KEY: Torque and Statics

Recap

Statics

- ★ The study of forces in equilibrium
- ★ Conditions
  - ○ Net F=0N
    - ■ The first condition is that the net external force on the system is equal to 0
  - ○ Net τ=0
    - ■ A rotating body or system can be in equilibrium if its rate of rotation is constant and remains unchanged by the forces acting on it.

Torque

- ★ The rotational equivalent of a force
- ★ Counter-clockwise is positive
- ★ Clockwise is negative

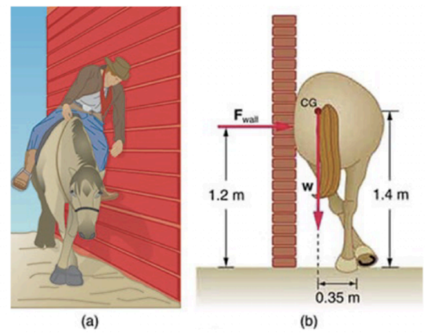
$$\tau = rF\sin\theta = r_{\perp}F$$

➢ $r_{\perp} = r\sin\theta$

- ★ Units: newtons times meter (N•m)
- ★ If Net τ = 0
  - ○ Then $\tau_1 - \tau_2 = 0$
    - ■ So $\tau_1 = \tau_2$

Practice

Suppose a horse leans against a wall as in the figure, emulating a scene in the comedy movie Cat Ballou. Calculate the force exerted on the wall, assuming that the force is horizontal, while using in the schematic representation of the situation. Note that the force exerted on the wall is equal in magnitude and opposite in direction to the force exerted on the horse, keeping it in equilibrium. The total mass of the horse and rider is 500 kg. Take data to be accurate to three digits.



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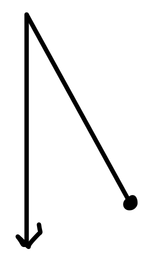
[Video on how to solve]

$m = 500kg \quad g = 9.8\,m/s^2 \quad r_1 = .35 \quad r_2 = 1.4m$



$\Sigma \tau = 0$

$\tau_1 - \tau_2 = 0$

$\tau_1 = \tau_2$

$r_1 F_1 = r_2 F_2$

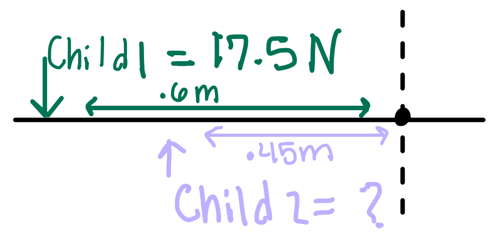
$F_2 = \frac{r_1 F_1}{r_2} = \frac{r_1 (m \cdot a)}{r_2} = \frac{.35 \cdot (500 \cdot 9.8)}{1.4} = 1430N$

Two children push on opposite sides of a door during play. Both push horizontally and perpendicular to the door. One child pushes with a force of 17.5 N at a distance of 0.600 m from the hinges, and the second child pushes at a distance of 0.450 m. What force must the second child exert to keep the door from moving? Assume friction is negligible.

Video on how to solve

Child 1: $F_1 = 17.5$ $r = .600\,m$

Child 2: $F_2 = ?$ $r_2 = .450\,m$

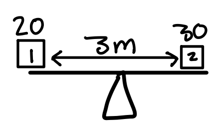


$$\Sigma \tau = 0$$
$$\tau_1 + \tau_2 = 0$$
$$\tau_1 = -\tau_2$$
$$r_1 F_1 \sin\theta_1 = -r_2 F_2 \sin\theta$$
$$F_2 = \frac{r_1 F_1 \sin\theta}{r_2 \sin\theta} = \frac{.600 \cdot 17.5}{-.450} \approx -23.3N$$

Two children of mass 20.0 kg and 30.0 kg sit balanced on a seesaw with the pivot point located at the center of the seesaw. If the children are separated by a distance of 3.00 m, at what distance from the pivot point is the small child sitting in order to maintain the balance?

Video on how to solve

$m_1 = 20kg$ $m_2 = 30.0kg$ $x = 3.00m$



$d = r_1 + r_2 \rightarrow r_2 = d - r_1$

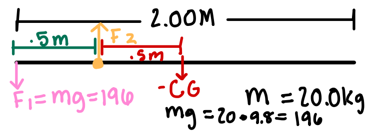
$$\tau_1 = \tau_2$$
$$r_1 m_1 g = r_2 m_2 g$$
$$r_1 \cdot m_1 = (d - r_1) m_2$$
$$r_1 \cdot m_1 = d m_2 - r_1 \cdot m_2$$
$$r_1 m_1 + r_1 m_2 = d m_2$$
$$r_1 (m_1 + m_2) = d m_2$$

$$r_1 = \frac{d m_2}{(m_1 + m_2)} = \frac{3 \cdot 30}{(20+30)} = \frac{90}{50} = 1.8\,m$$

$$r_2 = d - r_1 = 3 - 1.8 = 1.2m$$

A person carries a plank of wood 2.00 m long with one hand pushing down on it at one end with a force F1 and the other hand holding it up at .500 m from the end of the plank with force F2. If the plank has a mass of 20.0 kg and its center of gravity is at the middle of the plank, what are the magnitudes of the forces F1 and F2? [Video on how to solve]

$d = 2.00m \quad m = 20.0kg \quad r_1 = .500m$



$\Sigma \tau = 0$

$\tau_2 - \tau_3 = 0$

$\tau_1 = \tau_3$

$r_2 F_1 = r_3 F_3$

$F_2 = \frac{r_3 F_3}{r_1}$

$\Sigma \tau = 0$

$\tau_2 - \tau_3 = 0$

$\tau_2 = \tau_3$

$r_2 F_2 = r_3 F_3$

$F_2 = \frac{r_3 F_3}{r_2} = \frac{1 \cdot 20 \cdot 9.8}{.500} = 392$

$\Sigma F = 0 \rightarrow -F_1 + F_2 - F_3 = 0 \longrightarrow F_1 = 392 - 196 = 196N$