Today 11.1, 11.2, 11.3

$\boxed{L33}$

Today 11.1, 11.2, 11.3

$\boxed{L33}$

Conditions for equilibrium

Today 11.1, 11.2, 11.3

$\boxed{L33}$

Conditions for equilibrium

Center of gravity

Today 11.1, 11.2, 11.3

L33

Conditions for equilibrium

Center of gravity

Solving rigid-body equilibrium problems

Today 11.1, 11.2, 11.3

$\boxed{L33}$

Wednesday 11.4, 11.5

Today 11.1, 11.2, 11.3

$\boxed{L33}$

Wednesday 11.4, 11.5

Stress,

Strain,

Elastic

Moduli

Today 11.1, 11.2, 11.3

L33

Wednesday $\underbrace{11.4}$, $\underbrace{11.5}$

Stress,
Strain,
Elastic
Moduli

Elasticity
& plasticity

ASU

Today 11.1, 11.2, 11.3

Wednesday 11.4, 11.5

L33

SI session today

Today 11.1, 11.2, 11.3

Wednesday 11.4, 11.5

L33

SI session today

* 5:00 to 6:00 pm

Today 11.1, 11.2, 11.3 $\boxed{L33}$

Wednesday 11.4, 11.5

SI session today

* 5:00 to 6:00 pm
* Conditions of equilibrium (§11.1)

Today 11.1, 11.2, 11.3

Wednesday 11.4, 11.5

L33

SI session today

* 5:00 to 6:00 pm
* Conditions of equilibrium (§11.1)
* Center of gravity (§11.2)

<u>Today</u> 11.1, 11.2, 11.3 $\boxed{L33}$

<u>Wednesday</u> 11.4, 11.5

<u>Important dates:</u>

Today 11.1, 11.2, 11.3

L33

Wednesday 11.4, 11.5

Important dates:

* Friday Nov. 27th no class

Today 11.1, 11.2, 11.3

L33

Wednesday 11.4, 11.5

Important dates:

* Friday Nov. 27th no class
* Monday Nov 30th Exam 4

Today 11.1, 11.2, 11.3

Wednesday 11.4, 11.5

L33

Important dates:

* Friday Nov. 27th no class
* Monday Nov 30th Exam 4
* Wednesday Dec 2nd Day of Reckoning

Today 11.1, 11.2, 11.3

Wednesday 11.4, 11.5

L33

Important dates:

* Friday Nov. 27th no class
* Monday Nov 30th Exam 4
* Wednesday Dec 2nd Day of Reckoning
* Friday Dec 4th Final exam

Conditions for equilibrium

Conditions for equilibrium

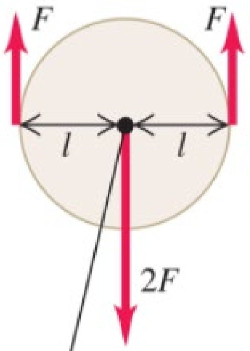
First condition: $\sum \vec{F} = 0$

Conditions for equilibrium

First condition: $\sum \vec{F} = 0$

Second condition: $\sum \vec{\tau} = 0$

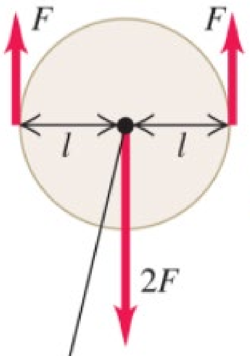
(a) This object is in static equilibrium.



Axis of rotation (perpendicular to figure)

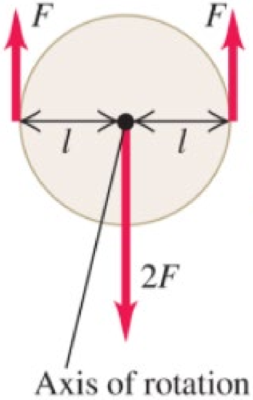
(a) This object is in static equilibrium.

Equilibrium conditions:



Axis of rotation (perpendicular to figure)

(a) This object is in static equilibrium.

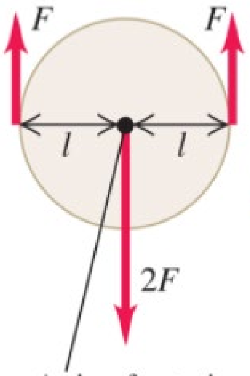


Equilibrium conditions:

First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

(a) This object is in static equilibrium.

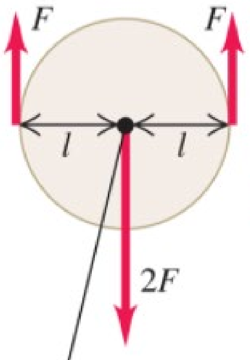
Equilibrium conditions:



First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition satisfied:
Net torque about the axis = 0, so object at rest has no tendency to start rotating.

(a) This object is in static equilibrium.



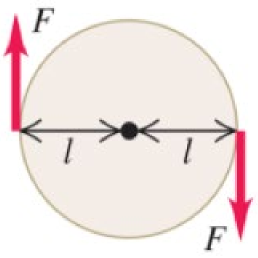
Equilibrium conditions:

First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition satisfied:
Net torque about the axis = 0, so object at rest has no tendency to start rotating.

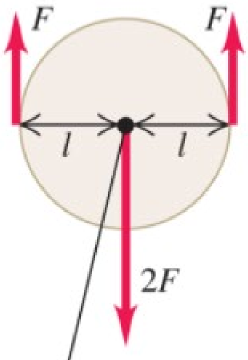
Axis of rotation (perpendicular to figure)

(b) This object has no tendency to accelerate as a whole, but it has a tendency to start rotating.



(a) This object is in static equilibrium.

Equilibrium conditions:

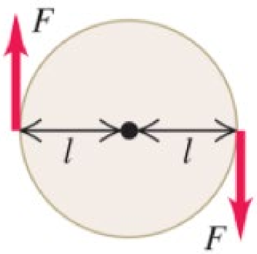


First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition satisfied:
Net torque about the axis = 0, so object at rest has no tendency to start rotating.

Axis of rotation (perpendicular to figure)

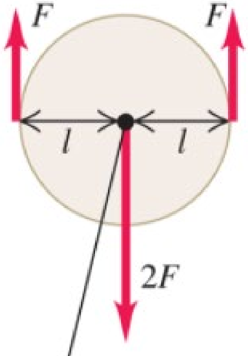
(b) This object has no tendency to accelerate as a whole, but it has a tendency to start rotating.



First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

(a) This object is in static equilibrium.

Equilibrium conditions:

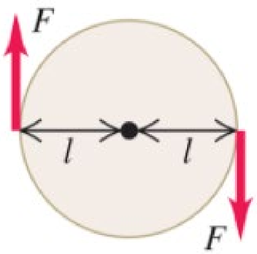


Axis of rotation (perpendicular to figure)

First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition satisfied:
Net torque about the axis = 0, so object at rest has no tendency to start rotating.

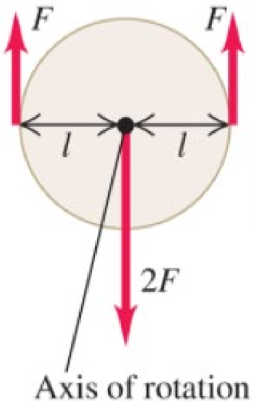
(b) This object has no tendency to accelerate as a whole, but it has a tendency to start rotating.



First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition NOT satisfied: There is a net clockwise torque about the axis, so object at rest will start rotating clockwise.

(a) This object is in static equilibrium.

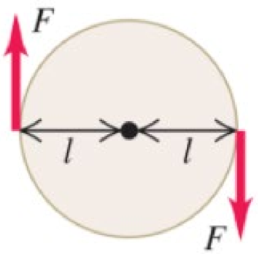


Equilibrium conditions:

First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition satisfied:
Net torque about the axis = 0, so object at rest has no tendency to start rotating.

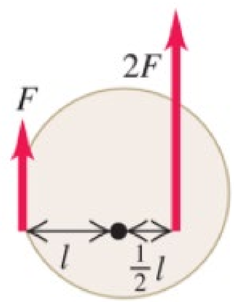
(b) This object has no tendency to accelerate as a whole, but it has a tendency to start rotating.



First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

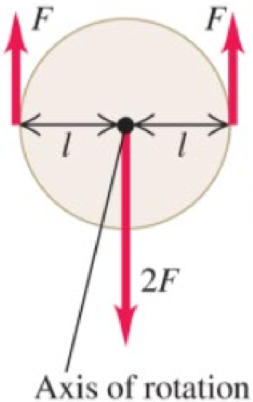
Second condition NOT satisfied: There is a net clockwise torque about the axis, so object at rest will start rotating clockwise.

(c) This object has a tendency to accelerate as a whole but no tendency to start rotating.



(a) This object is in static equilibrium.

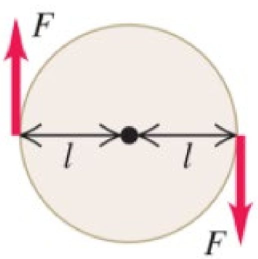
Equilibrium conditions:



First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition satisfied:
Net torque about the axis = 0, so object at rest has no tendency to start rotating.

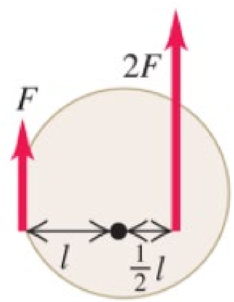
(b) This object has no tendency to accelerate as a whole, but it has a tendency to start rotating.



First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

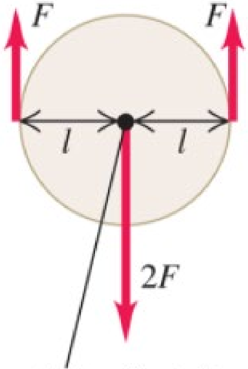
Second condition NOT satisfied: There is a net clockwise torque about the axis, so object at rest will start rotating clockwise.

(c) This object has a tendency to accelerate as a whole but no tendency to start rotating.



First condition NOT satisfied: There is a net upward force, so object at rest will start moving upward.

(a) This object is in static equilibrium.



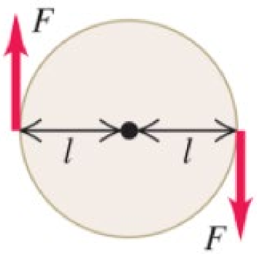
Axis of rotation (perpendicular to figure)

Equilibrium conditions:

First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition satisfied:
Net torque about the axis = 0, so object at rest has no tendency to start rotating.

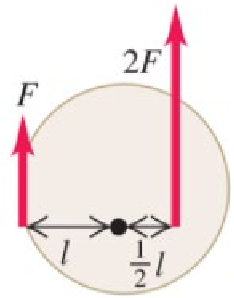
(b) This object has no tendency to accelerate as a whole, but it has a tendency to start rotating.



First condition satisfied:
Net force = 0, so object at rest has no tendency to start moving as a whole.

Second condition NOT satisfied: There is a net clockwise torque about the axis, so object at rest will start rotating clockwise.

(c) This object has a tendency to accelerate as a whole but no tendency to start rotating.

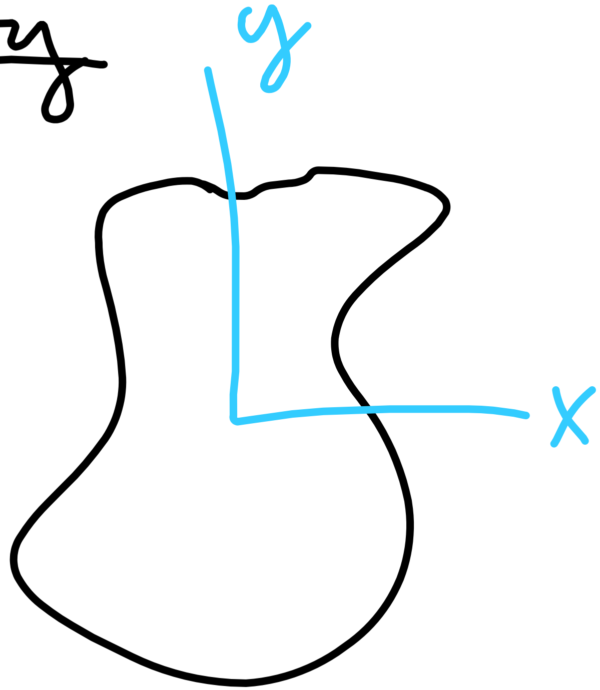


First condition NOT satisfied: There is a net upward force, so object at rest will start moving upward.

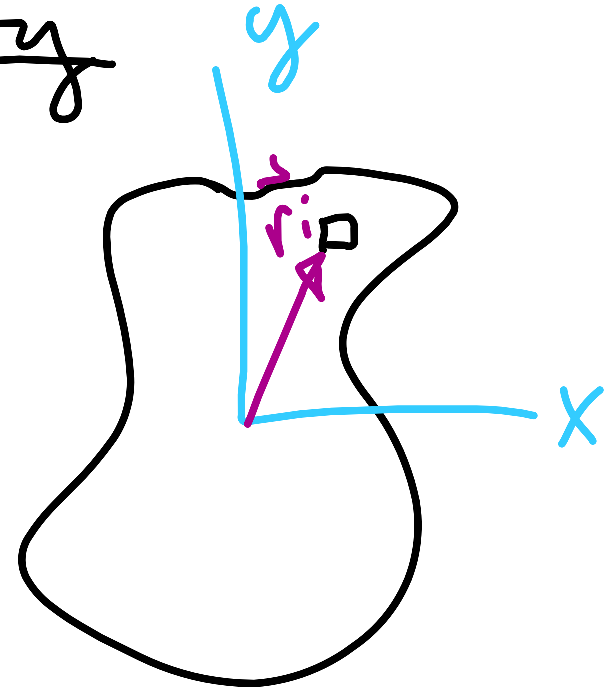
Second condition satisfied:
Net torque about the axis = 0, so object at rest has no tendency to start rotating.

Center of gravity

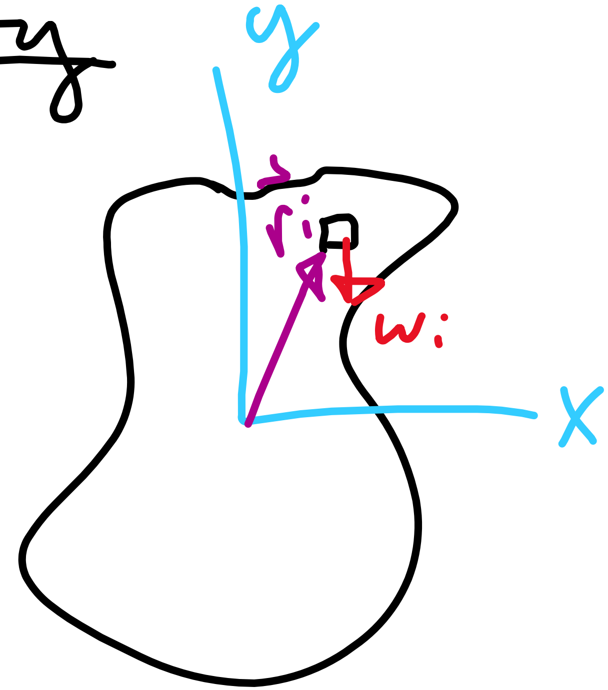
Center of gravity



Center of gravity

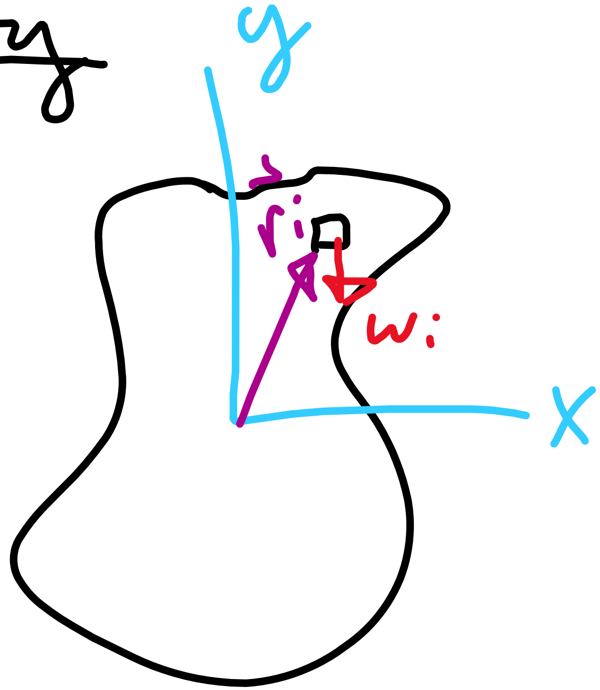


Center of gravity



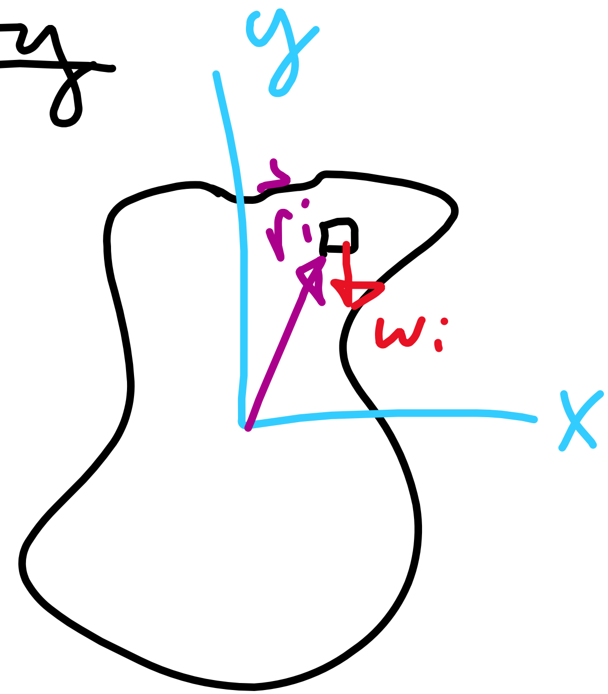
Center of gravity

$\vec{\tau} = \sum \vec{\tau}_i$



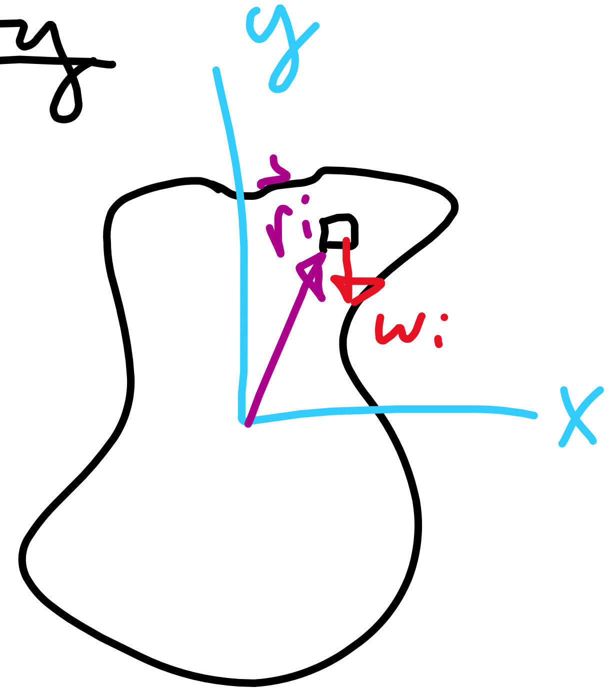
Center of gravity

$\vec{\tau} = \sum \vec{\tau}_i = \sum \vec{r}_i \times \vec{w}_i$



Center of gravity

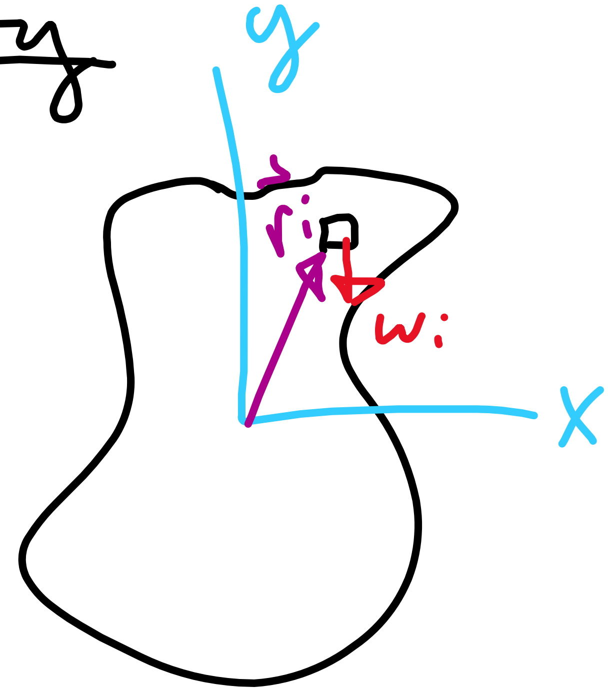
$$\vec{\tau} = \sum \vec{\tau}_i = \sum \vec{r}_i \times \vec{w}_i = \sum \vec{r}_i \times m_i \vec{g}$$



