STATICS

Chapter 9

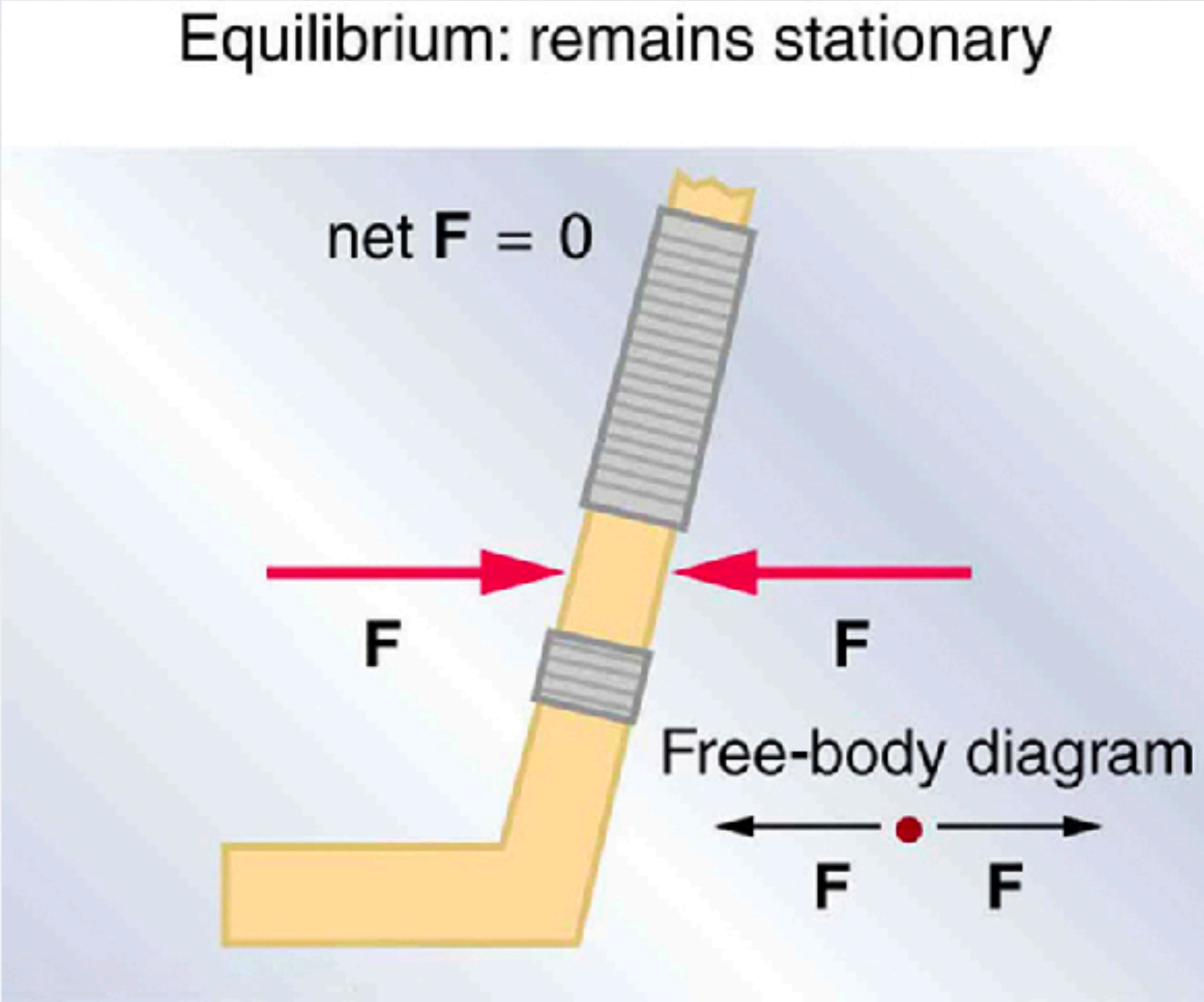
EQUILIBRIUM

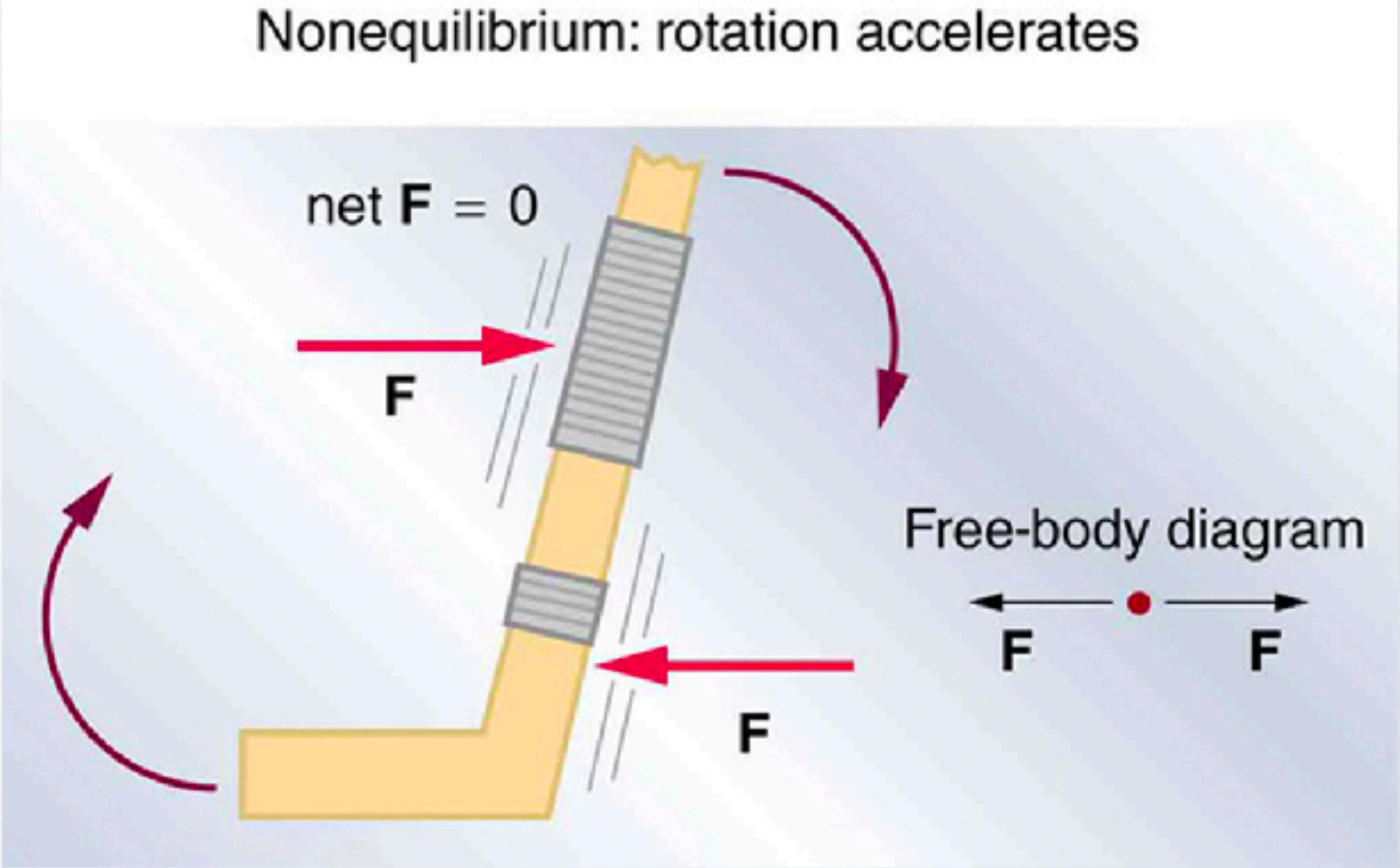
- Statics is the study of what does it take to keep something staying the way it is. From what we have learned already we know the net force on an object must be zero or it will accelerate.
- This is called being in equilibrium when there is no net force on an object.

TORQUE

- However, this is not enough to keep an object static. The hokey stick has net force equal zero in both cases. But in the bottom example the stick will rotate.

- A force that causes an object to rotate is called a torque. Thus we see to have equilibrium we also need the net torque on an object to be zero.



