Today 5.1

L 14

# Today 5.1

L 14

Using Newton's 1st law

Today 5.1

Monday 5.2

L 14

Today 5.1

Monday 5.2

Using Newton's 2nd law

L 14

# Using Newton's First Law

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

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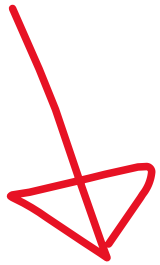
Example problems



A gymnast with mass $m_G = 50.0\ \mathrm{kg}$ suspends herself from the lower end of a hanging rope of negligible mass. The upper end of the rope is attached to the gymnasium ceiling. (a) What is the gymnast's weight? (b) What force (magnitude and direction) does the rope exert on her? (c) What is the tension at the top of the rope?

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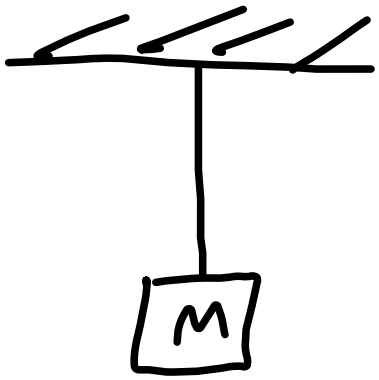

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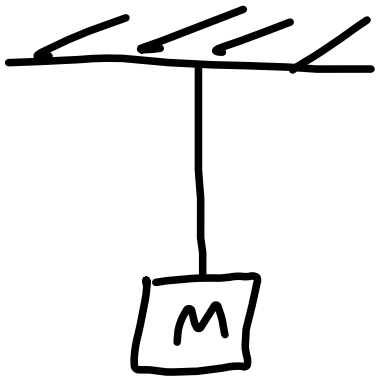

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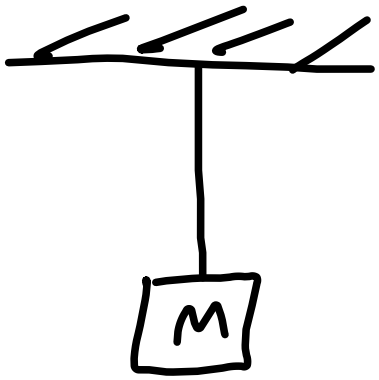


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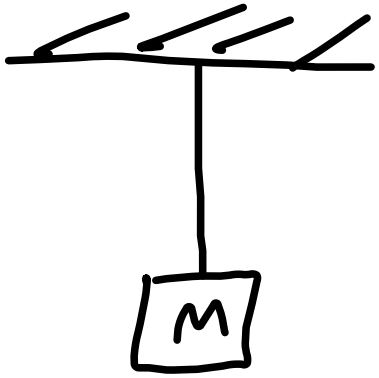


$M = 50\ \text{kg}$

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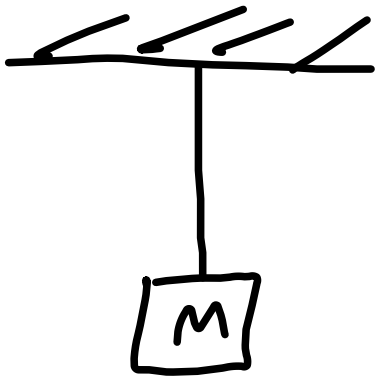


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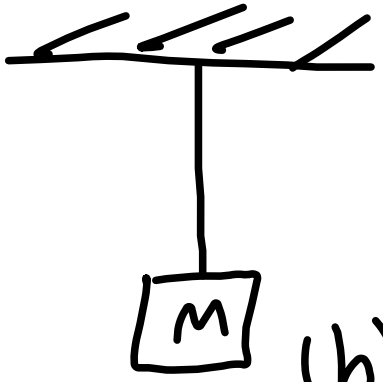


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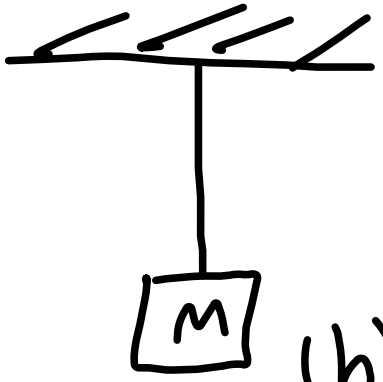


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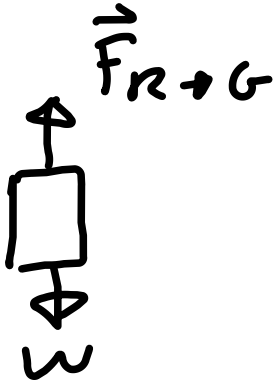

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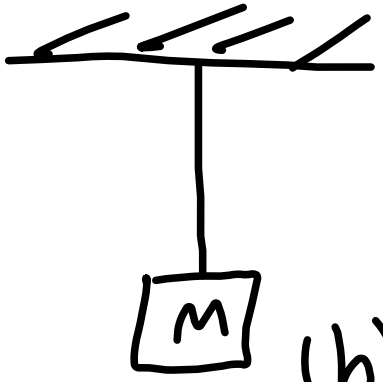


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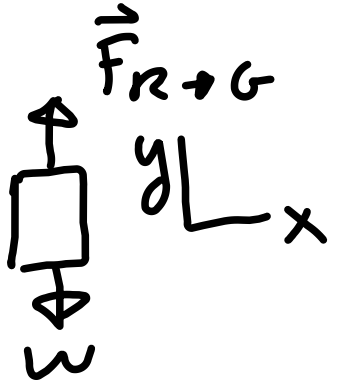

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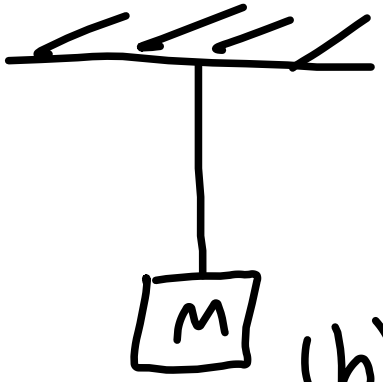


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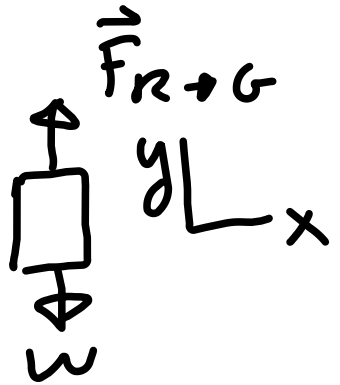


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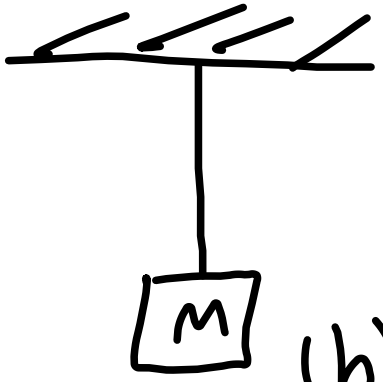


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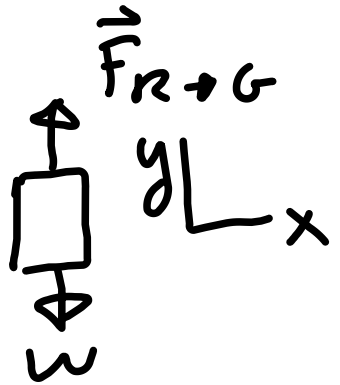


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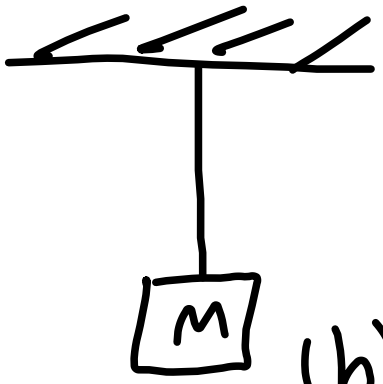


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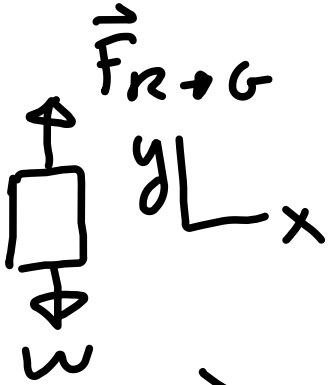


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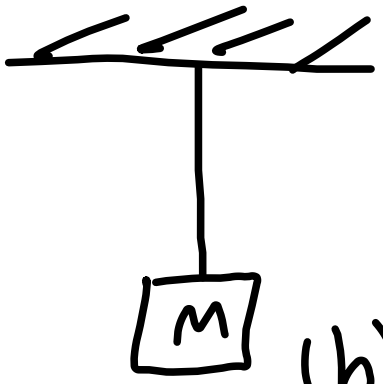


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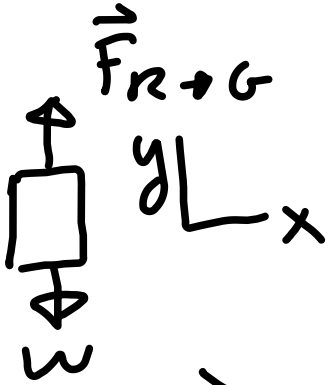


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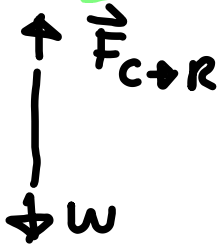

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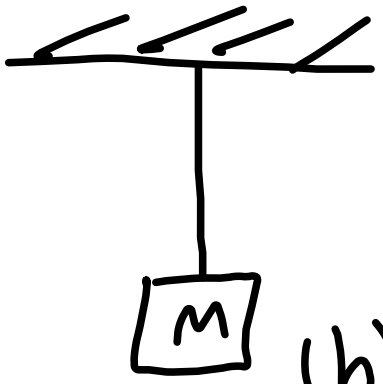


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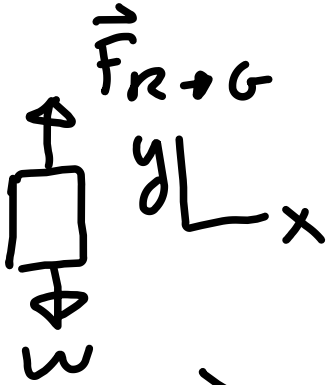


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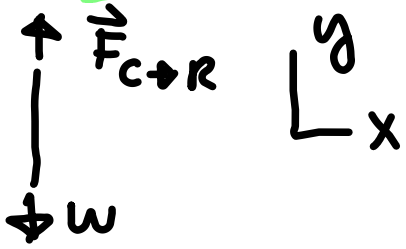

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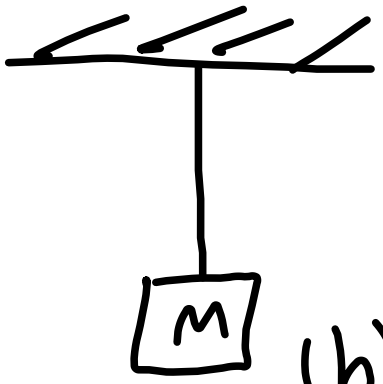


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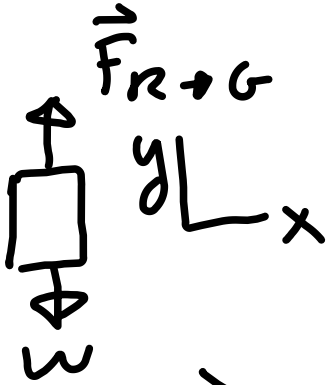


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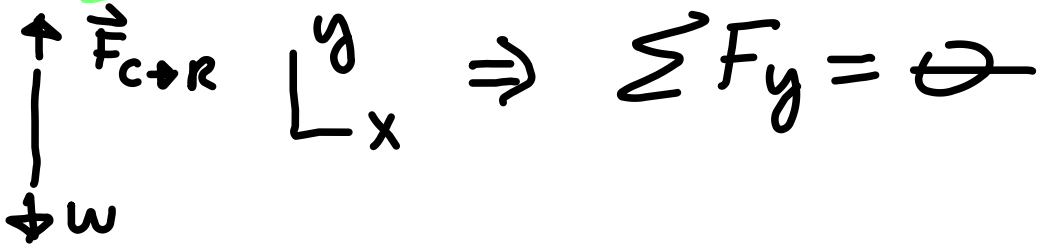


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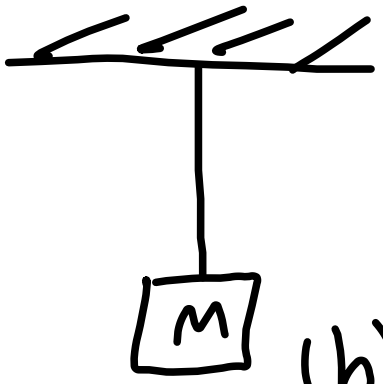


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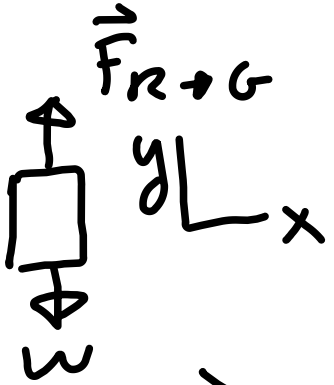


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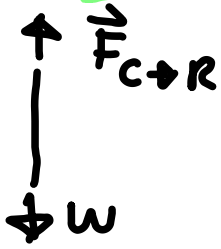


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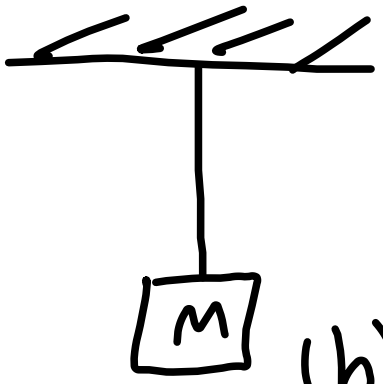


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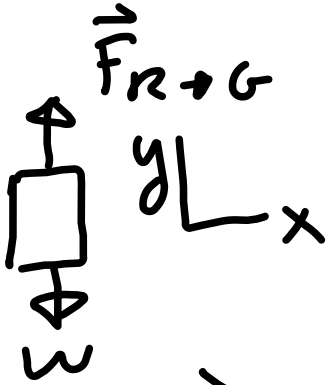


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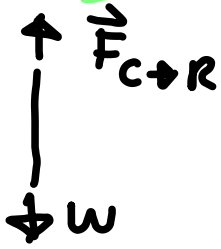


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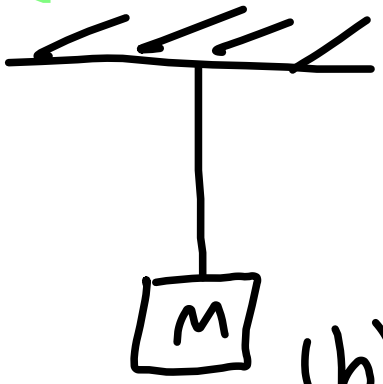


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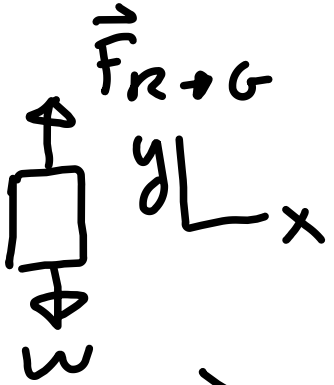


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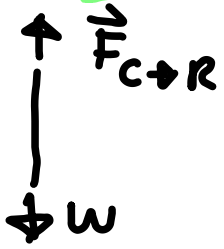
$\Rightarrow \boxed{F_{R\to G} = w = 490\ \text{N}}$

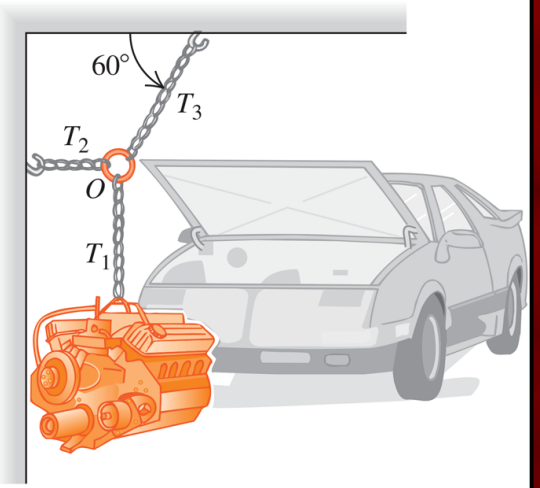
(c) Find $\vec{F}_{C\to R}$




$\Rightarrow \Sigma F_y = 0 \Rightarrow F_{C\to R} - w = 0$

$\Rightarrow \boxed{F_{C\to R} = w = 490\ \text{N}}$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.