Center of gravity

$$\vec{\tau} = \sum \vec{\tau}_i = \sum \vec{r}_i \times \vec{w}_i = \sum \vec{r}_i \times m_i \vec{g}$$

$$\Rightarrow \vec{\tau} = \left(\sum \vec{r}_i m_i\right) \times \vec{g}$$

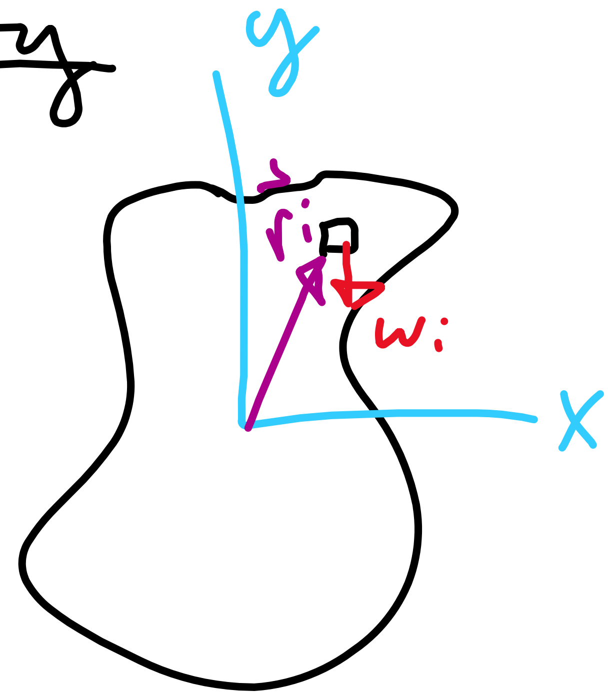


Center of gravity

$\vec{\tau} = \sum \vec{\tau}_i = \sum \vec{r}_i \times \vec{w}_i = \sum \vec{r}_i \times m_i \vec{g}$

$\Rightarrow \vec{\tau} = \left(\sum \vec{r}_i m_i\right) \times \vec{g}$ But

$\vec{r}_{cm} = \left(\sum \vec{r}_i m_i\right) / \left(\sum m_i\right)$



Center of gravity

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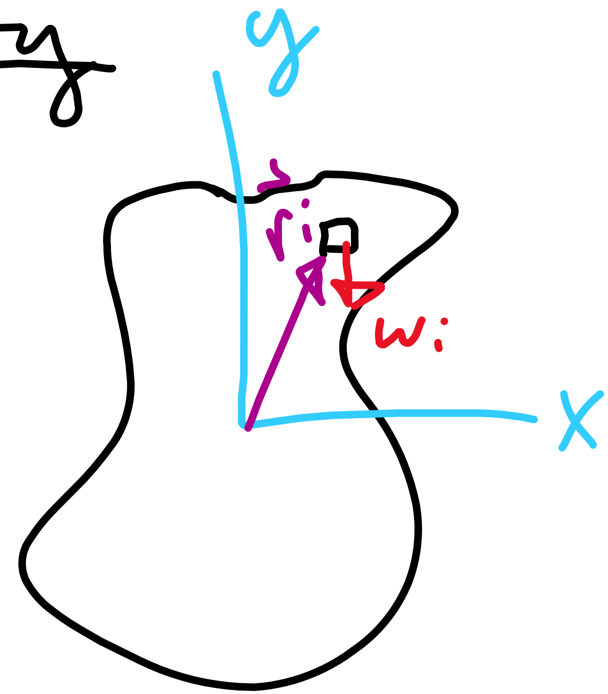
$\vec{r}_{cm} = \left(\sum \vec{r}_i m_i\right) / \left(\sum m_i\right)$ so

$\sum \vec{r}_i m_i = \vec{r}_{cm} M$



Center of gravity

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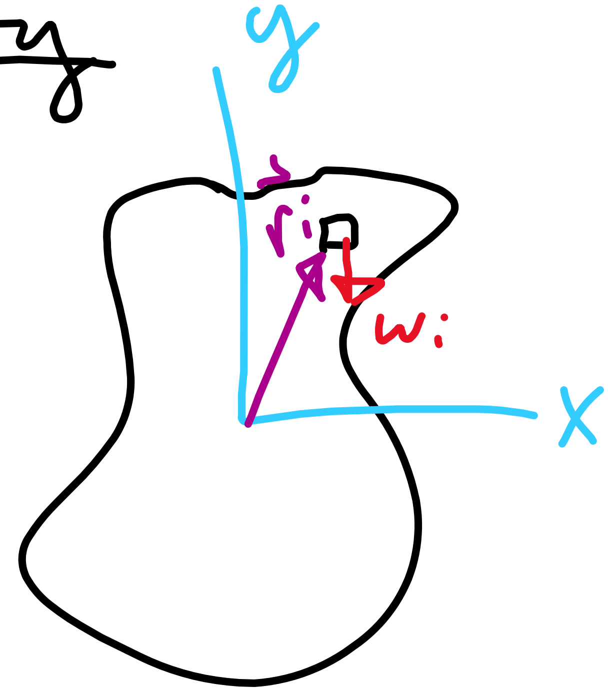
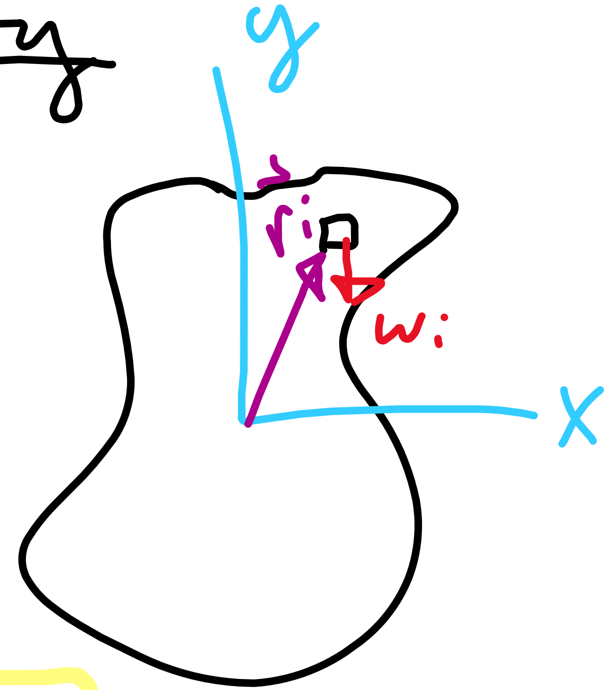
$$\vec{r}_{cm} = \left(\sum \vec{r}_i m_i\right) / \left(\sum m_i\right)$$ so

$$\sum \vec{r}_i m_i = \vec{r}_{cm} M \Rightarrow$$

$$\vec{\tau} = \vec{r}_{cm} \times M\vec{g}$$



Center of gravity



$$\vec{\tau} = \sum \vec{\tau}_i = \sum \vec{r}_i \times \vec{w}_i = \sum \vec{r}_i \times m_i \vec{g}$$

$\Rightarrow \vec{\tau} = \left(\sum \vec{r}_i m_i\right) \times \vec{g}$ But

$\vec{r}_{cm} = \left(\sum \vec{r}_i m_i\right) / \left(\sum m_i\right)$ so

$$\sum \vec{r}_i m_i = \vec{r}_{cm} M \Rightarrow$$

$$\vec{\tau} = \vec{r}_{cm} \times M\vec{g} \Rightarrow \boxed{\vec{\tau} = \vec{r}_{cm} \times \vec{w}}$$

Center of gravity

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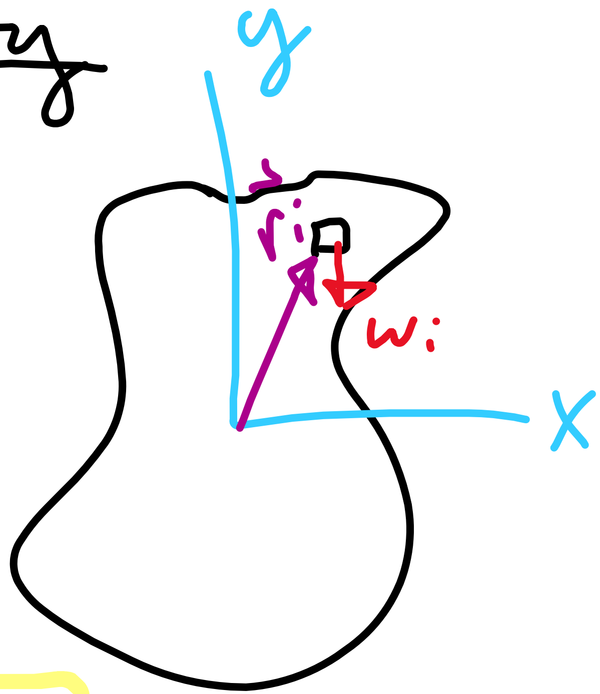
$\sum \vec{r}_i m_i = \vec{r}_{cm} M \Rightarrow$

$\vec{\tau} = \vec{r}_{cm} \times M\vec{g} \Rightarrow \boxed{\vec{\tau} = \vec{r}_{cm} \times \vec{w}}$ we

take center of gravity to be $= \vec{r}_{cm}$



Center of gravity

$\vec{\tau} = \sum \vec{\tau}_i = \sum \vec{r}_i \times \vec{w}_i = \sum \vec{r}_i \times m_i \vec{g}$

$\Rightarrow \vec{\tau} = \left(\sum \vec{r}_i m_i\right) \times \vec{g}$ But

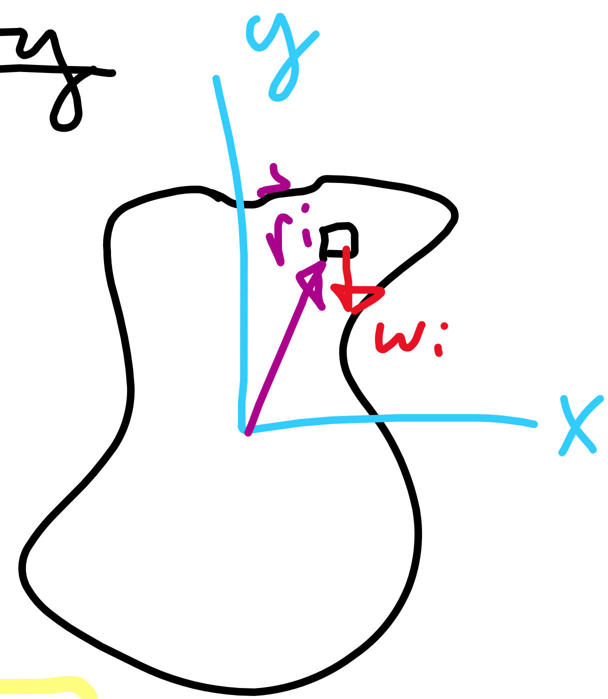
$\vec{r}_{cm} = \left(\sum \vec{r}_i m_i\right) / \left(\sum m_i\right)$ so

$\sum \vec{r}_i m_i = \vec{r}_{cm} M \Rightarrow$

$\vec{\tau} = \vec{r}_{cm} \times M\vec{g} \Rightarrow \boxed{\vec{\tau} = \vec{r}_{cm} \times \vec{w}}$ we

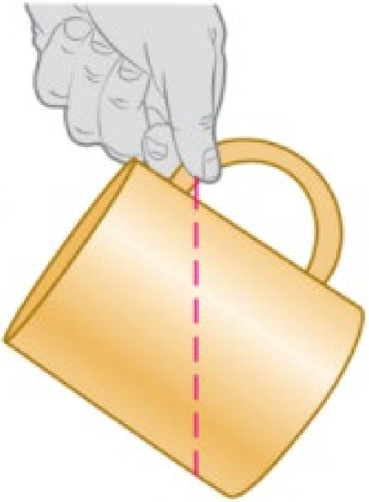
take center of gravity to be $= \vec{r}_{cm}$

Acts as if all weight is located at $\vec{r}_{cm}$



Where is the center of gravity of this mug?

1 Suspend the mug from any point. A vertical line extending down from the point of suspension passes through the center of gravity.



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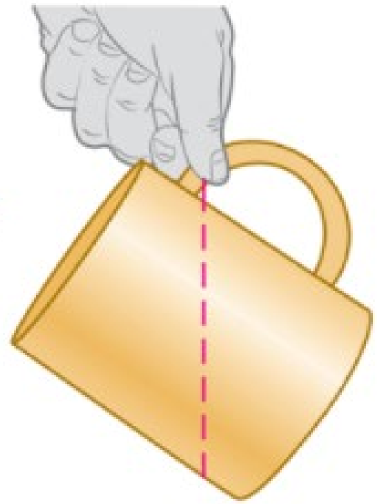
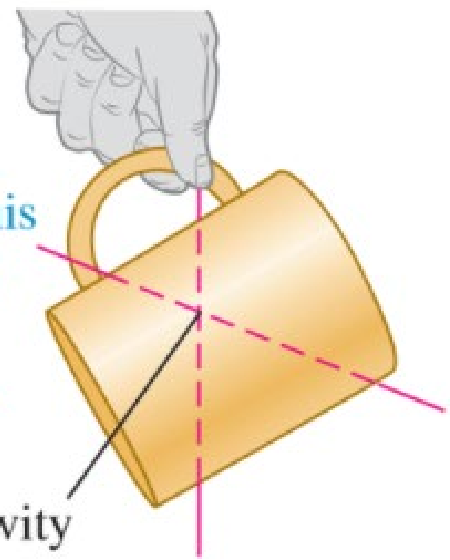
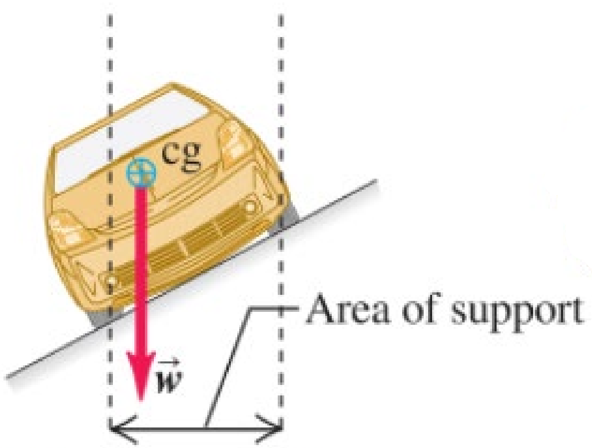
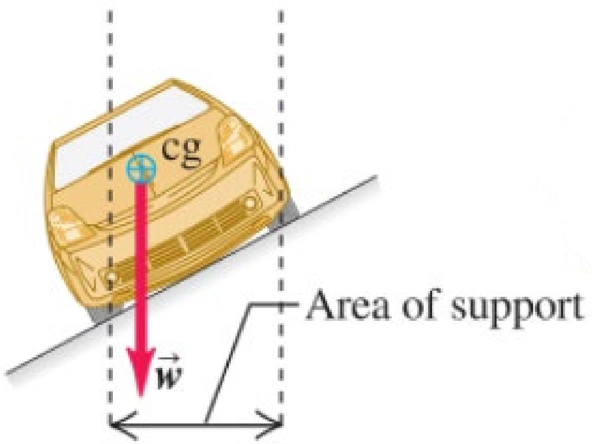


2 Now suspend the mug from a different point. A vertical line extending down from this point intersects the first line at the center of gravity (which is inside the mug).

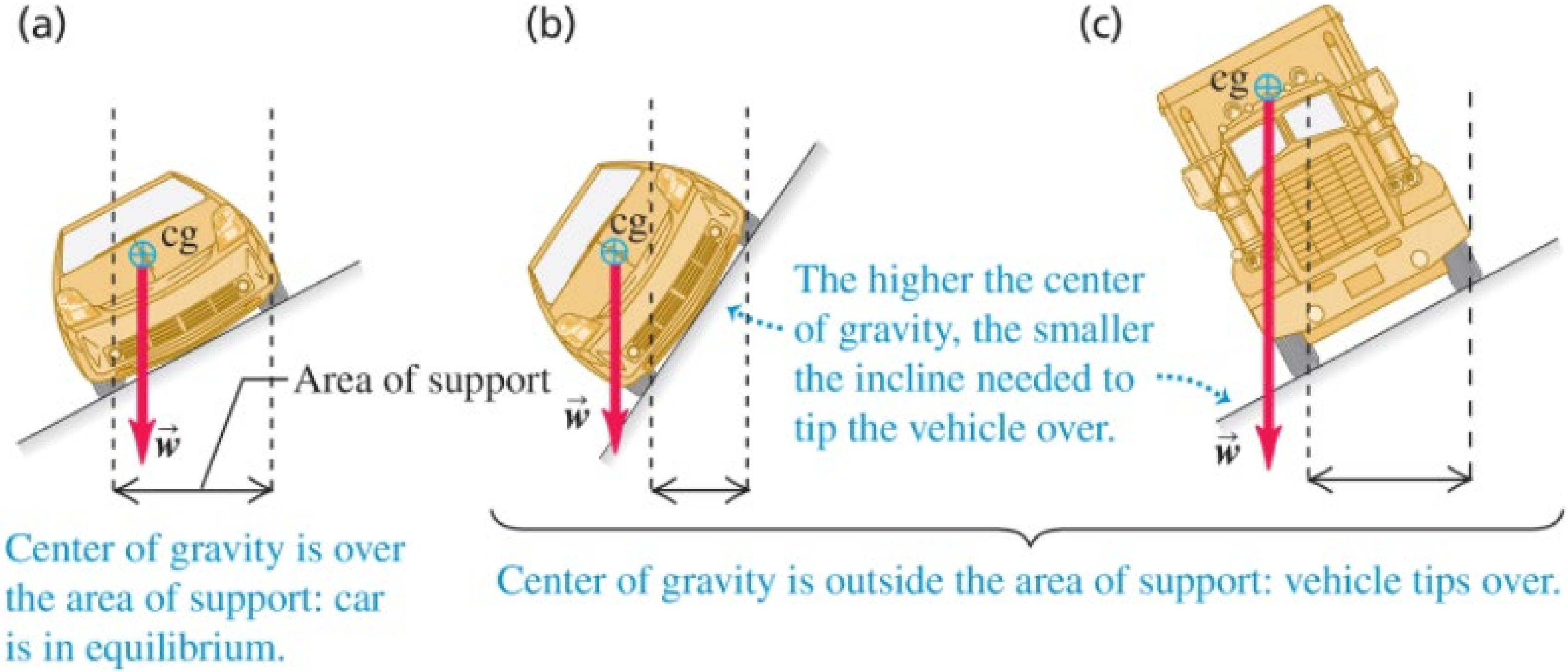


(a)

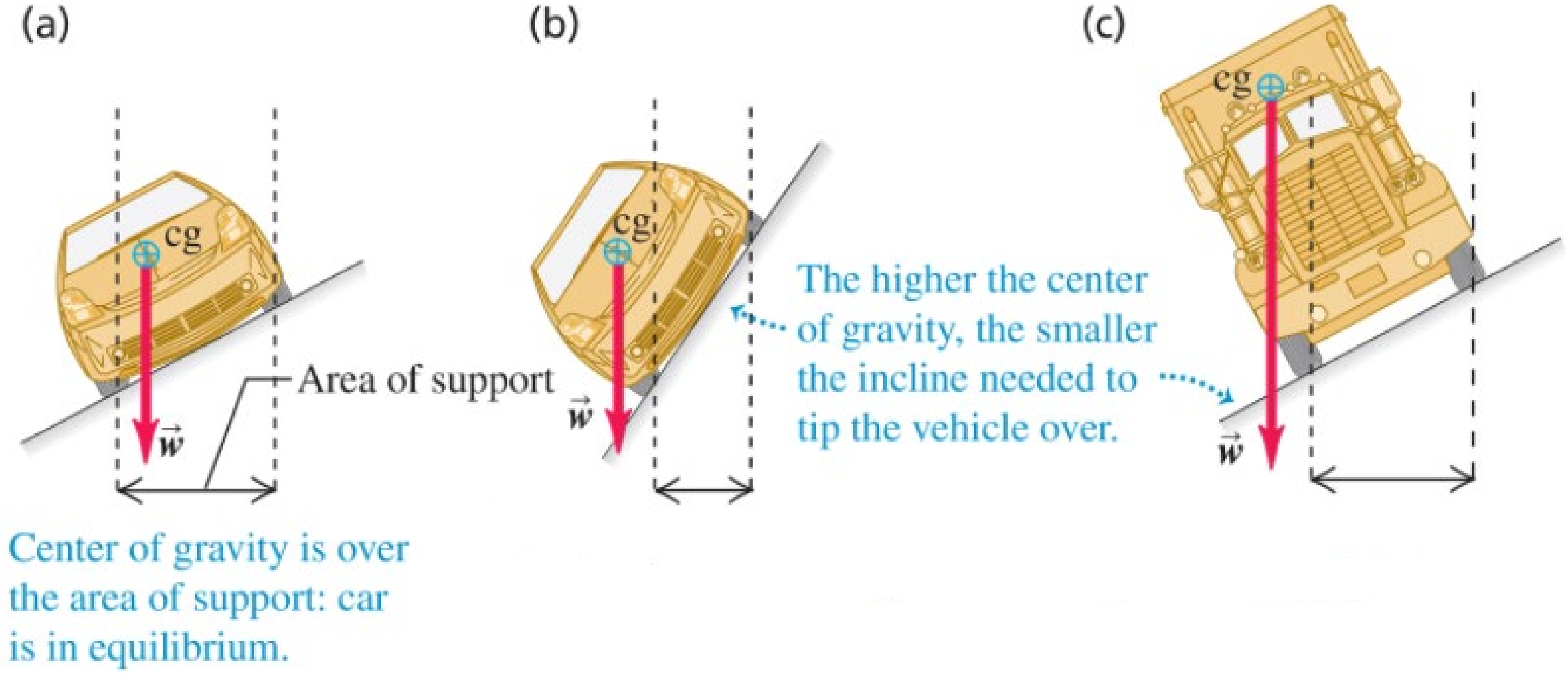




Center of gravity is over the area of support: car is in equilibrium.