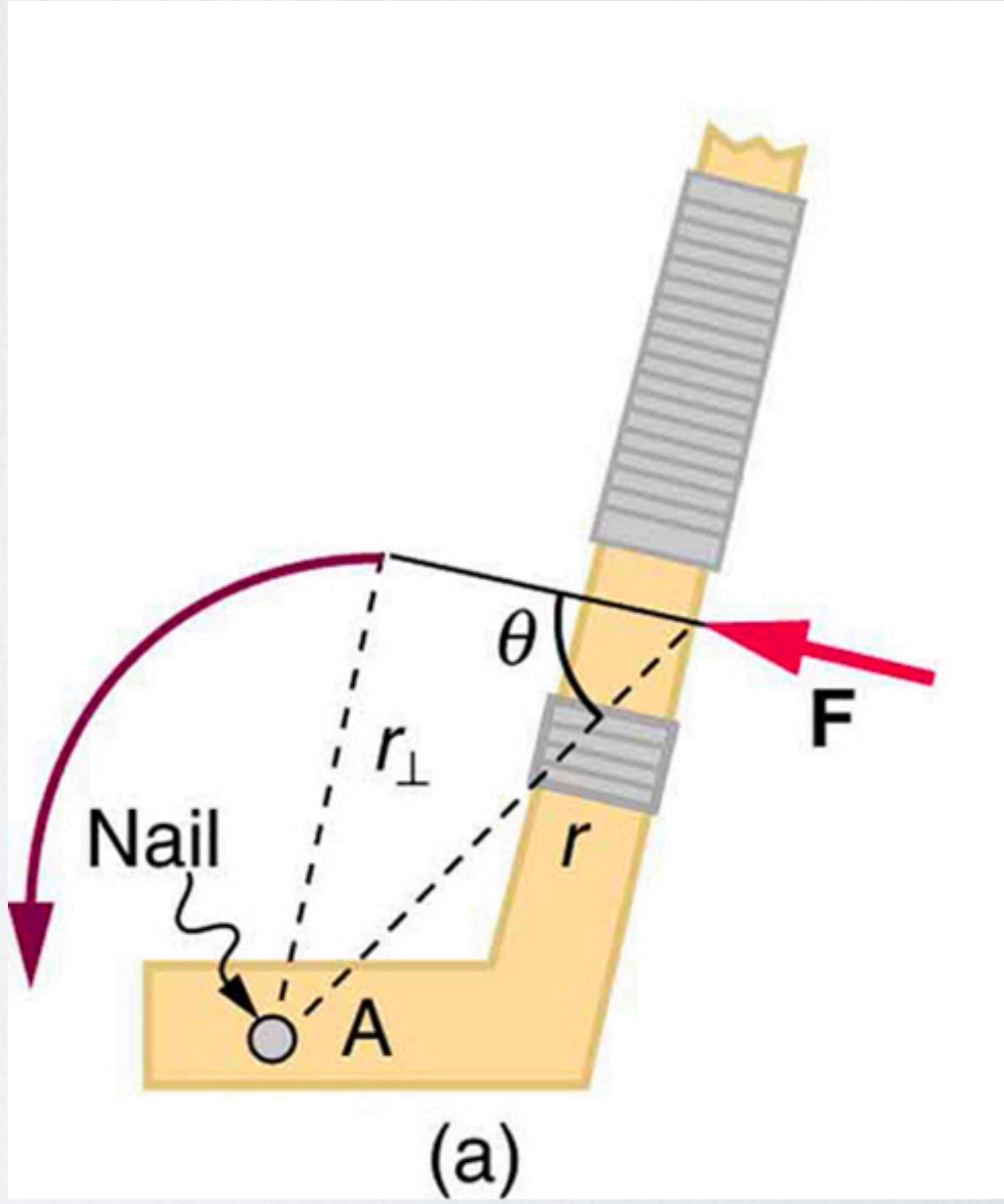


TORQUE

- The torque on an object depends on force, but it also depends on the distance that force is applied from the axis of rotation and the direction of the force. We can write

$$\tau = rF\sin\theta$$

- where τ is the torque and θ the angle between the force and line to the pivot point.

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How much force (torque) must be applied to the truck to flip it?

Looking up properties of an 18 wheeler.

mass = 15000kg
length = 16m
height = 4m

In order for the truck to flip the torque from the force F must be greater than the torque from the weight.

$$\tau = RF\sin\theta \qquad \tau_F = \frac{1}{2}hF \qquad \tau_W = \frac{1}{2}lmg$$

$$\tau_F > \tau_W => \frac{1}{2}hF > \frac{1}{2}4hmg => F > 4mg = 4(15000kg)(9.8m/s^2) = 588,000N$$