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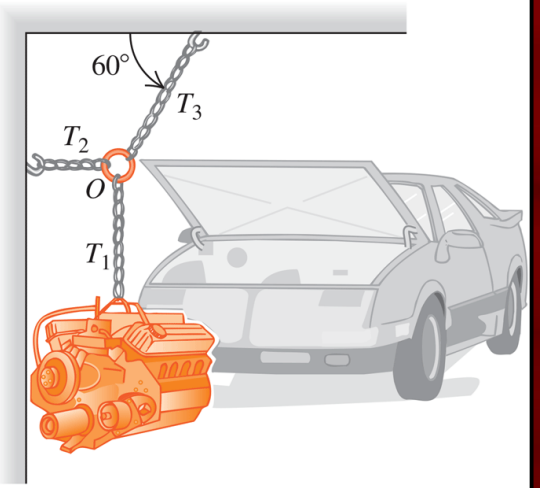

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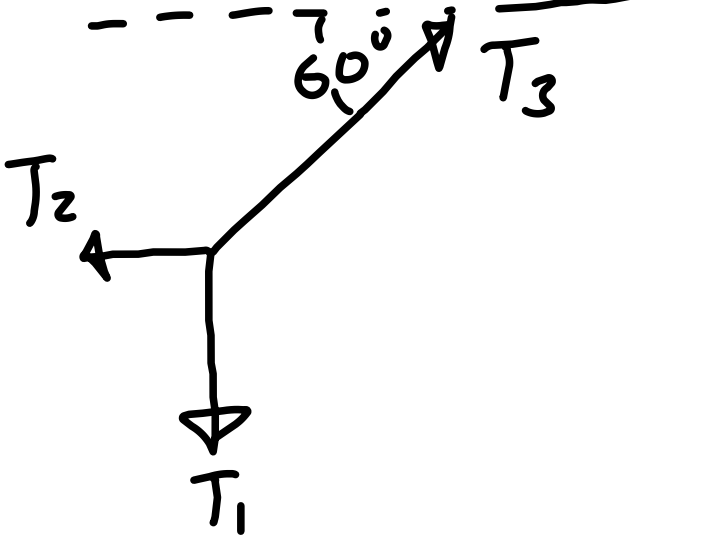


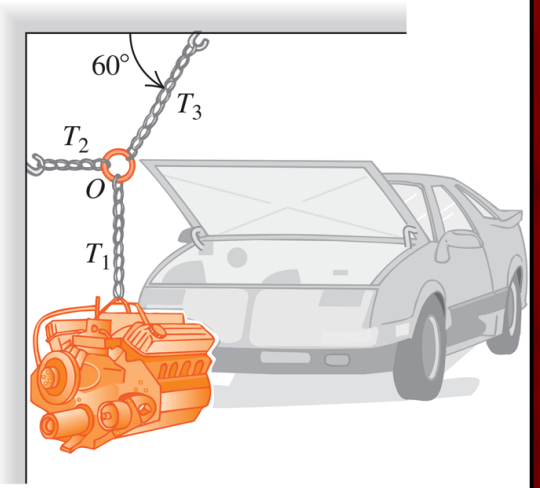

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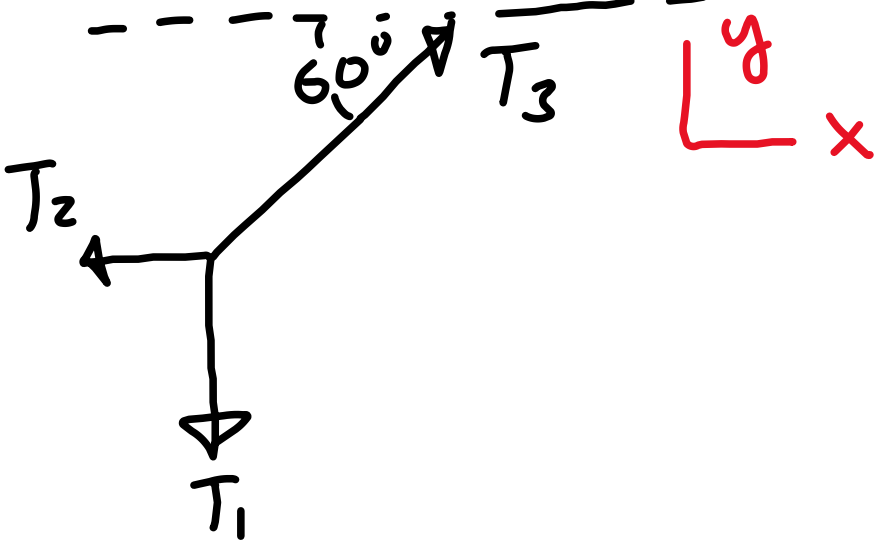


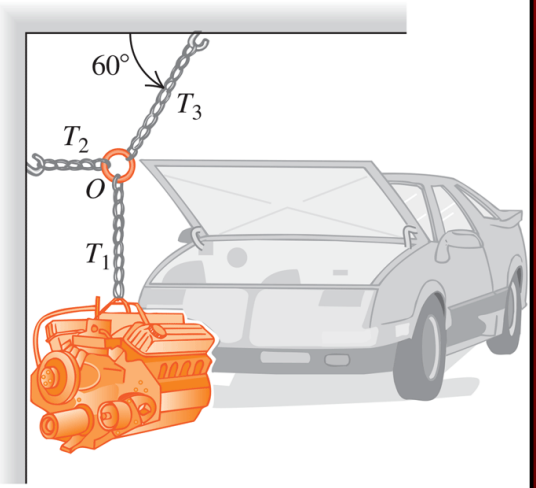

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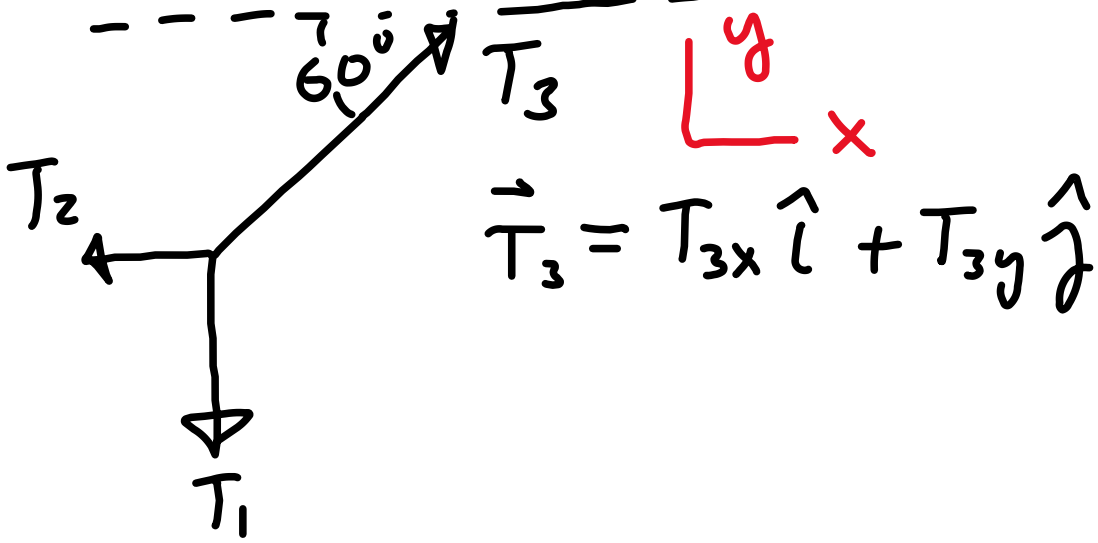


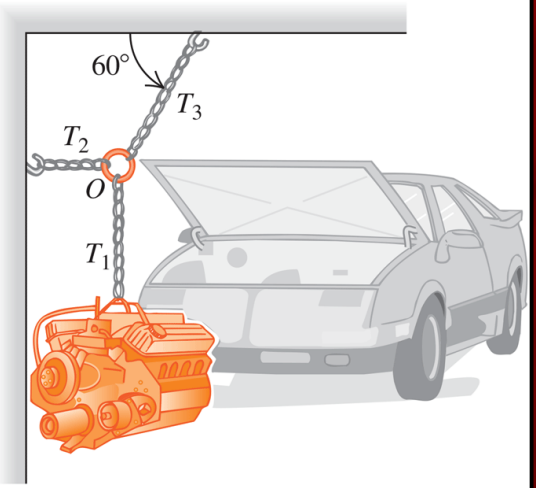

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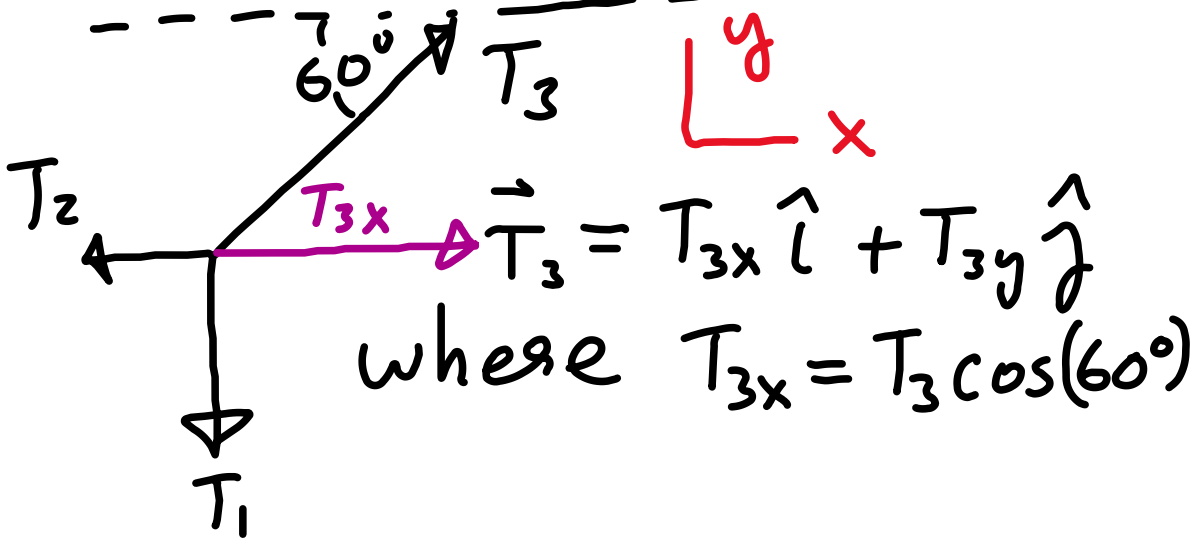


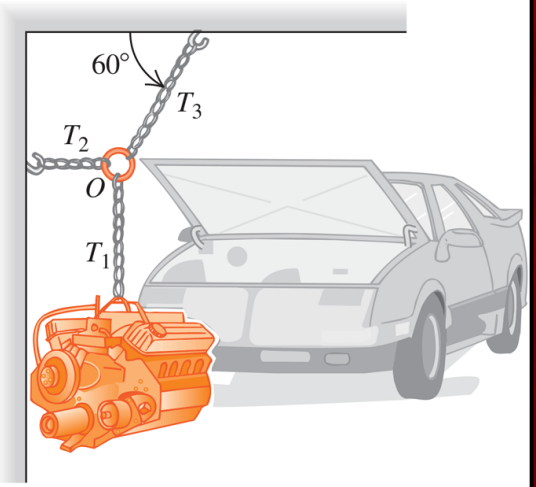

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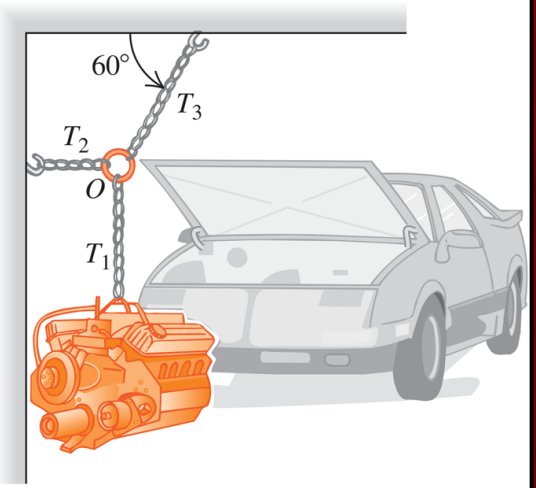
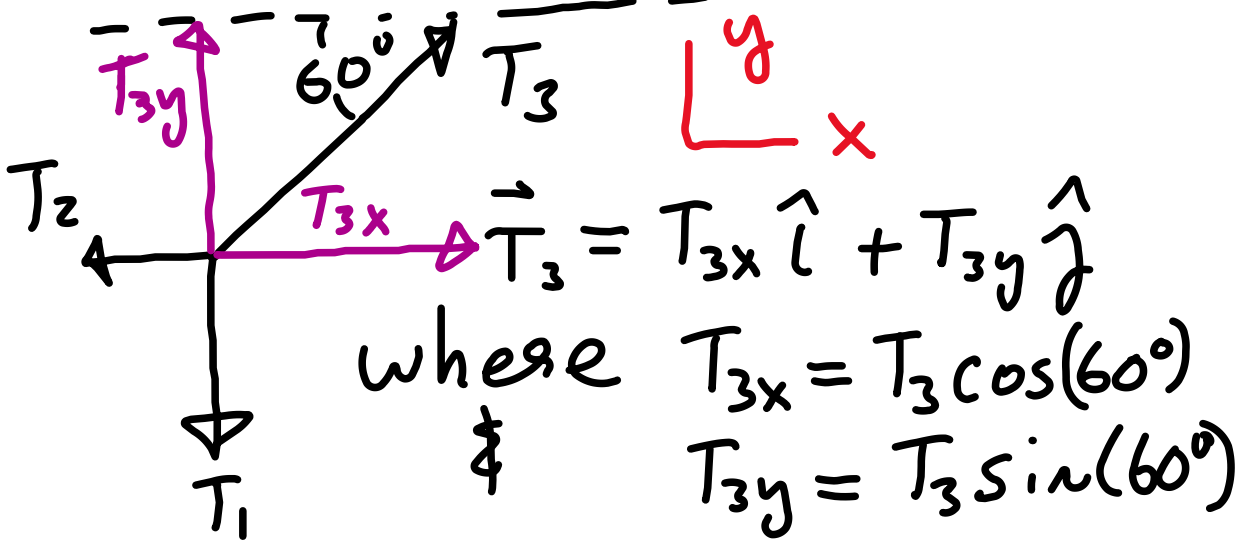


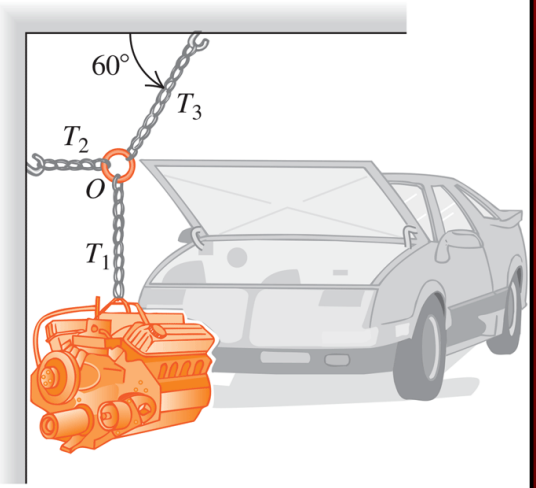



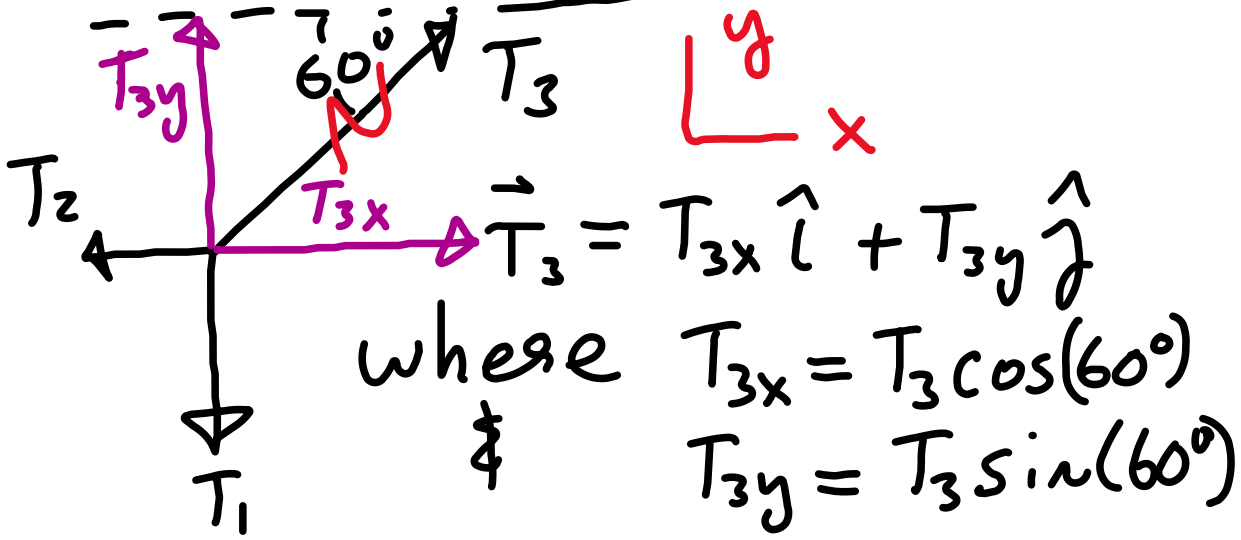

$\vec{T}_3 = T_{3x}\,\hat{\imath} + T_{3y}\,\hat{\jmath}$

where $T_{3x} = T_3 \cos(60°)$

& $T_{3y} = T_3 \sin(60°)$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.