(a)
(b)
(c)
cg
cg
cg
$\vec{w}$
$\vec{w}$
$\vec{w}$
Area of support
The higher the center of gravity, the smaller the incline needed to tip the vehicle over.
Center of gravity is over the area of support: car is in equilibrium.
Center of gravity is outside the area of support: vehicle tips over.

ASU


(a)
(b)
(c)
cg
cg
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The higher the center of gravity, the smaller the incline needed to tip the vehicle over.
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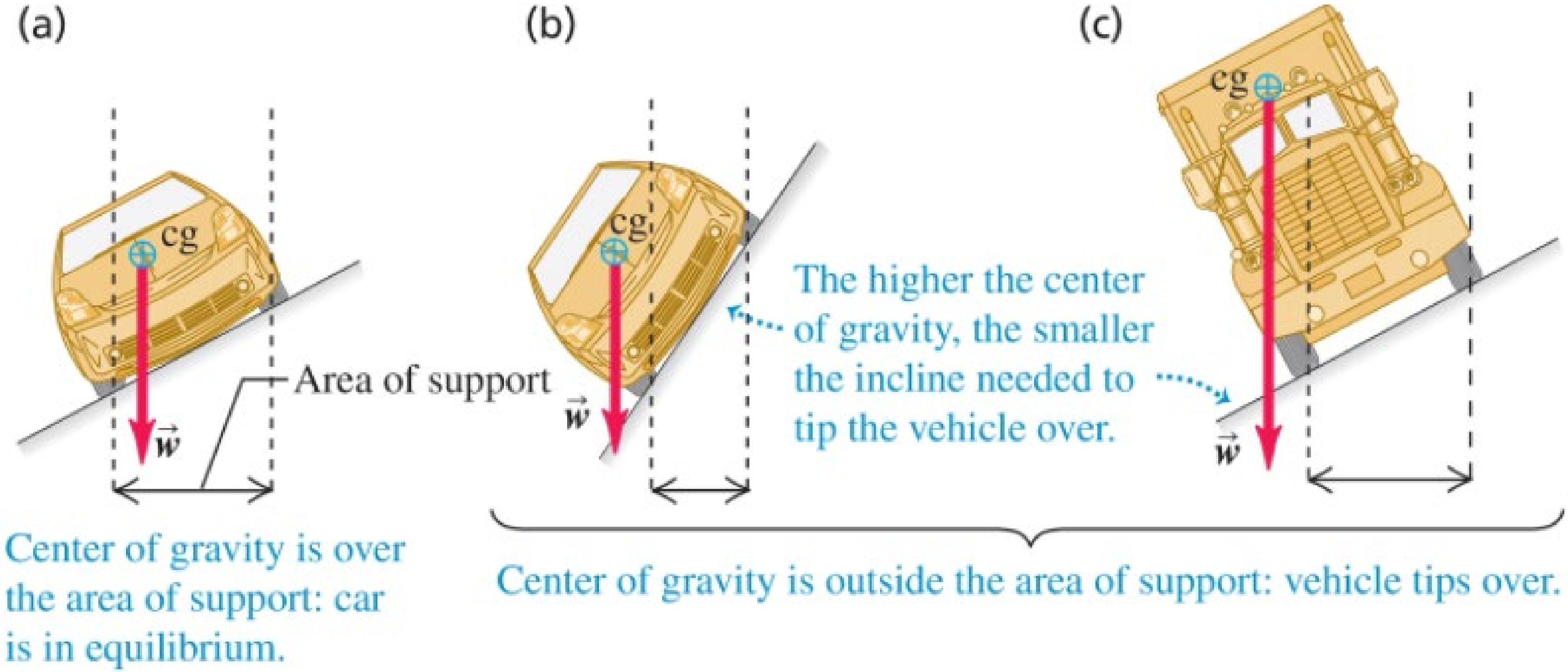
(a)
(b)
(c)
cg
cg
cg
$\vec{w}$
$\vec{w}$
$\vec{w}$
Area of support
The higher the center of gravity, the smaller the incline needed to tip the vehicle over.
Center of gravity is over the area of support: car is in equilibrium.
Center of gravity is outside the area of support: vehicle tips over.

A uniform plank of length $L = 6.0\ \mathrm{m}$ and mass $M = 90\ \mathrm{kg}$ rests on sawhorses separated by $D = 1.5\ \mathrm{m}$ and equidistant from the center of the plank. Cousin Throckmorton wants to stand on the right-hand end of the plank. If the plank is to remain at rest, how massive can Throckmorton be?

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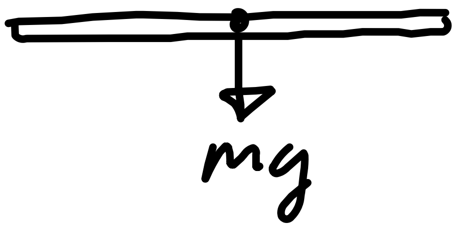

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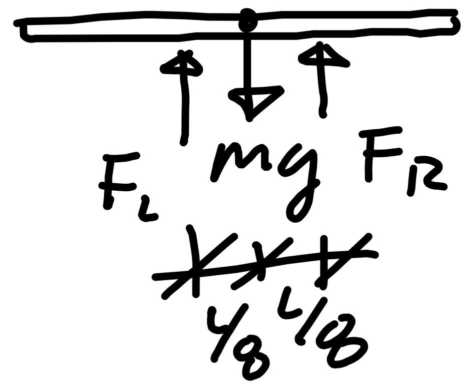

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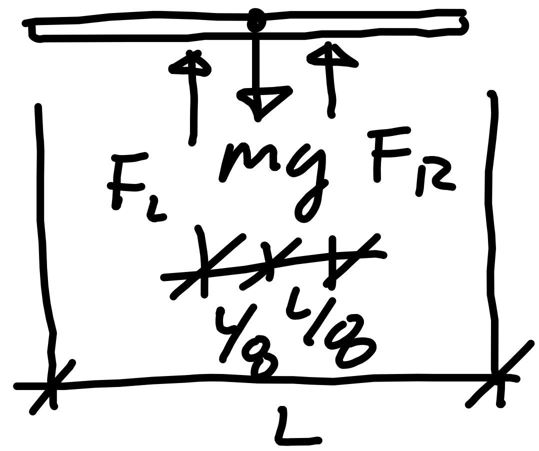

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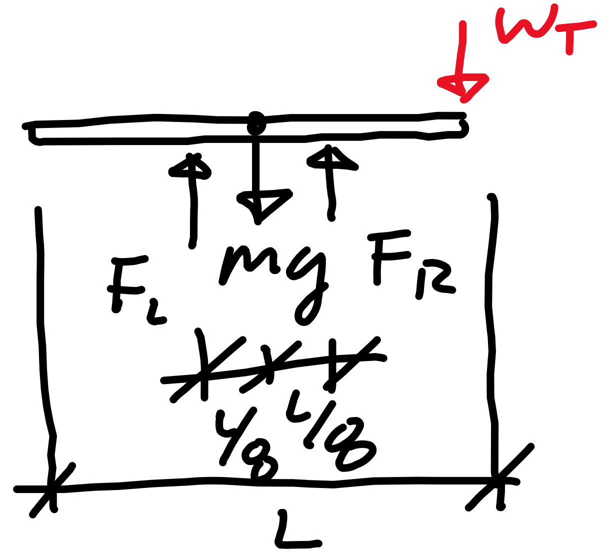

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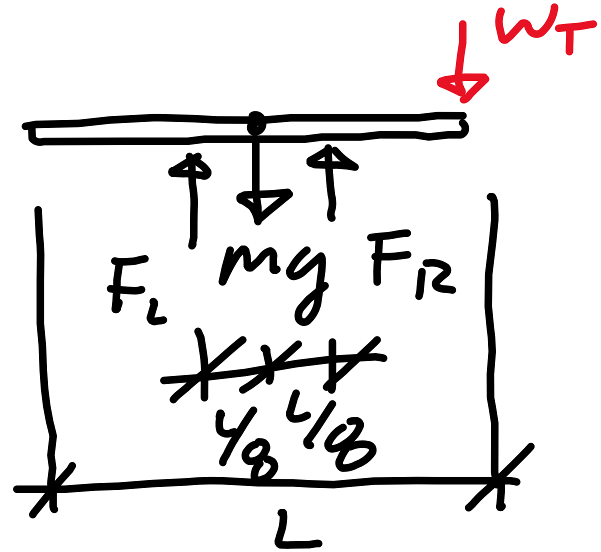
$F_L = 0$ &



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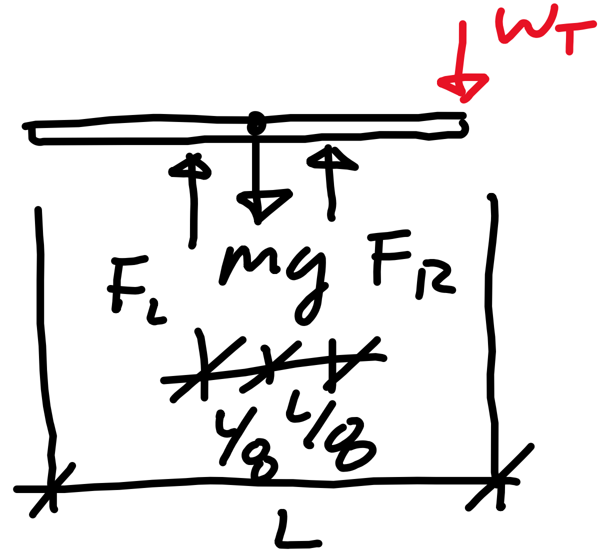

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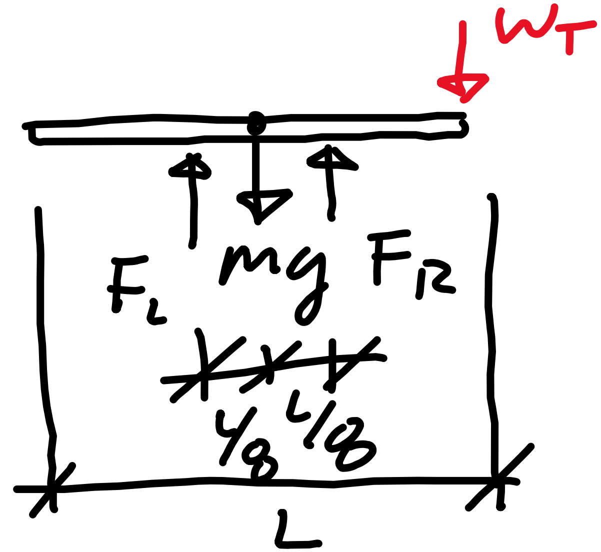
$\Rightarrow$ C.M. at F_R



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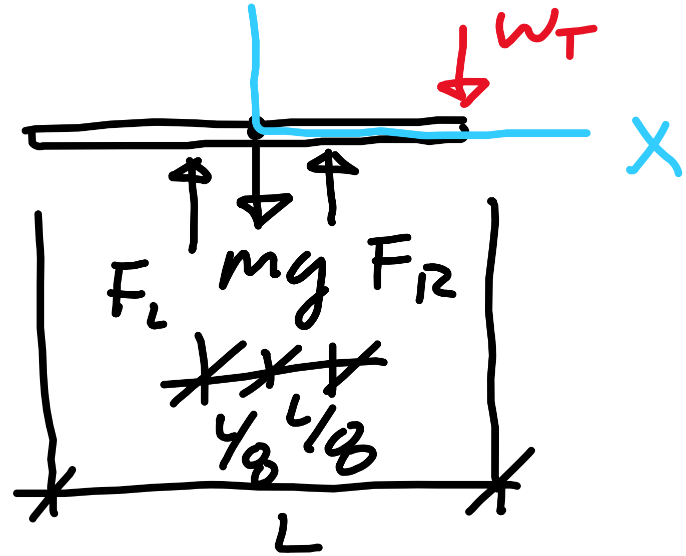
$\Rightarrow$ $x_{cm} = \frac{L}{8}$



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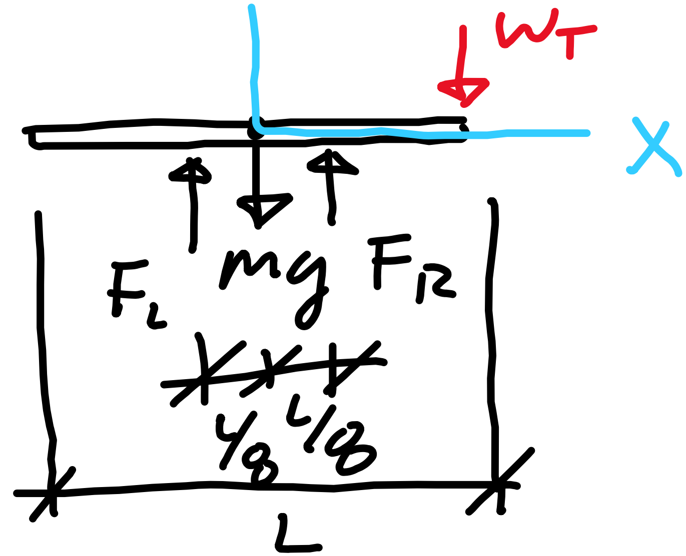
$\Rightarrow$ C.M. at F_R

$\Rightarrow$

$$X_{cm} = \frac{L}{8} = \frac{M_T \frac{L}{2}}{M_p + M_T}$$



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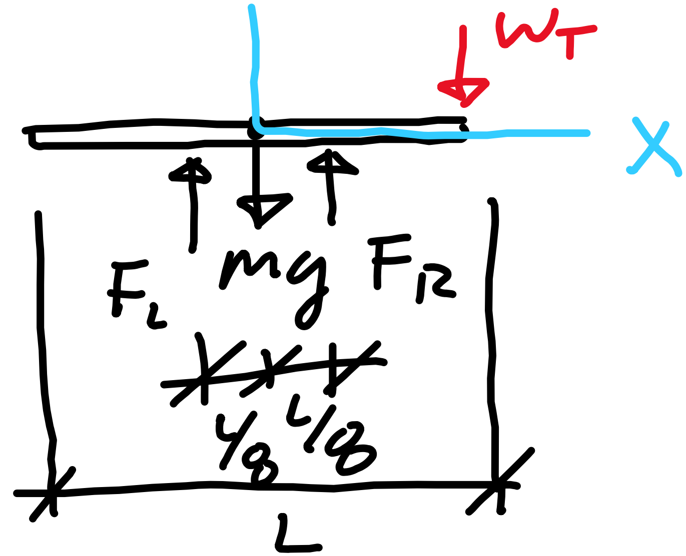
$$\Rightarrow x_{cm} = \frac{L}{8} = \frac{M_T \frac{L}{2}}{M_p + M_T}$$

$$\Rightarrow \left(\frac{L}{8}\right)(M_p + M_T) = \left(\frac{L}{2}\right) M_T$$



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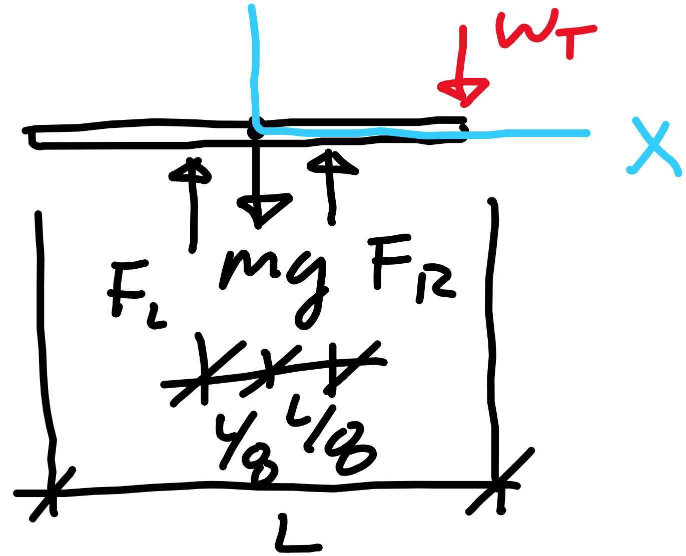

$$\Rightarrow X_{cm} = \frac{L}{8} = \frac{M_T \frac{L}{2}}{M_p + M_T}$$

$$\Rightarrow \left(\frac{L}{8}\right)(M_p + M_T) = \left(\frac{L}{2}\right) M_T \Rightarrow M_p + M_T = 4 M_T$$

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$W_T = \max$ when

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$\Rightarrow$

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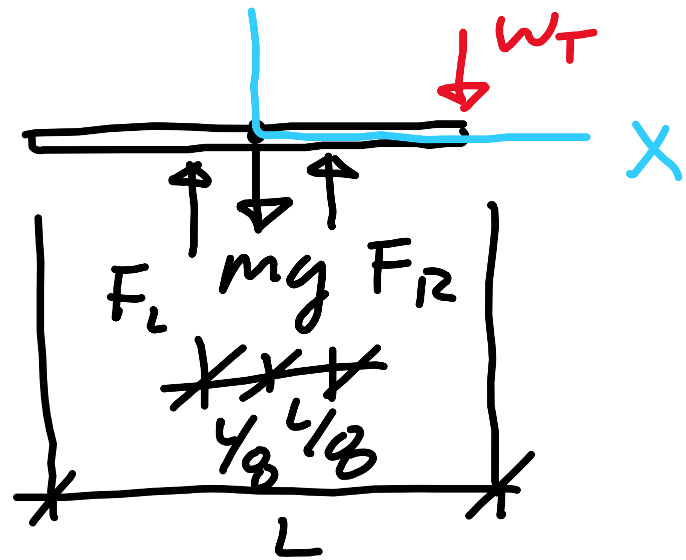
$$\Rightarrow \quad M_p = 3 M_T$$



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$W_T = \max$ when

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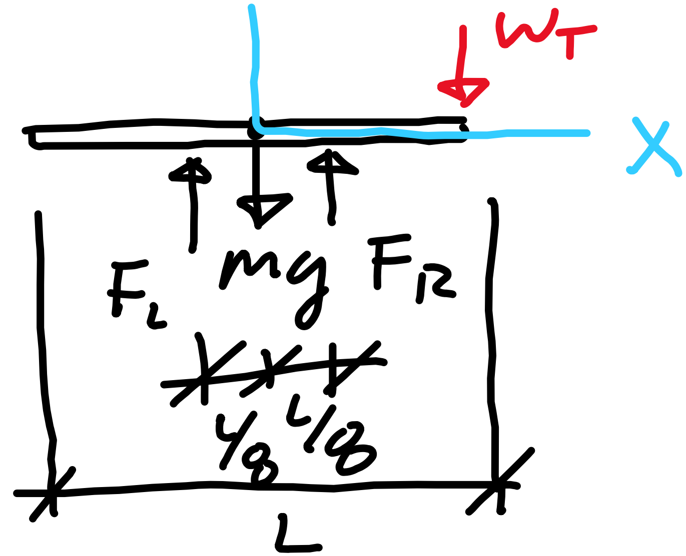

$$\Rightarrow X_{cm} = \frac{L}{8} = \frac{M_T \frac{L}{2}}{M_p + M_T}$$

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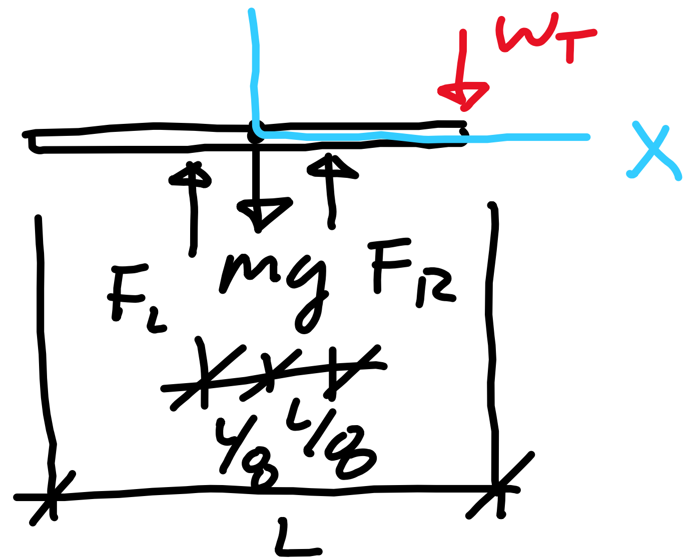

