Center of Mass

We will need to determine the center of mass of objects for upcoming problems. The center of mass is a point in an object where the mass seems to be concentrated.

Types of Motion - Large Objects

The motion of large objects can be divided into two types, ***translational*** and ***rotational***.

translational motion - the motion of an object from one point to another

rotational motion - the motion of an object about one point (pivot point or fulcrum)

Physics - McGraw-Hill Ryerson, Page 491

Torque can be defined as:

$$\vec{\tau} = r\vec{F}\sin\theta$$

τ^* -> torque (Nm) $= rF_\perp$

* this symbol represents the Greek letter *tau*

r -> distance from pivot point to the application of the force (m)

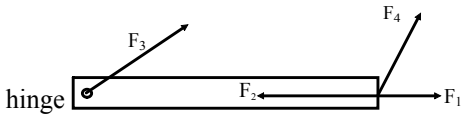
F -> force applied (N)

θ -> angle between r and F when they start at the same point (degrees)

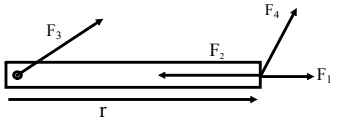
Torque is a ***vector***. The direction of torque is based on the direction in which the force would cause the object to rotate if it were acting alone.

CW: clockwise (-)
CCW: counter-clockwise (+)

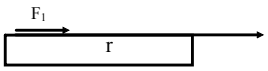
The diagram below shows four forces acting on a door. Which forces will cause the door to rotate?



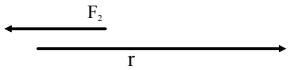
Only the component of F_4 perpendicular to r produces torque.



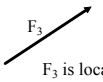
We can verify our previous answers by examining the equation.



F_1: $\theta = 0^o$
$\sin 0^o = 0$
$\tau = 0$ Nm

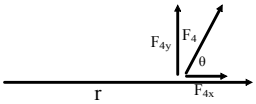


F_2: $\theta = 180^o$
$\sin 180^o = 0$
$\tau = 0$ Nm



F_3 is located at the pivot point.

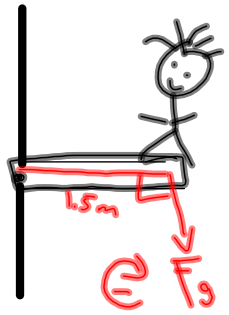
F_3: r = 0 m
$\tau = 0$ Nm



F_4: $r \neq 0$ m and $\sin\theta \neq 0$
F_{4x} will cause the door to rotate!

Label the Pivot Point

Example: A 490 N man stands at the end of a diving board at a distance of 1.5 m from the point at which it is attached to the tower. What is the torque the man exerts on the board? (735 Nm, CW or -735 Nm)

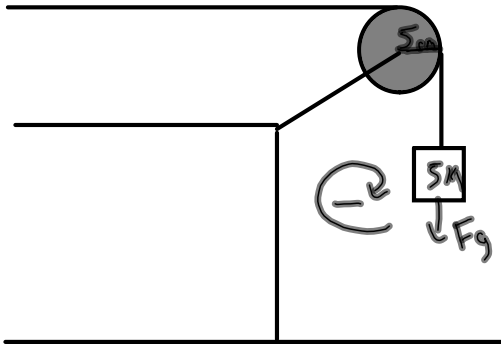


$\tau = r F \sin\theta$

$\tau = (1.5\,m)(490)\sin 90°$

$\tau = 735\ Nm\ CW$

Example: A 5.0 kg mass is attached as shown to a pulley of radius 5.0 cm. What torque is produced by the mass? (2.5 Nm, CW or -2.5 Nm)