$\vec{T}_3 = T_{3x}\hat{\imath} + T_{3y}\hat{\jmath}$

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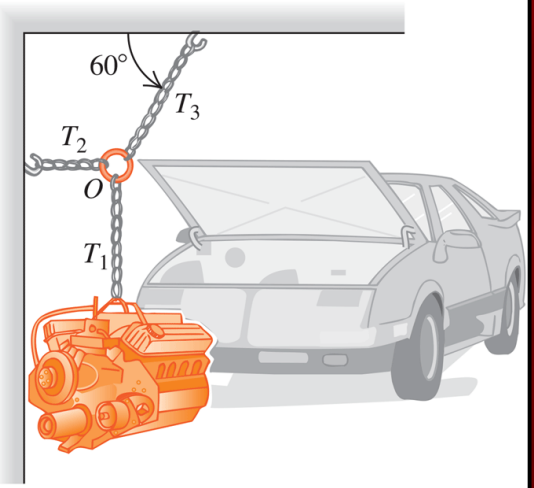


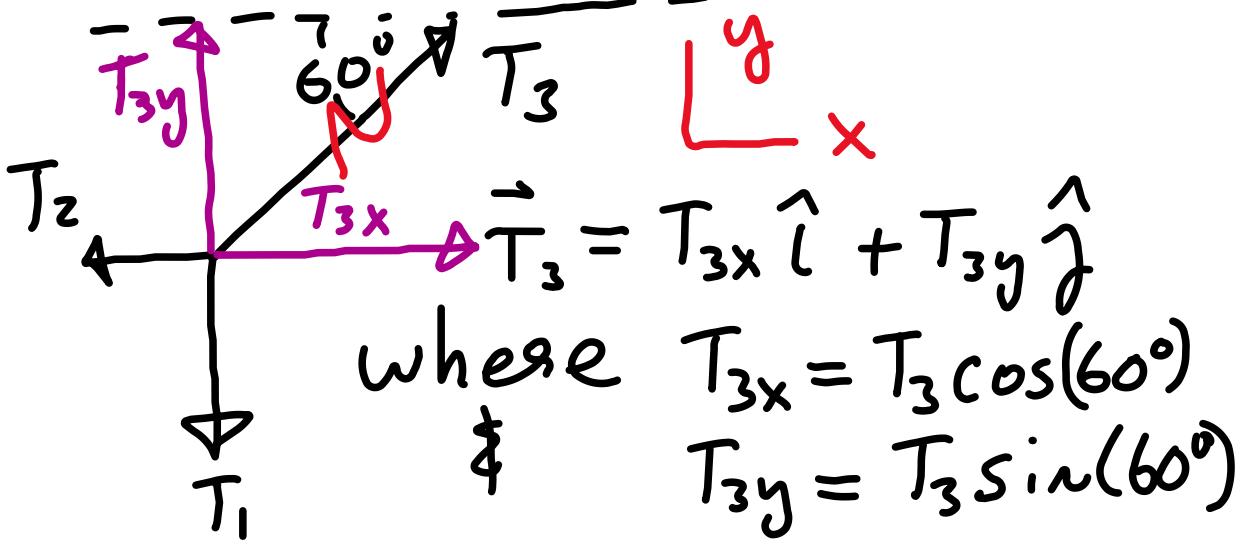


$\vec{T}_3 = T_{3x}\hat{\imath} + T_{3y}\hat{\jmath}$

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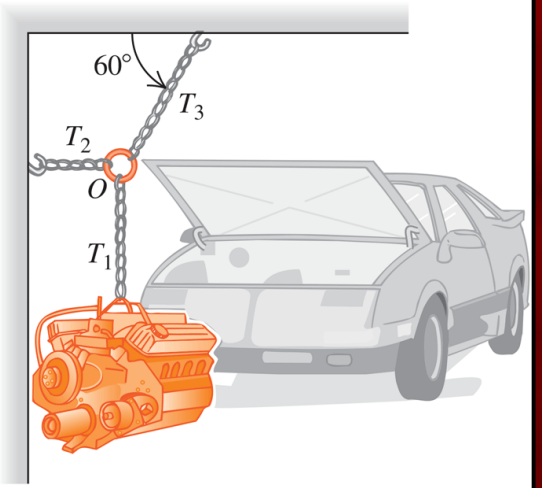
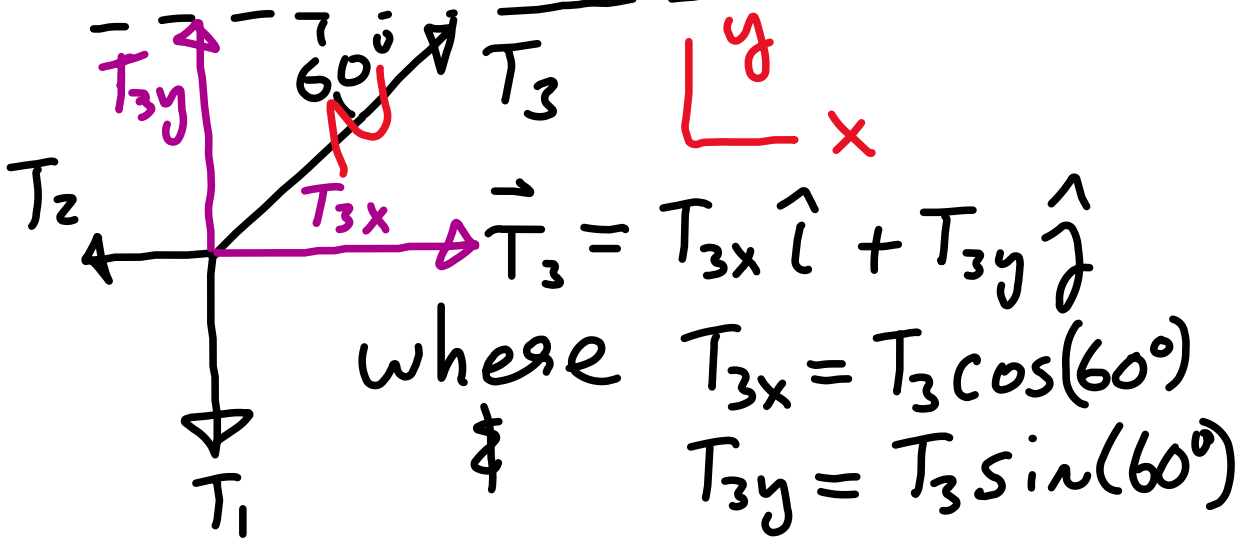
$\Sigma F_x = 0$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.




$$\vec{T}_3 = T_{3x}\,\hat{\imath} + T_{3y}\,\hat{\jmath}$$

where

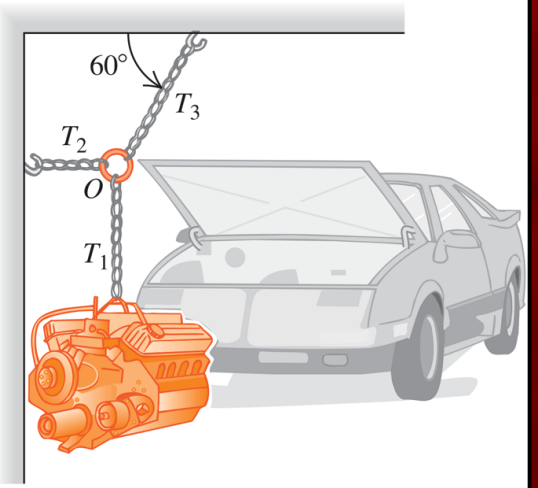
$$T_{3x} = T_3\cos(60^\circ)$$

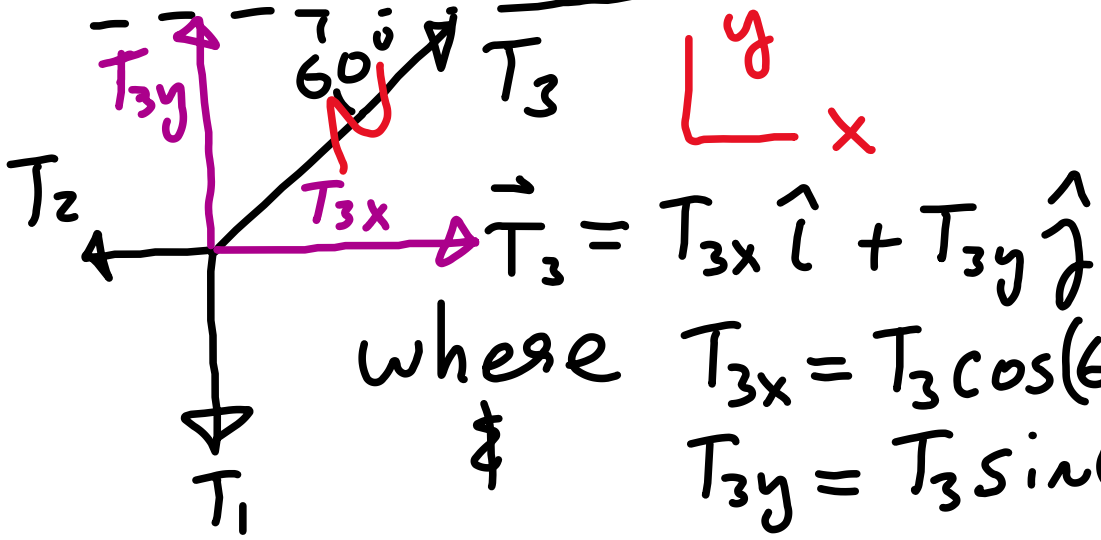
&

$$T_{3y} = T_3\sin(60^\circ)$$

$$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0$$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.



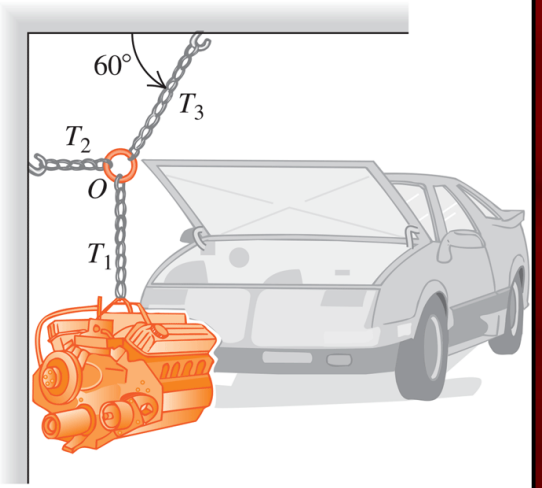



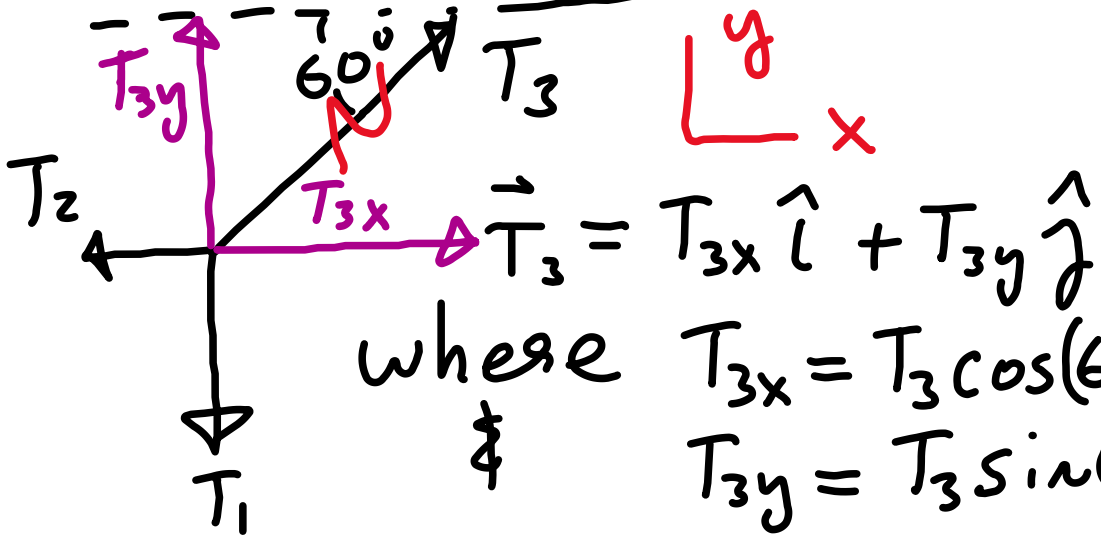

$\vec{T}_3 = T_{3x}\,\hat{\imath} + T_{3y}\,\hat{\jmath}$

where $T_{3x} = T_3\cos(60°)$ & $T_{3y} = T_3\sin(60°)$

$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.




$\vec{T}_3 = T_{3x}\,\hat{\imath} + T_{3y}\,\hat{\jmath}$

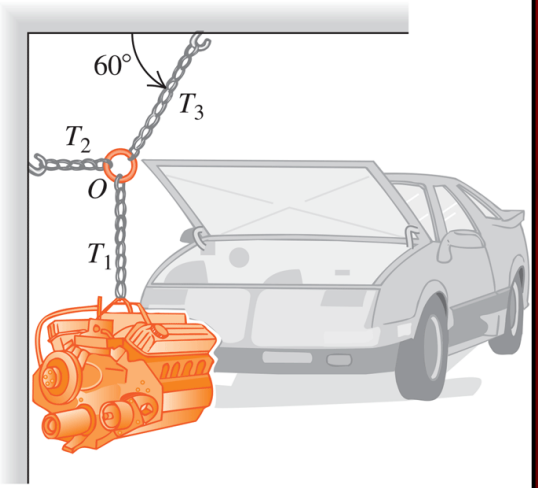
where $T_{3x} = T_3 \cos(60°)$

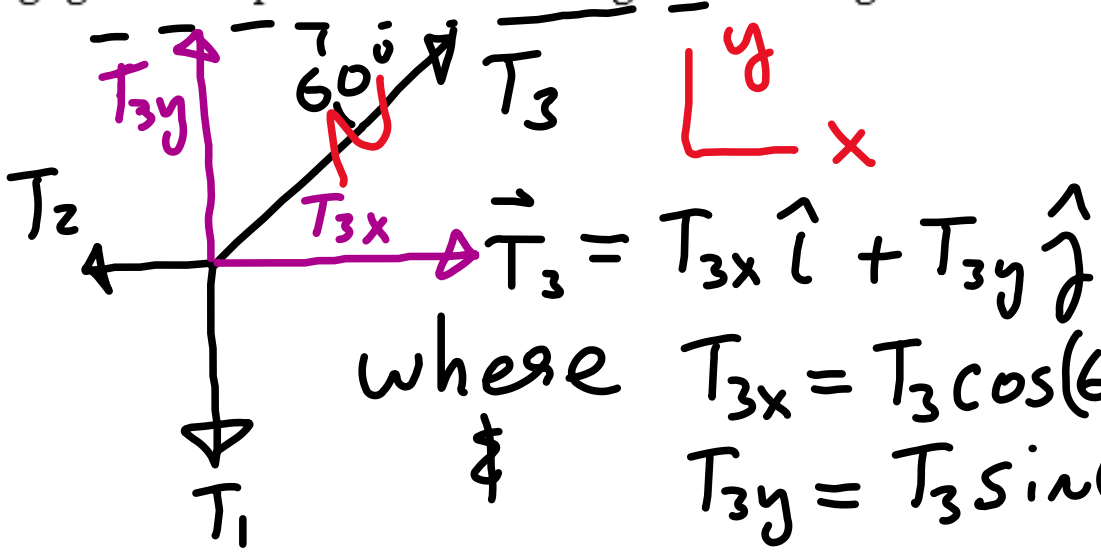
& $T_{3y} = T_3 \sin(60°)$

$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$

$\Sigma F_y = 0$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.




$\vec{T}_3 = T_{3x}\hat{\imath} + T_{3y}\hat{\jmath}$

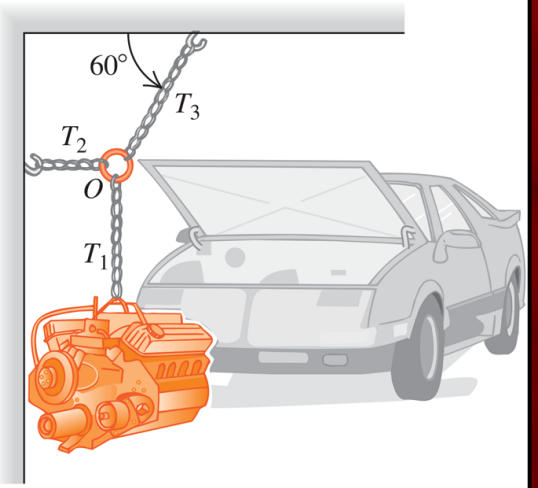
where & $T_{3x} = T_3\cos(60°)$

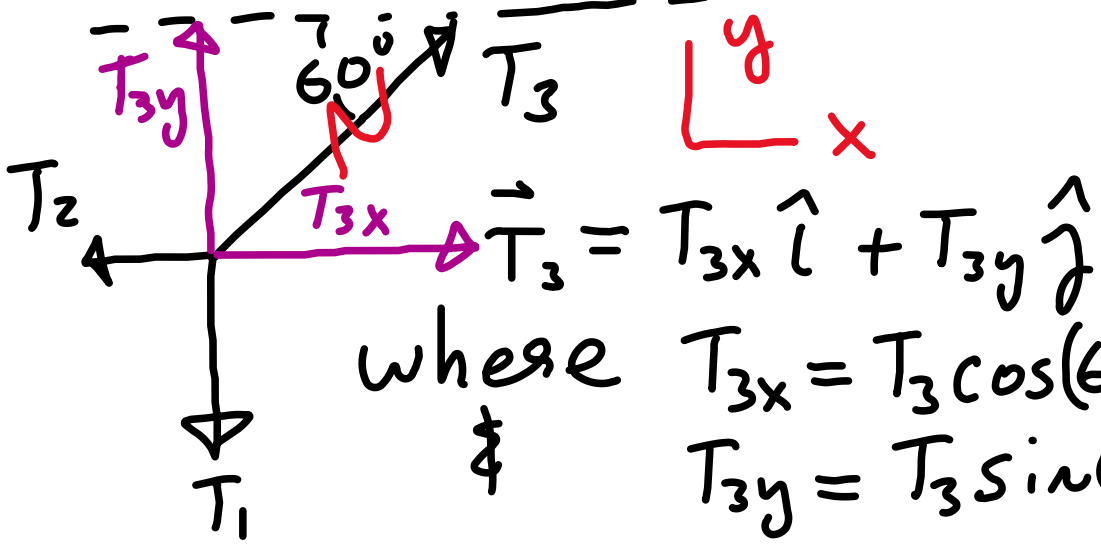
$T_{3y} = T_3\sin(60°)$

$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$

$\Sigma F_y = 0 \Rightarrow T_{3y} - T_1 = 0$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.




$$\vec{T}_3 = T_{3x}\,\hat{\imath} + T_{3y}\,\hat{\jmath}$$

where & $T_{3x} = T_3\cos(60°)$

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$$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$$

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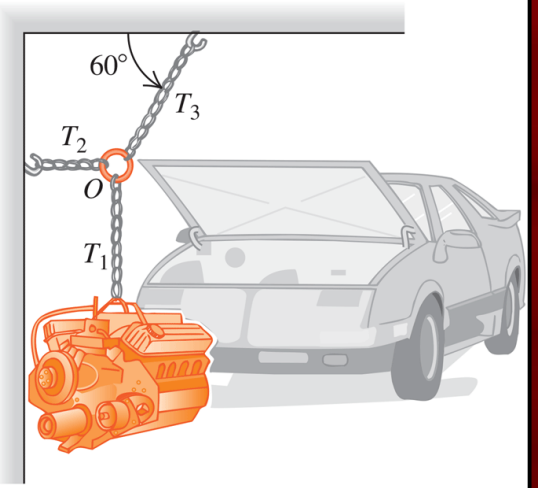
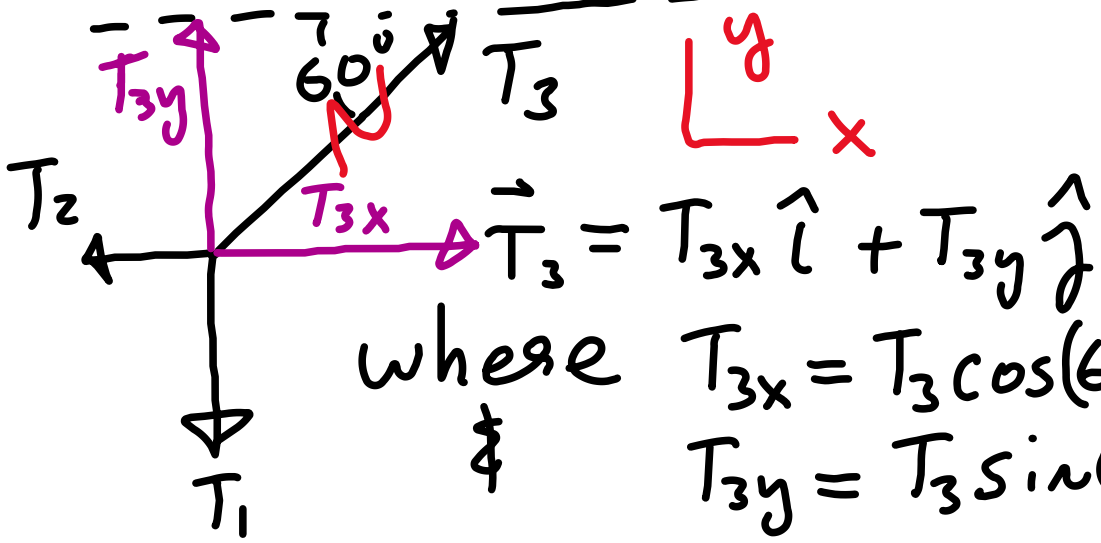



$\vec{T}_3 = T_{3x}\hat{\imath} + T_{3y}\hat{\jmath}$

where & $T_{3x} = T_3\cos(60°)$

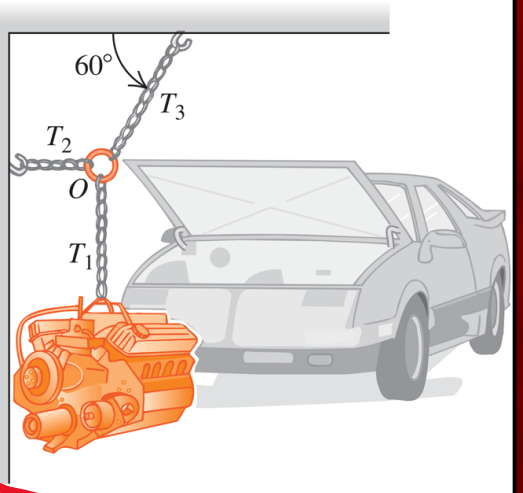
$T_{3y} = T_3\sin(60°)$

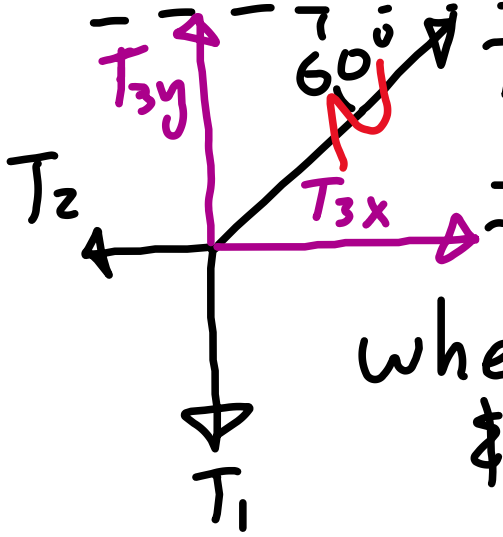
$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$

$\Sigma F_y = 0 \Rightarrow T_{3y} - T_1 = 0 \Rightarrow T_{3y} = T_1$

But $T_1 = w$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.




