General Physics

Lecture 5

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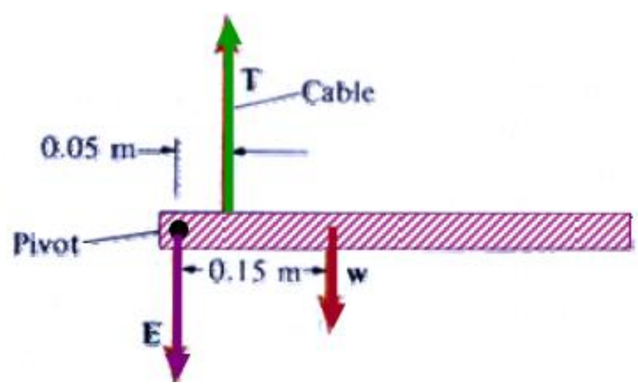


Equilibrium of Rigid Bodies

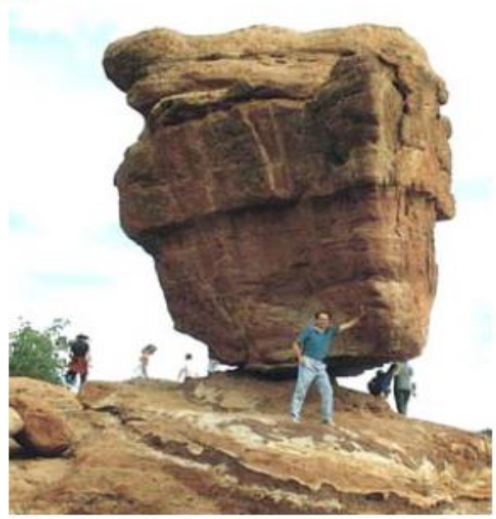
First Condition of Equilibrium

- The net external force must be zero

$$\Sigma \vec{F} = 0$$

$$\Sigma F_x = 0 \text{ and } \Sigma F_y = 0$$

- This is a necessary, but not sufficient, condition to ensure that an object is in complete mechanical equilibrium
- This is a statement of translational equilibrium



Second Condition of Equilibrium

- The net external torque must be zero

$$\Sigma \tau = 0$$

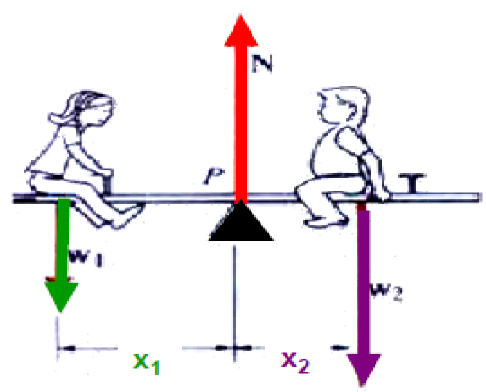
- This is a statement of rotational equilibrium

Example3

- **Two children of weights w_1 and w_2 are balanced on a board pivoted about its center.**

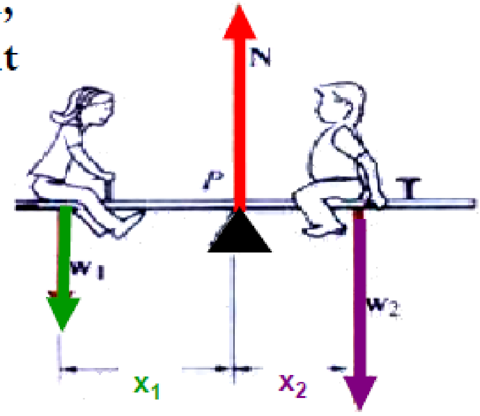
(a) What is the ratio of their distances x_2/x_1 from the pivot?

(b) If w_1=200N, w_2=400N, and x_1=1m, what is x_2?