That's a tremendous amount of force and if you watch the clip carefully you'll see they don't rotate the truck from the force of the wires, but there is an explosion in the middle of the truck that flips in over. Since the explosion occurs at half the length its force only need to be mg to overcome gravity.

EXAMPLE 9.1

- **She Saw Torques On A Seesaw:** The two children shown in the Figure are balanced on a seesaw of negligible mass. (This assumption is made to keep the example simple—more involved examples will follow.) The first child has a mass of 26.0 kg and sits 1.60 m from the pivot.(a) If the second child has a mass of 32.0 kg, how far is she from the pivot? (b) What is F_p, the supporting force exerted by the pivot?

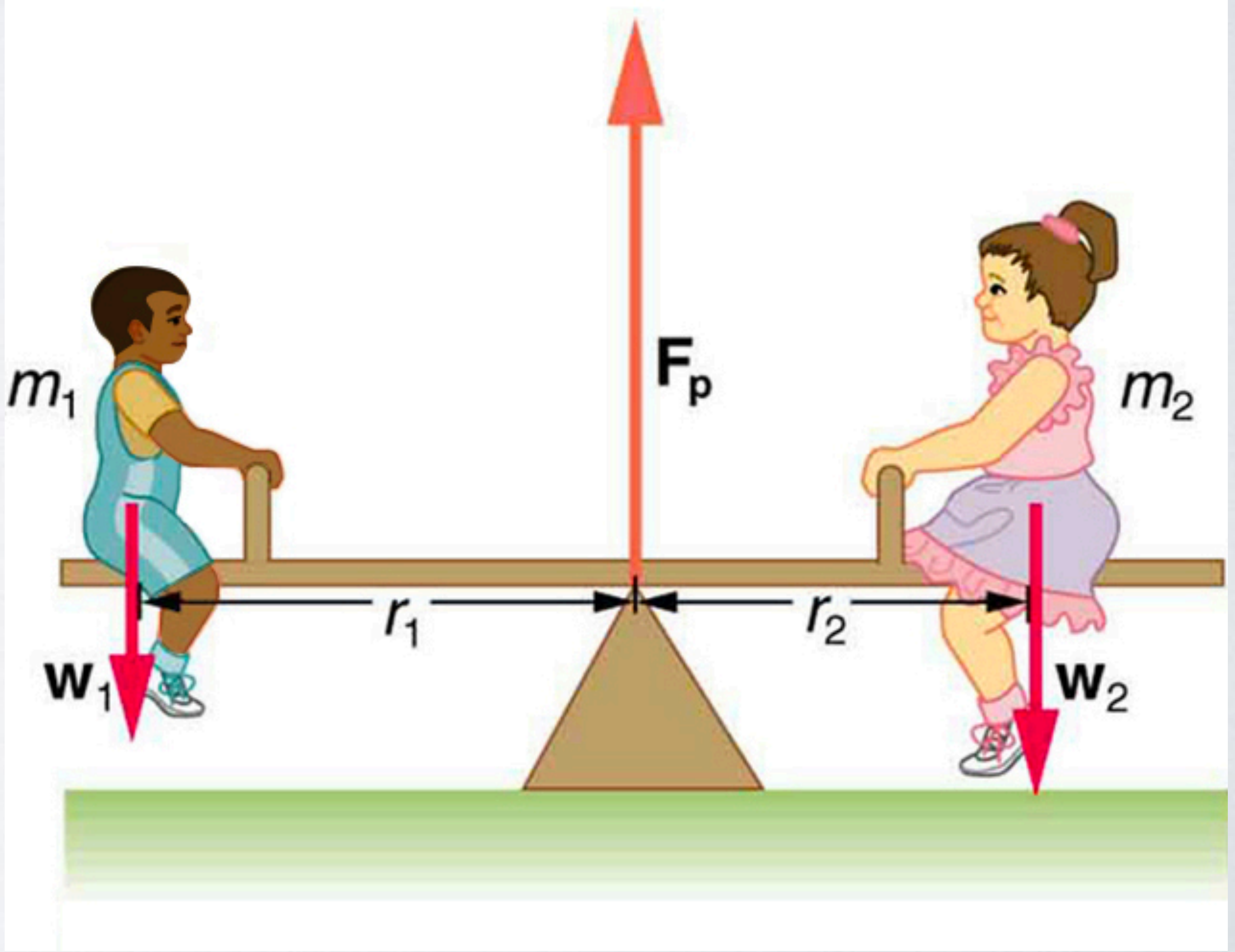
$m_1 = 26.0$ kg
$r_1 = 1.6$ m
$m_2 = 32.0$ kg
$r_2 = ?$
$F_p = ?$