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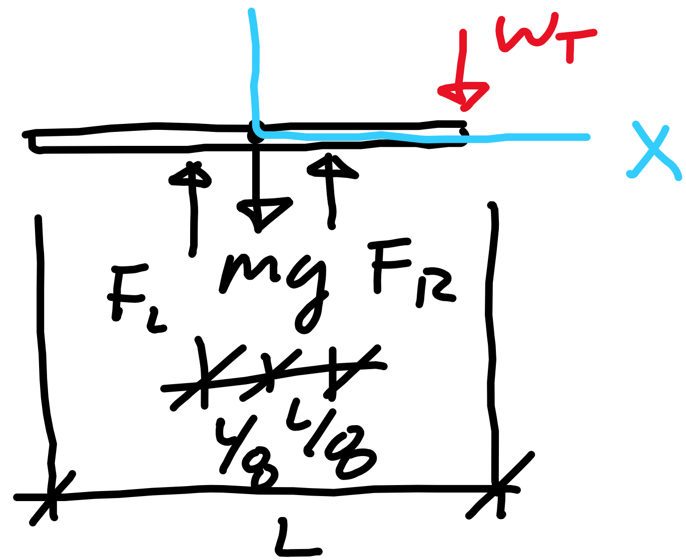

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$$\Rightarrow M_p = 3M_T \Rightarrow M_T = \frac{M_p}{3}$$

$$\Rightarrow \boxed{M_T = 30\,\text{kg}}$$

Solving rigid-body equilibrium problems

Solving rigid-body equilibrium problems

$$\sum \vec{F} = 0$$

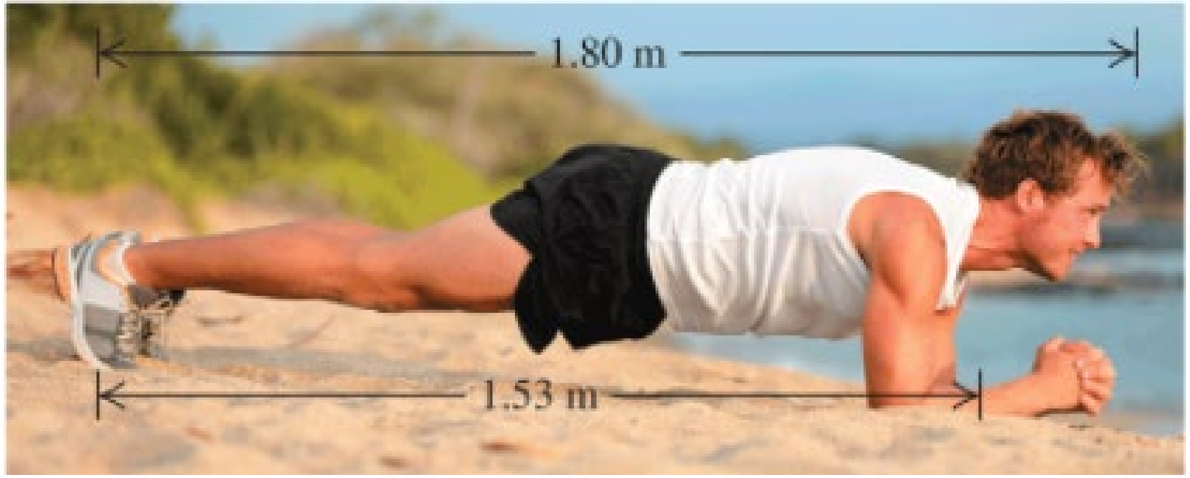
Solving rigid-body equilibrium problems

$$\sum \vec{F} = 0$$

$$\&$$

$$\sum \vec{\tau} = 0$$

The *plank* (Fig. 11.8a) is a great way to strengthen abdominal, back, and shoulder muscles. You can also use this exercise position to locate your center of gravity. Holding plank position with a scale under his toes and another under his forearms, one athlete measured that 66.0% of his weight was supported by his forearms and 34.0% by his toes. (That is, the total normal forces on his forearms and toes were $0.660w$ and $0.340w$, respectively, where w is the athlete's weight.) He is 1.80 m tall, and in plank position the distance from his toes to the middle of his forearms is 1.53 m. How far from his toes is his center of gravity?



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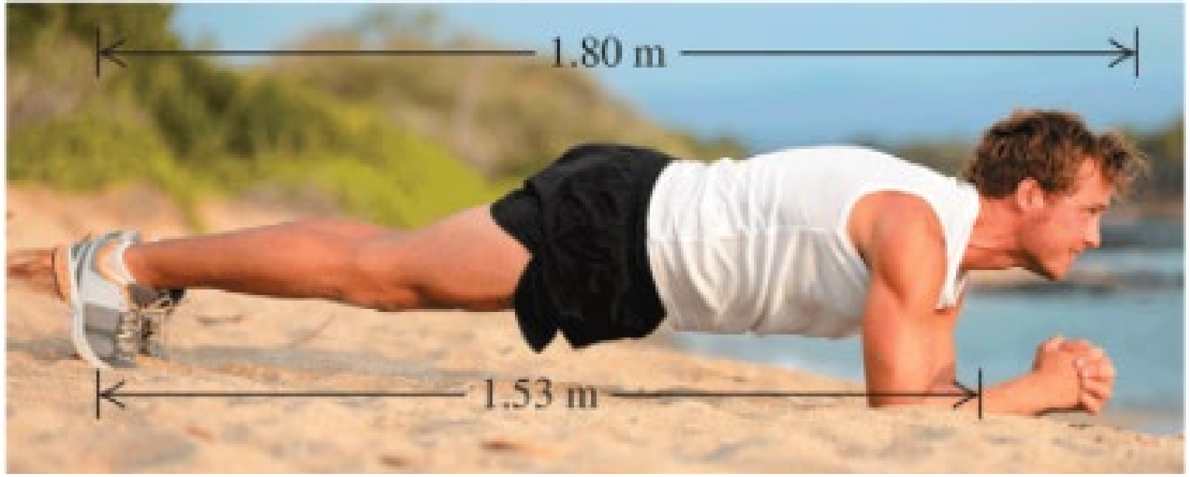

ASU

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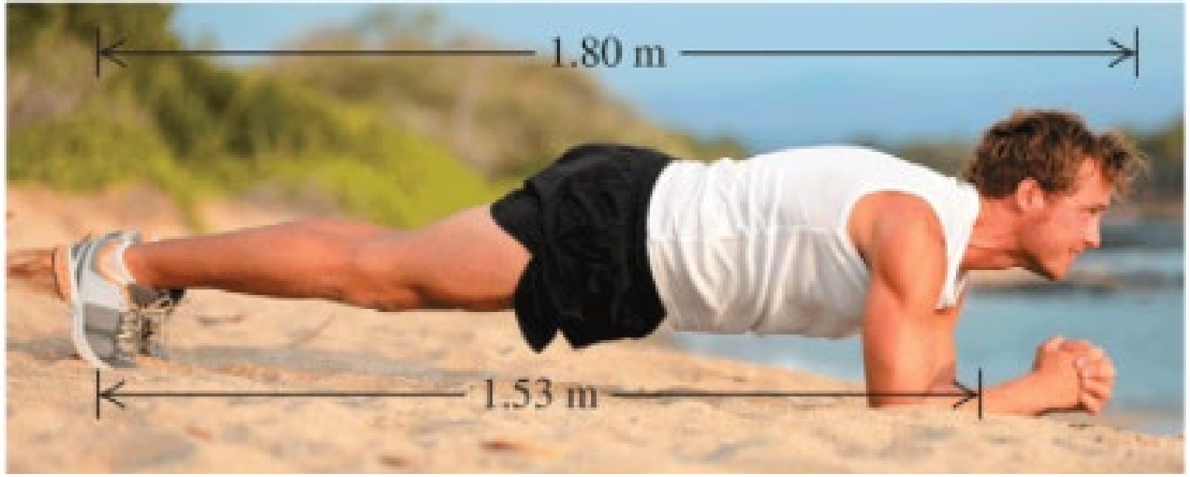

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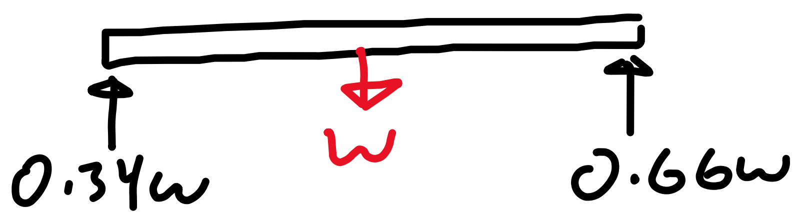

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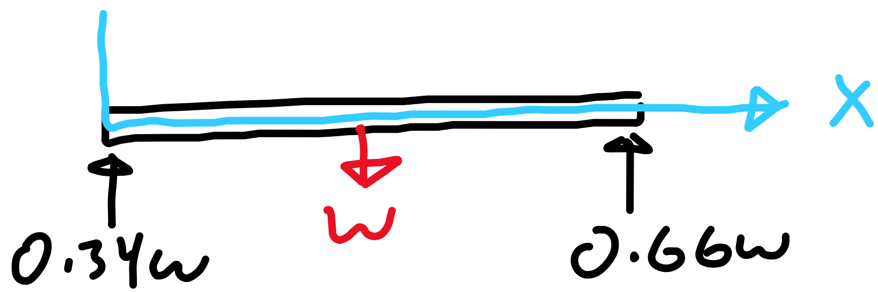

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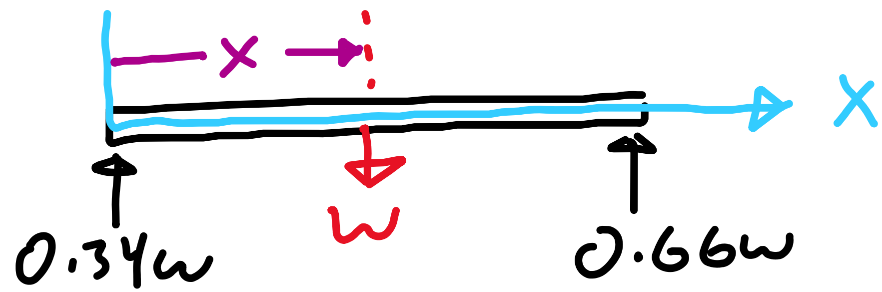

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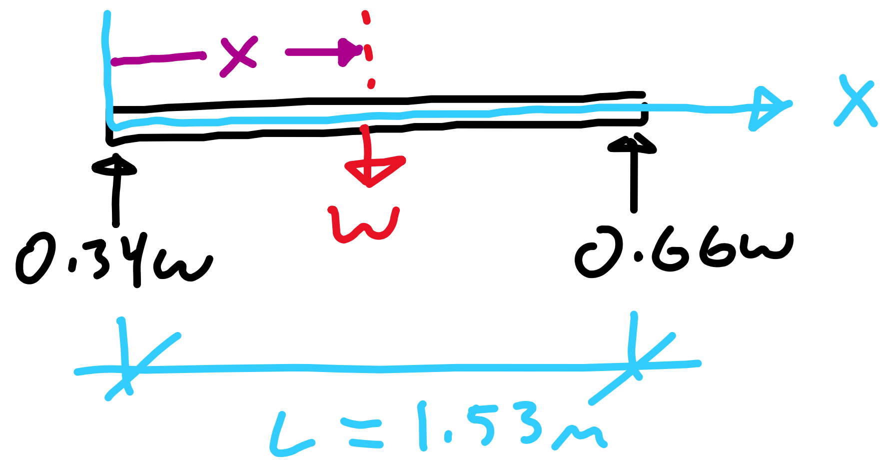

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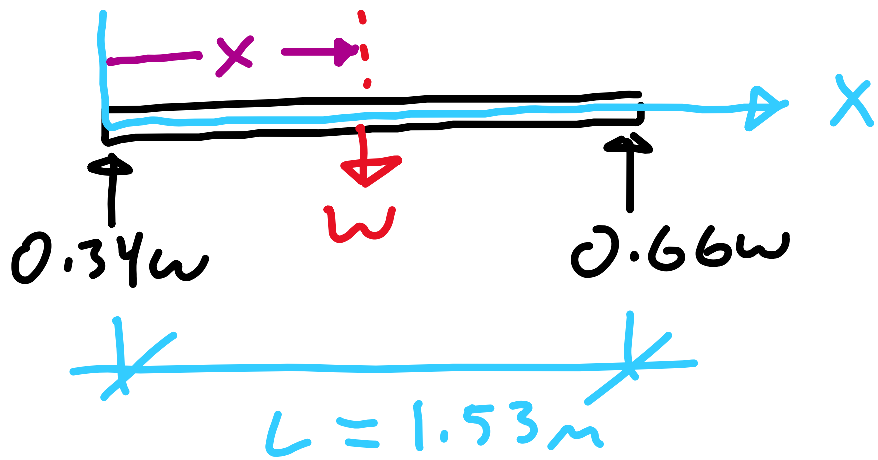
$$\sum \vec{\tau} = 0 \Rightarrow$$



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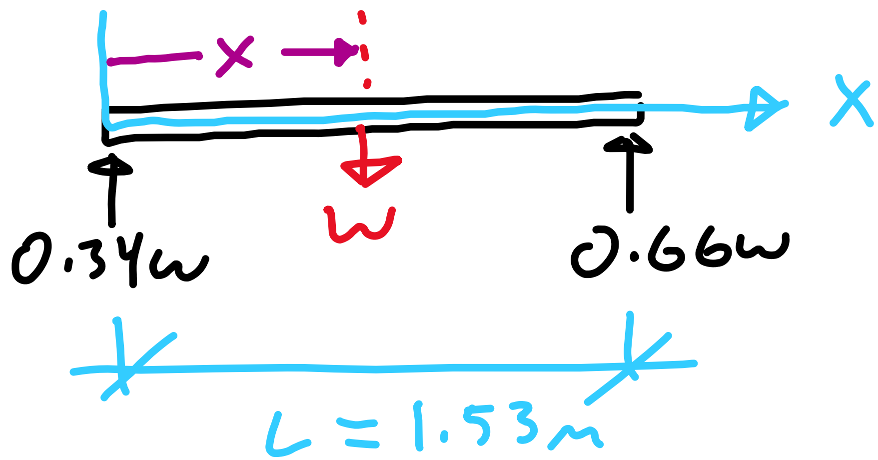
$\sum \vec{\tau} = 0 \Rightarrow$

$-wx\hat{z} + 0.66wL\hat{z} = 0$



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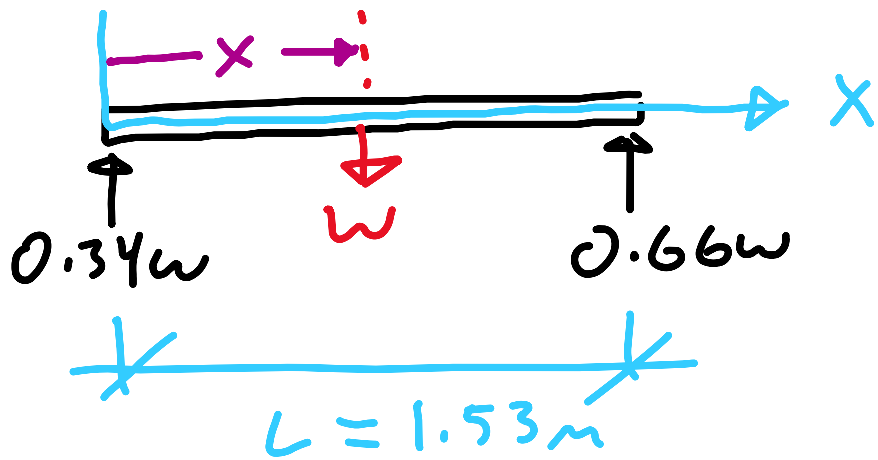
$$\Rightarrow \quad wx = 0.66wL$$



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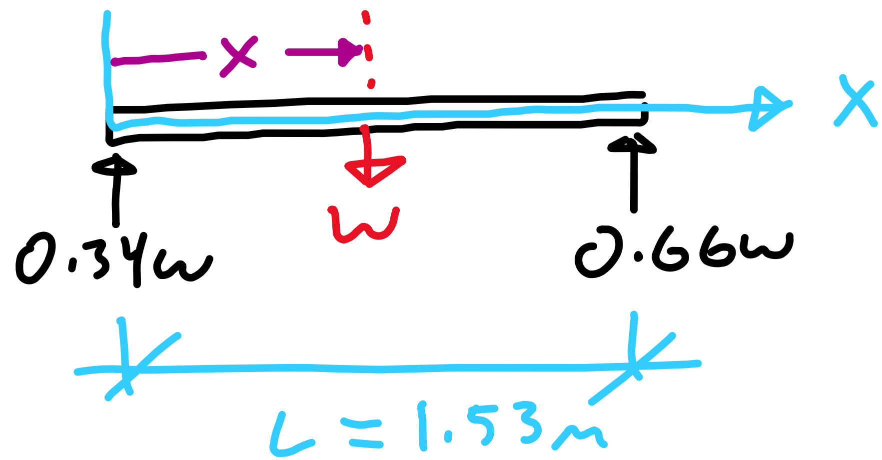
$$\sum \vec{\tau} = 0 \Rightarrow$$

$$-wx\hat{z} + 0.66wL\hat{z} = 0$$

$$\Rightarrow \quad wx = 0.66wL$$

$$\Rightarrow \quad x = 0.66L$$



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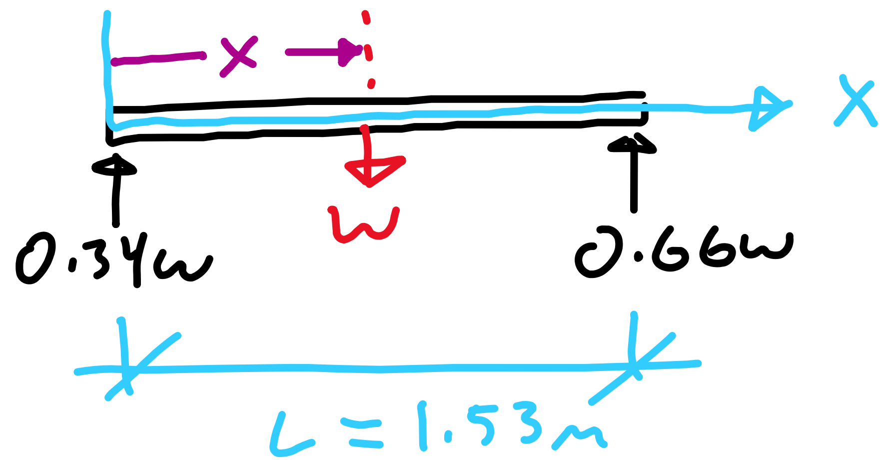
$$\sum \vec{\tau} = 0 \Rightarrow$$

$$-wx\hat{z} + 0.66wL\hat{z} = 0$$

$$\Rightarrow wx = 0.66wL$$

$$\Rightarrow x = 0.66L$$

$$= 0.66 * 1.53\,m$$



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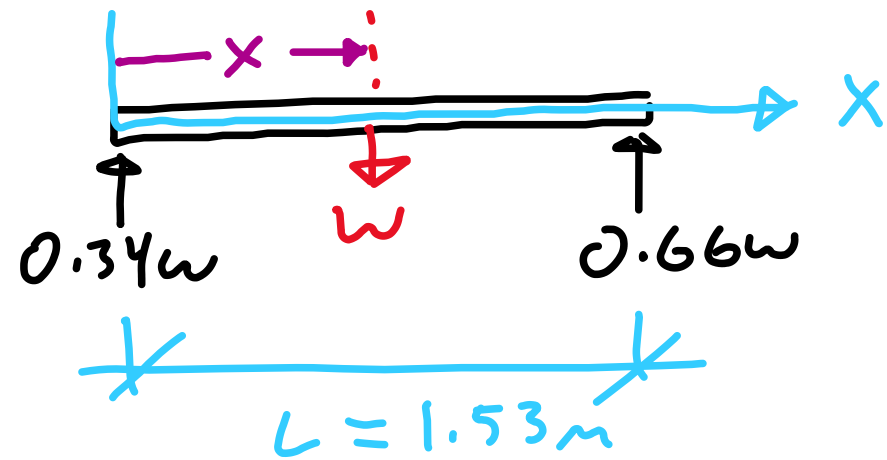
$$\sum \vec{\tau} = 0 \Rightarrow$$

$$-wx\hat{z} + 0.66wL\hat{z} = 0$$

$$\Rightarrow wx = 0.66wL$$

$$\Rightarrow x = 0.66L$$

$$= 0.66 * 1.53\,m \Rightarrow \boxed{x = 1.01\,m}$$



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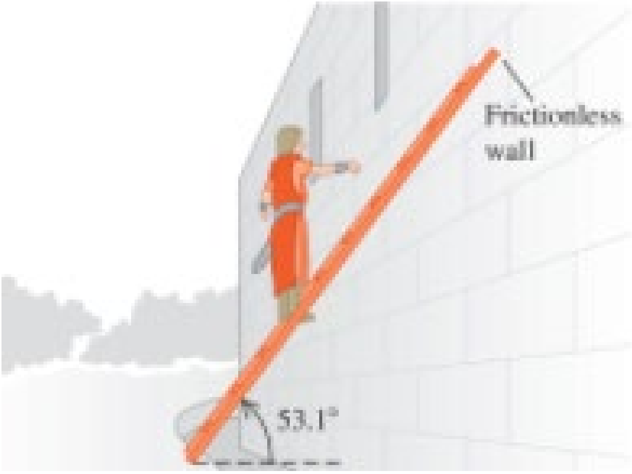