Solution

(a) From the first equilibrium condition, the force N must balance their weight so that the net force is zero.



$$N - w_1 - w_2 = 0 \qquad N = w_1 + w_2$$

- From the second condition the torque about the pivot P is zero

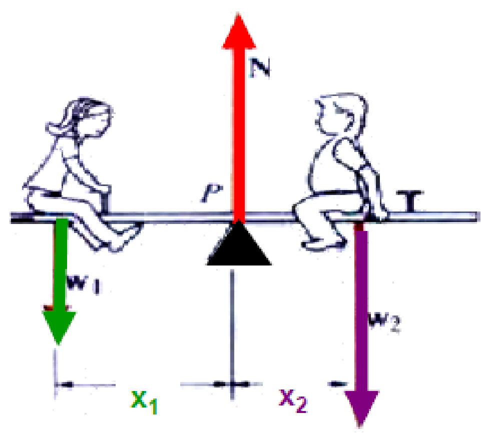
$$\Sigma\tau = 0$$
$$\tau = \tau_1 + \tau_2 = 0$$

$$\tau_1 = x_1 w_1$$
$$\tau_2 = -x_2 w_2$$

$$x_1 w_1 - x_2 w_2 = 0 \longrightarrow \frac{x_2}{x_1} = \frac{w_1}{w_2}$$

(b) If w_1=200N, w_2=400N, and x_1=1m, what is x_2?

- From the equation



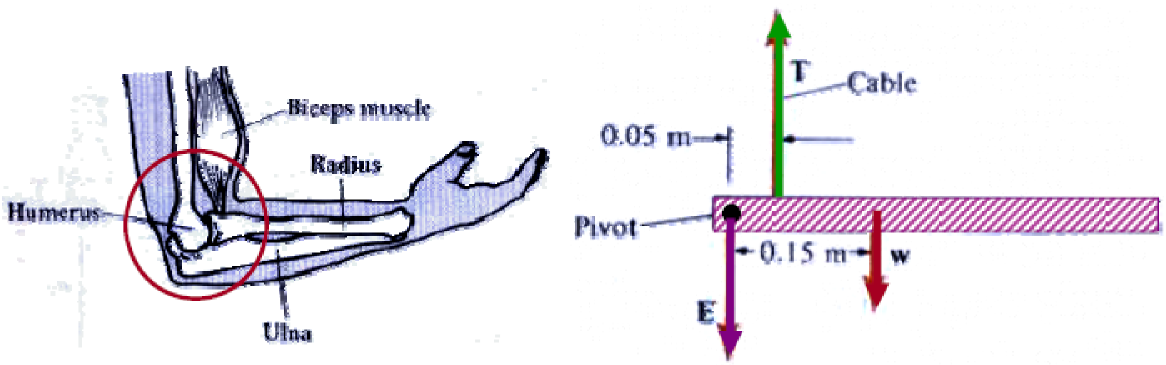
$$\frac{x_2}{x_1} = \frac{w_1}{w_2}$$

$$x_2 = x_1 \frac{w_1}{w_2} = (1m)(\frac{200N}{400N}) = 0.5m$$

وهذا متفق مع افتراضنا أن احد الطفلين أثقل من الأخر بمرتين ولذلك هو أو هي يجب أن يجلس عند منتصف المسافة من نقطة الارتكاز

Example 5

- **A model for the forearm in the position shown in the figure is pivoted bar supported by a cable.**



The weight w of the forearm is 12N and can be treated as concentrated at the point shown.

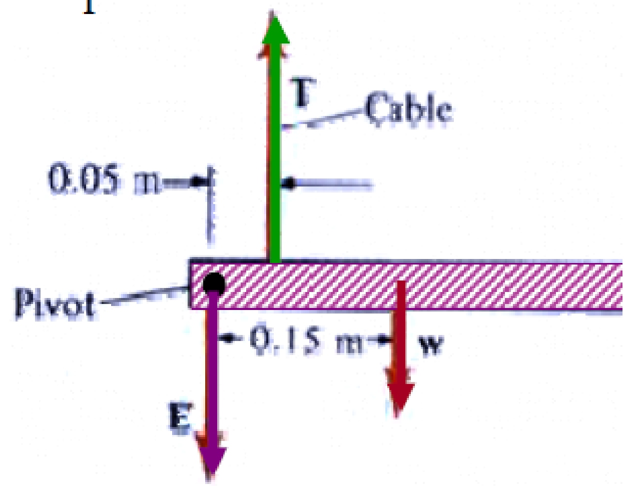
Find the tension T exerted by the biceps muscle and the force E exerted by the elbow joint.