$y$
$x$

$\vec{T}_3 = T_{3x}\,\hat{\imath} + T_{3y}\,\hat{\jmath}$

where $T_{3x} = T_3\cos(60°)$

& $T_{3y} = T_3\sin(60°)$

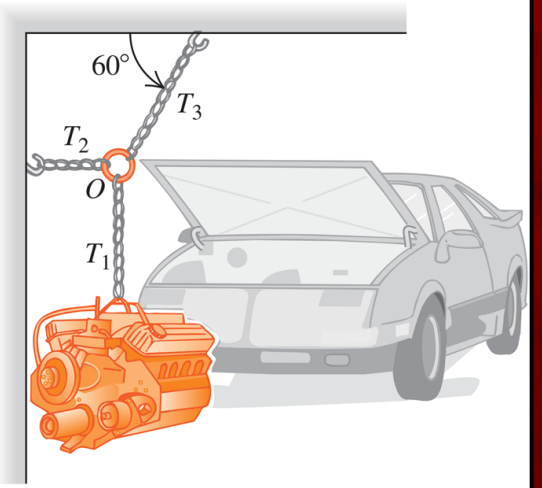
$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$

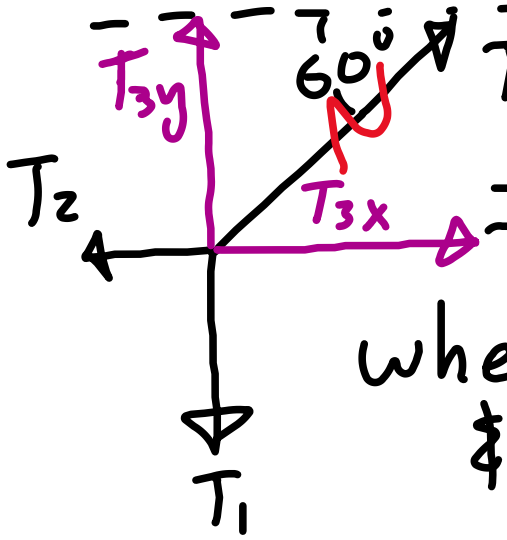
$\Sigma F_y = 0 \Rightarrow T_{3y} - T_1 = 0 \Rightarrow T_{3y} = T_1$

But $T_1 = w$ so $T_3\sin(60) = w$

ASU

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.





$\vec{T}_3 = T_{3x}\,\hat{\imath} + T_{3y}\,\hat{\jmath}$

where $T_{3x} = T_3 \cos(60°)$

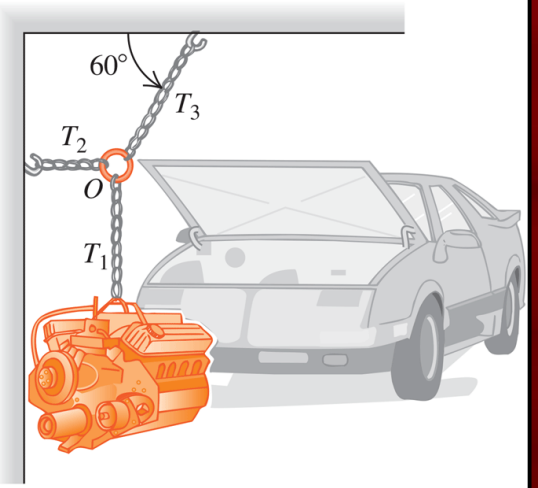
& $T_{3y} = T_3 \sin(60°)$

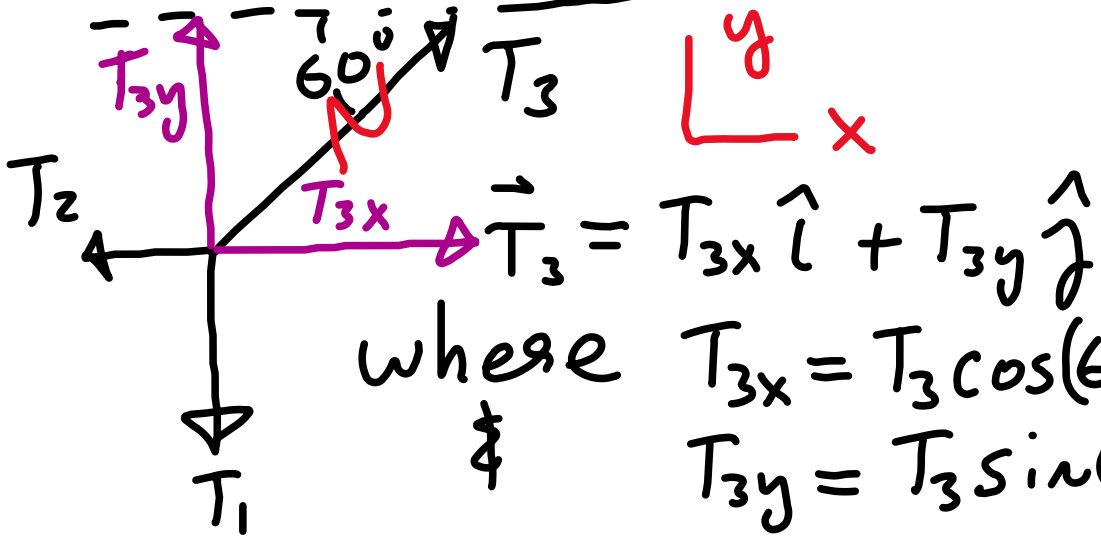
$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$

$\Sigma F_y = 0 \Rightarrow T_{3y} - T_1 = 0 \Rightarrow T_{3y} = T_1$

But $T_1 = w$ so $T_3 \sin(60) = w \Rightarrow T_3 = \dfrac{w}{\sin(60°)}$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.




$\vec{T}_3 = T_{3x}\,\hat{\imath} + T_{3y}\,\hat{\jmath}$

where $T_{3x} = T_3\cos(60°)$

& $T_{3y} = T_3\sin(60°)$

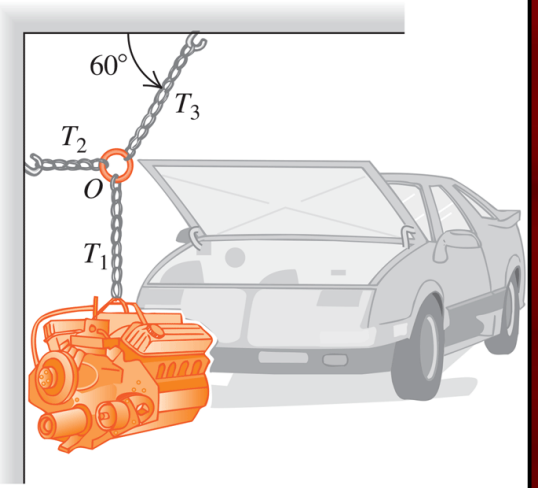
$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$

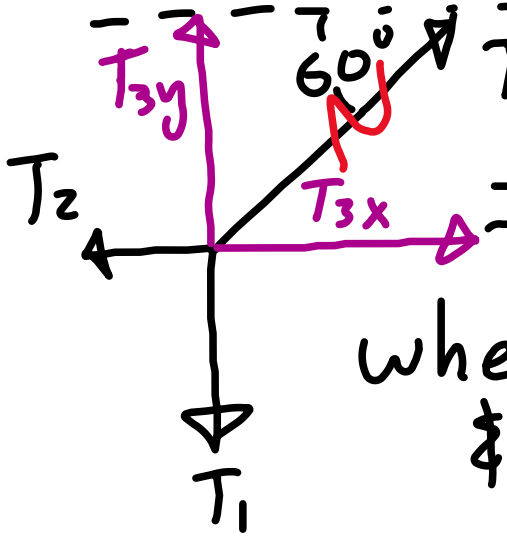
$\Sigma F_y = 0 \Rightarrow T_{3y} - T_1 = 0 \Rightarrow T_{3y} = T_1$

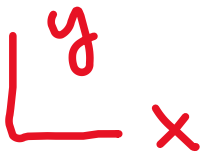
But $T_1 = w$ so $T_3\sin(60) = w \Rightarrow T_3 = \dfrac{w}{\sin(60°)}$

$\Rightarrow T_2 = \left(\dfrac{w}{\sin 60°}\right)\cos(60°)$

In Fig. 5.3a, a car engine with weight $w$ hangs from a chain that is linked at ring $O$ to two other chains, one fastened to the ceiling and the other to the wall. Find expressions for the tension in each of the three chains in terms of $w$. The weights of the ring and chains are negligible compared with the weight of the engine.




$\vec{T}_3 = T_{3x}\,\hat{i} + T_{3y}\,\hat{j}$

where & $T_{3x} = T_3 \cos(60°)$

$T_{3y} = T_3 \sin(60°)$

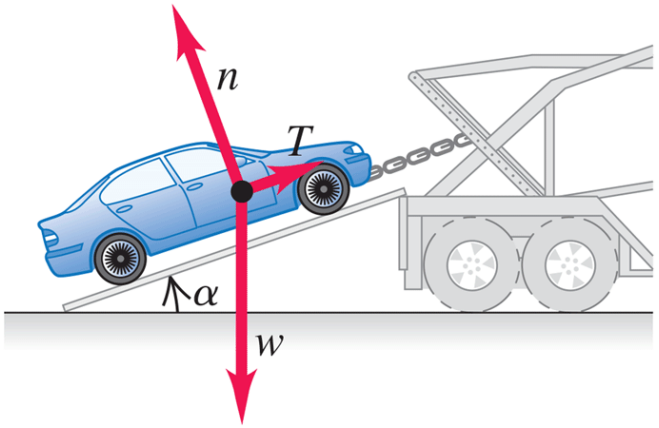
$\Sigma F_x = 0 \Rightarrow T_{3x} - T_2 = 0 \Rightarrow T_{3x} = T_2$

$\Sigma F_y = 0 \Rightarrow T_{3y} - T_1 = 0 \Rightarrow T_{3y} = T_1$

But $T_1 = w$ so $T_3 \sin(60) = w \Rightarrow T_3 = \frac{w}{\sin(60°)}$

$\Rightarrow T_2 = \left(\frac{w}{\sin 60°}\right)\cos(60°) \Rightarrow T_2 = w \cot(60°)$

A car of weight $w$ rests on a slanted ramp attached to a trailer (Fig. 5.4a). Only a cable running from the trailer to the car prevents the car from rolling off the ramp. (The car's brakes are off and its transmission is in neutral.) Find the tension in the cable and the force that the ramp exerts on the car's tires.



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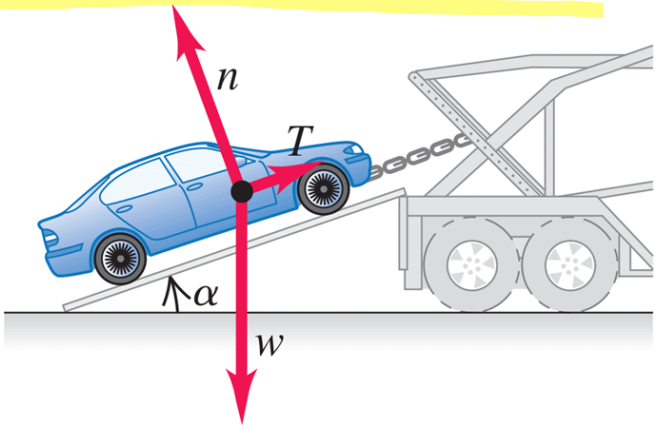

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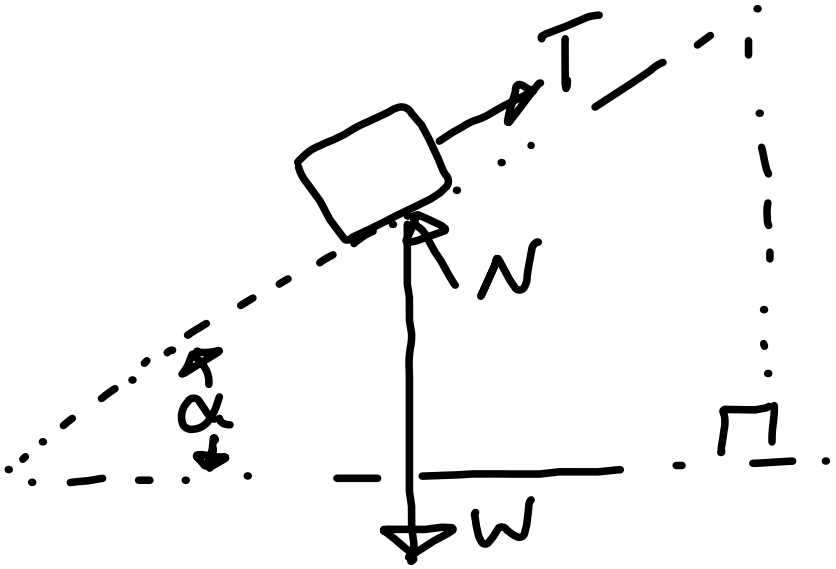


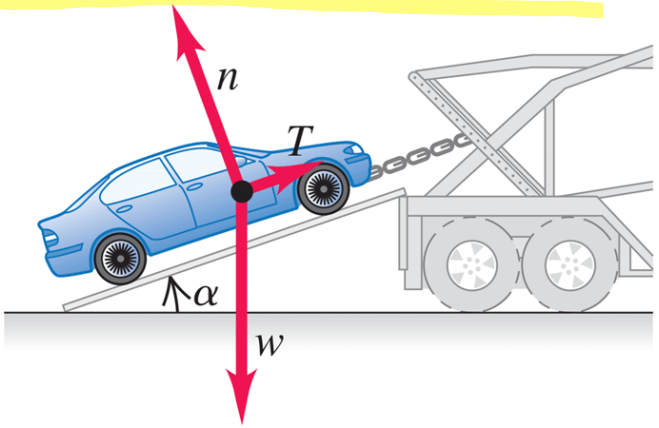

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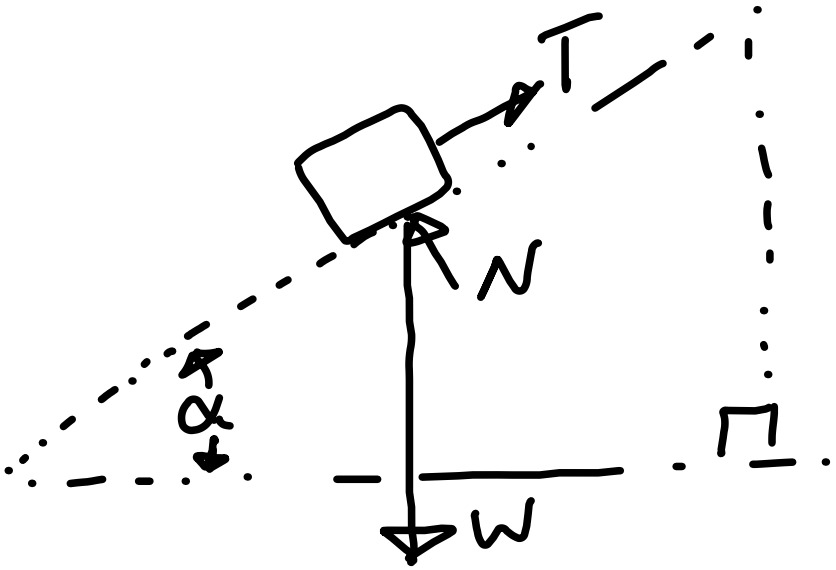


