

Torque & Rotational Motion

Center of Mass

- Average location of an object's mass

The diagrams show: 1) A wheel with its center of mass at the center. 2) A map of the USA with its center of mass marked. 3) An L-shaped block with its center of mass at the corner. 4) A duck with its center of mass marked. 5) A crescent moon with its center of mass marked. 6) A meter stick with an upward arrow labeled 'Upward push by finger' and a downward arrow labeled 'Entire weight of stick' at the center.

Equilibrium

- A body is in stable equilibrium if it returns to its equilibrium position after it has been displaced slightly
 - Displacement raises cg
- A body is in unstable equilibrium if it does not return to its equilibrium position and does not remain in the displaced position after it has been displaced slightly.
 - Displacement lowers cg
- A body is in neutral equilibrium if it stays in the displaced position after it has been displaced slightly.
 - neither raises nor lowers cg

The diagrams show: 1) A cone on a flat surface with its center of mass (cg) below the point of contact, representing stable equilibrium. 2) A cone on a flat surface with its cg above the point of contact, representing unstable equilibrium. 3) A cone on a flat surface with its cg at the point of contact, representing neutral equilibrium.

Center of Mass Path

The diagram shows a wrench being thrown into the air. The path of the wrench is a parabola. The center of mass of the wrench follows a parabolic path. The acceleration of the center of mass is labeled as g .

- Projectile center of mass follows parabolic path.

Fosbury Flop

Dick Fosbury

- In the Fosbury Flop, the center of mass of the high jumper actually passes under the bar.

Concept Test

- A meter stick is suspended at the center. If a 1 kg weight is placed at $x=0$. Where do you need to place a 2 kg weight to balance it?

A) $x = 25$ B) $x = 50$ C) $x = 75$ D) $x = 100$
 E) 1 kg can't balance a 2 kg weight.

The diagram shows a meter stick with a fulcrum at the 50 cm mark. A 1 kg weight is placed at the 0 cm mark, and a 2 kg weight is placed at the 75 cm mark.

Torque

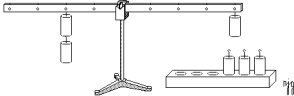
$\text{Torque} = \text{Force} \times \text{Torque Arm}$

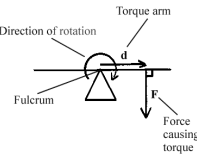
Net Torque = 0 for rotational equilibrium


MECHANICS 1J40.20 STATICS OF RIGID BODIES

Static Torque
TORQUE BEAM

- Use different combinations of masses and distances to show torques in equilibrium.
- Distances from the pivot point are integer multiples: 1r, 2r, 3r, 4r.
- Masses are identical.







Torque

- Rotational effect of force. Tells how effective force is at twisting or rotating an object or at changing the rate of rotation.

$$\tau = \pm r F_{\text{perpendicular}} = r F \sin \theta$$

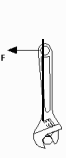
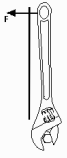
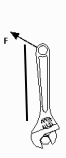
- Units N m
- Sign: CCW rotation is positive

Concept Test

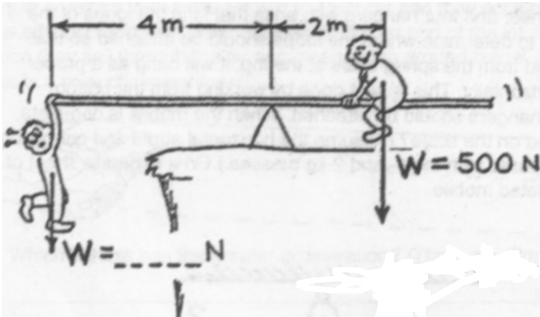
The picture below shows three different ways of using a wrench to loosen a stuck nut. Assume the applied force F is the same in each case.

In which of the cases is the torque on the nut the biggest?

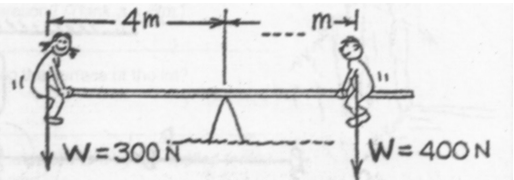
- Case 1
- Case 2
- Case 3

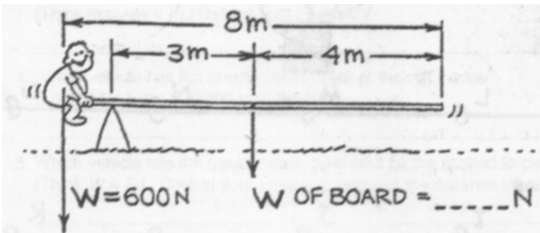
Torque Example 1



Torque Example 2

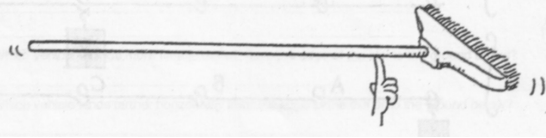


Torque Example 3

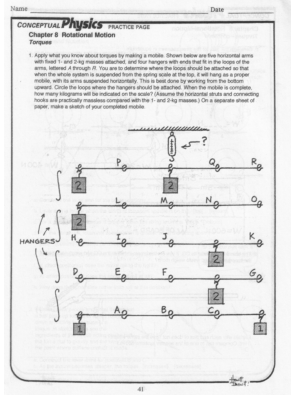


ConceptTest

The broom balances at its CG. If you cut the broom in half at the CG and weigh each part of the broom, which end would weigh more?

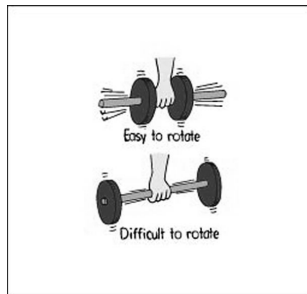


- a. the handle end
- b. the bristle end
- c. they weigh the same



Rotational Inertia

- Resistance to a change in rotational motion
- Depends on the distribution of the mass about the axis of rotation

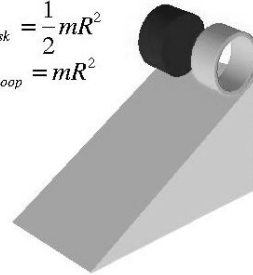


$$\sum mr^2$$

Hoop versus Disk

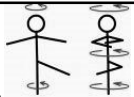
$$I_{\text{disk}} = \frac{1}{2}mR^2$$

$$I_{\text{hoop}} = mR^2$$



- A solid cylinder will reach the bottom first because of its lesser rotational inertia.

Angular Momentum



- Linear Momentum: mass x velocity
- Angular Momentum:
 - rotational inertia x angular velocity
- An object or system of objects will maintain its angular momentum unless acted upon by an unbalanced external torque.