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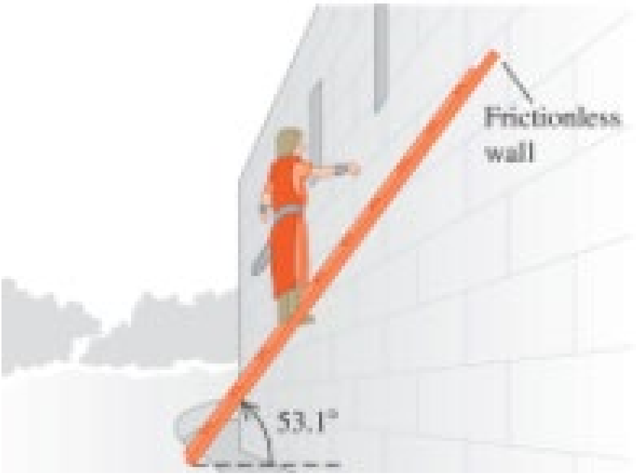

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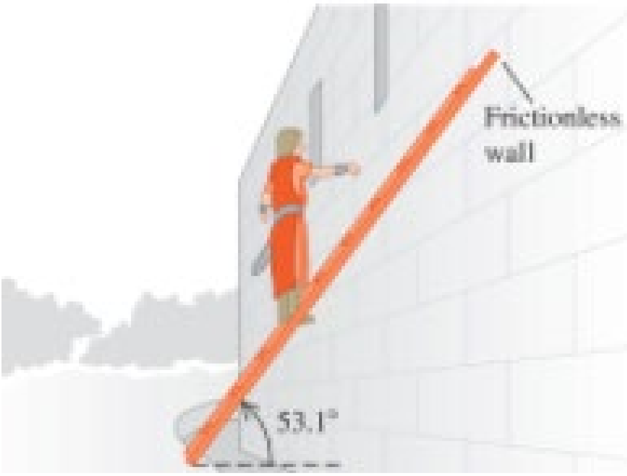
$W_s = 800N$



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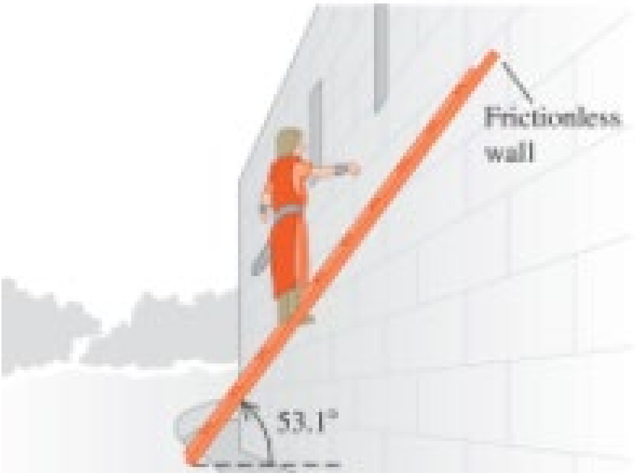
$W_s = 800N, \ L = 5.0m$



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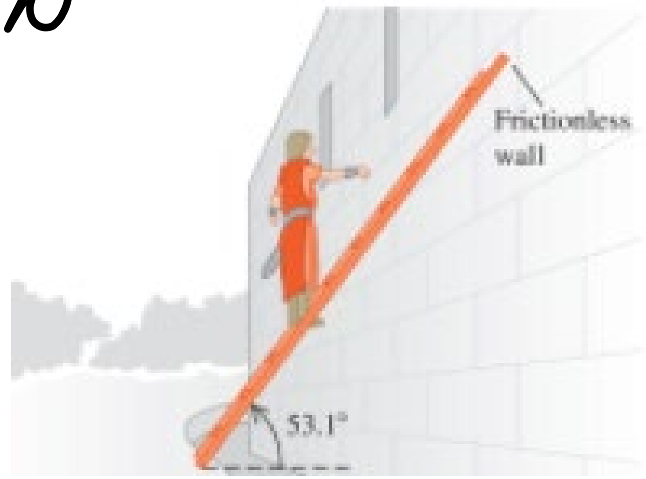
$W_s = 800N$, $L = 5.0m$, $W_L = 180N$



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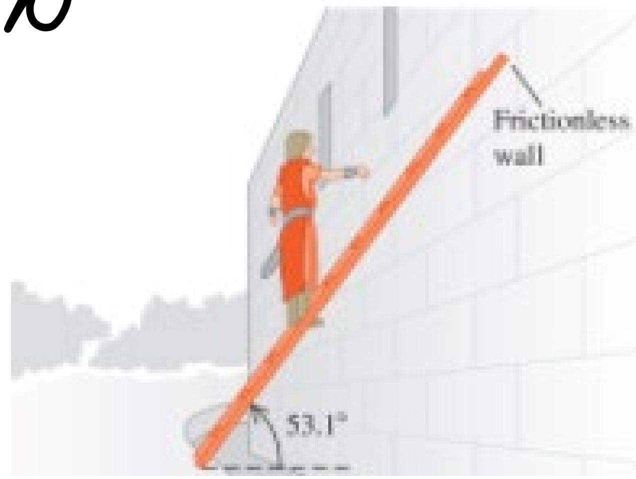
$\theta = 53.1°$



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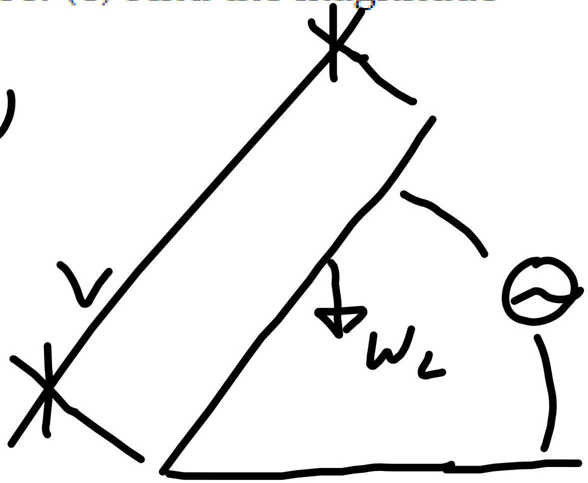

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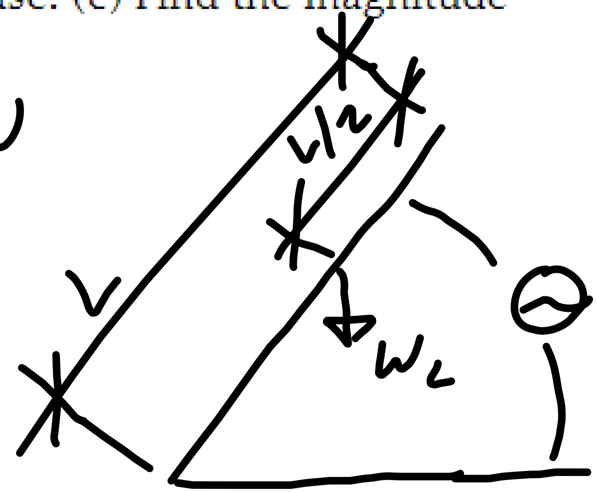

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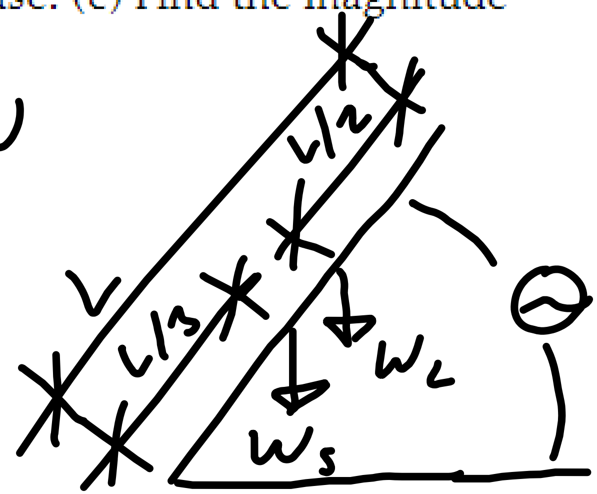

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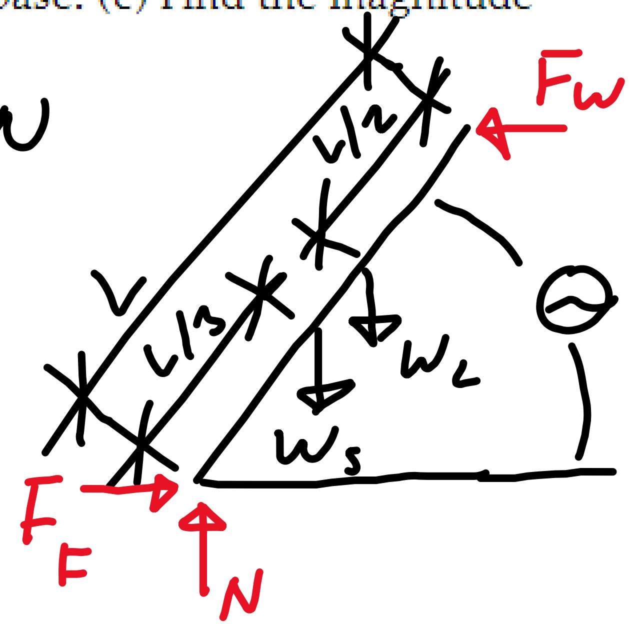

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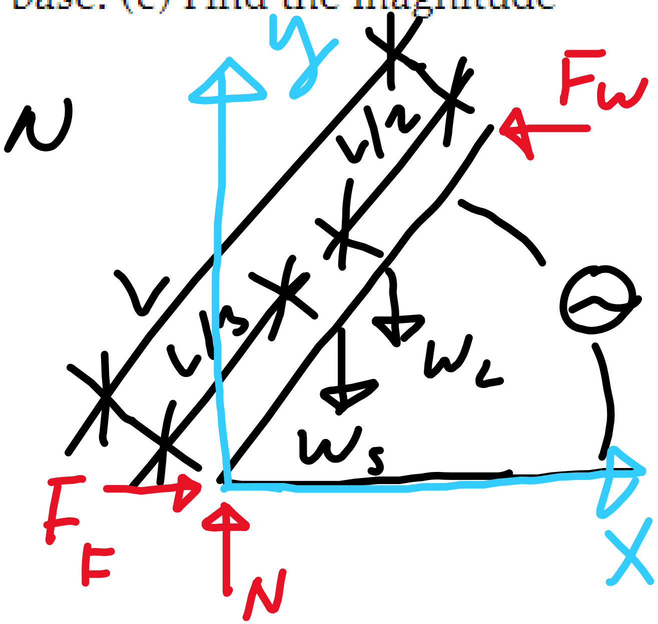

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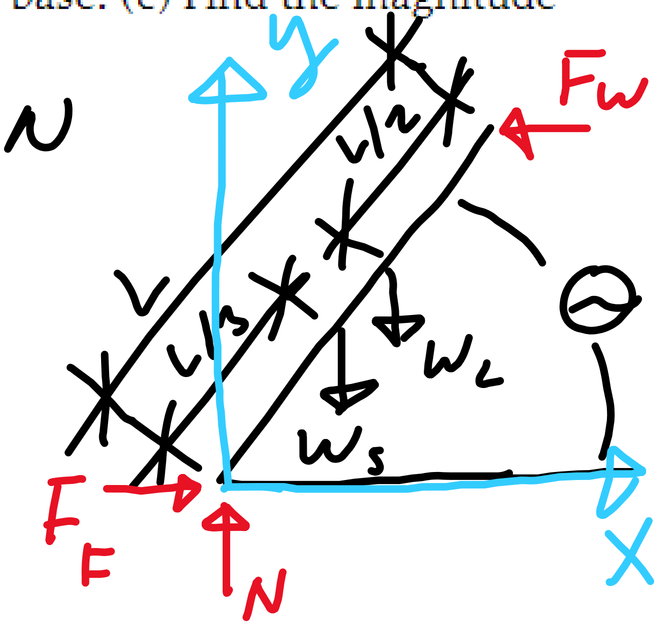

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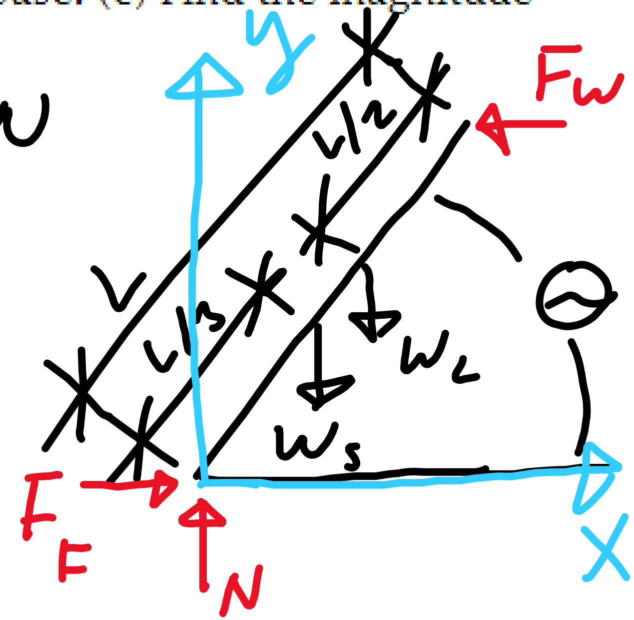
$W_s = 800N,\ L = 5.0m,\ W_L = 180N$

$\Theta = 53.1^\circ \quad \Sigma F_x = 0$



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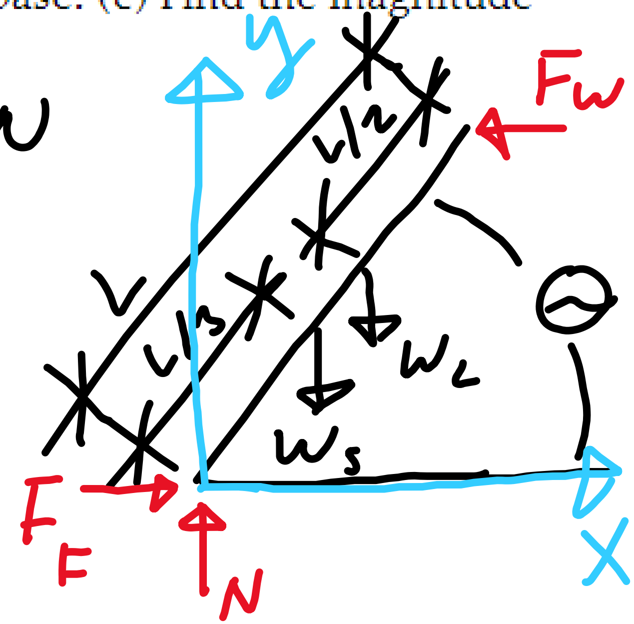

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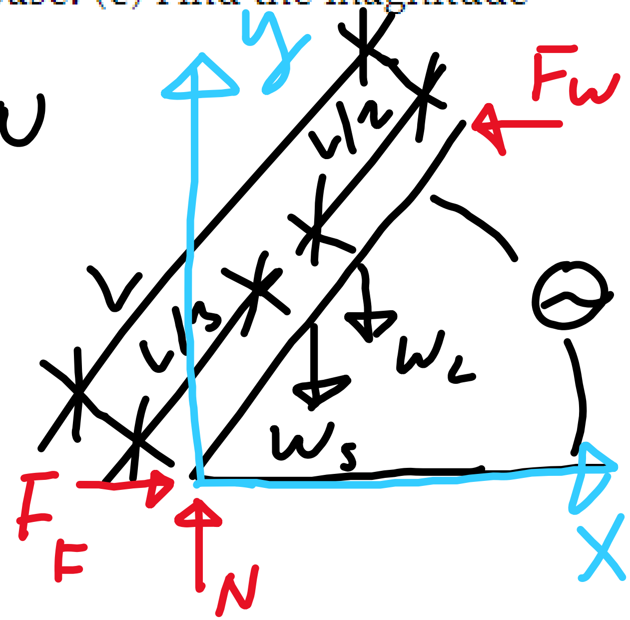
$\Theta = 53.1°$ $\quad \Sigma F_x = 0 \Rightarrow F_w = F_F$

$\Sigma \tau_z = 0$



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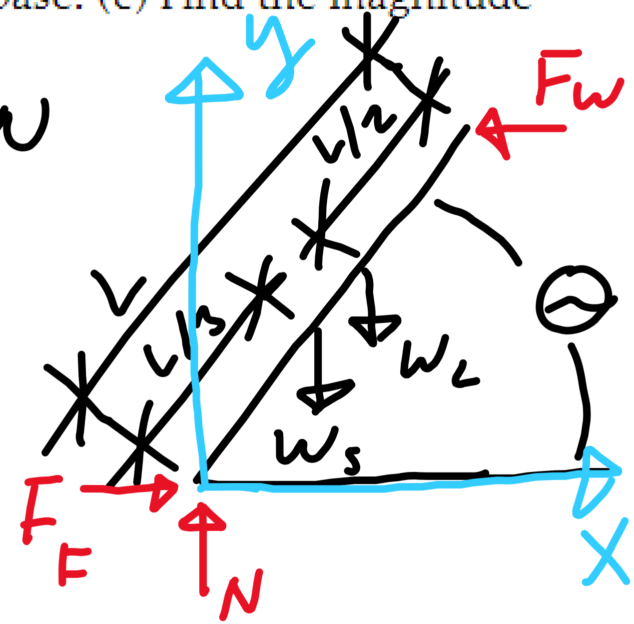
$\Sigma \tau_z = 0 \Rightarrow$

$-\frac{L}{3} W_s \cos\Theta -$



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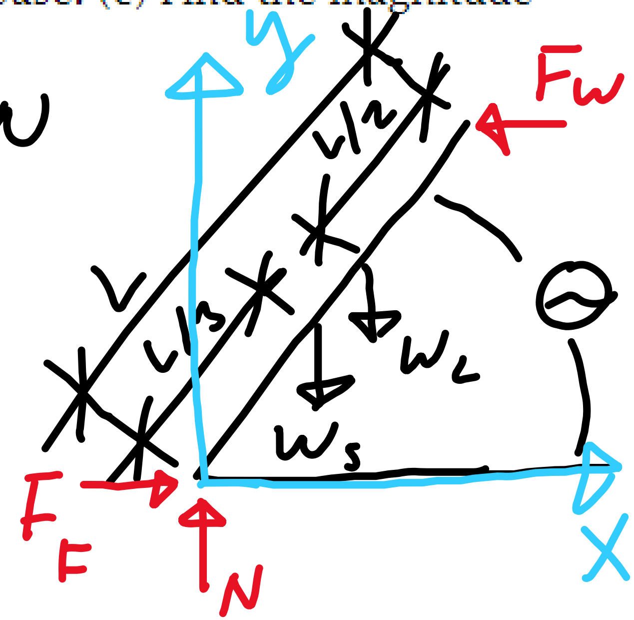
$W_s = 800N,\ L = 5.0m,\ W_L = 180N$

$\theta = 53.1^\circ \quad \Sigma F_x = 0 \Rightarrow F_W = F_F$

$\Sigma \tau_z = 0 \Rightarrow$

$-\frac{L}{3} W_s \cos\theta - \frac{L}{2} W_L \cos\theta +$



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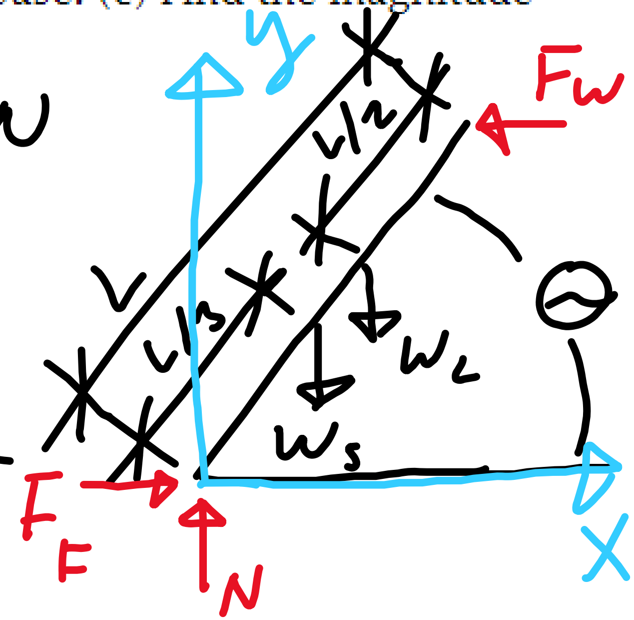
$\theta = 53.1^\circ \quad \sum F_x = 0 \Rightarrow F_W = F_F$

$\sum \tau_z = 0 \Rightarrow$

$-\frac{L}{3} W_s \cos\theta - \frac{L}{2} W_L \cos\theta + L F_W \sin\theta = 0$



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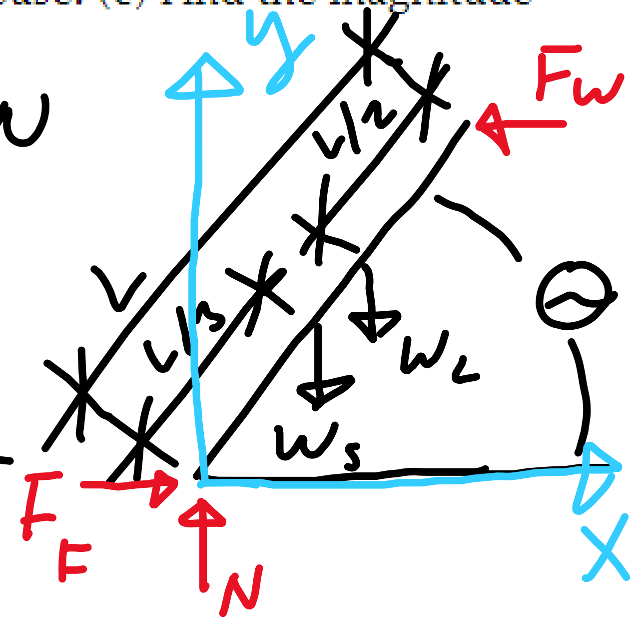
$-\frac{L}{3} W_s \cos\theta - \frac{L}{2} W_L \cos\theta + L F_W \sin\theta = 0$

