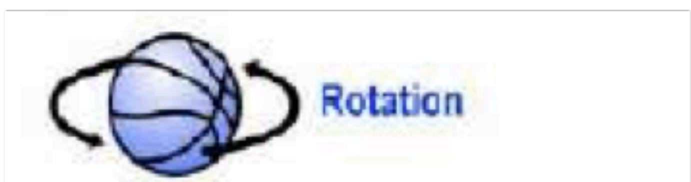
# Getting objects to Rotate

- **Net Force** is needed to get an object to move

$F = ma$

- **Net Torque** is needed to get an object to rotate

$\tau$



# Torque

- Newton's second law of rotation

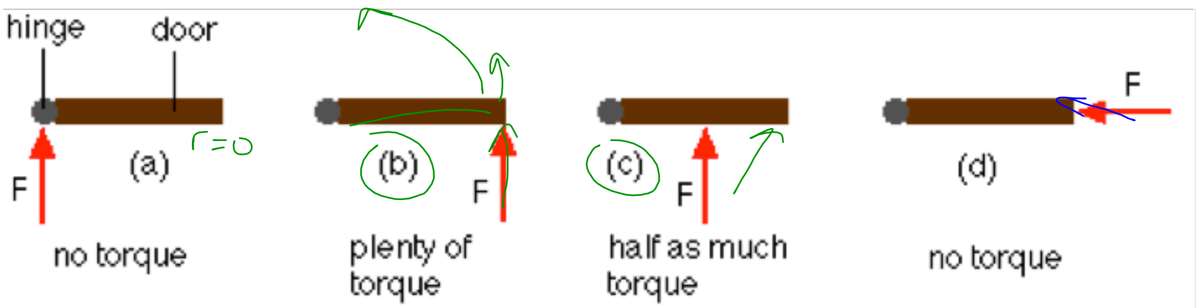
F = ma (Forces cause masses to accelerate)

$\tau = rxF$ sinθ (Torque cause masses to rotate)

r: radius, distance from axis of rotation; x: cross product

$$\begin{bmatrix} 2 & 2 \\ 1 & 0 \end{bmatrix}$$

- Torque are most effective when applied . . . perpendicularly



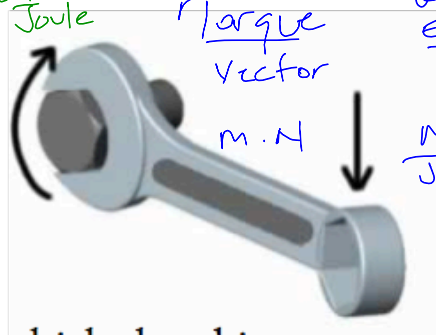
# Torque

- Torque ( $\tau$ ) – the ability of a force to turn an object about an axis. 'Turning Power
  - **SI Units: Newton meter (m N)**

F . d → Work Joule

m N

$\tau = r \times F \sin\theta$



Torque Vector m · N

Work Energy Scalar N · m Joule

- Vocab:
  - Axis of rotation - the point around which the object rotates
  - Lever arm (radius) - the distance from the axis of rotation to the applied force

# Effectiveness of Torque

- Only forces perpendicular to the lever arm will cause any movement. *Or a perpendicular component

$$\tau = r \perp F \longrightarrow \tau = rF\sin\theta$$

- r = distance of lever arm
- F = force

$\tau = r \times F \sin\theta$

$\tau = (5)\, 8 \sin 90°$

$\tau = 40$ m·N

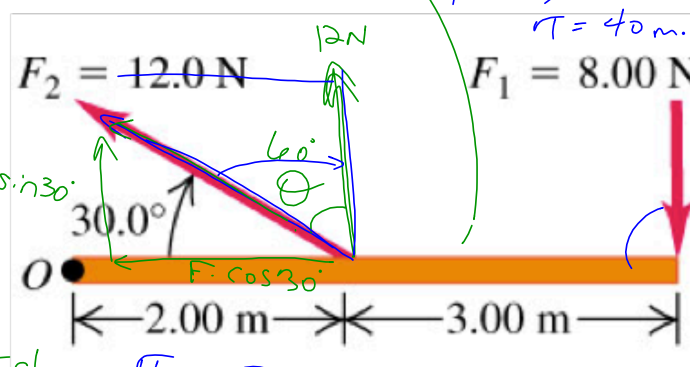
- The θ is the angle needed to give you the perpendicular component

