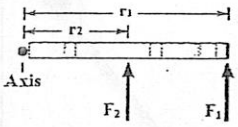
POINT 2 Torque and Rotational Equilibrium

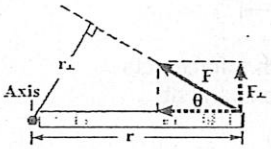
A. Torque

a. Torque is a measure of the twist produced by a force about a particular pivot point.

b. Torque, a vector quantity, is the product of a force and its lever arm.

$\tau = r_\perp F = rF_\perp = rF \sin\theta$ (unit: N·m)





B. Center of gravity

Center of gravity (CG) is the point at which the force of gravity can be considered to act, and is generally at the same point as the center of mass.

C. Rotational equilibrium: The second condition for equilibrium

In rotational equilibrium, the sum of the external torques about any pivot point is zero.

$\Sigma\tau = 0$: $\tau_{clockwise} + \tau_{counterclockwise} = 0$

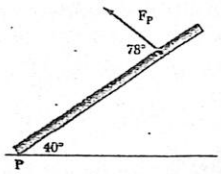
D. Static equilibrium

A body is in static equilibrium if it is at rest. In static equilibrium, the sum of the external forces is zero, and the sum of the external torques about any pivot point is zero.

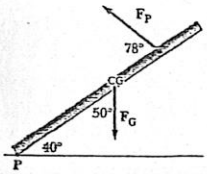
$\Sigma F = 0$ $\Sigma\tau = 0$

PROBLEM 2 Torque

A uniform 8.0 m-long beam of mass 20 kg has a force of 210 N applied 6.5 m from the point P as shown in the diagram. Find the magnitude and direction of net torque acting on the beam about the pivot point P.



Solution m = 20 kg, F_P = 210 N, d_P = 6.5 m, d_{CG} = 4.0 m

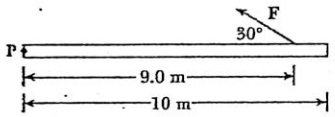


Draw a free-body diagram and determine the directions of torques.
$\tau_{CC} = F_P \cdot d_P \sin\theta = (210)(6.5)\sin 78° = 1335$ N·m
$\tau_C = (mg)d_{CG} \sin\theta = (20)(9.8)(4.0)\sin 50° = 600$ N·m

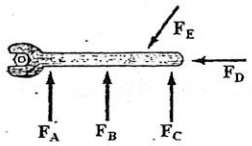
Net torque: $\Sigma\tau = \tau_{CC} + \tau_C$
$\Sigma\tau = \tau_{CC} + (-\tau_C) = 1335 - 600 = 735 \approx 740$ N·m (counter-clockwise)

RELATED PROBLEMS

9. A uniform horizontal beam of length 10 m has a force of 55 N applied 9.0 m from the pivot point P as shown. Find the magnitude and direction of the torque about the pivot point P produced by this force.



10. The figure shows situations in which a force acts on a wrench along different directions and at different points.



a) If the forces have the same magnitude, in which situation will the force produce the greatest torque about the bolt?

b) In which situation is the greatest force required to loose the bolt?

c) In which situation does the force produce a clockwise torque about the bolt?

11. A 70 kg firefighter stands 4.8 m from the bottom of the 6.0-m ladder as shown in the figure. What are the magnitude and direction of the torque about the base of the ladder at P produced by the firefighter?