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)

Figure 10.15 The wrench is rotating around the mark on the wrench while the mark is moving in a straight line.

Physics - McGraw-Hill Ryerson, Page 491

Torque (MHR - Page 490)

Torque occurs when a force is applied to an object and that force causes the object to rotate.

"Seesaw" Demonstration

1. Balance the rod on the coffe can.

2. a) What happens if a 20 g mass is placed at the center of the seesaw (the pivot point)?

   Even though a force has been applied to the rod, the rod does not rotate.

   b) What happens if a 20g mass is placed to the right of the pivot point?

   The rod rotates, therefore torque has been produced.

   c) What was different about the two trials?

   A force must be applied at some distance from the pivot point.

3. Place a 20 g mass on one side of the pivot point. Where would another 20 g mass have to be placed in order to keep the rod balanced?

   The second mass must be placed at the same distance from the pivot point as the first, but on the other side of the pivot point.

4. Place a 50 g mass on one side of the pivot point. Where would a 100 g mass have to be placed in order for the masses to be in a state of equilibrium?

   The 100 g has to be placed at half the distance from the pivot point as the 50 g mass.

☆

Torque can be defined as:

$$\tau = r F_{\perp} = r F \sin\theta$$

τ * -> torque (Nm)

* this symbol represents the Greek letter *tau*

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

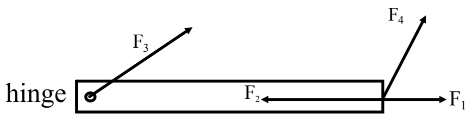
F -> force applied (N)

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

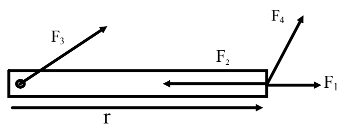
Torque is a ***vector***. The direction of torque is based on the direction in which the force would cause the object to rotate if it were acting alone.

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

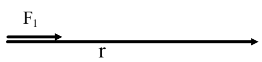
The diagram below shows four forces acting on a door. Which forces will cause the door to rotate?



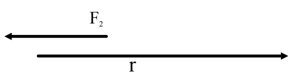
Only the component of F_4 perpendicular to r produces torque.



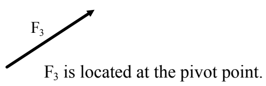
We can verify our previous answers by examining the equation.



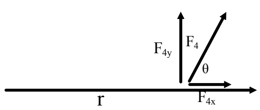
F_1: $\theta = 0^\circ$
$\sin 0^\circ = 0$
$\tau = 0$ Nm



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



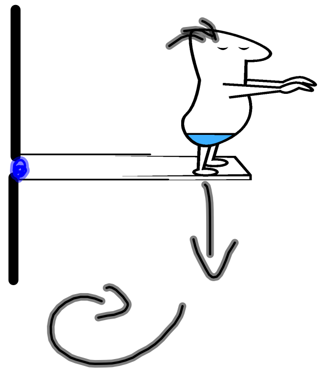
F_3: $r = 0$ m
$\tau = 0$ Nm



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~~ Mr. Martin 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)



$\tau = r F_{\perp}$

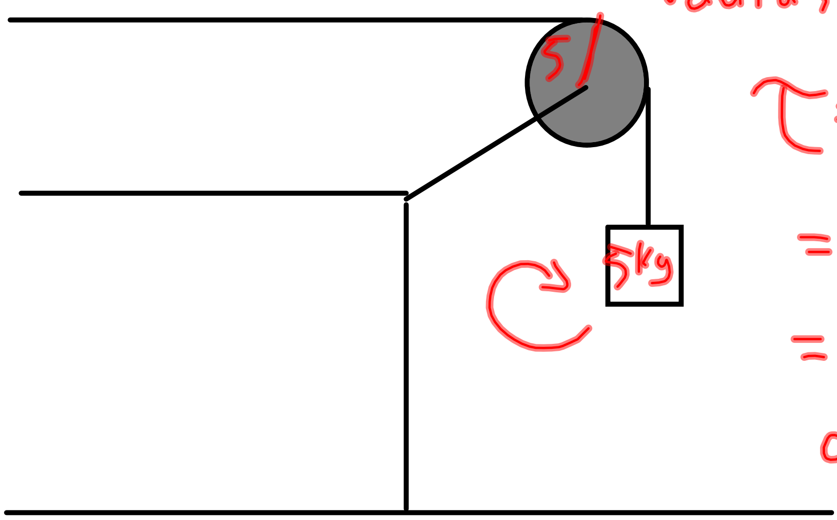
$= (1.5\,m)(490)$

$= 735$ Nm CW

or -735 Nm

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)