$$F_{net} = 0$$

$$\tau_{net} = 0$$

$$F_p - m_1 g - m_2 g = 0$$

$$m_1 g r_1 - m_2 g r_2 = 0$$



$$r_2 = \frac{m_1}{m_2} r_1 = \frac{26kg}{32kg} 1.6m = 1.30m$$

$$F_p = m_1 g + m_2 g = (26kg)(9.8m/s^2) + (32kg)(9.8m/s^2) = 568N$$

EXAMPLE 9.2

- **What Force Is Needed to Support a Weight Held Near Its CG?** For the situation shown in the Figure, calculate: (a) F_R, the force exerted by the right hand, and (b) FL, the force exerted by the left hand. The hands are 0.900 m apart, and the cg of the pole is 0.600 m from the left hand. The pole's mass is 5.00kg.

m = 5.00kg
R_L = 0.600m
R_{RL} = 0.900m
F_L = ?
F_R = ?

$$F_{net} = 0$$

$$\tau_{net} = 0$$

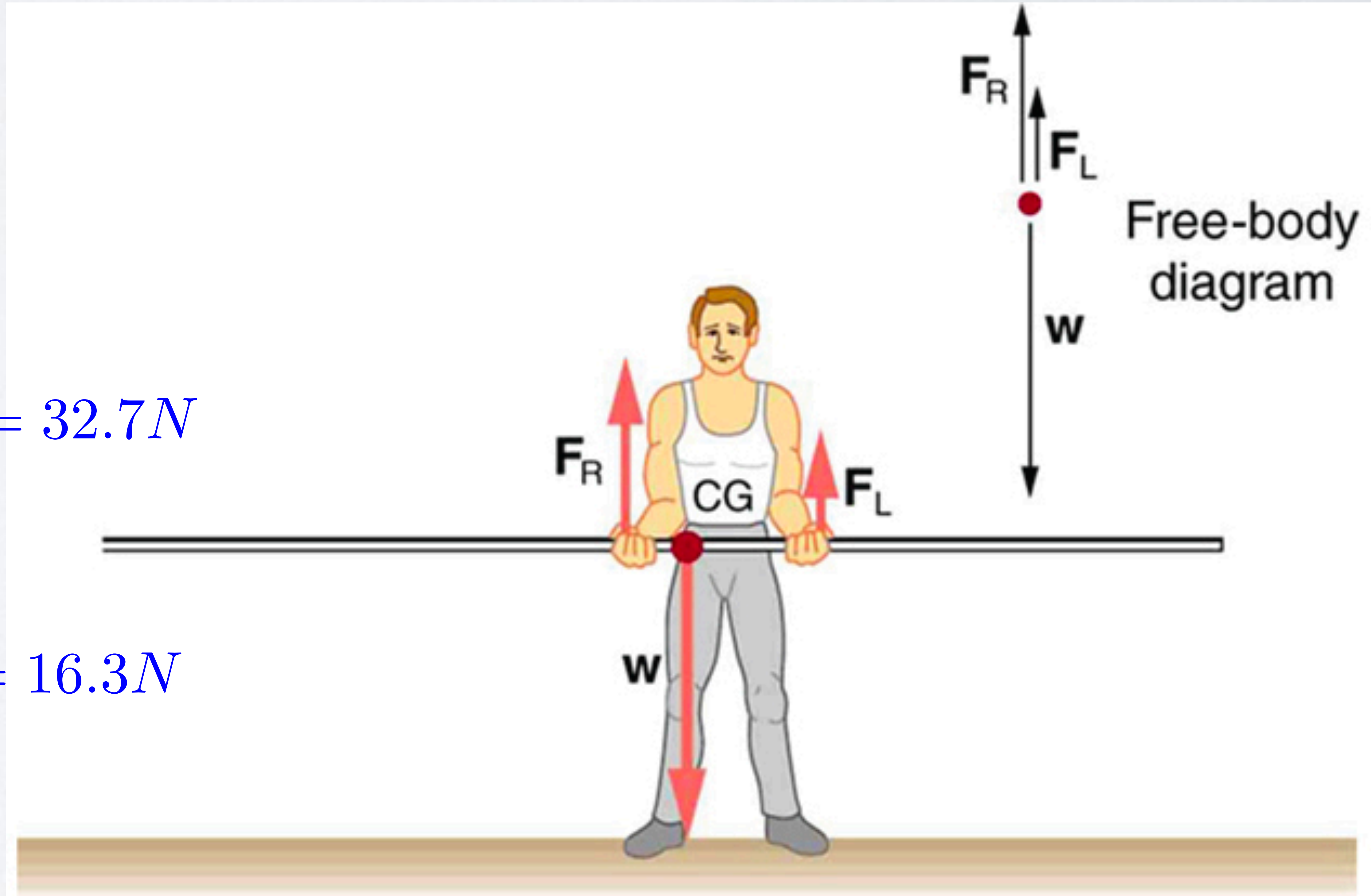
$$F_R + F_L - mg = 0$$

free to choose pivot

$$F_R R_{RL} - mg R_L = 0$$

$$F_R = mg\frac{R_L}{R_{RL}} = (5kg)(9.8m/s^2)\frac{0.600m}{0.900m} = 32.7N$$

$$F_L = mg - F_R = (5kg)(9.8m/s^2) - 32.7N = 16.3N$$



EXAMPLE 9.4

- **Muscles Exert Bigger Forces Than You Might Think.** Calculate the force the biceps muscle must exert to hold the forearm and its load as shown in the Figure, and compare this force with the weight of the forearm plus its load.

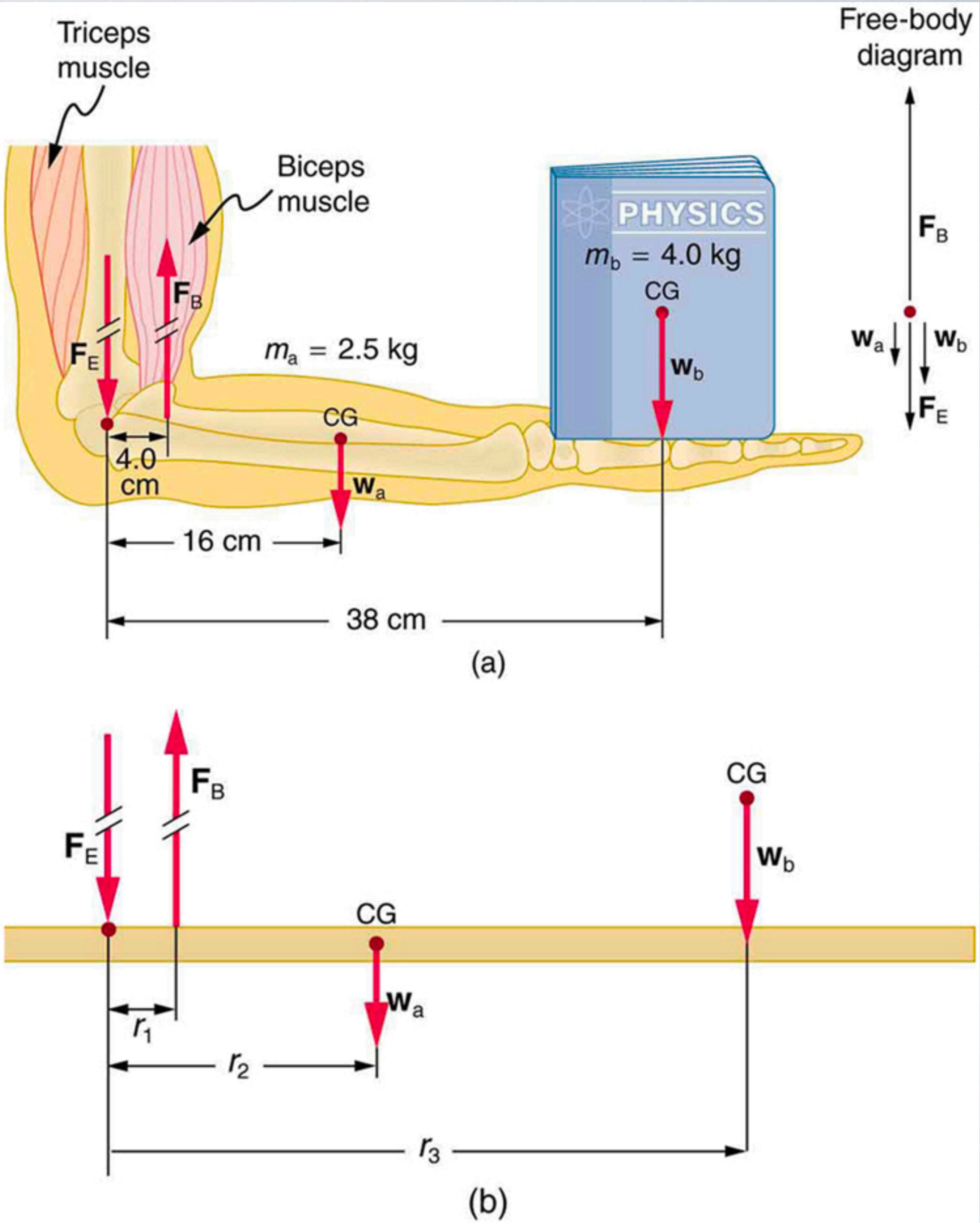
$$F_{net} = 0 \qquad F_B - F_E - m_a g - m_b g = 0$$