Applying the First condition of equilibrium

$$F = 0$$

Then

$$T - E - w = 0$$



Applying the Second condition of equilibrium

$$\boxed{\sum \tau = 0}$$

Force E produce torque = 0

Force w produce torque = -(0.15)w

Force T produce torque = (0.05)T

In equilibrium the sum of these torques must be zero

$$\boxed{\sum \tau = 0}$$

$$-0.15\ w + 0.05\,T = 0$$

or

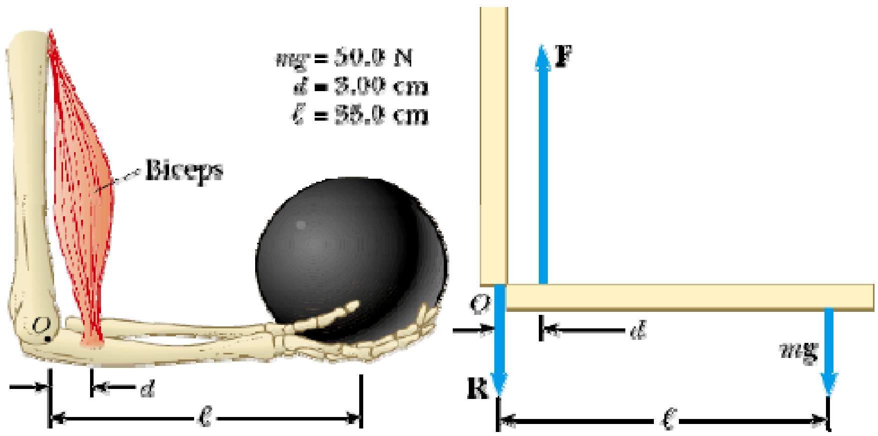
$$T = 3\ w = 3x12 = 36\ N$$

From the First equation we get the value of E

$$E = T - w = 36 - 12 = +24N$$

Exercise 3

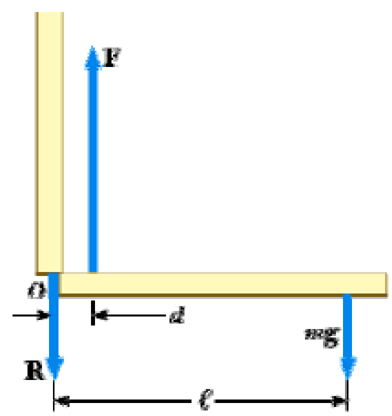
A person holds a 50.0-N sphere in his hand. The forearm is horizontal, as shown in Figure. The biceps muscle is attached 3.00 cm from the joint, and the sphere is 35.0 cm from the joint. Find the upward force exerted by the biceps on the forearm and the downward force exerted by the upper arm on the forearm and acting at the joint. Neglect the weight of the forearm.



F=583N
R=533N

Solution:

We simplify the situation by modeling the forearm as shown in the figure, where F is the upward force exerted by the biceps and R is the downward force exerted by the upper arm at the joint. From the first condition of equilibrium we have,



$$\sum F_y = F - R - 50.0\text{ N} = 0$$

From the second condition of equilibrium about point O we have,

$$\sum \tau = Fd - mg\ell = 0$$

$$F(3.00\text{ cm}) - (50.0\text{ N})(35.0\text{ cm}) = 0$$

$$F = 583\text{ N}$$

$$R = 533\text{ N}$$