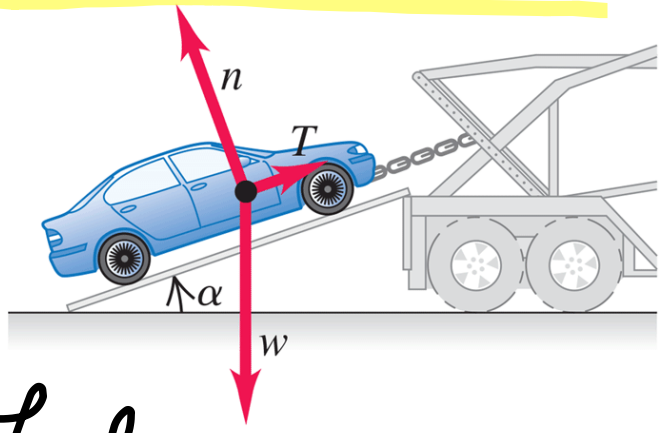


Let $\beta = 90 - \alpha$

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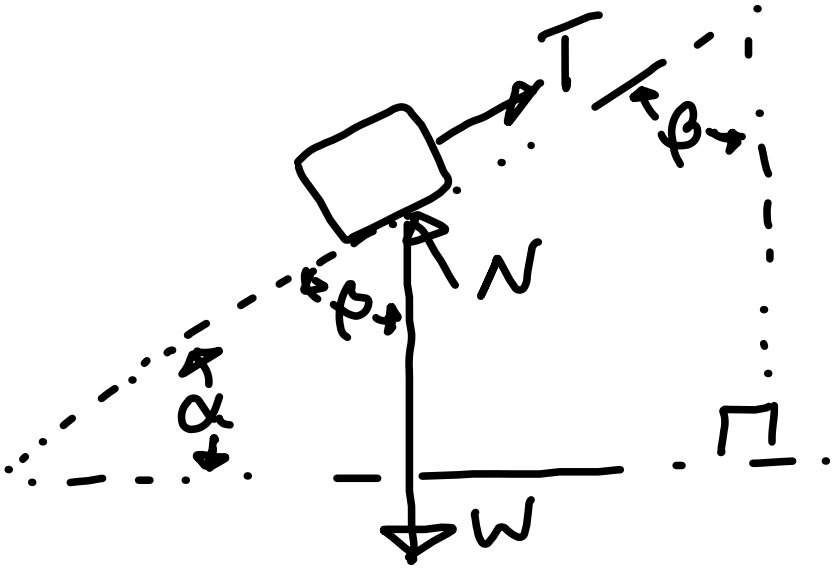


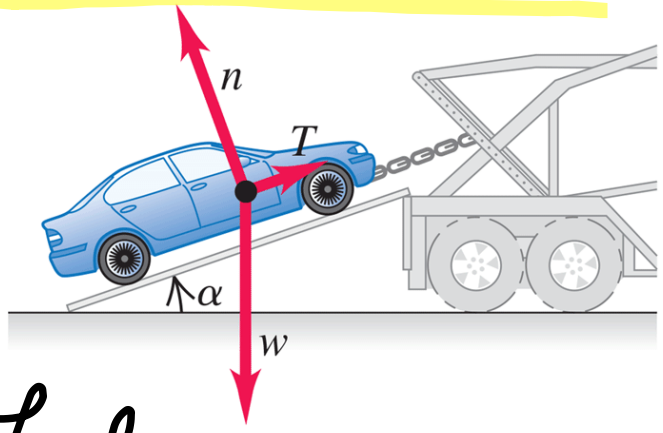


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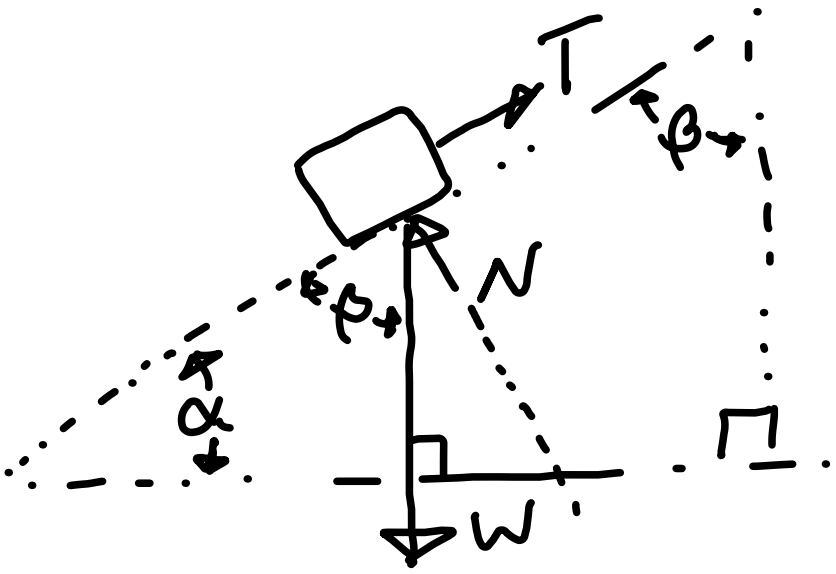


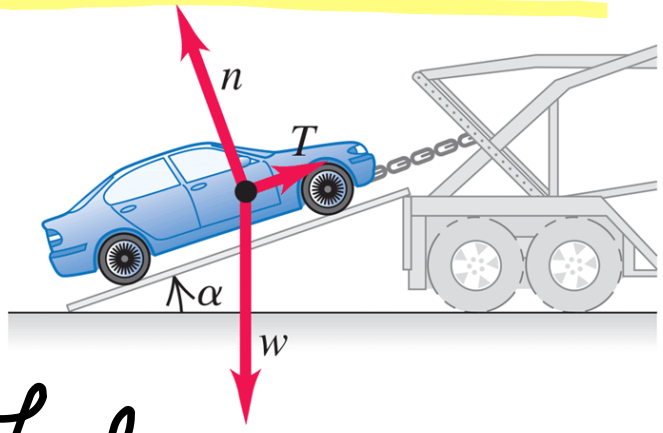


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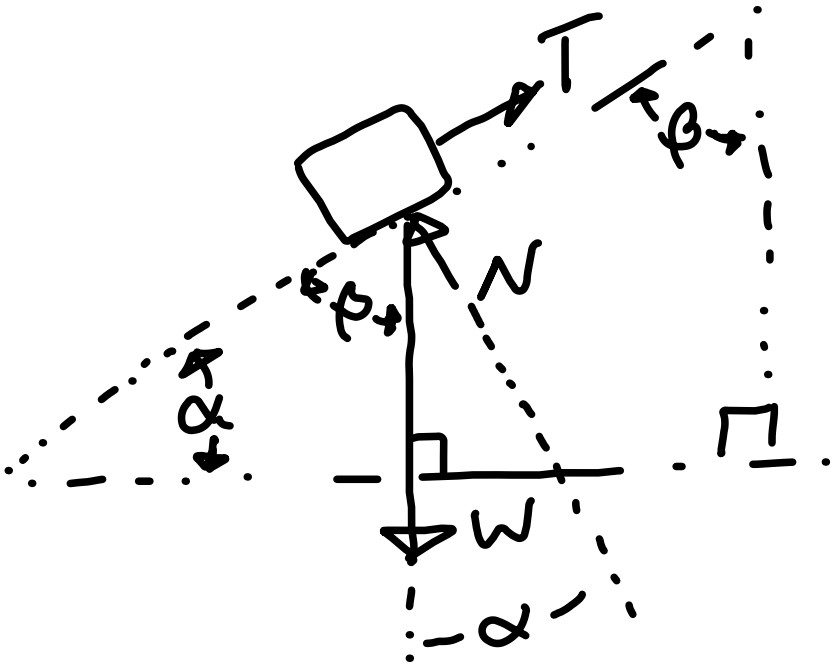


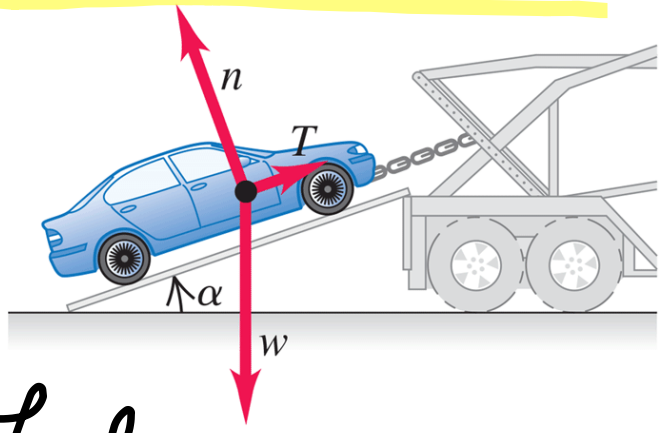


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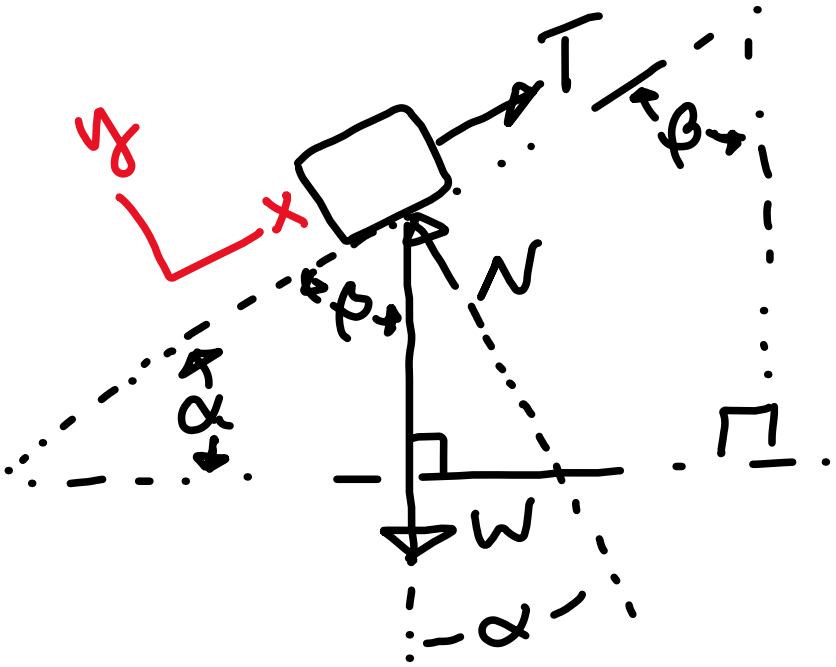


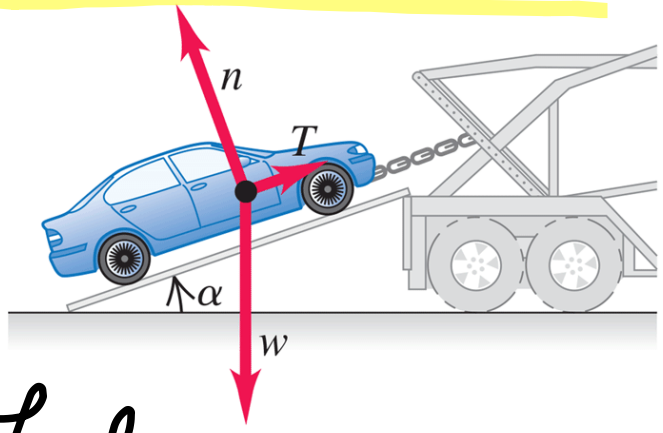


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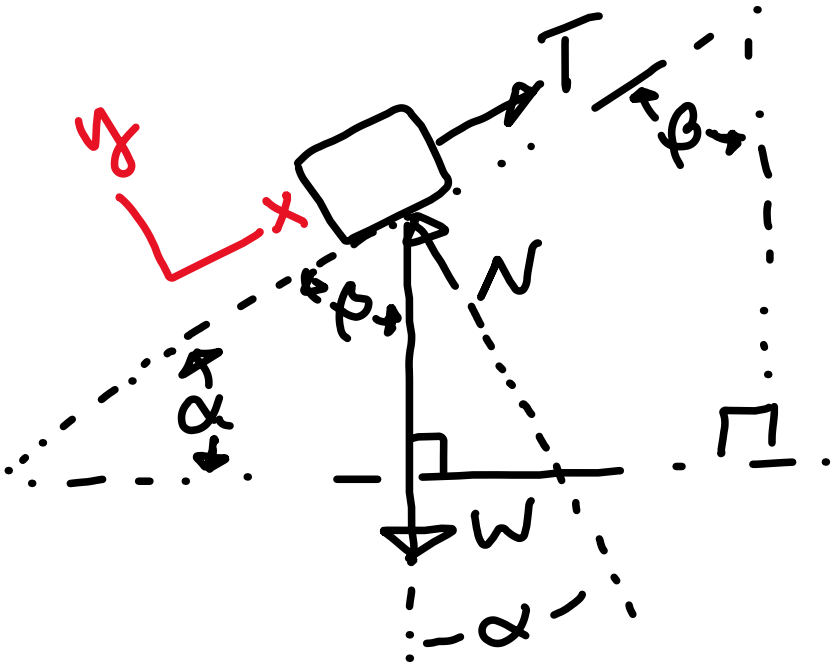


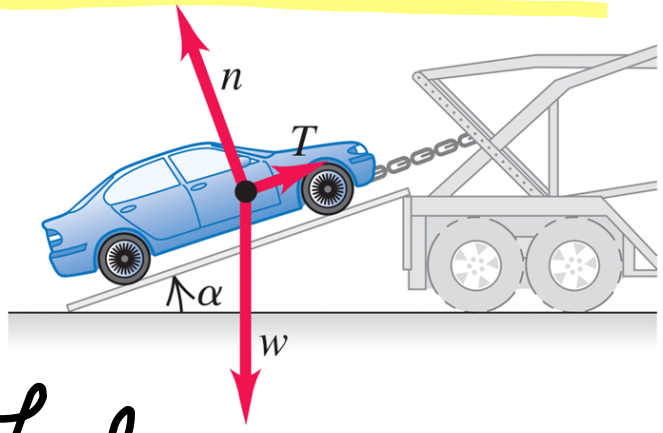


Let $\beta = 90 - \alpha$

$\vec{w} = w_x \hat{\imath} + w_y \hat{\jmath}$

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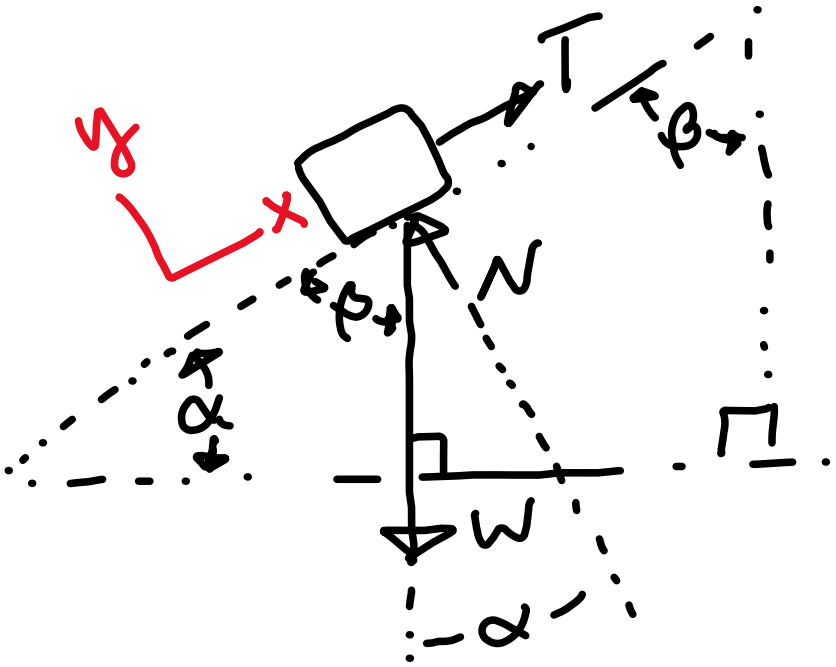


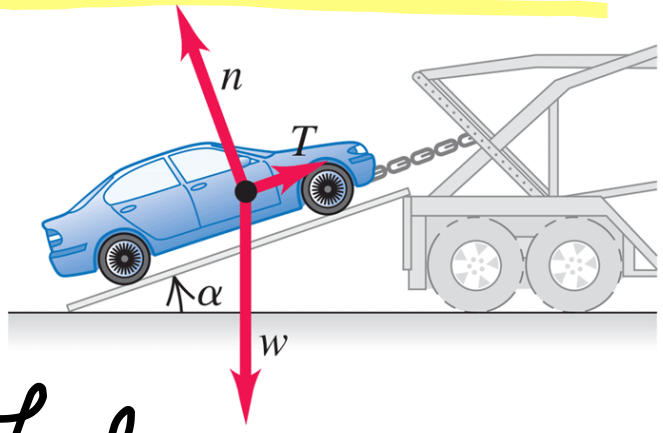


Let $\beta = 90 - \alpha$

$\vec{w} = w_x \hat{i} + w_y \hat{j}$,

where $w_x = w \sin\alpha$

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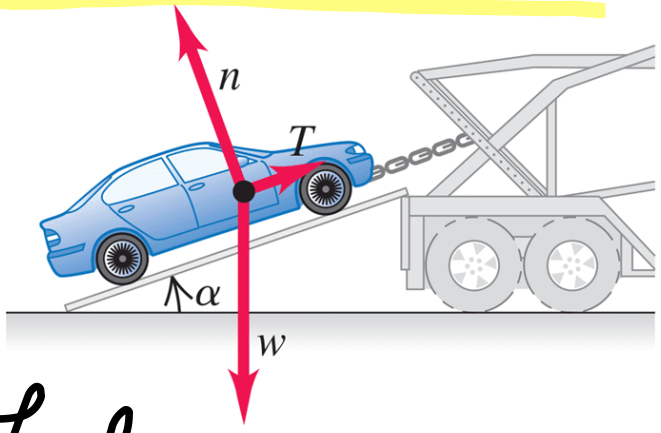


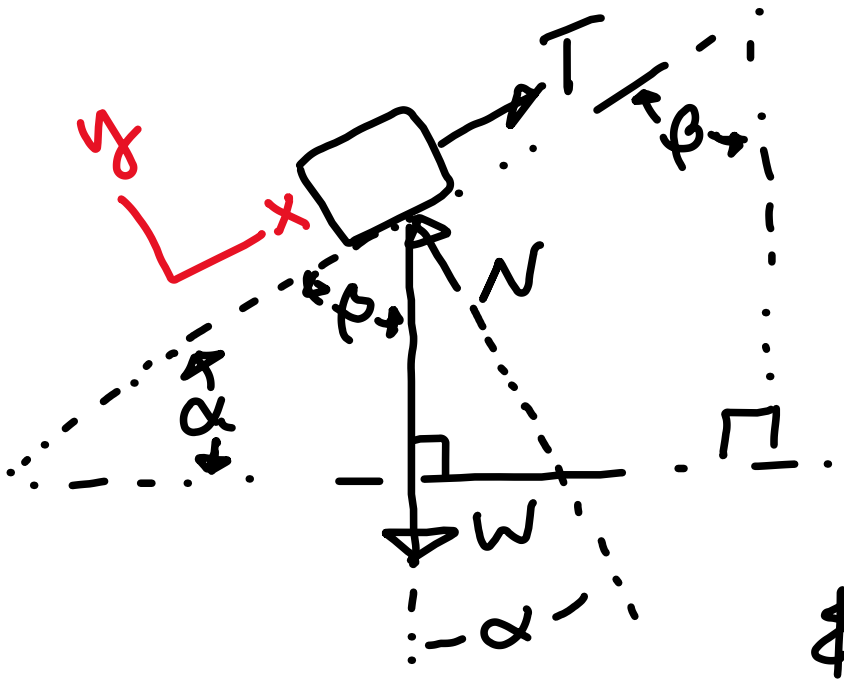


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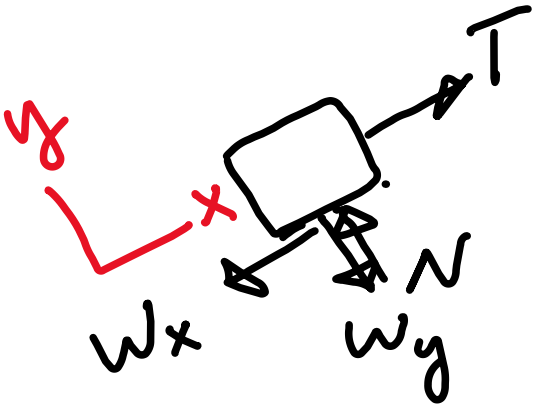