$\Rightarrow \left(\frac{W_s}{3} + \frac{W_L}{2}\right)\cos\theta = F_W \sin\theta$



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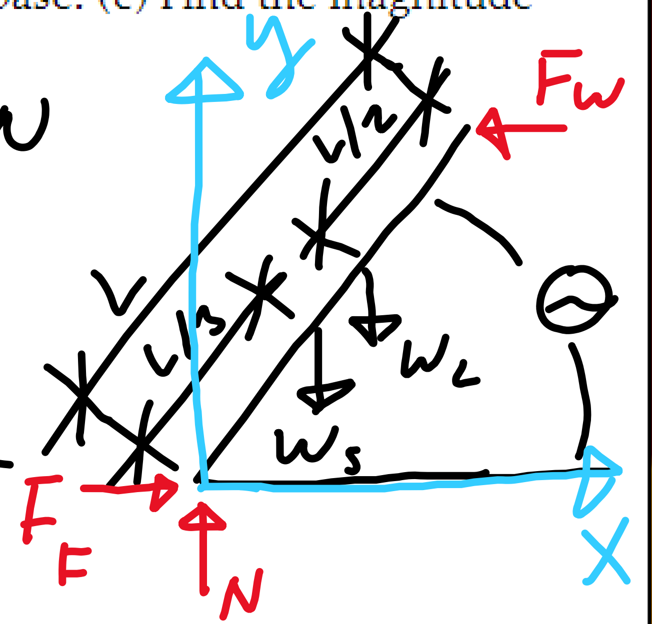
$\Rightarrow \left(\frac{W_s}{3} + \frac{W_L}{2}\right)\cos\theta = F_W \sin\theta$

$\Rightarrow \quad F_W = \left(\frac{W_s}{3} + \frac{W_L}{2}\right)\cot\theta$



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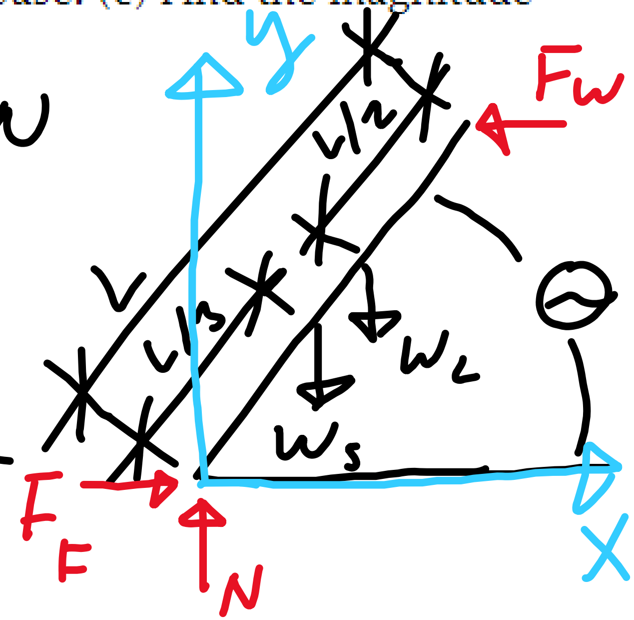
$\sum \tau_z = 0 \Rightarrow$

$-\frac{L}{3} W_s \cos\theta - \frac{L}{2} W_L \cos\theta + L F_w \sin\theta = 0$

$\Rightarrow \left(\frac{W_s}{3} + \frac{W_L}{2}\right)\cos\theta = F_w \sin\theta$

$\Rightarrow \quad F_w = \left(\frac{W_s}{3} + \frac{W_L}{2}\right)\cot\theta = \left(\frac{800}{3} + 90\right)N \cot(53.1^\circ)$



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$W_s = 800N,\ L = 5.0m,\ W_L = 180N$

$\theta = 53.1^\circ \quad \sum F_x = 0 \Rightarrow F_w = F_F$

$\sum \tau_z = 0 \Rightarrow$

$-\frac{L}{3}W_s\cos\theta - \frac{L}{2}W_L\cos\theta + LF_w\sin\theta = 0$

$\Rightarrow \left(\frac{W_s}{3} + \frac{W_L}{2}\right)\cos\theta = F_w\sin\theta$

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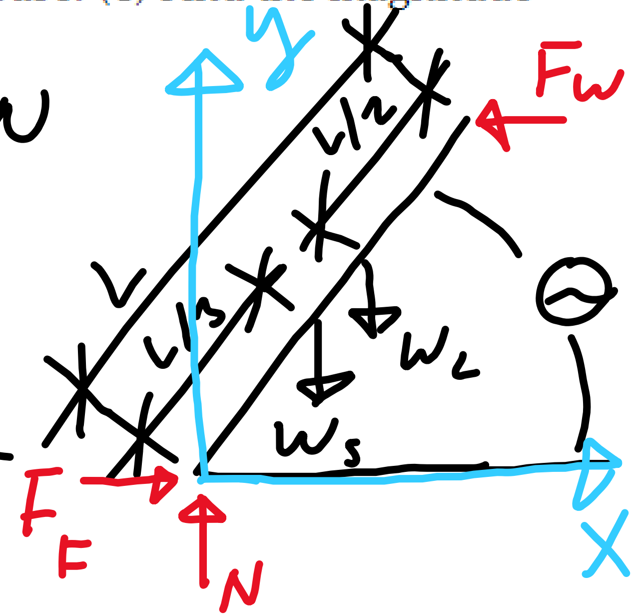
$\Rightarrow \boxed{F_F = F_w = 268N}$



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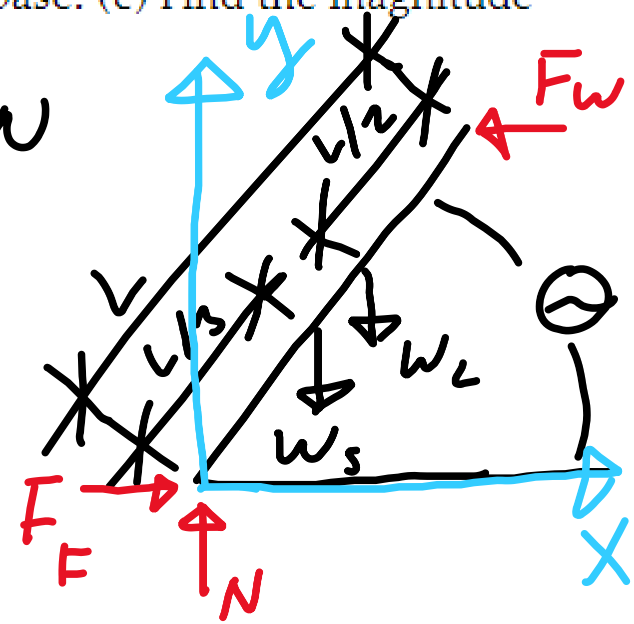

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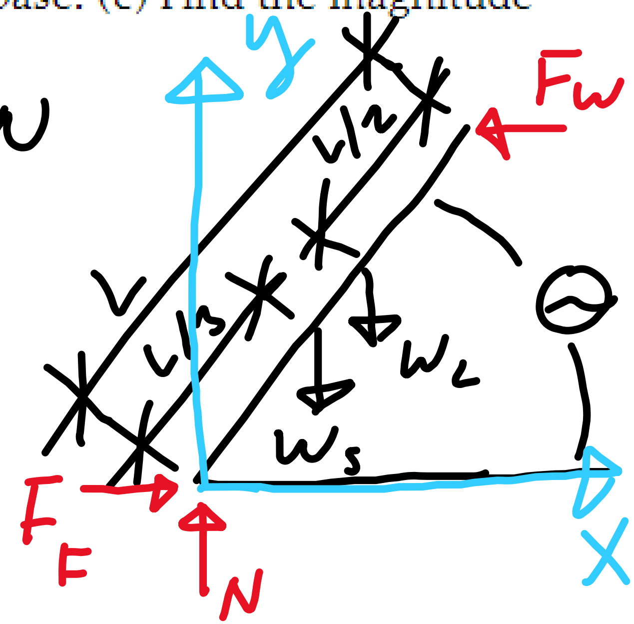
$\theta = 53.1°,\ F_F = F_w = 268N$

$\sum F_y = 0$



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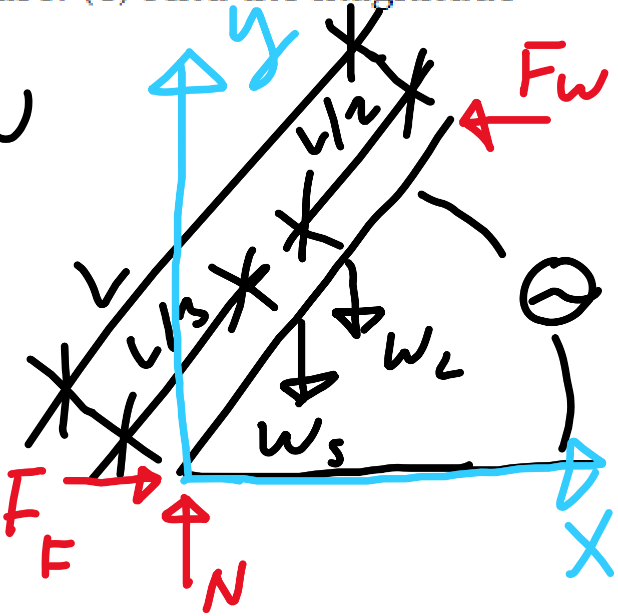
$W_s = 800N, \; L = 5.0m, \; W_L = 180N$

$\theta = 53.1^\circ, \; F_F = F_W = 268N$

$\sum F_y = 0 \Rightarrow N = W_L + W_s$



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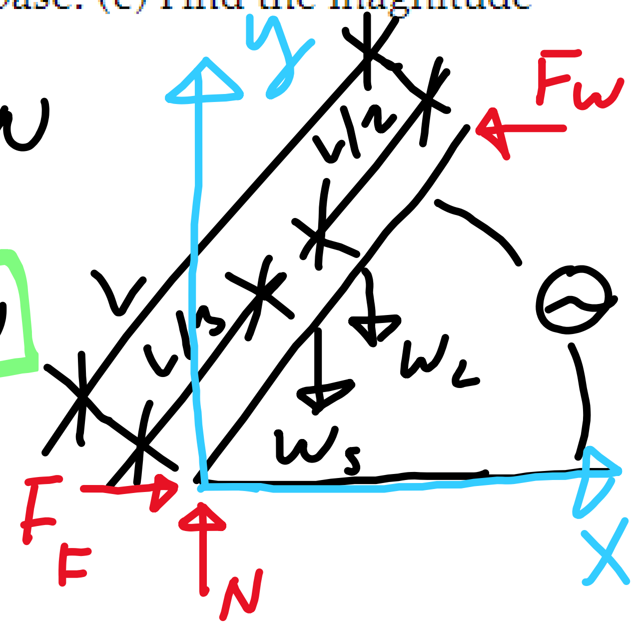
$W_s = 800N,\ L = 5.0m,\ W_L = 180N$

$\theta = 53.1°,\ \boxed{F_F = F_W = 268N}$

$\sum F_y = 0 \Rightarrow \boxed{N = W_L + W_s = 980N}$



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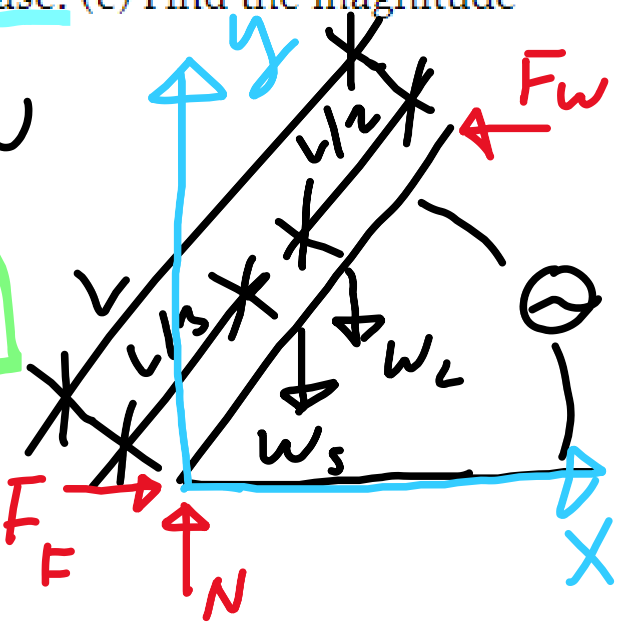

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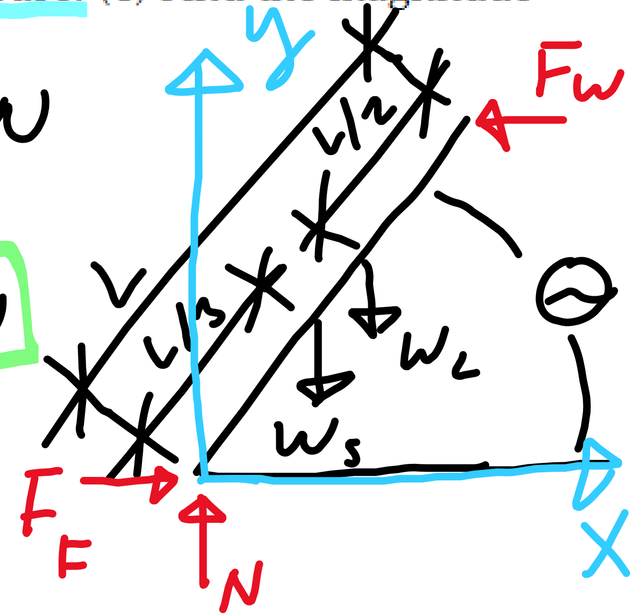
$F_F \leq N\mu_s$



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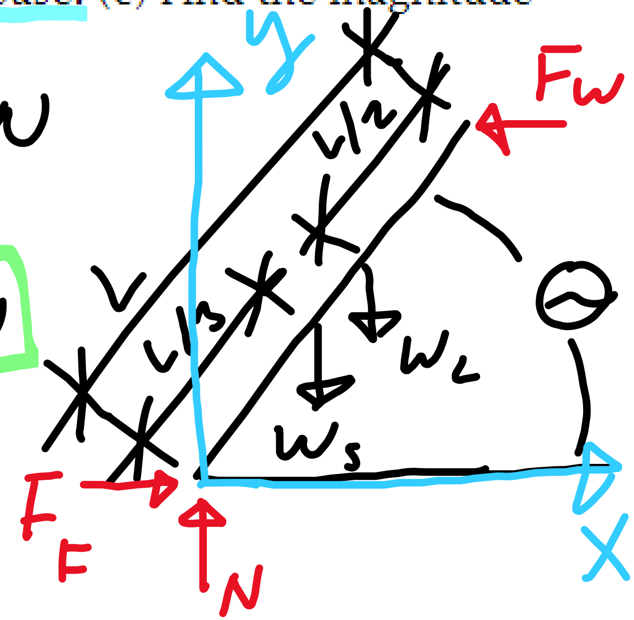
$\theta = 53.1°,\ \boxed{F_F = F_W = 268N}$

$\sum F_y = 0 \Rightarrow \boxed{N = W_L + W_s = 980N}$

$F_F \leq N\mu_s \Rightarrow (\mu_s)_{min} = F_F/N$



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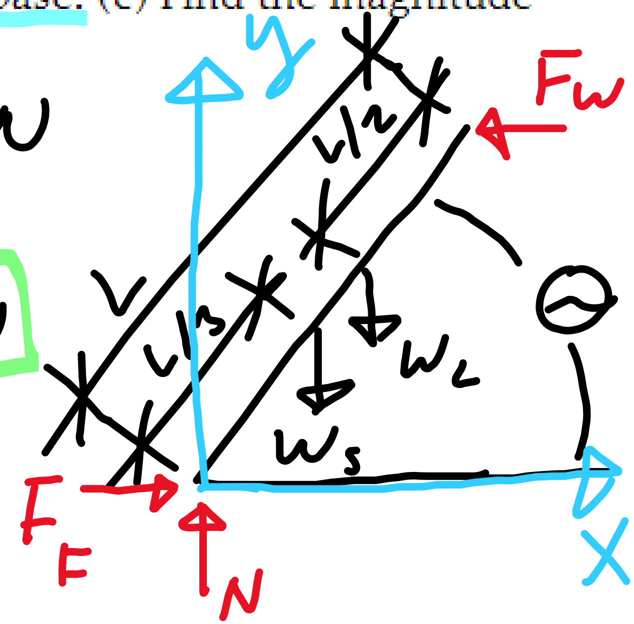

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$F_F \le N\mu_s \Rightarrow (\mu_s)_{min} = F_F/N$

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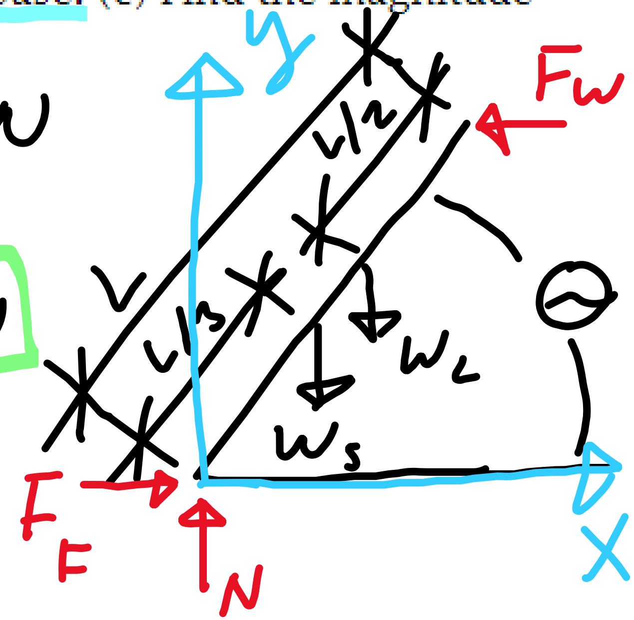

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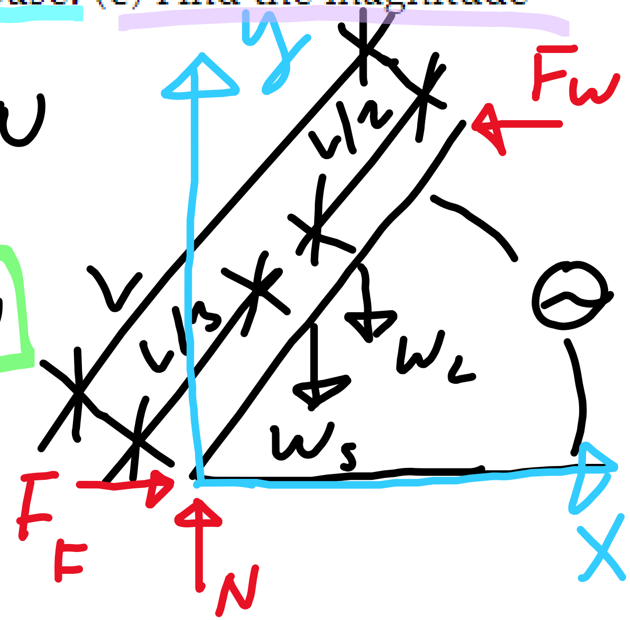
$F_{CF} = \sqrt{N^2 + F_F^2}$



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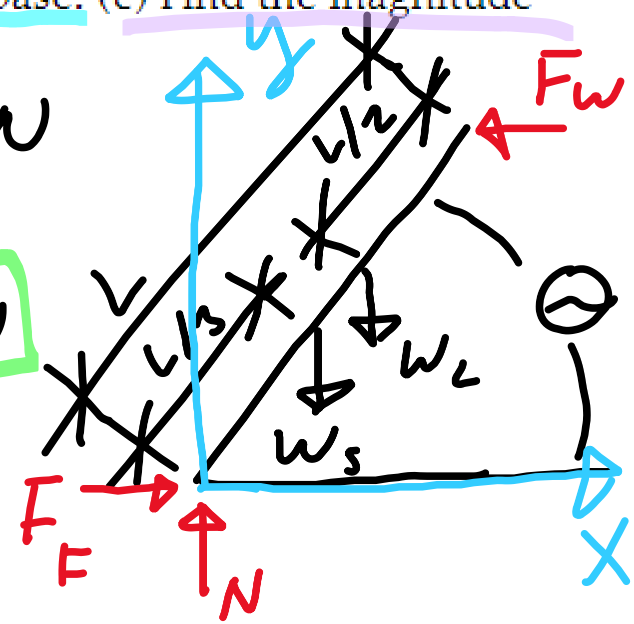
$F_{CF} = \sqrt{N^2 + F_F^2} = \sqrt{980^2 + 268^2}\ N$