radius = 0.05 m



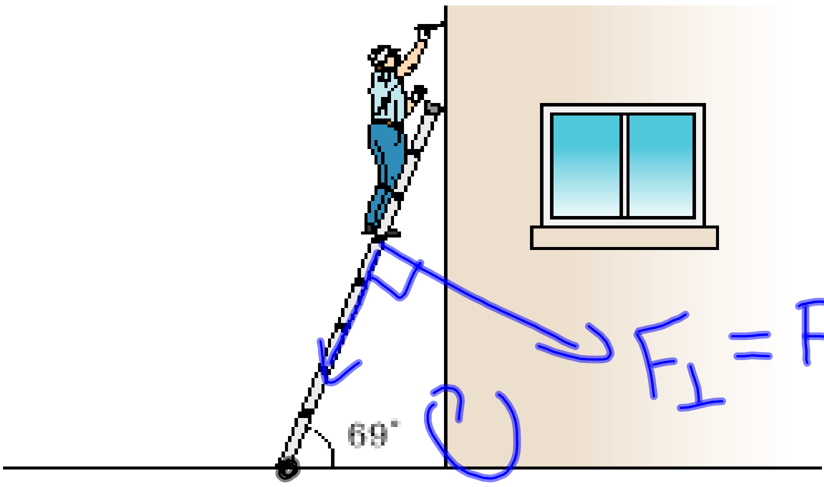
$\tau = r F_{\perp}$

$= (0.05)(5)(9.81)$

$= 2.5$ Nm CW

or -2.5 Nm

<u>Example</u>: 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)



$F_\perp = F\cos\theta$

$\tau = rF_\perp = rF\cos\theta$

$= (0.75)(3\,m)(64)(9.81)\cos 69°$

≈ 510 Nm, CW

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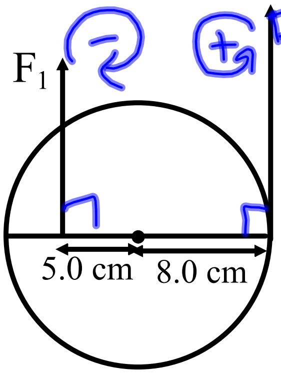
Net Torque

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

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

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)



(+) CCW

$$\tau_1 = r_1 F_1 \qquad \tau_2 = r_2 F_2$$

$$\tau_1 = -(0.05)(10) = -0.5 \text{ Nm}$$

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

$$\tau_{net} = \tau_1 + \tau_2$$

$$= -0.5 + 1.2$$

$$\boxed{= +0.7 \text{ Nm}}$$

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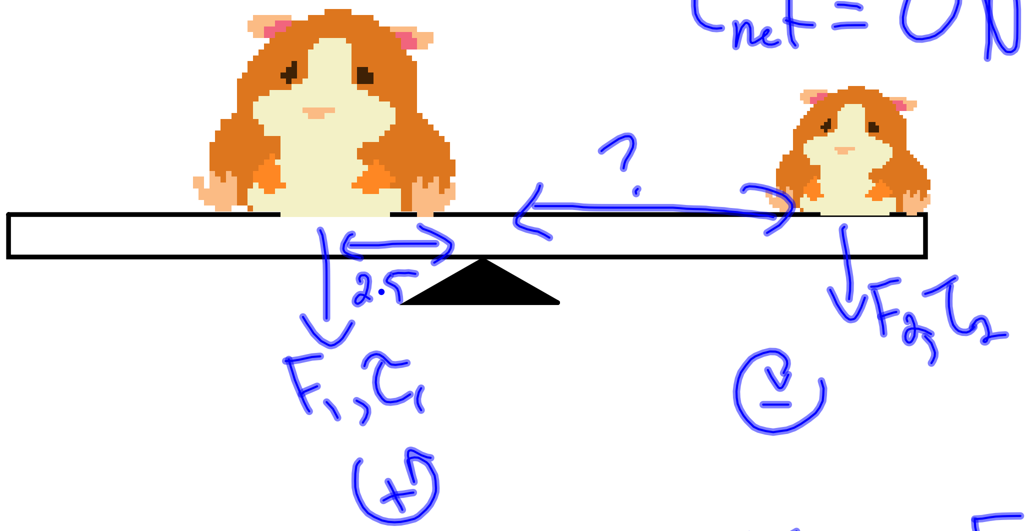
Example: A massless board serves as a seesaw for two giant hamsters as shown below. One hamster has a mass of 30 kg and sits 2.5 m from the pivot point. At what distance from the pivot point must a 25 kg hamster place himself to balance the seesaw? (3.0 m)