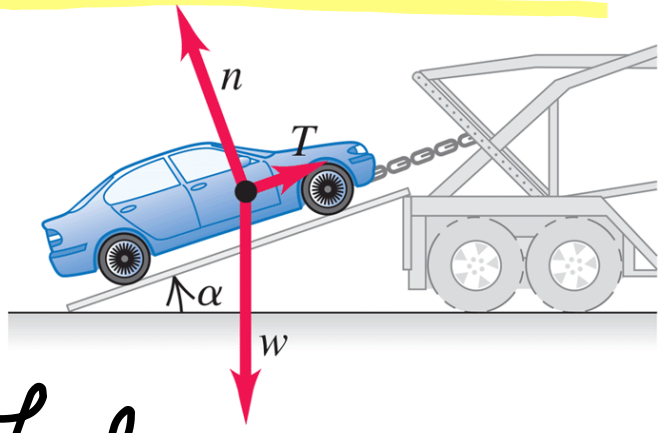


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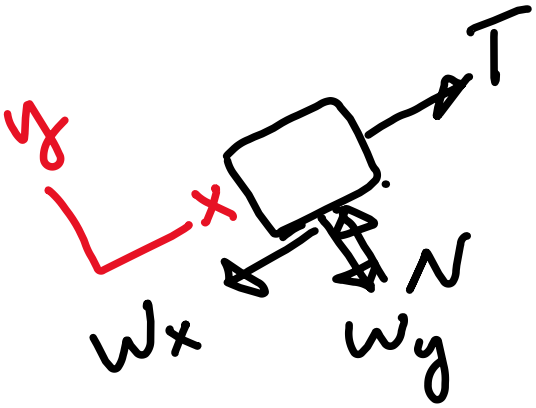
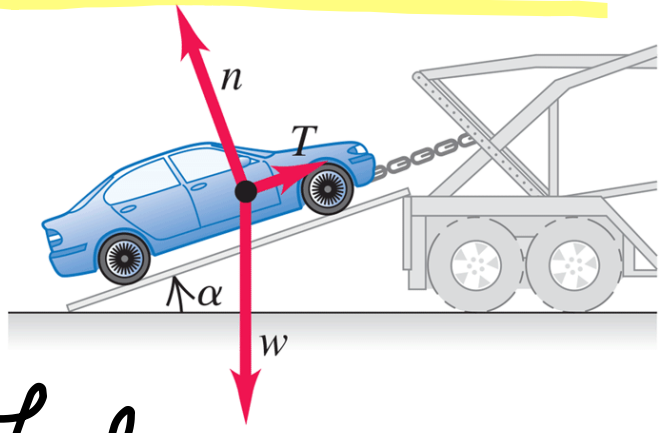



$\Sigma F_x = 0$

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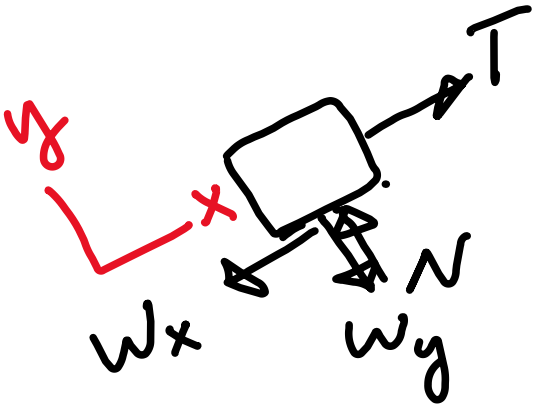
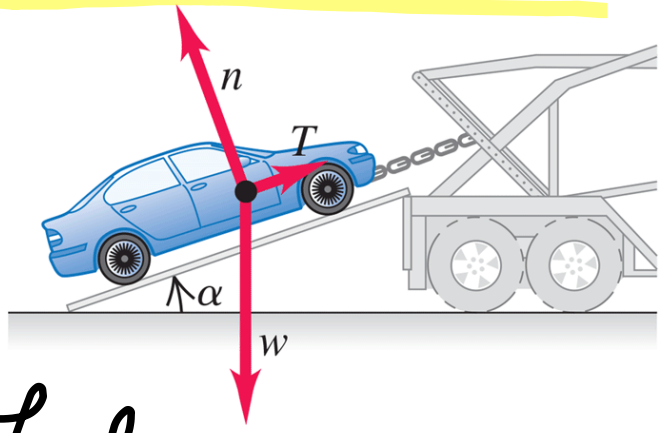



$$\Sigma F_x = 0 \Rightarrow T - w_x = 0$$

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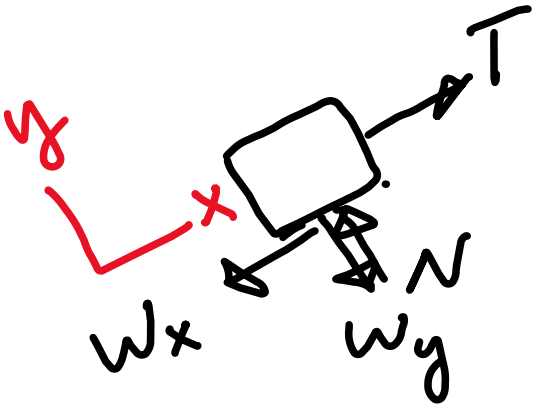
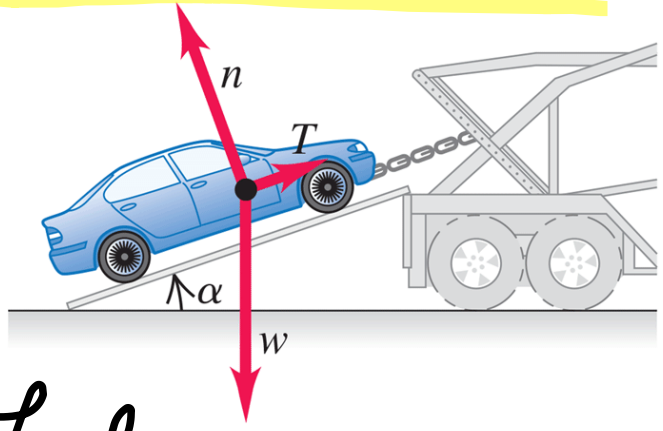



$\Sigma F_x = 0 \Rightarrow T - w_x = 0$

$\Rightarrow T = w \sin\alpha$

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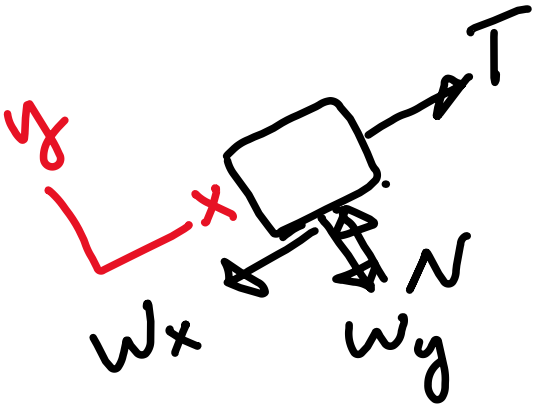
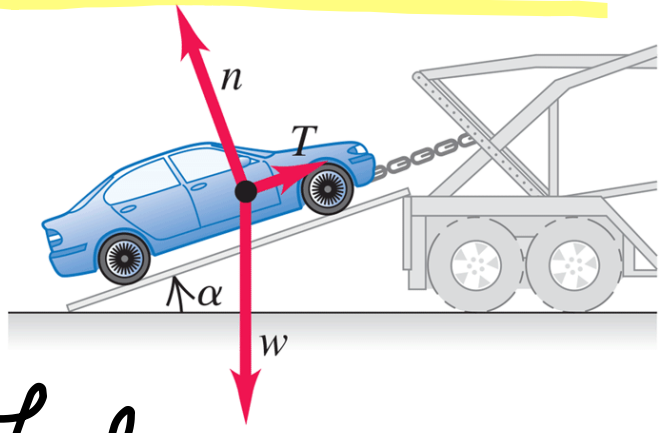



$\Sigma F_x = 0 \Rightarrow T - w_x = 0$

$\Rightarrow T = w \sin\alpha$

$\Sigma F_y = 0$

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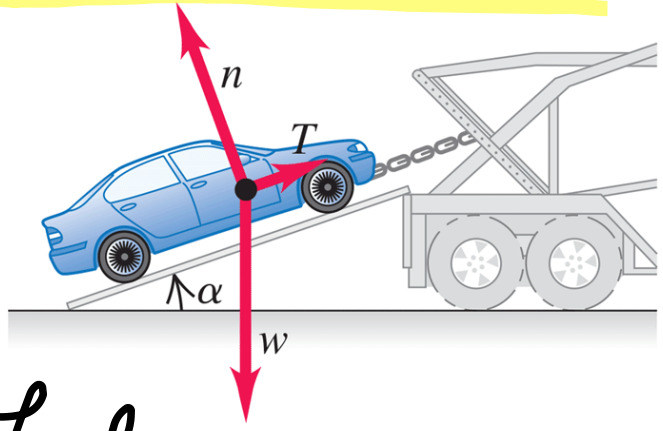


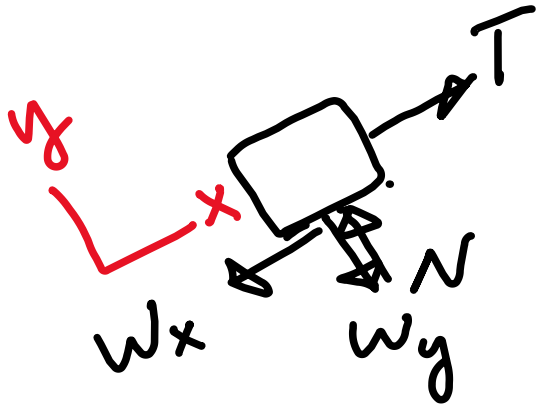


$\Sigma F_x = 0 \Rightarrow T - w_x = 0$

$\Rightarrow T = w \sin\alpha$

$\Sigma F_y = 0 \Rightarrow N - w_y = 0$

Let $\beta = 90 - \alpha$

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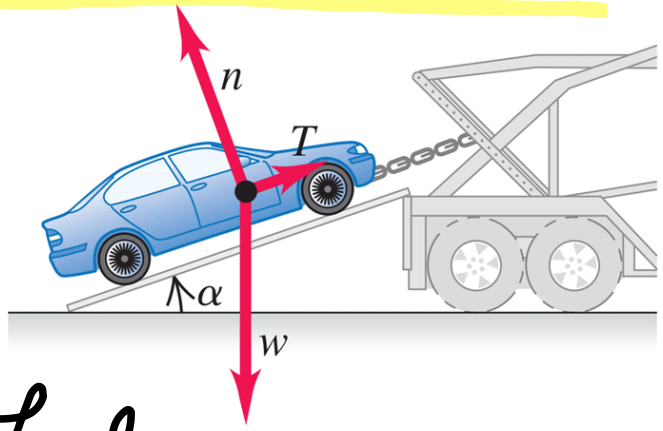
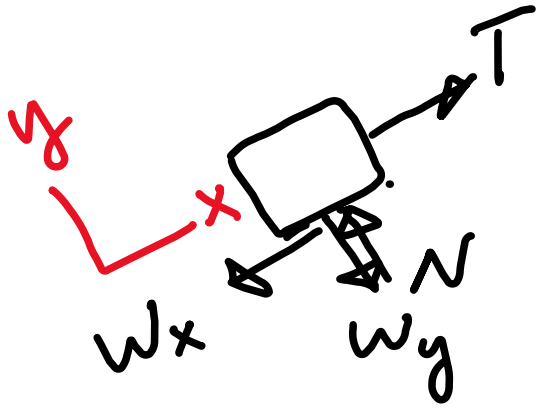



Let $\beta = 90 - \alpha$

$\vec{w} = w_x \hat{i} + w_y \hat{j}$,

where $w_x = w \sin\alpha$

& $w_y = w \cos\alpha$

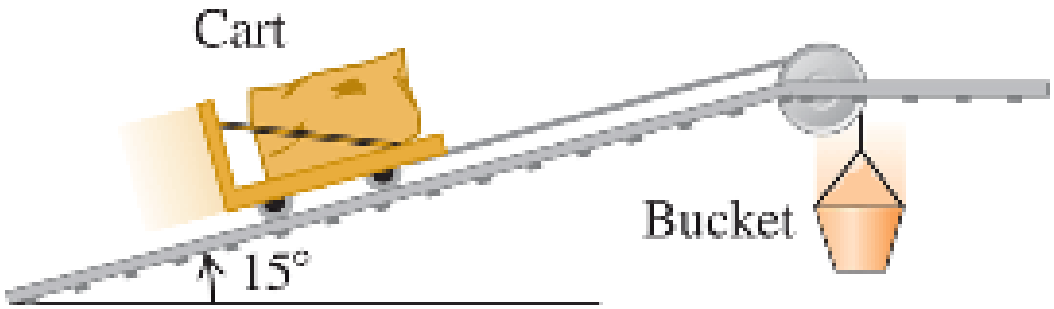
$\Sigma F_x = 0 \Rightarrow T - w_x = 0$

$\Rightarrow \boxed{T = w \sin\alpha}$

$\Sigma F_y = 0 \Rightarrow N - w_y = 0$

$\Rightarrow \boxed{N = w \cos\alpha}$

Your firm needs to haul granite blocks up a 15° slope out of a quarry and to lower dirt into the quarry to fill the holes. You design a system in which a granite block on a cart with steel wheels (weight $w_1$, including both block and cart) is pulled uphill on steel rails by a dirt-filled bucket (weight $w_2$, including both dirt and bucket) that descends vertically into the quarry (Fig. 5.5a). How must the weights $w_1$ and $w_2$ be related in order for the system to move with constant speed? Ignore friction in the pulley and wheels, and ignore the weight of the cable.



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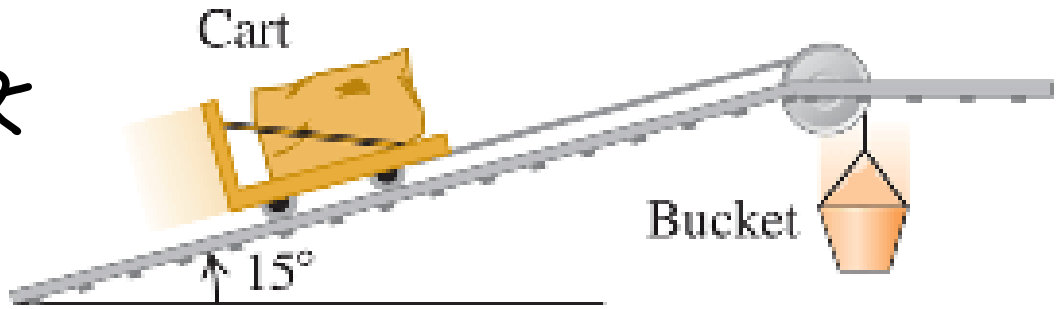
I'll start with the bucket



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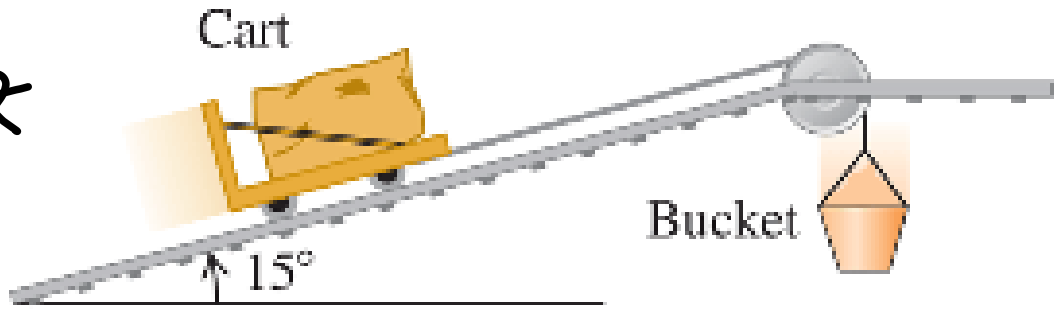


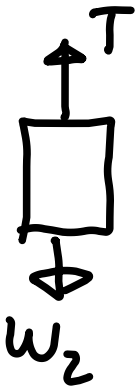

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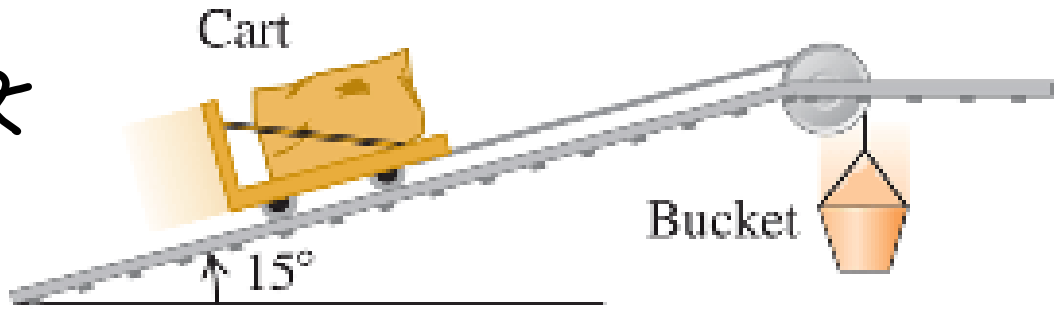