$r = 5\,cm = 0.05\,m$

$F_g = mg = (5\,kg)(9.8\,m/s^2)$

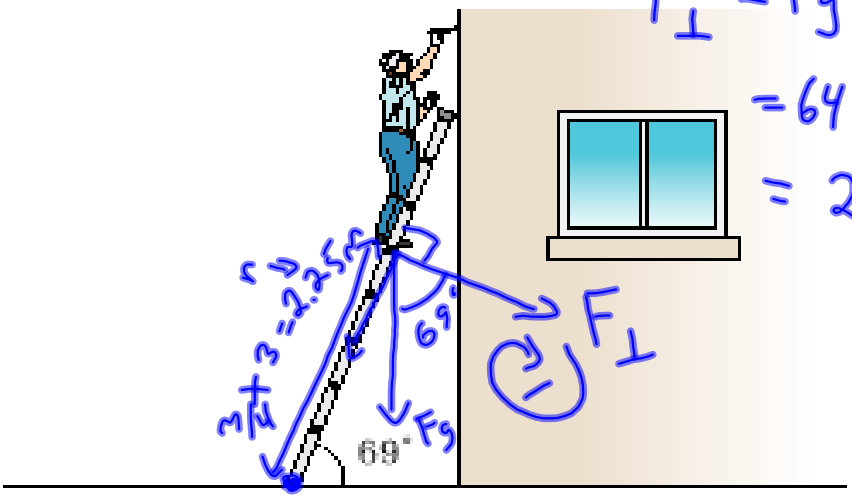
$= 49.05\,N$

$\tau = r F \sin\theta$

$\tau = (0.05)(49)\sin 90°$

$\tau = 2.5\ CW$

Example: A 64 kg painter is standing three fourths of the distance up a ladder that is 3.0 m long. If the ladder makes an angle of 69° with the ground, what torque does the painter's weight exert on the ladder? (5.1×10^2 Nm, CW)



$F_\perp = F_g \cos 69°$

$= 64 \times 9.81 \cos 69°$

$= 225$ N

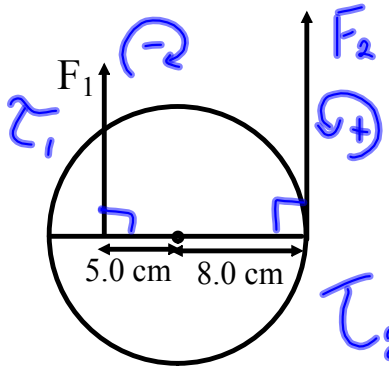
$\tau = r F_\perp = (2.25\text{ m})(225\text{ N})$

$= 506$ Nm CW

Net Torque

Just as net force sometimes plays a part in a problem, so does net torque. Net torque is the vector sum of all torques.

Example: Two forces act on the cylinder as shown in the diagram below. If $F_1 = 10$ N and $F_2 = 15$ N, what is the net torque on the cylinder? (0.70 Nm, CCW)



τ_1 (−) $F_2 \cdot \tau_2$ (+)