$\tau_{net} = 0 \text{ Nm}$



$\tau_1 = r_1 F_1$

$= +(2.5)(30)(9.81)$

$\tau_2 = r_2 F_2$

$= -r_2(25)(9.81)$

$\tau_{net} = \tau_1 + \tau_2$

$0 = +(2.5)(30)(\cancel{9.81}) - r_2(25)(\cancel{9.81})$

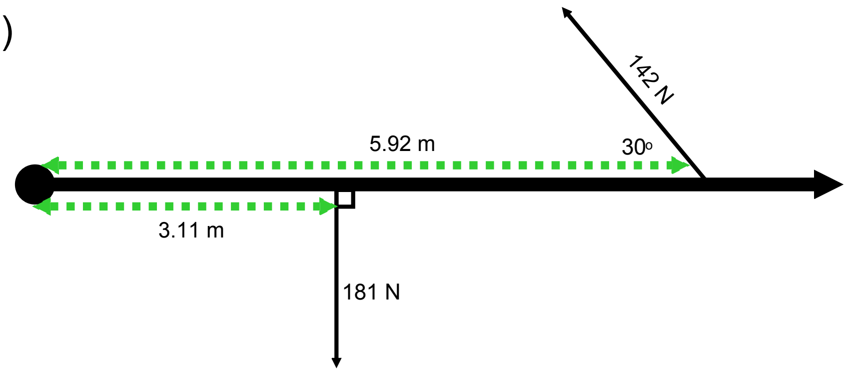
$0 = 75 - 25r_2$

$-75 = -25r_2$

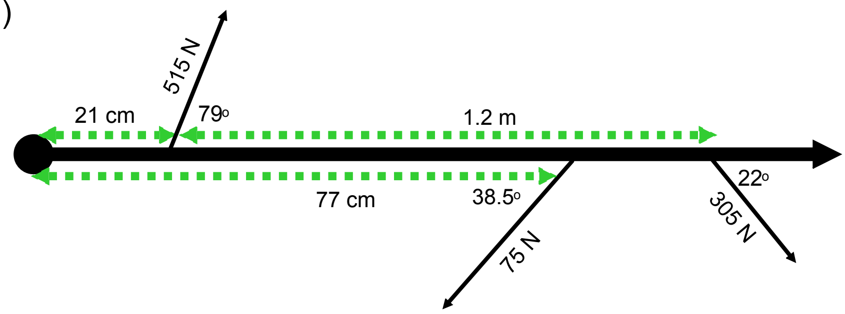
$\boxed{3.0\text{ m} = r_2}$

Net Torque Practice

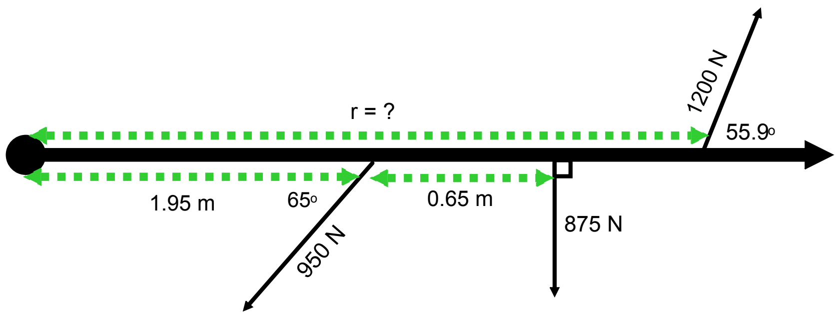
#1)