$$\tau_{net} = 0 \qquad r_2 m_a g + r_3 m_b g - r_1 F_B = 0$$

$$F_B = (r_2 m_a g + r_3 m_b g)/r_1$$
$$= ((16cm)(2.5kg) + (38cm)(4.0kg))(9.8m/s^2)/4.0cm = 470N$$

$$(2.5kg)(9.8m/s^2) + (4.0kg)(9.8m/s^2) = 63.7N$$

$$\frac{470N}{63.7N} = 7.38$$

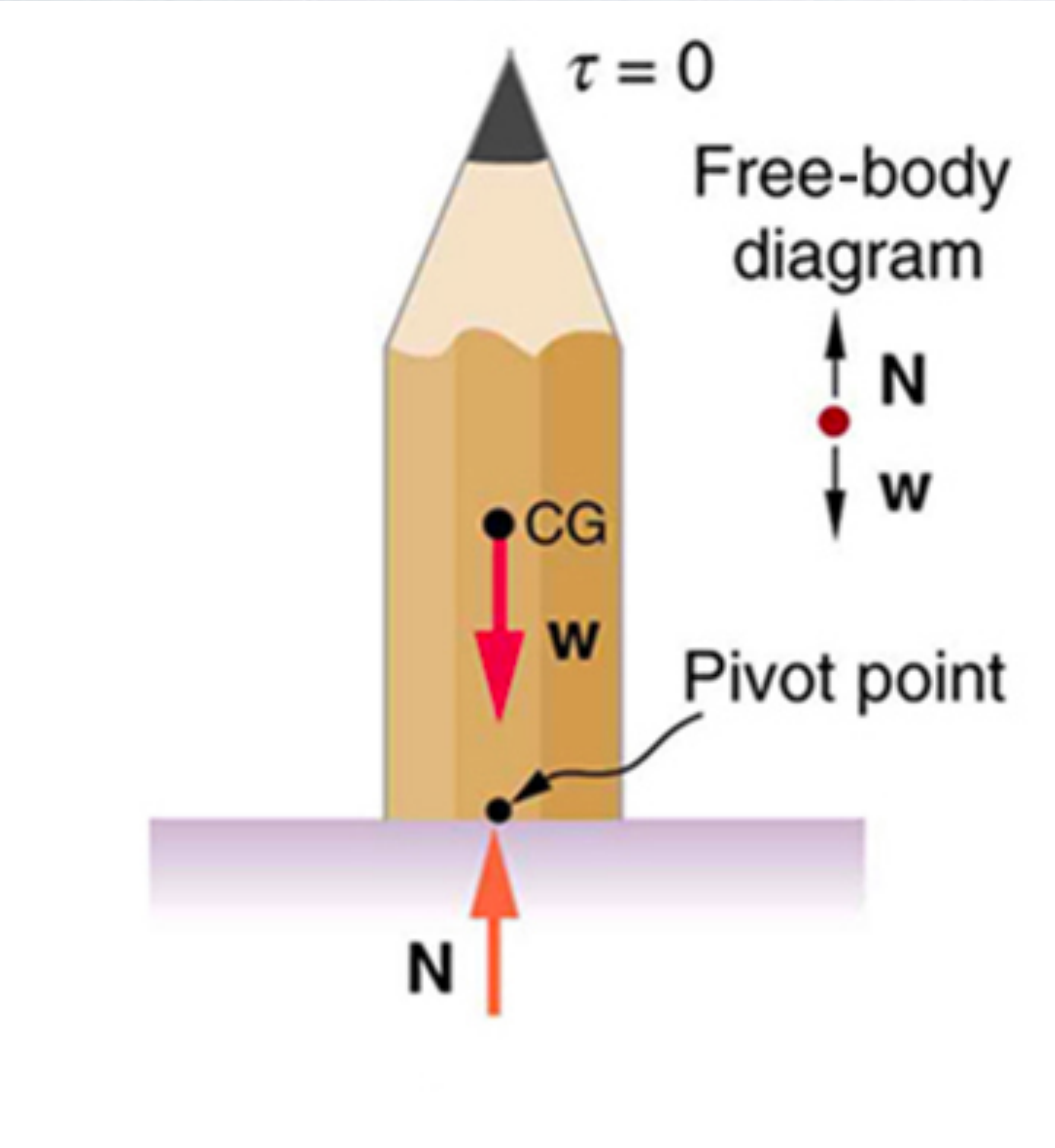


STABILITY

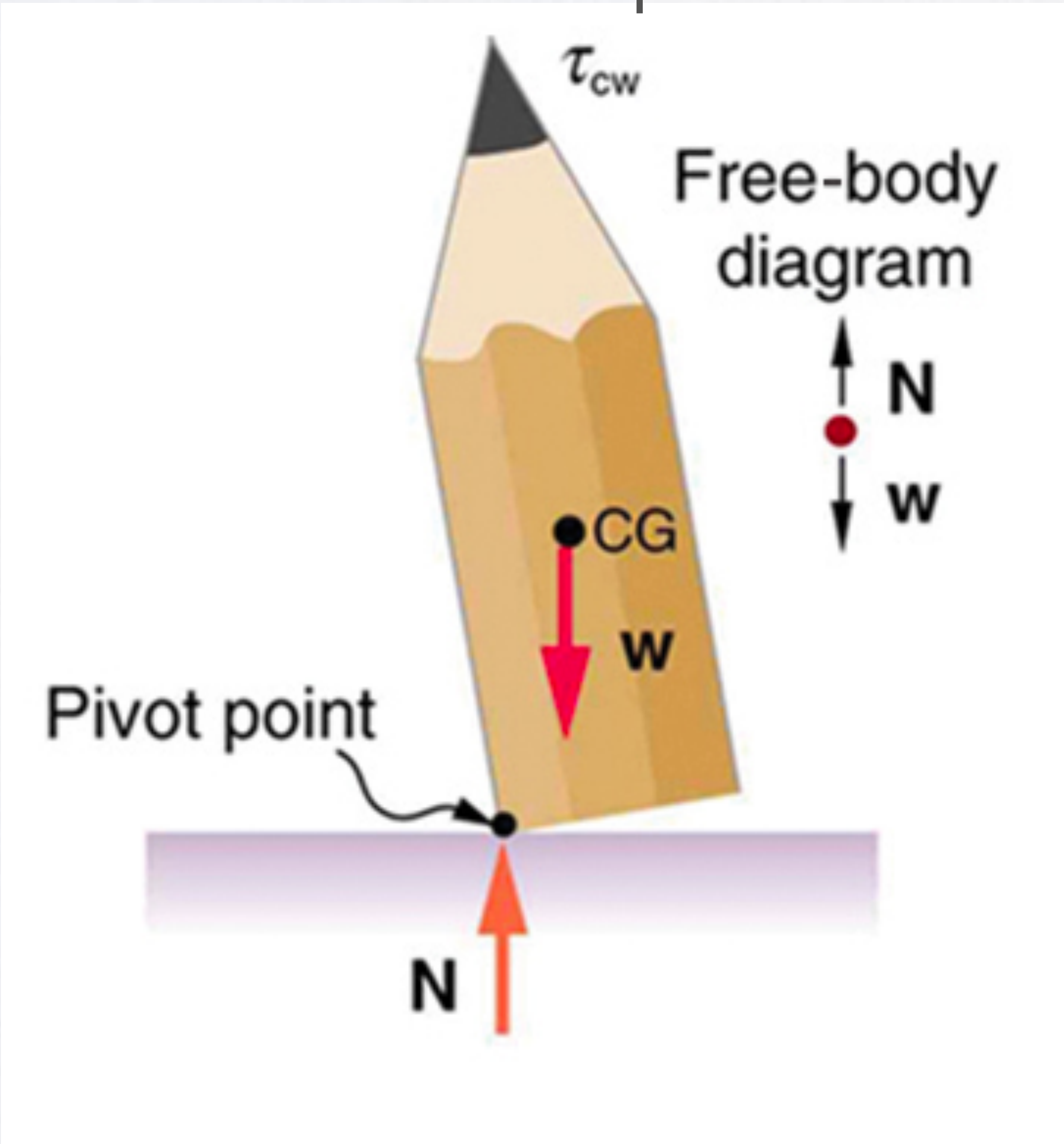
- Equilibrium is not the same as stability. An object can be in equilibrium, but still unstable like a pencil balanced on its point.

- For an object to be stable not only does it have to be in equilibrium, but a small change has to bring it back to equilibrium instead of moving increasingly away from it.