$\tau = r \times F \sin\theta$

$\tau = (2)(12) \sin 30°$

$\tau = 12$ m·N

counterclo

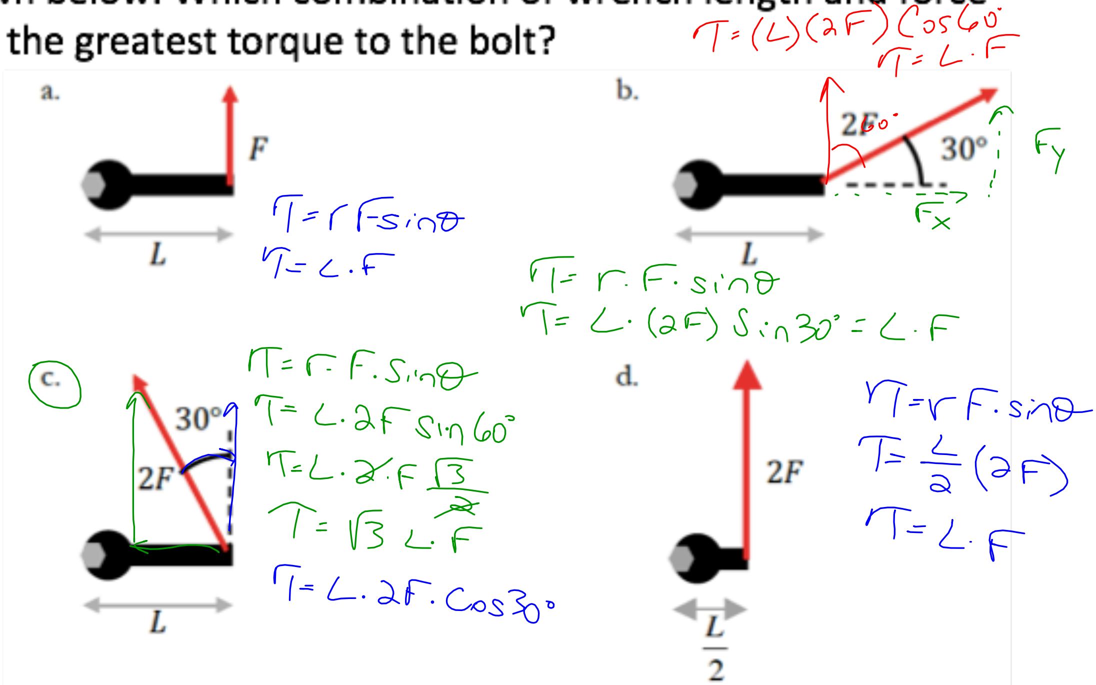



$\tau = r F \cos 60°$

$(2)(12) \cos 60°$

# Torque Practice

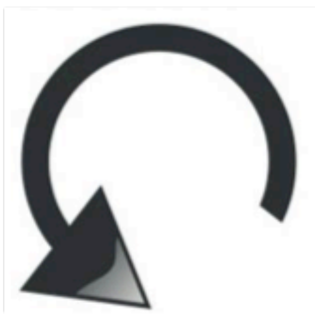
A series of wrenches of different lengths is used on a hexagonal bolt, as shown below. Which combination of wrench length and force applies the greatest torque to the bolt?



# Directions for Torque

*By convention

- Positive: Counter-clockwise
- Negative: Clockwise



# Example 4

Calculate the net torque about the axel of the wheel shown assume that there is a frictional torque of 0.40 Nm that opposes the resulting motion.

$\Sigma \tau = \tau_3 - \tau_2 - \tau_1 \; (-0.40)$

$\Sigma \tau = (0.24)(28)\sin 90^\circ - (0.12)(35)\sin 90^\circ - (0.24)(18)\sin 90^\circ$

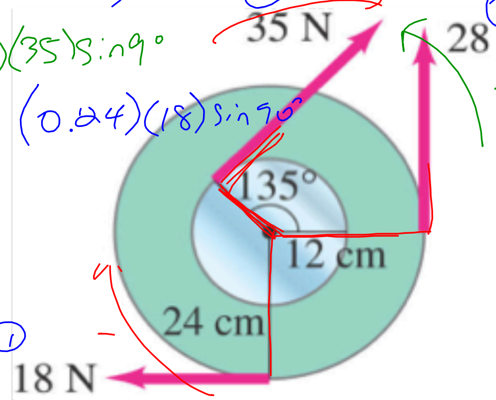
$\Sigma \tau = 6.72 - 4.2 - 4.32$

$\Sigma \tau = -1.8$

$\Sigma \tau = -1.4$ m·N

$\Sigma \tau = -2.2$

$\Sigma F$




$a = -1$ $\quad a = -100$

# Example 5

For the wheel-axle system shown, which of the following expresses the condition required for the system to be in static equilibrium?

A. $m_1 = m_2$

B. $a\ m_1 = b\ m_2$

C. $a\ m_2 = b\ m_1$

D. $a^2\ m_1 = b^2\ m_2$

E. $b^2 m_1 = a^2\ m_2$

$\Sigma \tau = a \cdot m_1 \cdot g \sin 90° - b\, m_2 \cdot g \cdot \sin 90°$

$0 = a\, m_1 g \sin 90° - b m_2 g \sin 90°$

$b m_2 g \sin 90° = a m_1 g \sin 90°$

$b m_2 = a m_1$

$F_g$ is causing torque

$F_g = mg$