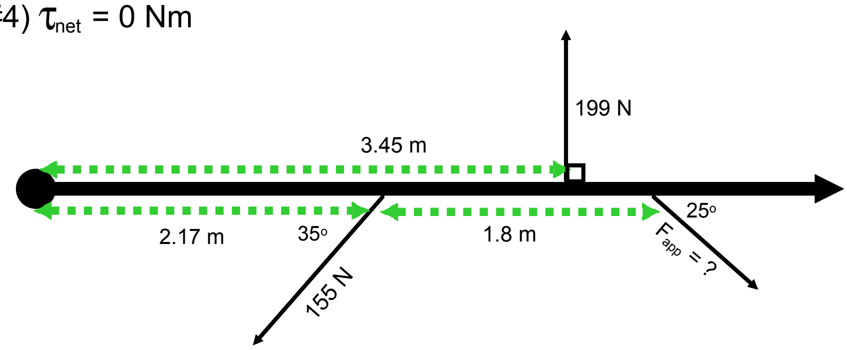
#2)



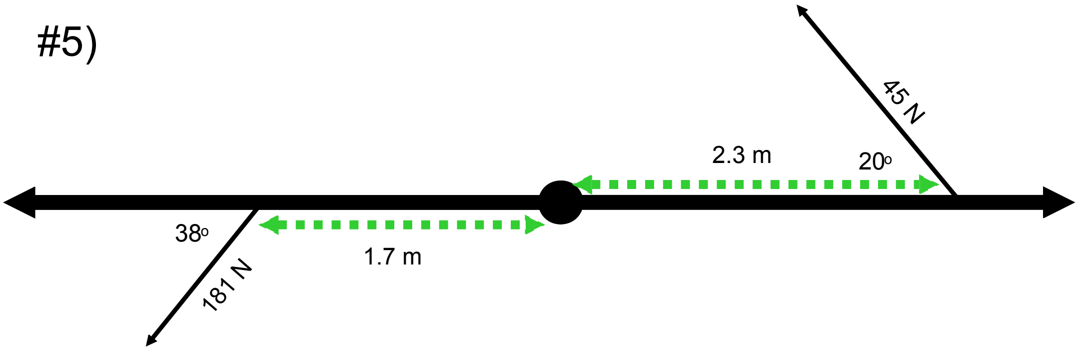
#3) τ_{net} = 0 Nm



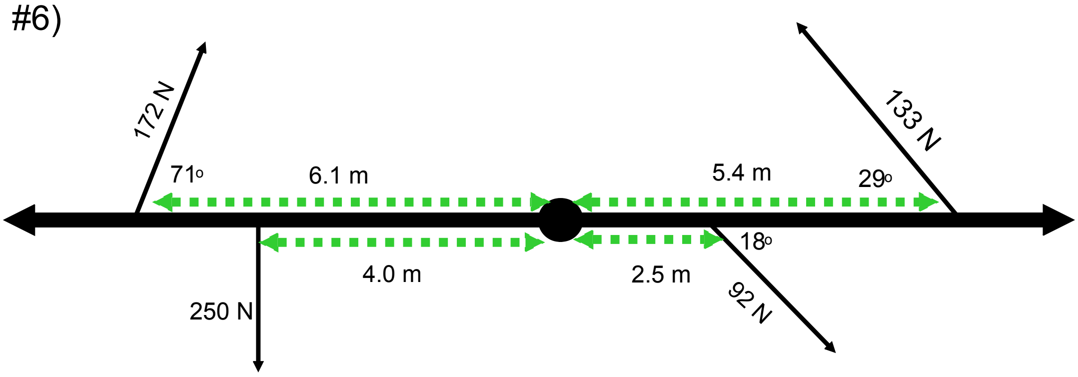
#4) τ_{net} = 0 Nm



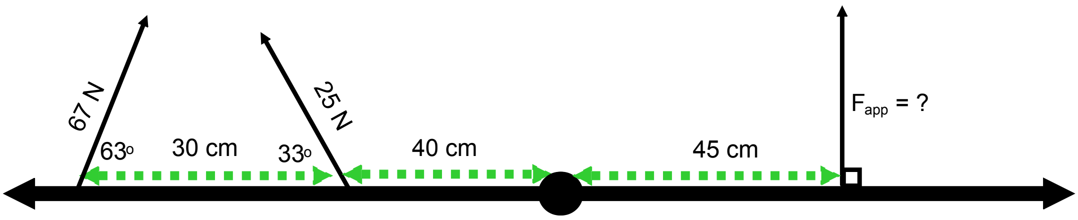
#5)



#6)



#7) τ_{net} = 0 Nm



#8) τ_{net} = 0 Nm