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$F_F \le N\mu_s \Rightarrow (\mu_s)_{min} = F_F/N$

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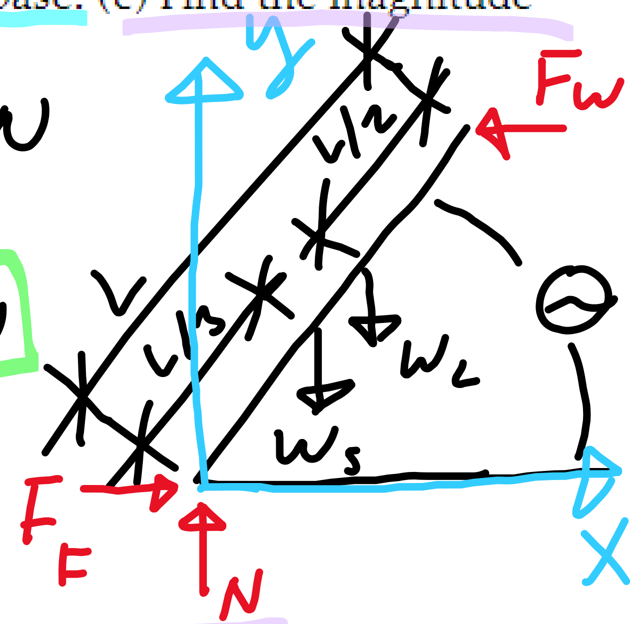
$\boxed{F_{CF} = \sqrt{N^2 + F_F^2} = \sqrt{980^2 + 268^2}\ N = 1020N}$



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$W_s = 800N,\ L = 5.0m,\ W_L = 180N$

$\theta = 53.1°,\ \boxed{F_F = F_W = 268N}$

$\Sigma F_y = 0 \Rightarrow \boxed{N = W_L + W_s = 980N}$

$F_F \leq N\mu_s \Rightarrow (\mu_s)_{min} = F_F/N$

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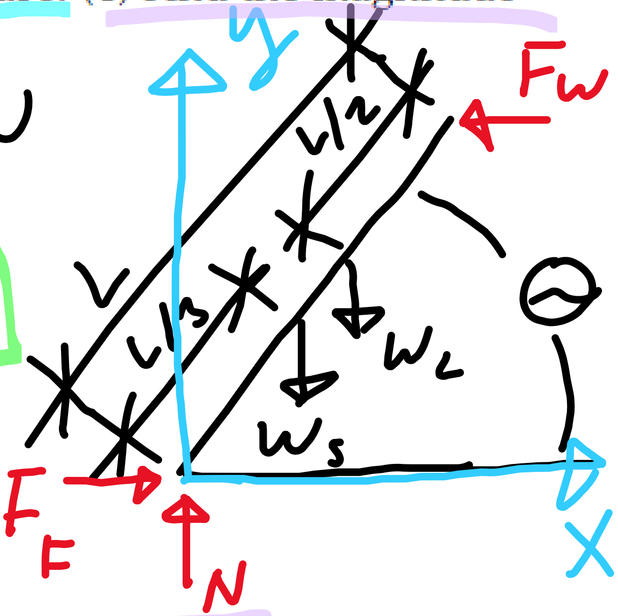
$\boxed{F_{CF} = \sqrt{N^2 + F_F^2} = \sqrt{980^2 + 268^2}\,N = 1020N}$

$\theta_{CF} = \tan^{-1}\frac{N}{F_F}$



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$W_s = 800N,\ L = 5.0m,\ W_L = 180N$

$\theta = 53.1°,\ \boxed{F_F = F_W = 268N}$

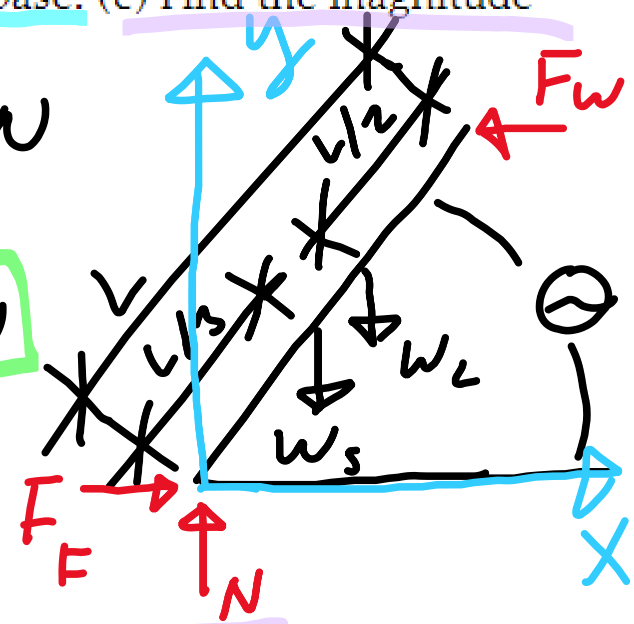
$\sum F_y = 0 \Rightarrow \boxed{N = W_L + W_s = 980N}$

$F_F \leq N\mu_s \Rightarrow (\mu_s)_{min} = F_F/N$

$\Rightarrow \boxed{(\mu_s)_{min} = (268/980) = 0.27}$

$\boxed{F_{CF} = \sqrt{N^2 + F_F^2} = \sqrt{980^2 + 268^2}\ N = 1020N}$

$\theta_{CF} = \tan^{-1}\frac{N}{F_F} = \tan^{-1}\left(\frac{980}{268}\right)$



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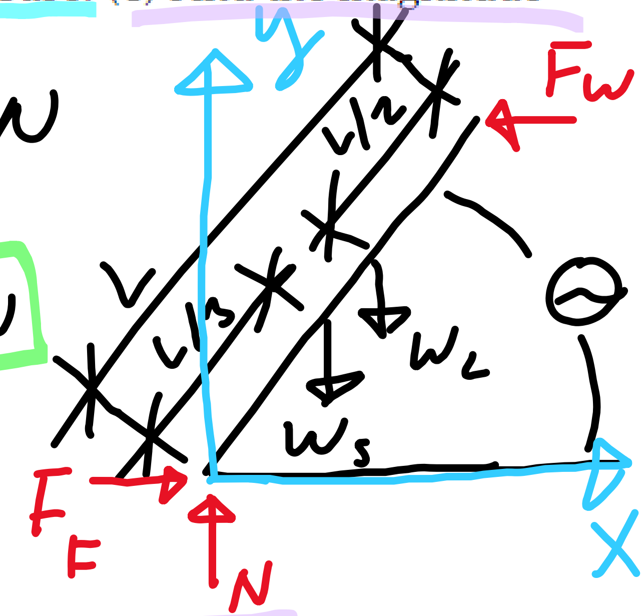

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$\theta = 53.1°,\ \boxed{F_F = F_W = 268N}$

$\sum F_y = 0 \Rightarrow \boxed{N = W_L + W_s = 980N}$

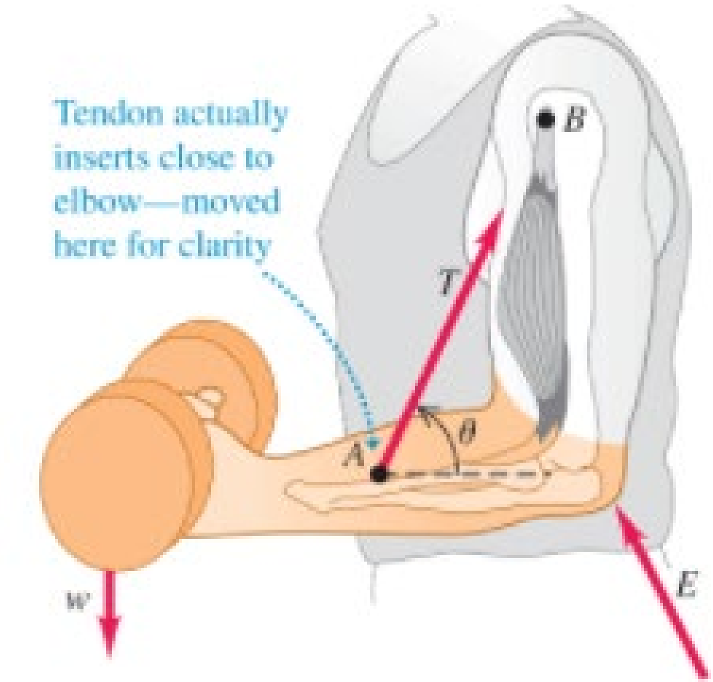
$F_F \leq N\mu_s \Rightarrow (\mu_s)_{min} = F_F/N$

$\Rightarrow \boxed{(\mu_s)_{min} = (268/980) = 0.27}$

$\boxed{F_{CF} = \sqrt{N^2 + F_F^2} = \sqrt{980^2 + 268^2}\,N = 1020N}$

$\boxed{\theta_{CF} = \tan^{-1}\frac{N}{F_F} = \tan^{-1}\left(\frac{980}{268}\right) = 75°}$

Figure 11.10a shows a horizontal human arm lifting a dumbbell. The forearm is in equilibrium under the action of the weight $\vec{w}$ of the dumbbell, the tension $\vec{T}$ in the tendon connected to the biceps muscle, and the force $\vec{E}$ exerted on the forearm by the upper arm at the elbow joint. We ignore the weight of the forearm itself. (For clarity, in the drawing we've exaggerated the distance from the elbow to the point A where the tendon is attached.) Given the weight w and the angle θ between the tension force and the horizontal, find T and the two components of $\vec{E}$ (three unknown scalar quantities in all).



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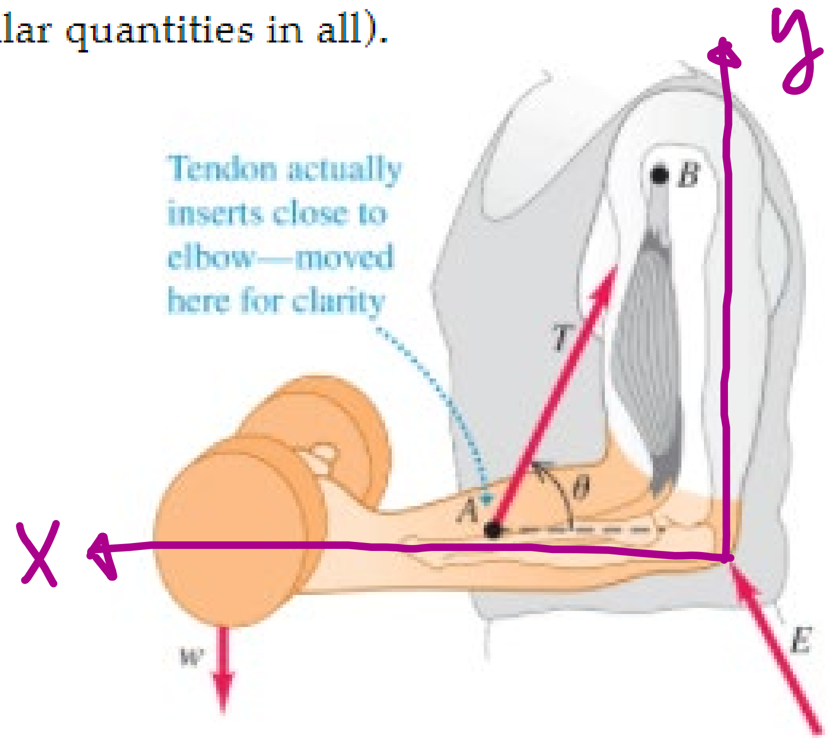

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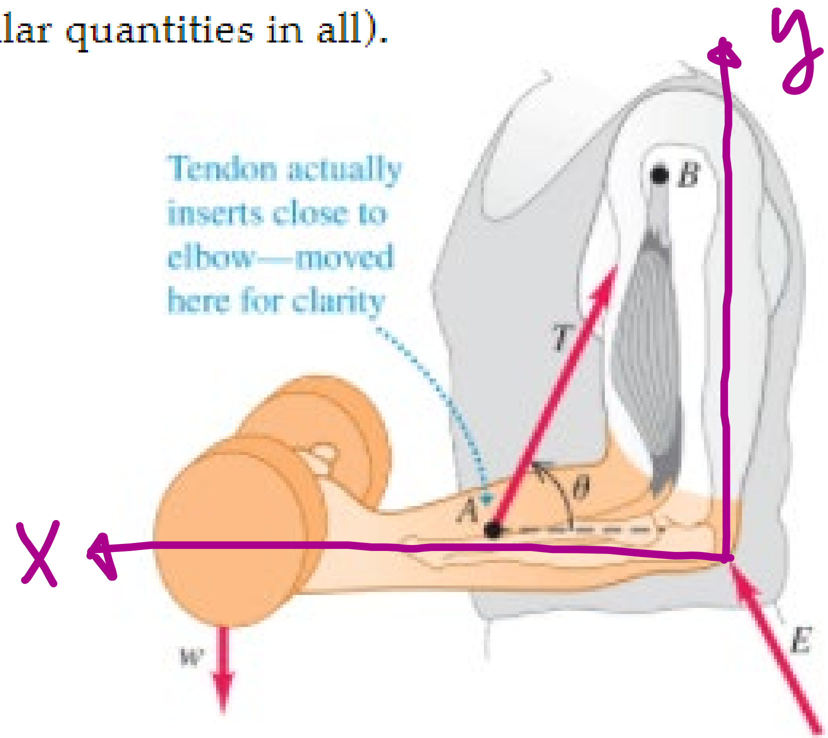

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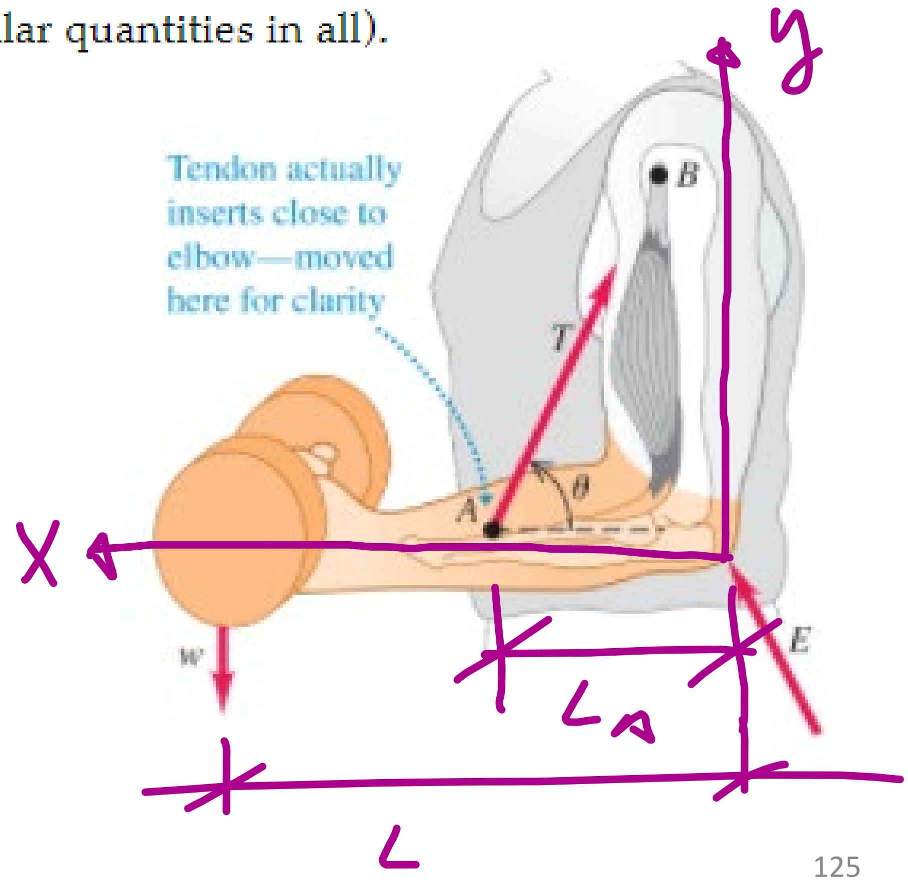
$$\Sigma \vec{\tau}_z = 0 \Rightarrow$$

$$L_A T \sin\theta - wL = 0$$



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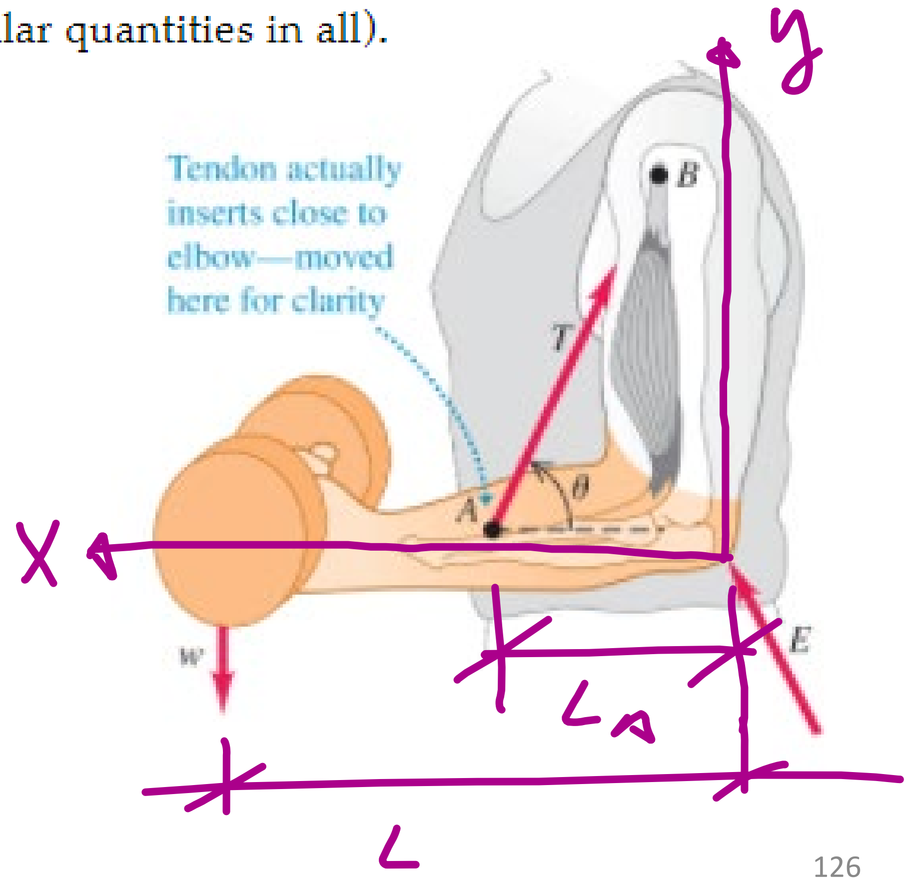

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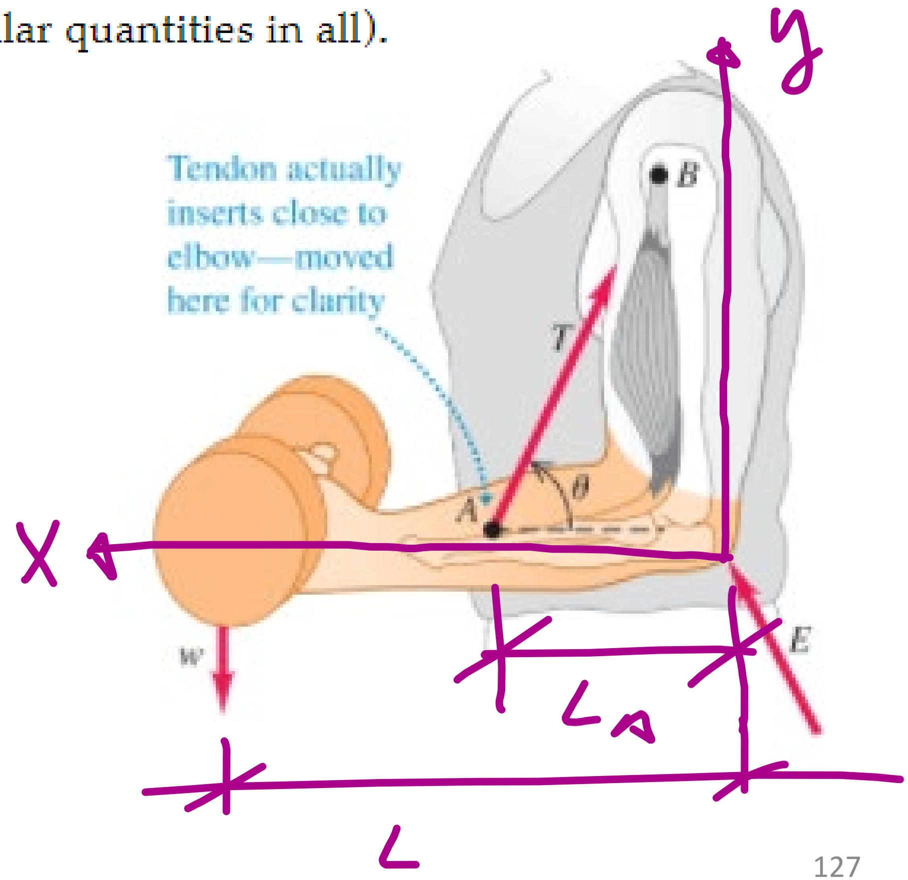
$$L_A T \sin\theta - wL = 0 \Rightarrow$$

$$\boxed{T = \frac{wL}{L_A \sin\theta}}$$



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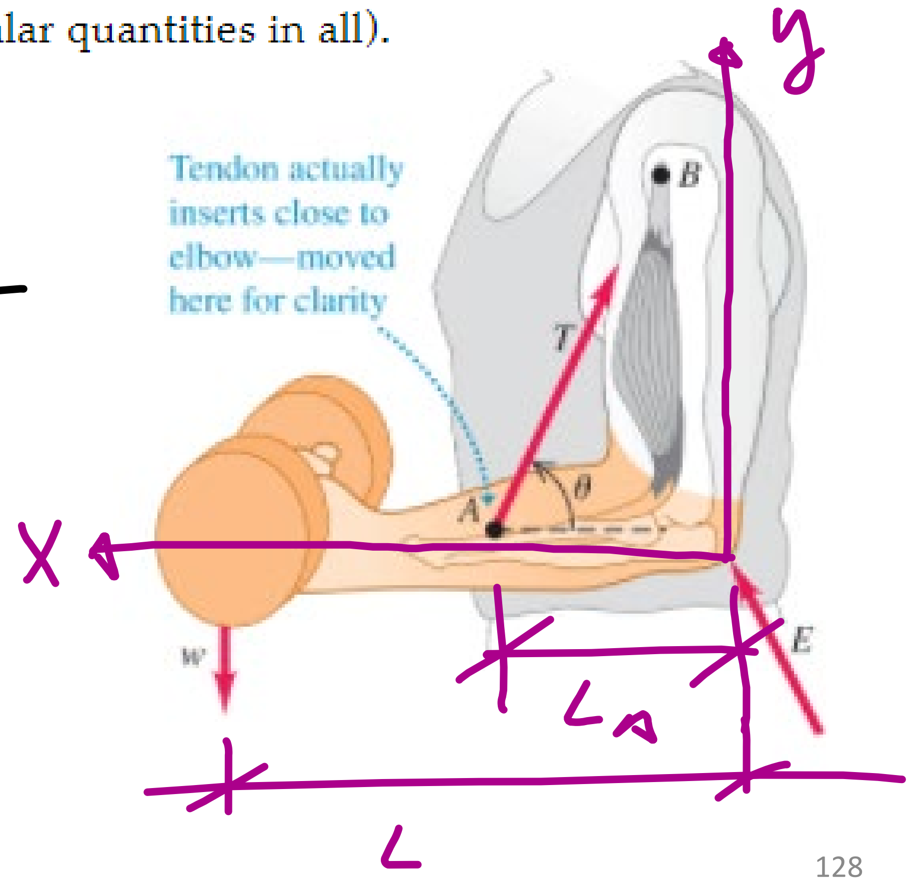