$\tau_1 = (0.05)(10)$

$\tau_1 = -0.5$ Nm

$\tau_2 = (0.08)(15\text{ N}) = +1.2$

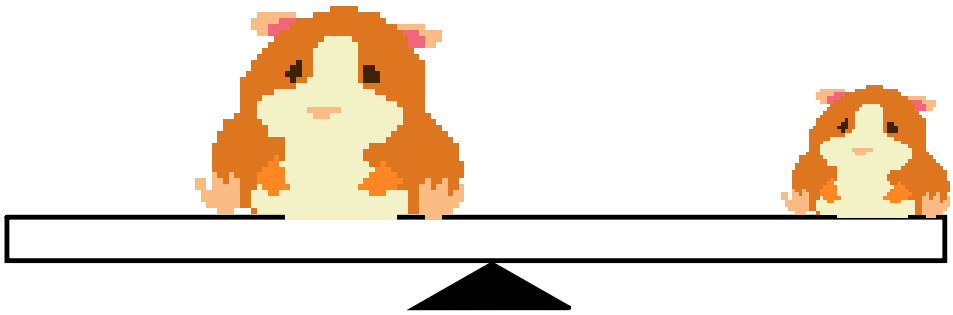
$\tau_{net} = \sum \tau_{torques}$

$= \tau_1 + \tau_2$

$= -0.5$ Nm $+ 1.2$ Nm

$= +0.7$ Nm

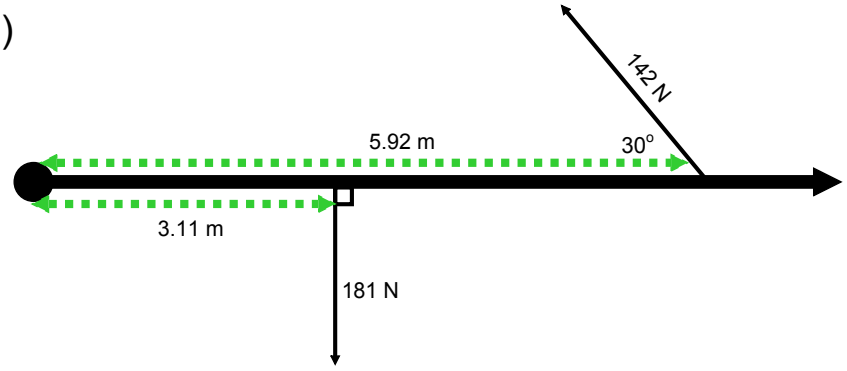
Example: A massless board serves as a seesaw for two giant hamsters as shown below. One hamster has a mass of 30 kg and sits 2.5 m from the pivot point. At what distance from the pivot point must a 25 kg hamster place himself to balance the seesaw? (3.0 m)



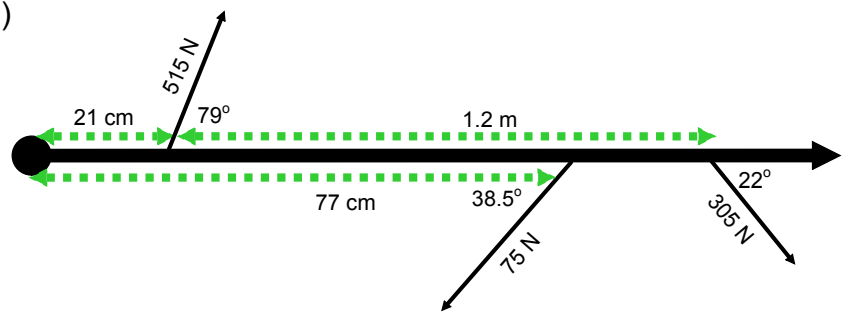
•

Net Torque Practice

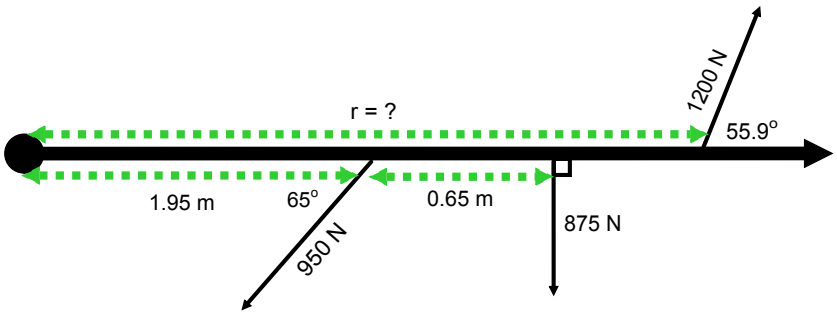
#1)



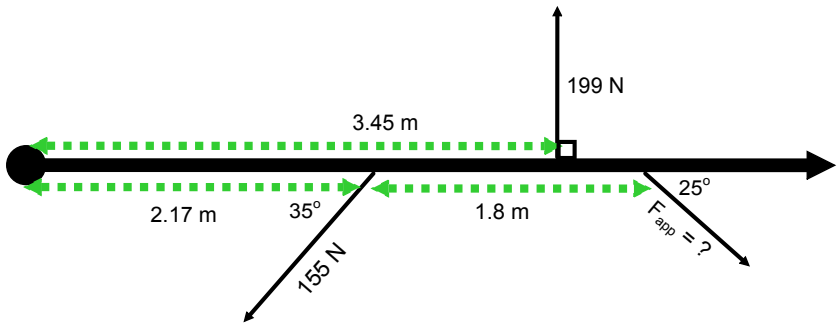
#2)