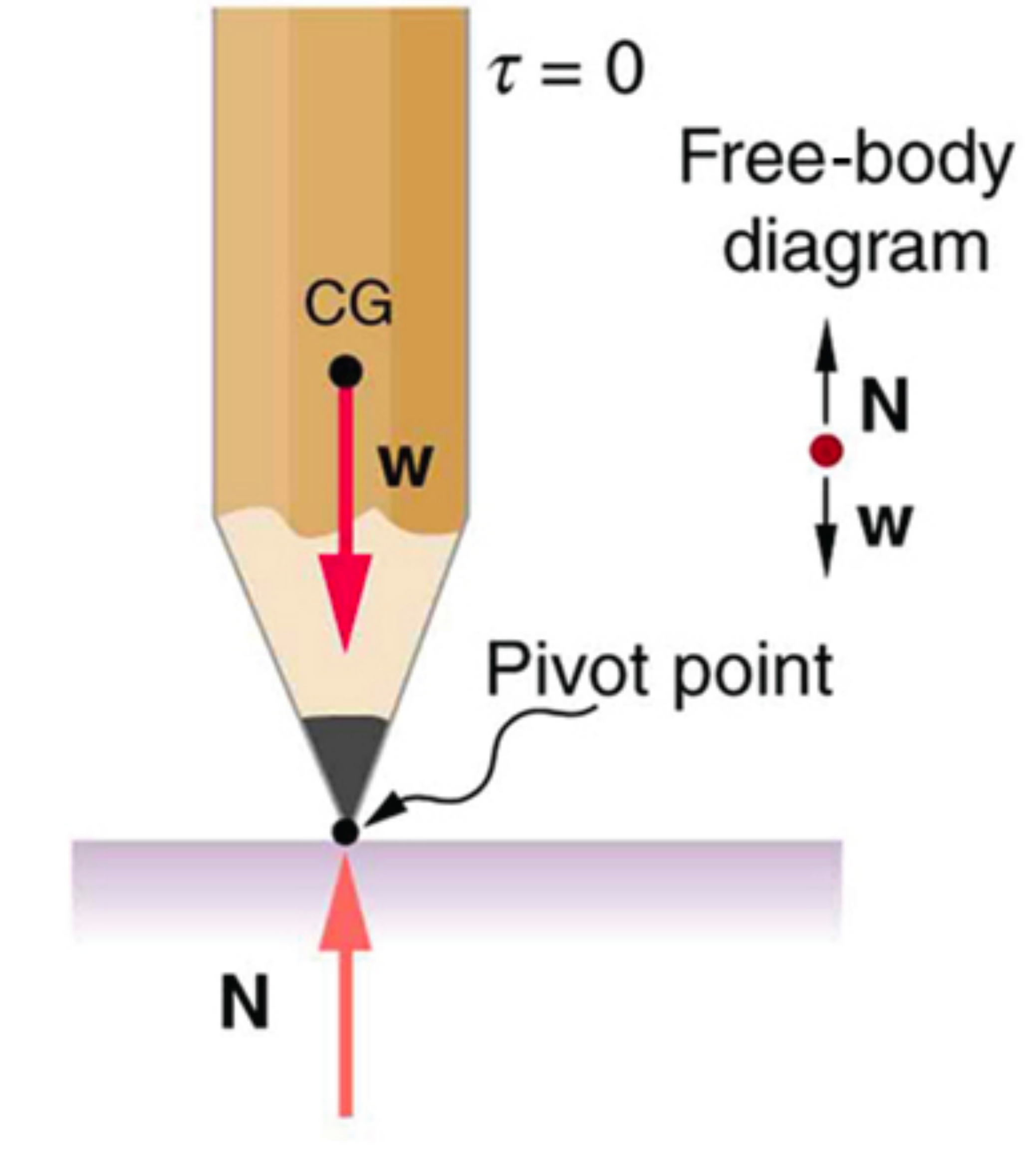
stable equilibrium



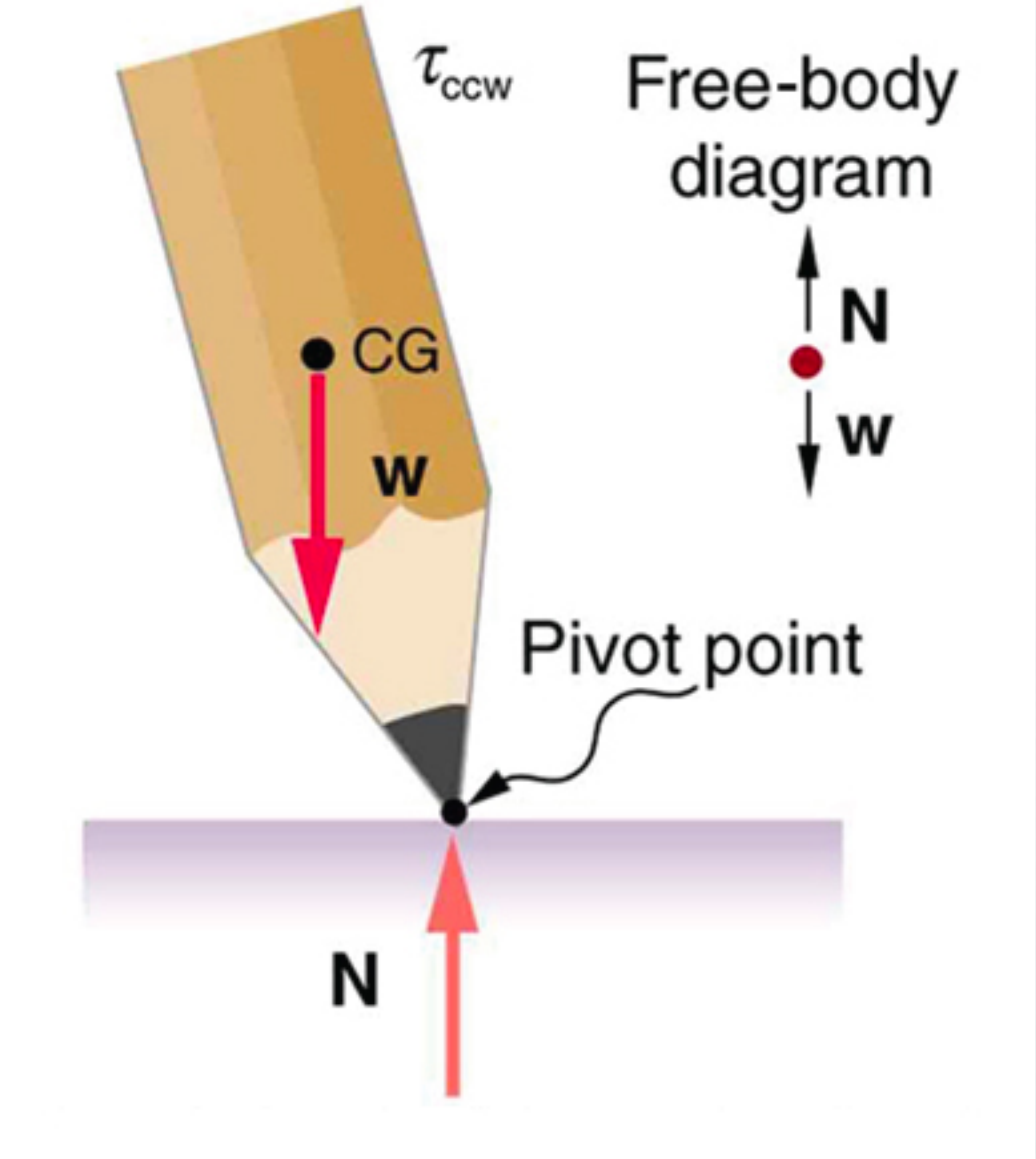
returns to equilibrium



unstable equilibrium



pencil falls over



HOME WORK

- Chap 9 - 2, 3, 9, 18