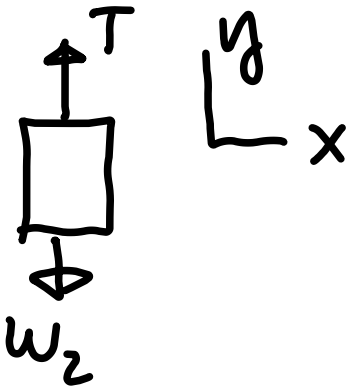

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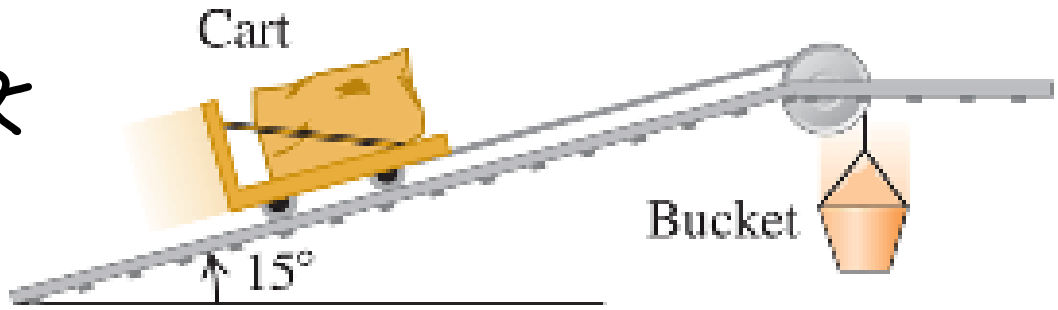


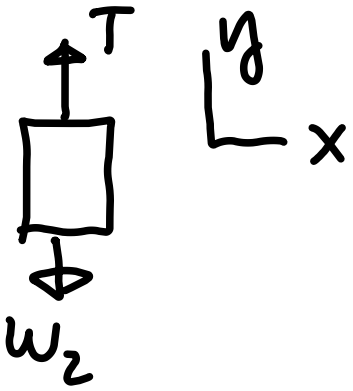


y
x

$\Sigma F_y = 0$

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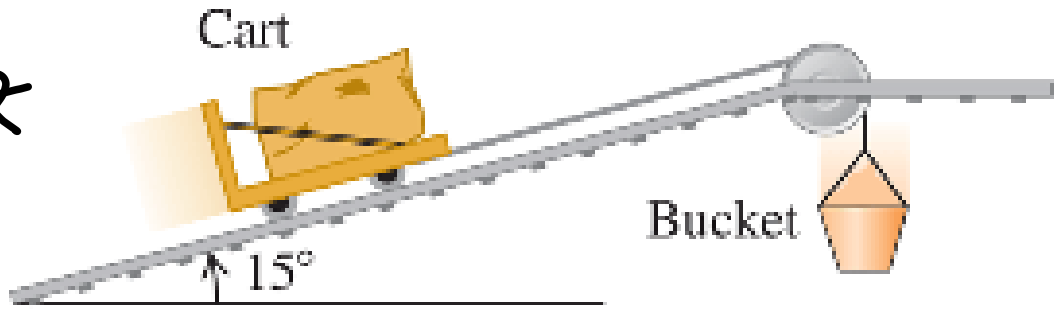


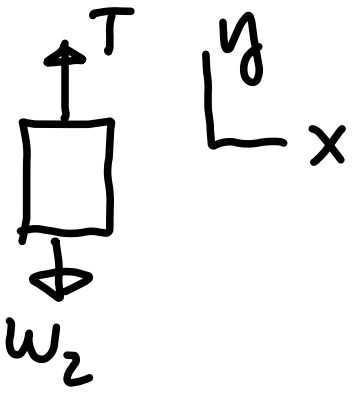


$\Sigma F_y = 0$

$\Rightarrow T - w_2 = 0$

Your firm needs to haul granite blocks up a 15° slope out of a quarry and to lower dirt into the quarry to fill the holes. You design a system in which a granite block on a cart with steel wheels (weight $w_1$, including both block and cart) is pulled uphill on steel rails by a dirt-filled bucket (weight $w_2$, including both dirt and bucket) that descends vertically into the quarry (Fig. 5.5a). How must the weights $w_1$ and $w_2$ be related in order for the system to move with constant speed? Ignore friction in the pulley and wheels, and ignore the weight of the cable.

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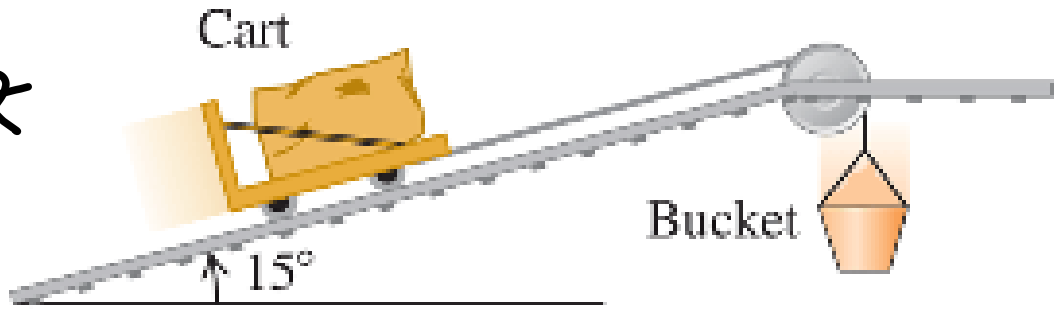


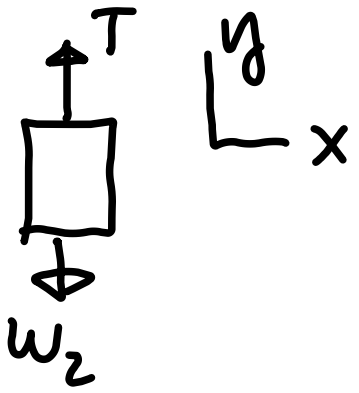


$\Sigma F_y = 0$

$\Rightarrow \quad T - w_2 = 0$

$\Rightarrow \quad T = w_2$

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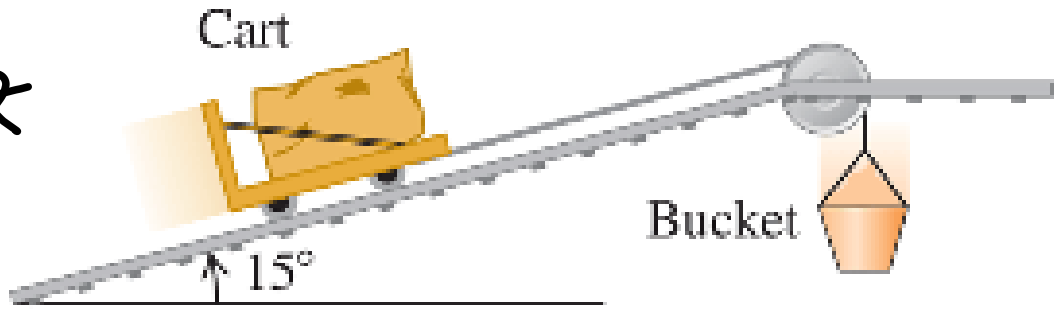
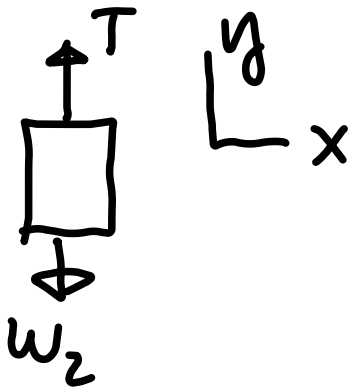
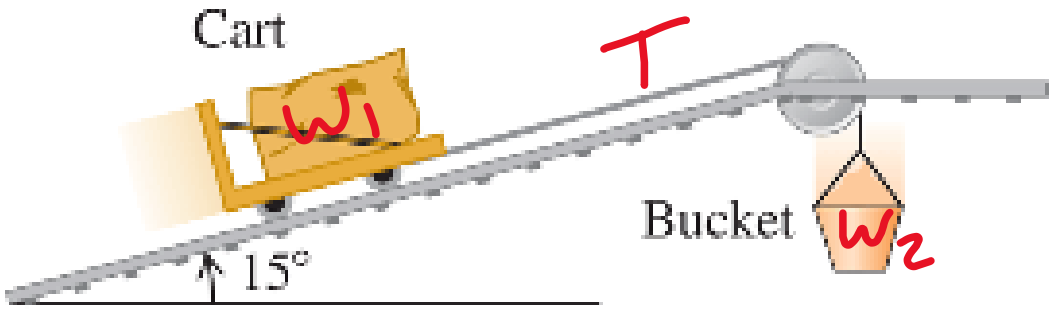


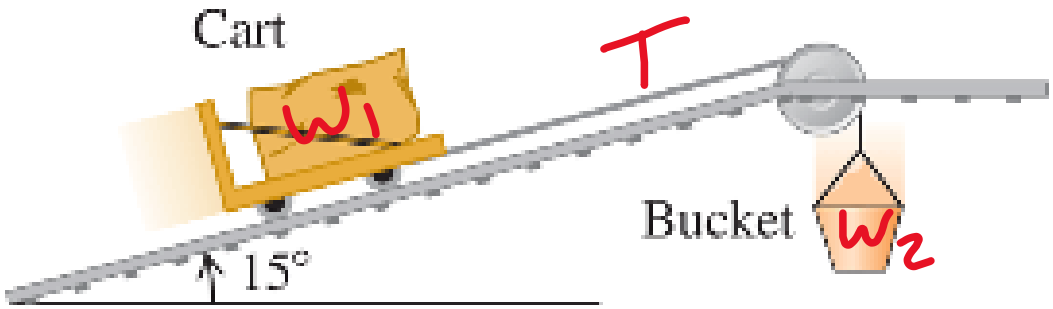

$\Sigma F_y = 0$

$\Rightarrow T - w_2 = 0$

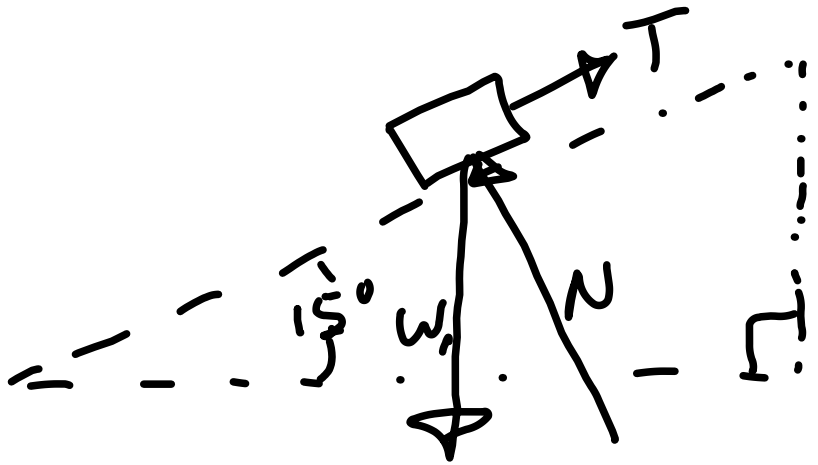
$\Rightarrow \boxed{T = w_2}$



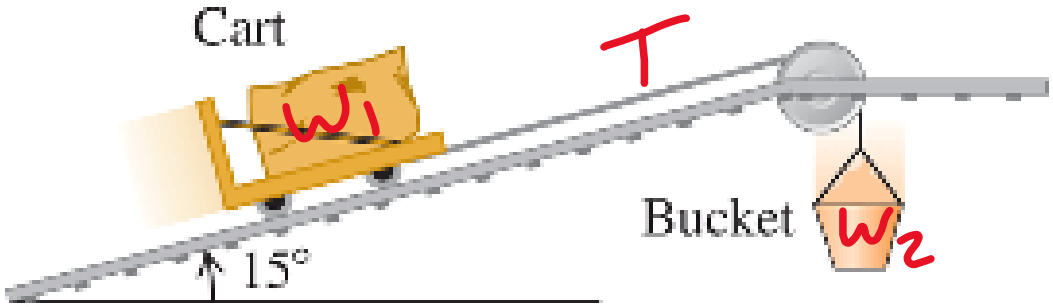

From previous slide $T = w_2$



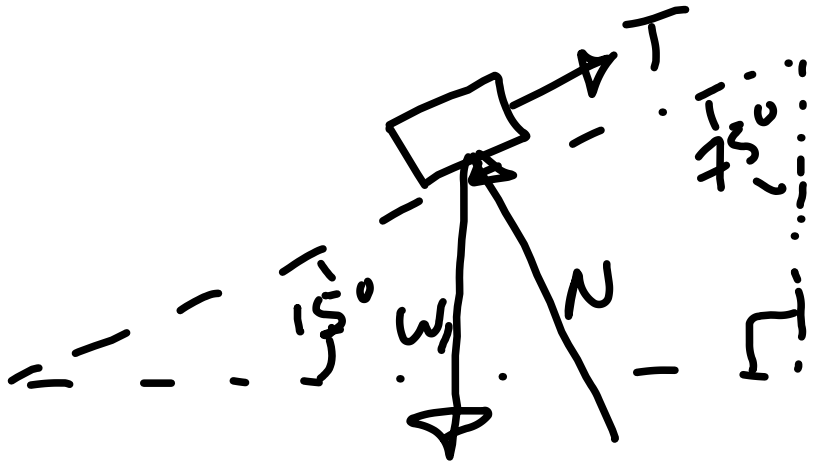

From previous slide $T = W_2$




$90° - 15° = 75°$




From previous slide $T = W_2$

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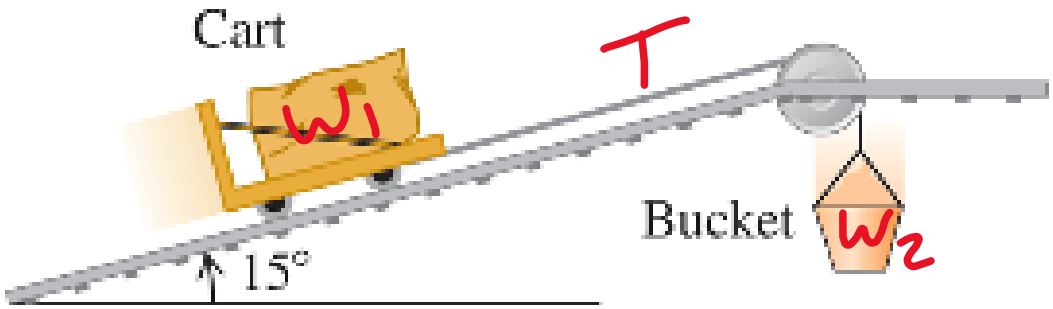


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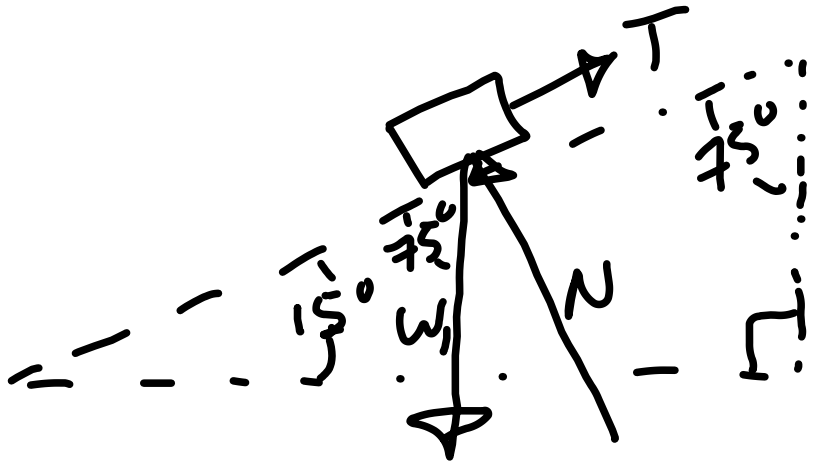


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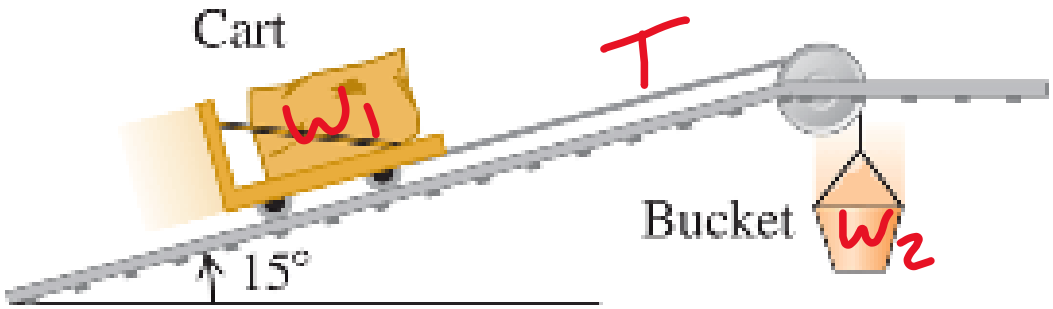


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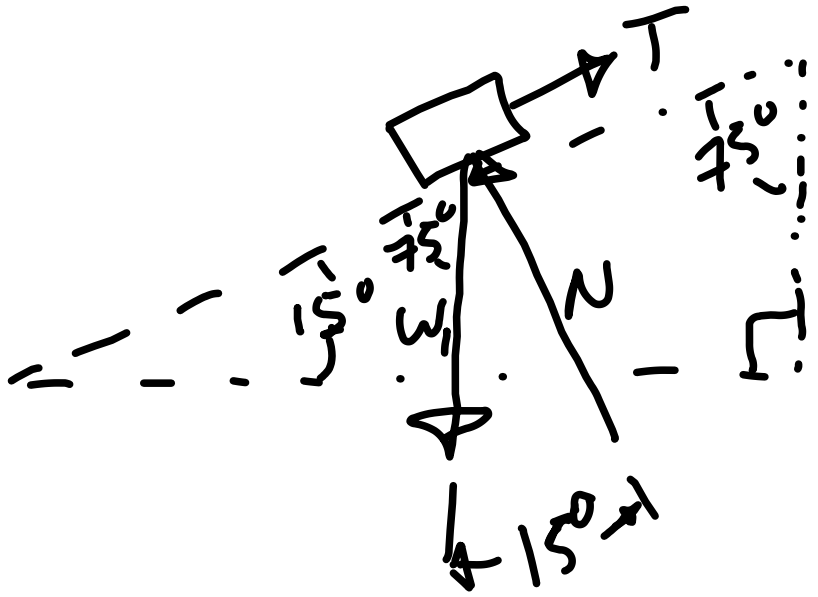