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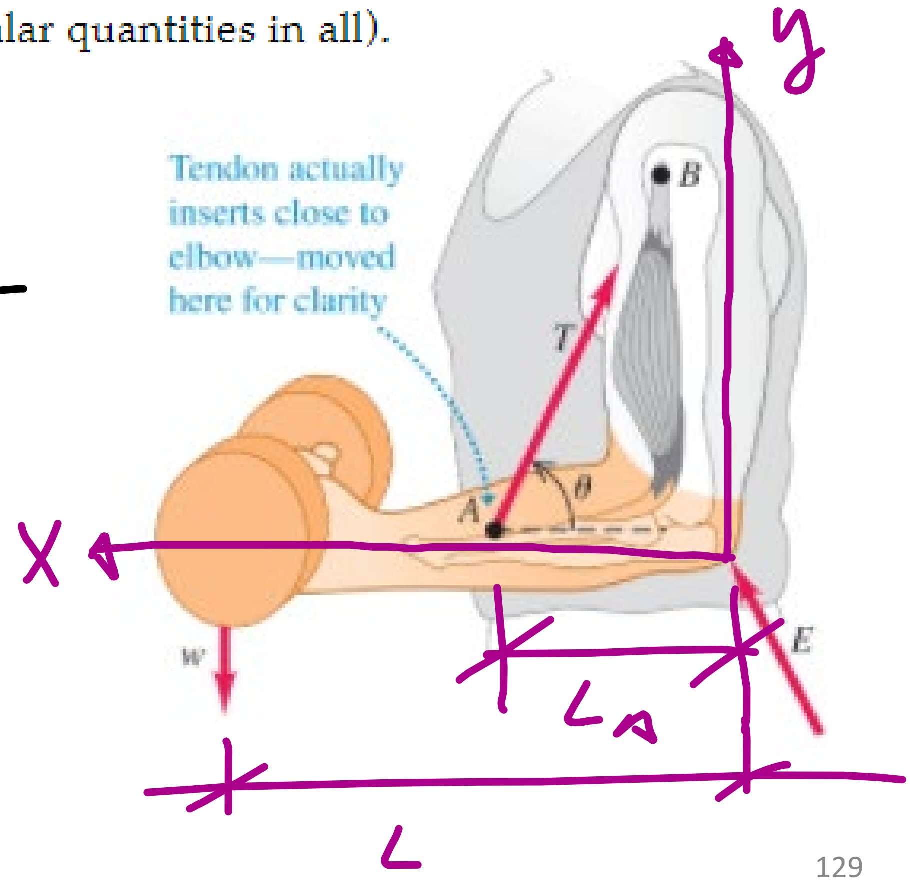
$$\sum F_x = 0 \Rightarrow$$

$$-T\cos\theta + E_x = 0$$



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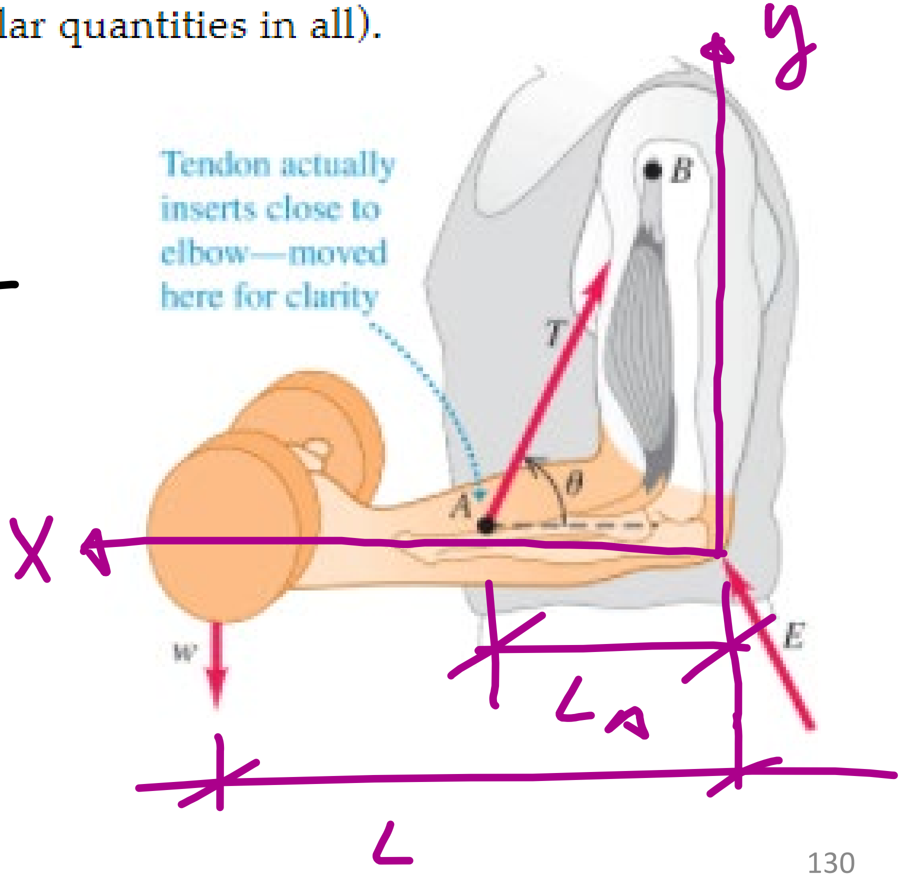
$$-T\cos\theta + E_x = 0 \Rightarrow$$

$$E_x = T\cos\theta$$



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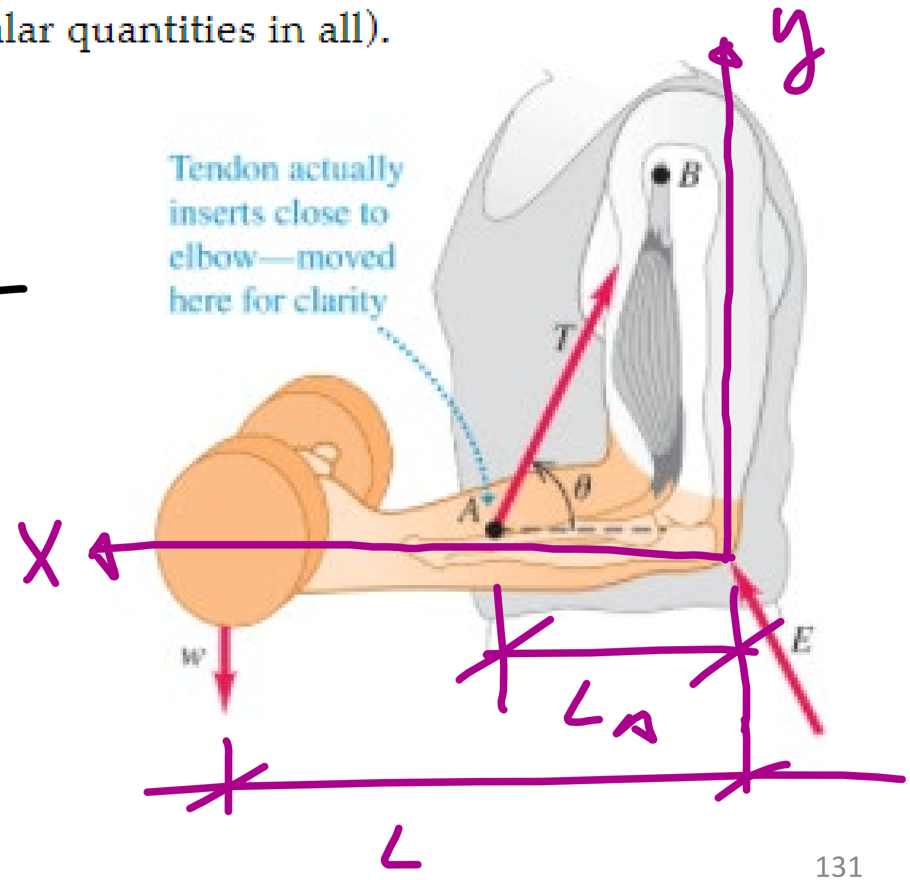
$$\boxed{T = \frac{wL}{L_A \sin\theta}}$$

$$\sum F_x = 0 \Rightarrow$$

$$-T\cos\theta + E_x = 0 \Rightarrow$$

$$E_x = T\cos\theta = \frac{wL}{L_A}\cot\theta$$



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$$\sum F_x = 0 \Rightarrow$$

$$-T\cos\theta + E_x = 0 \Rightarrow$$

$$E_x = T\cos\theta = \frac{wL}{L_A}\cot\theta$$

$$\sum F_y = 0$$

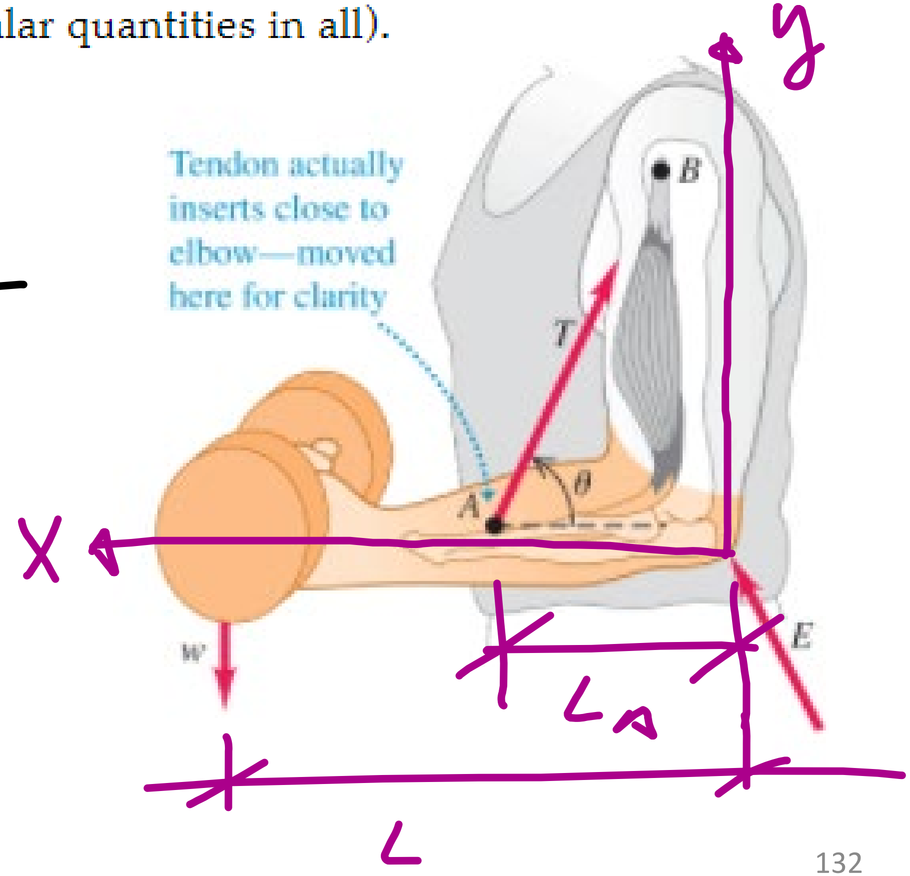


Figure 11.10a shows a horizontal human arm lifting a dumbbell. The forearm is in equilibrium under the action of the weight $\vec{w}$ of the dumbbell, the tension $\vec{T}$ in the tendon connected to the biceps muscle, and the force $\vec{E}$ exerted on the forearm by the upper arm at the elbow joint. We ignore the weight of the forearm itself. (For clarity, in the drawing we've exaggerated the distance from the elbow to the point A where the tendon is attached.) Given the weight w and the angle θ between the tension force and the horizontal, find T and the two components of $\vec{E}$ (three unknown scalar quantities in all).

$$\sum \vec{\tau}_z = 0 \Rightarrow$$

$$L_A T \sin\theta - wL = 0 \Rightarrow$$

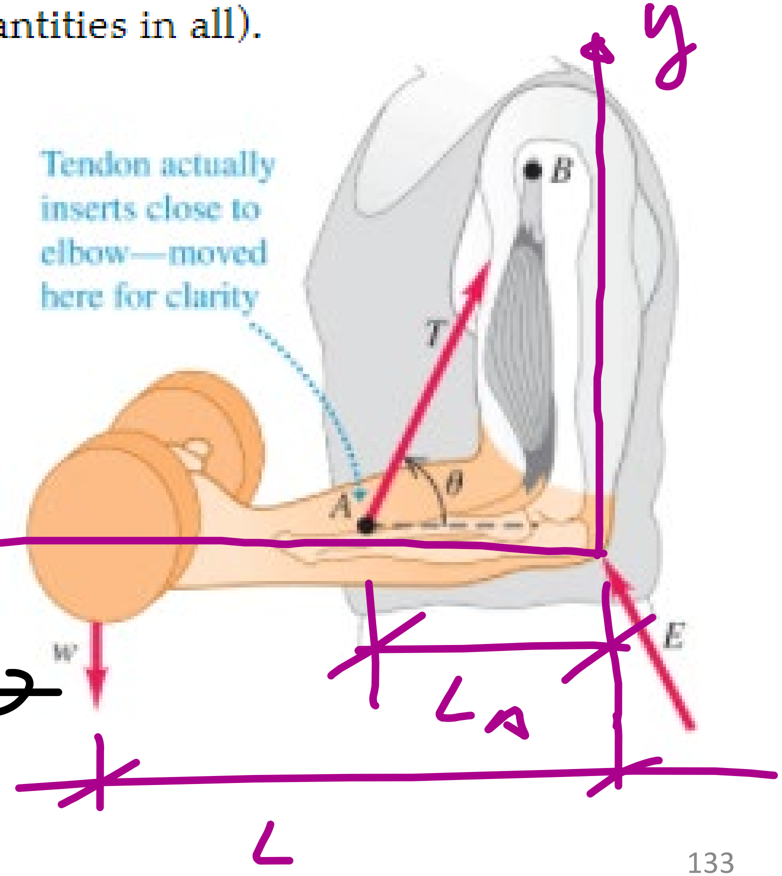
$$\boxed{T = \frac{wL}{L_A \sin\theta}}$$

$$\sum F_x = 0 \Rightarrow$$

$$-T\cos\theta + E_x = 0 \Rightarrow$$

$$E_x = T\cos\theta = \frac{wL}{L_A}\cot\theta$$

$$\sum F_y = 0 \Rightarrow E_y + T\sin\theta - w = 0$$



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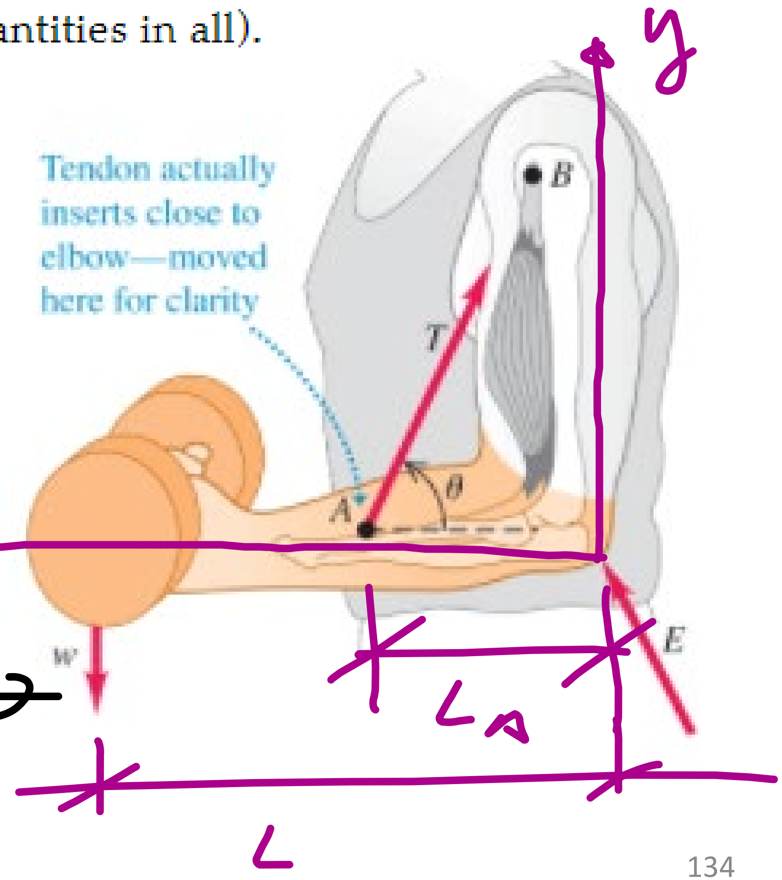
$\Rightarrow E_y = w - T\sin\theta$



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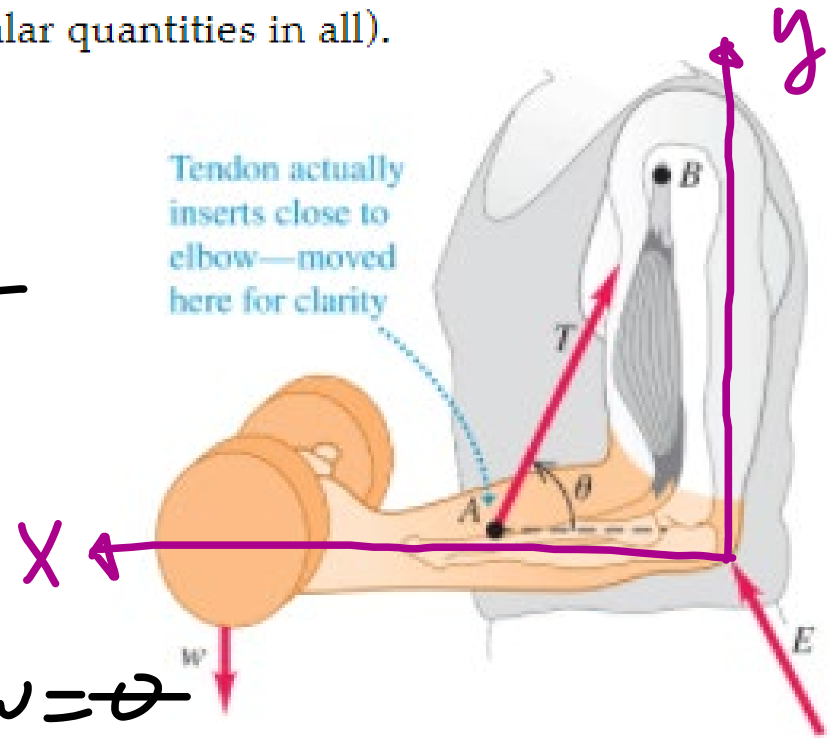

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$$\Rightarrow E_y = w - T\sin\theta \Rightarrow \boxed{E_y = w - \frac{wL}{L_A} = w\left(1 - \frac{L}{L_A}\right)}$$