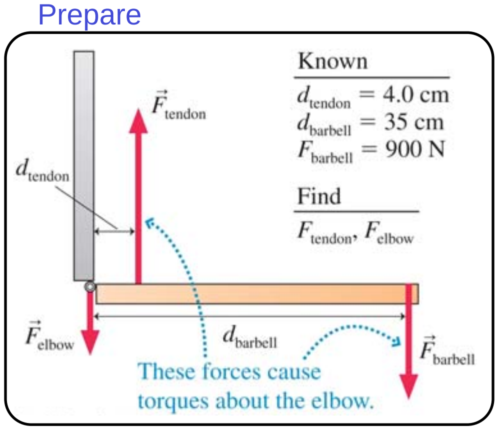
ASSESS Check that your result is reasonable and answers the question.

Lifting Weights…



Note: we neglect the weight of the forearm since it is small compared to the barbell

Prepare



Solve

$$\sum F_y = F_{tendon} - F_{elbow} - F_{barbell} = 0$$

$$\tau_{net} = F_{elbow} \times 0 + F_{tendon}\, d_{tendon} - F_{barbell}\, d_{barbell} = 0$$

$$\Rightarrow F_{tendon} - F_{barbell} = F_{elbow}$$

$$3900N - 450N = F_{elbow} = 3450N$$

$$\Rightarrow F_{tendon} = F_{barbell} \frac{d_{barbell}}{d_{tendon}}$$

$$\Rightarrow F_{tendon} = (450N)\frac{35cm}{4.0cm} = 3900N$$

Problem 7.10 (homework #7)

Force F_2 acts half as far from the pivot as force F_1. What magnitude of F_2 causes the net torque to be zero?

Problem 7.20 (homework #7)

A 3.60-m-long, 440 kg steel beam extends horizontally from the point where it has been bolted to the framework of a new building under construction. A 68.0 kg construction worker stands at the far end of the beam. What is the magnitude of the torque about the point where the beam is bolted into place?