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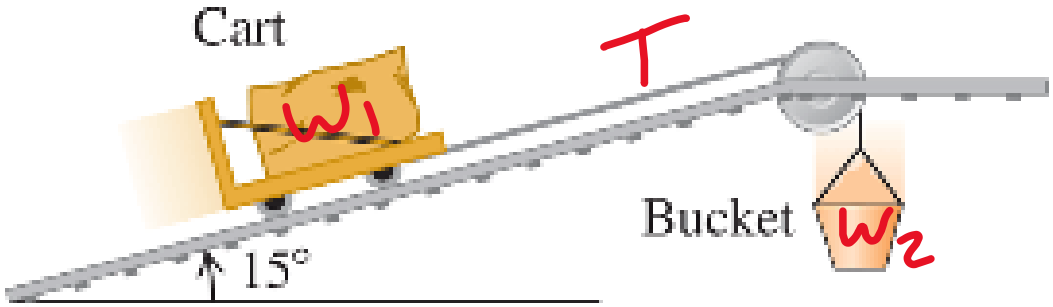


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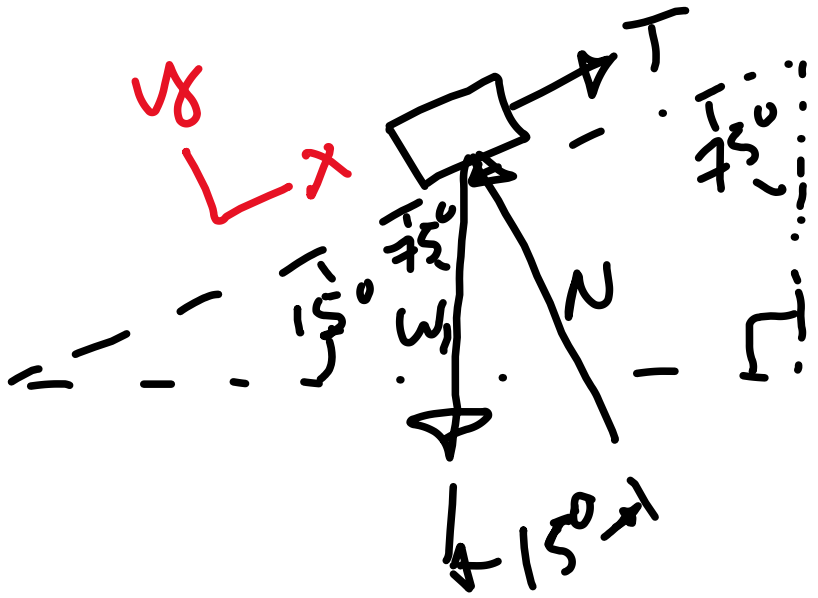


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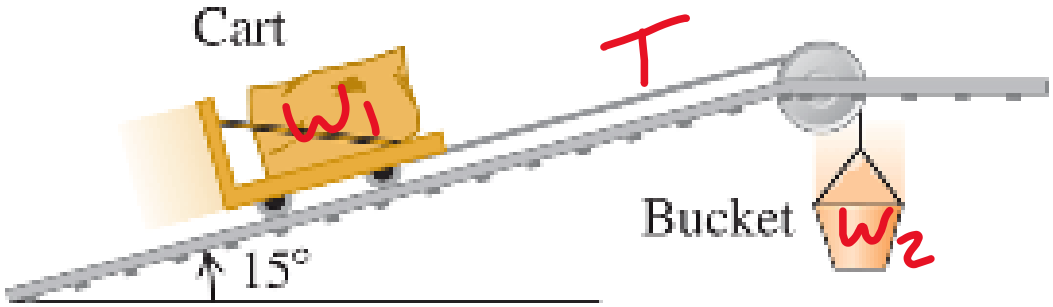


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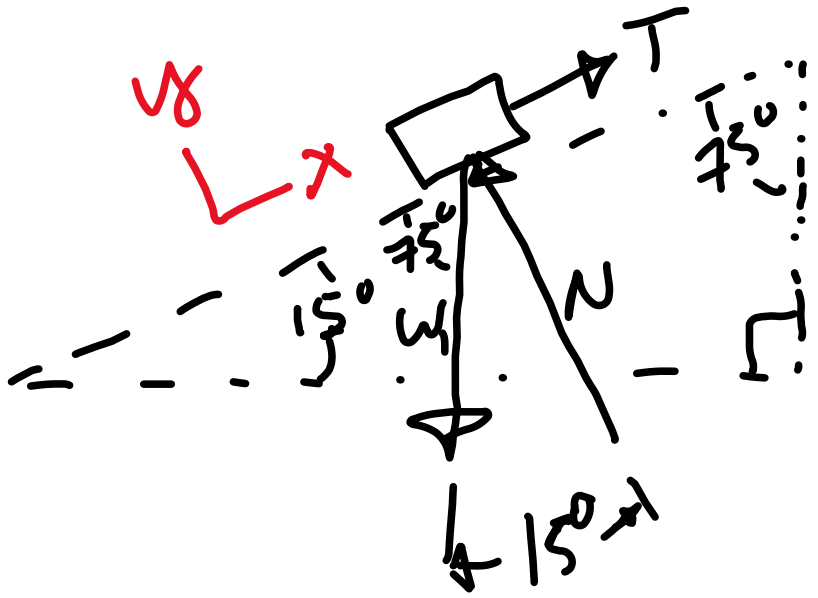
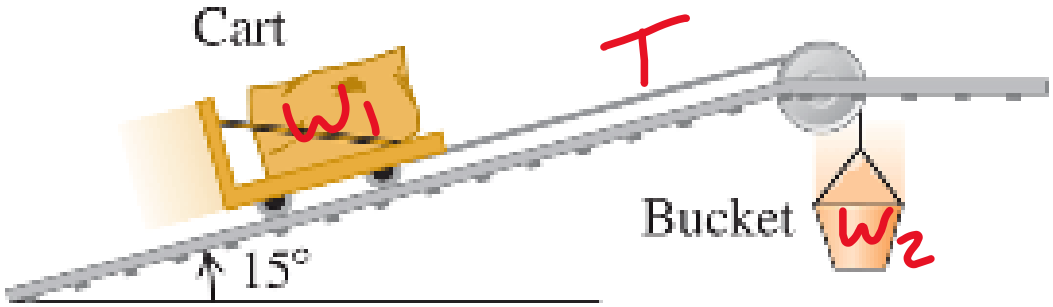



$90° - 15° = 75°$

$\vec{W}_1 = (W_1 \sin 15°)\hat{i} + (W_1 \cos 15°)\hat{j}$

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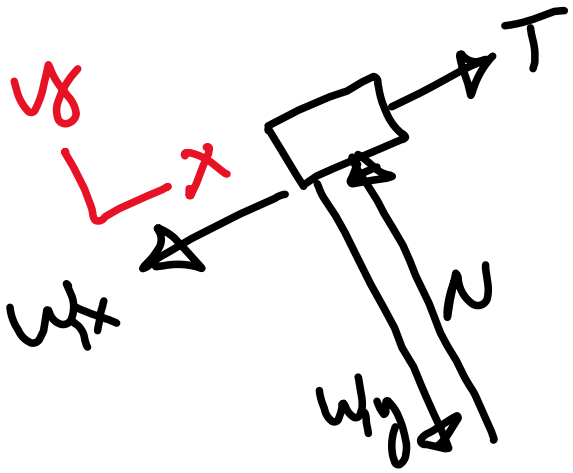
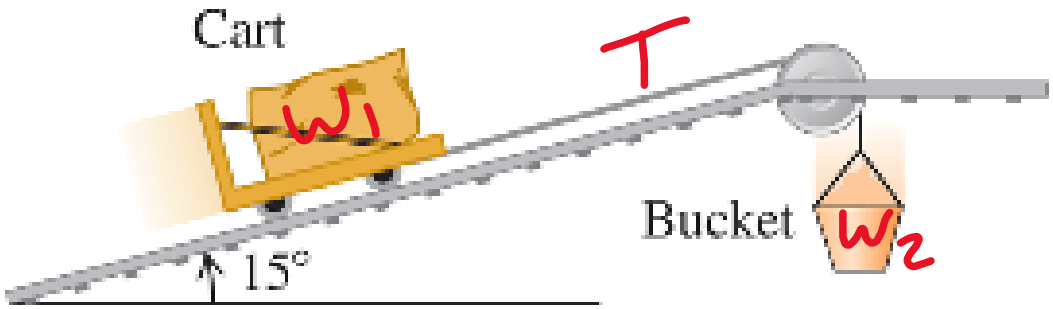
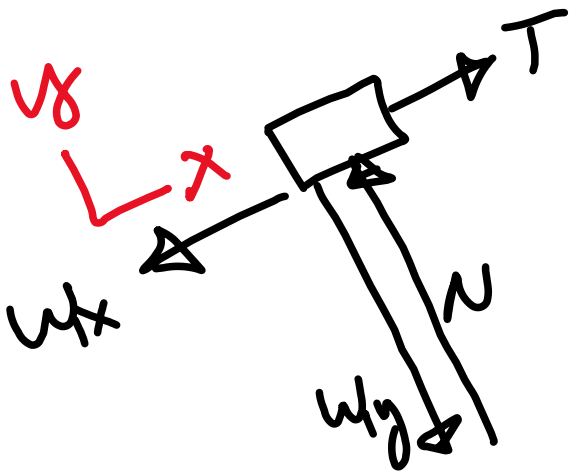



$$\vec{w}_1 = (w_1 \sin 15^\circ)\hat{i} + (w_1 \cos 15^\circ)\hat{j}$$

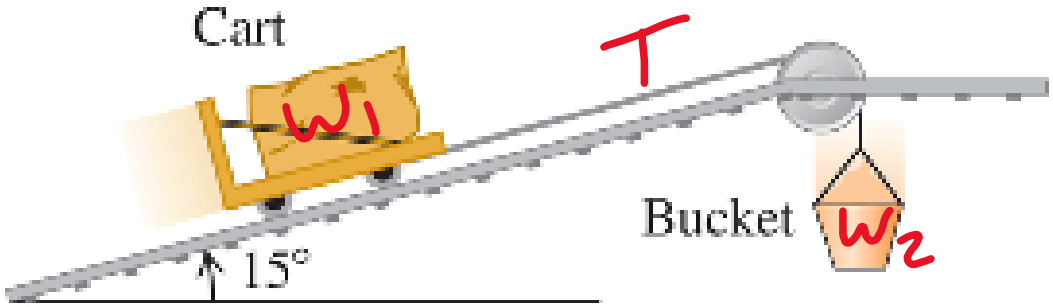



From previous slide $T = W_2$

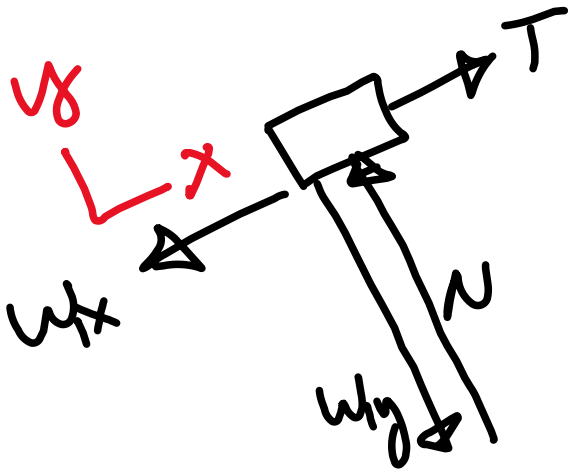



$$\vec{W}_1 = (W_1 \sin 15^\circ)\hat{i} + (W_1 \cos 15^\circ)\hat{j}$$

$$\Sigma F_x = 0$$

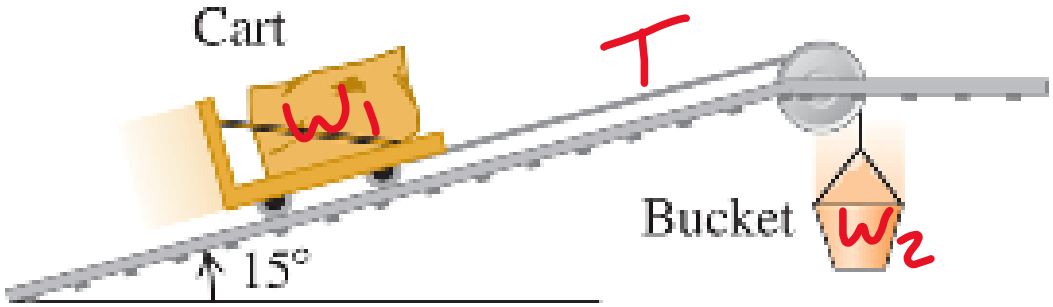



From previous slide $T = w_2$

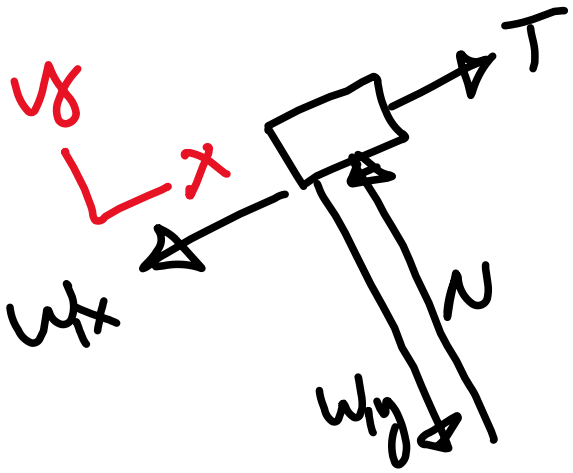



$$\vec{w}_1 = (w_1 \sin 15^\circ)\hat{i} + (w_1 \cos 15^\circ)\hat{j}$$

$$\Sigma F_x = 0 \Rightarrow T - w_x = 0$$



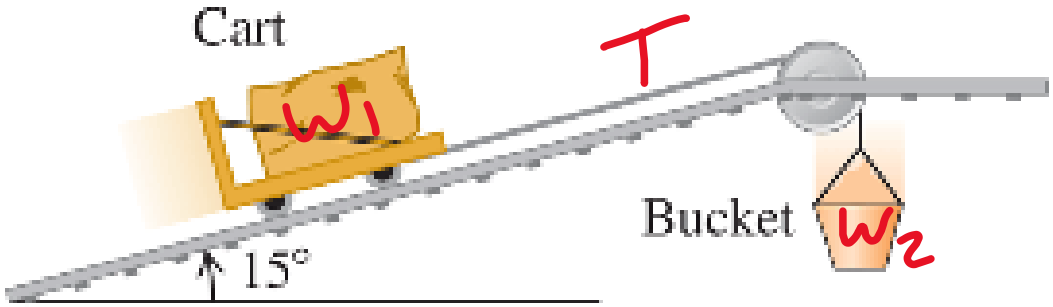

From previous slide $T = W_2$



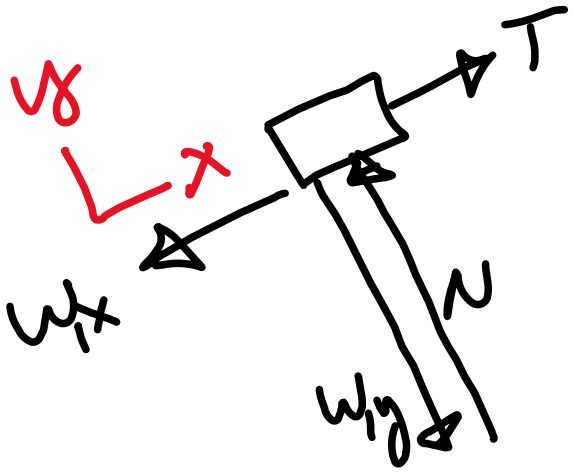

$$\vec{W}_1 = (W_1 \sin 15^\circ)\hat{i} + (W_1 \cos 15^\circ)\hat{j}$$

$$\Sigma F_x = 0 \Rightarrow T - W_x = 0$$

$$\Rightarrow T = W_1 \sin 15^\circ$$




From previous slide $T = W_2$

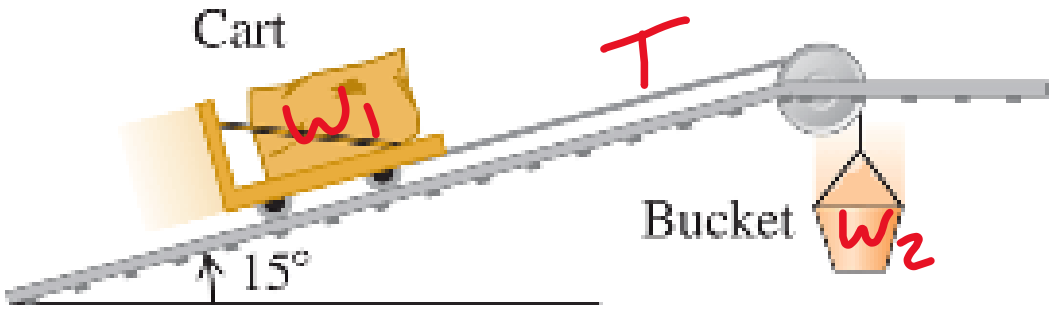



$\vec{W}_1 = (W_1 \sin 15^\circ)\hat{i} + (W_1 \cos 15^\circ)\hat{j}$

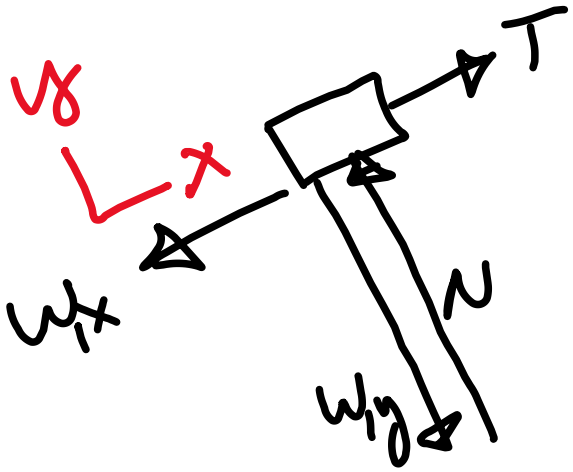
$\sum F_x = 0 \Rightarrow T - W_{1x} = 0$

$\Rightarrow T = W_1 \sin 15^\circ$

But $T = W_2$




From previous slide $T = W_2$




$\vec{W}_1 = (W_1 \sin 15^\circ)\hat{i} + (W_1 \cos 15^\circ)\hat{j}$

$\sum F_x = 0 \Rightarrow T - W_x = 0$

$\Rightarrow T = W_1 \sin 15^\circ$

But $T = W_2$ So $W_2 = W_1 \sin 15^\circ$