Torque

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- In order to make an object start rotating about an axis, you need a force.
- The direction of this force, and where it is applied, affects the rotation.

- Say you want to push open a door. It is very difficult to push it open if you apply your force near the hinge.
- The reason that doorknobs are always as from from the hinge side of the door as possible is because your force is more effective when it is applied far from the axis of rotation.

- This is the same principle that allowed the 100 g mass to balance the 200 g mass in the lab. By placing the 100 g mass twice as far from the axis of rotation as the 200 g mass, it was able to provide the same amount of **torque** as the heavier object.

Torque

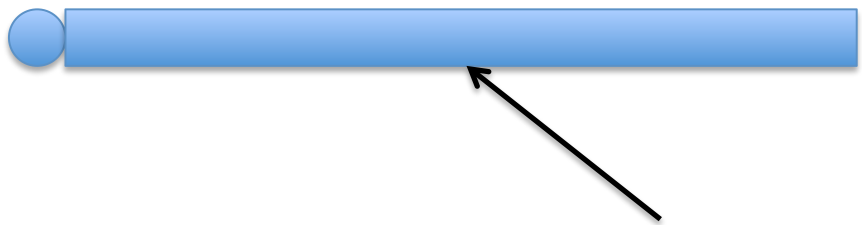
- Torque is the product of force x lever arm, where lever arm is the distance between the force and the axis of rotation.
- The unit of torque is the newton-meter [Nm].
- The direction of torque is clockwise (CW +) or counterclockwise (CCW -).

$$\tau = r \times F$$

Ex: A 15 kg mass is placed on a seesaw 30 cm to the left of the fulcrum. Where can a 5 kg mass be placed to balance the seesaw?

- In the torque lab, your groups figured out that $m_1r_1=m_2r_2$. Technically, this should be $F_1r_1=F_2r_2$, but since we can divide through by g, the first equation works for balancing the seesaw with weights.

- The direction of the force also matters. The diagram shows a bird's eye view of a door being rotated about its hinge on the left side.



- This force can be broken into two components – the part of the force perpendicular to the lever arm and the part of the force parallel to the lever arm.
- Only the **perpendicular** component exerts torque.
- Torque is a cross product (unlike work, which is a dot product).
- To find the magnitude of the torque, multiply the force by the lever arm and multiply by the **sine of the angle between force and lever arm**.

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

- This picks out the part of the force in the direction perpendicular to the lever arm.

Ex: A person exerts a force of 28 N on the end of a door that is 84 cm wide.

What is the magnitude of the torque if the force is exerted

(a) perpendicular to the door?

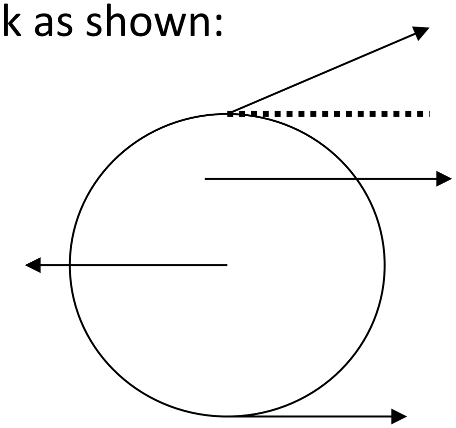
(b) at a 60º angle to the face of the door?

- Torque = rotational analogue of force. Forces cause acceleration. **Torques cause angular accelerations, that is, rotations.**

$$\sum F = ma \qquad\qquad \sum \tau = I\alpha$$

Ex: The disk shown to the right has a mass of 20 kg and a radius of 3.0 m and is free to rotate about an axis through its center. Four forces act on the disk as shown:

7 N at r = 0 m,
10 N at r = 2.0 m,
6 N at r = 3.0 m
8 N at r = 3.0 m at 30° to a line tangent to the disk.



Determine: (a) the net torque on the disk,
(b) the rotational inertia of the disk,
(c) the angular acceleration of the disk, and
(d) the tangential acceleration of a point on the rim of the disk?

Ex: A young mom pushes tangentially on a small merry-go-round and is able to accelerate it from rest to a spinning rate of 30 rpm in 10.0 s. Assume the merry-go-round is a disk of radius 2.5 m and has a mass of 800 kg, and two children (each with a mass of 25 kg) sit opposite each other on the edge. Ignore friction.

Find:

(a) the moment of inertia of the merry-go-round with children onboard

(b) the angular acceleration of the merry-go-round

(c) the minimum force required to achieve that torque.

Ex: An 80-gram meter stick is bolted to a wall on one end and supported by a thin string on the other end so that it lies parallel to the ground. The string is cut and the meter stick rotates about the bolted end. At the moment the string is cut, what is the angular acceleration of the meter stick?