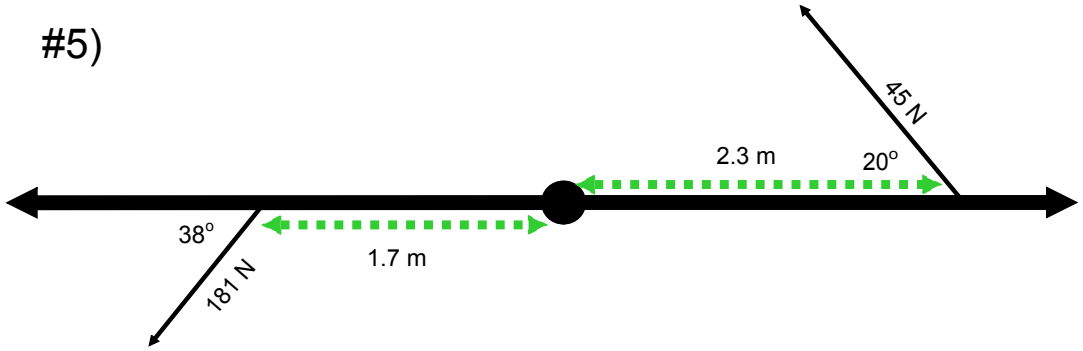
#3) τ_{net} = 0 Nm



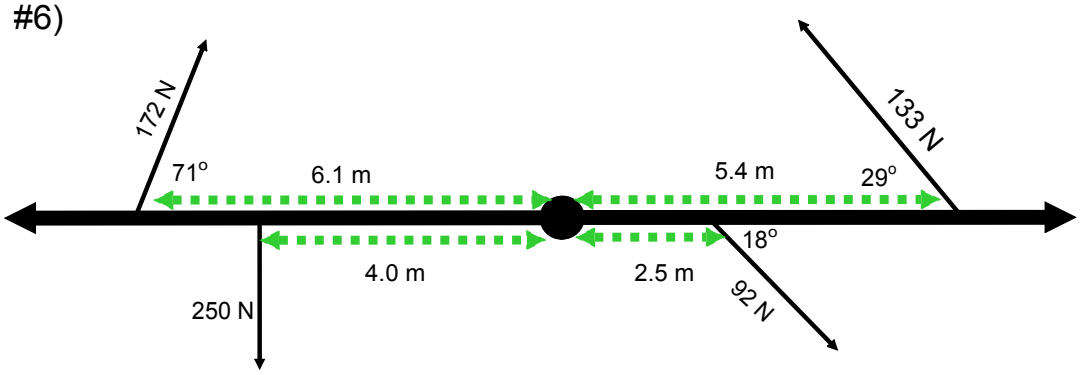
#4) τ_{net} = 0 Nm



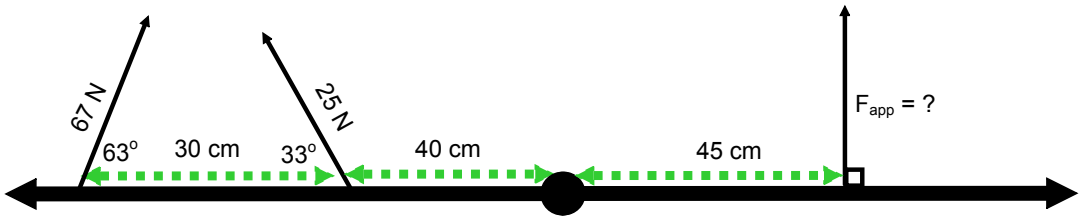
#5)



#6)



#7) τ_{net} = 0 Nm



#8) τ_{net} = 0 Nm