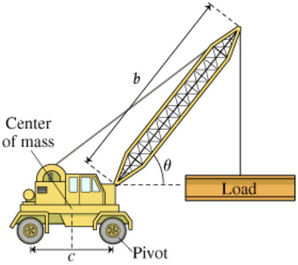
# Tipping Crane




A crane of weight $W$ has a length $c$, and its center of mass is midway between the wheels. The arm extending from the front of the crane has a length of $b$ and makes an angle $\theta$ with the horizontal. The crane contacts the ground only at its front and rear tires.

The questions are in the following slides.

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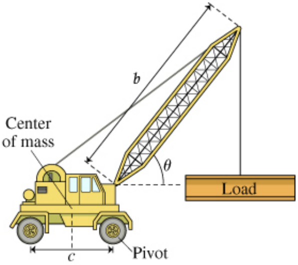


1. While watching the crane in operation an observer mentions to you that for a given load there is a maximum angle $\theta_{max}$ that the crane arm can make with the horizontal without tipping the crane over. Is this correct?

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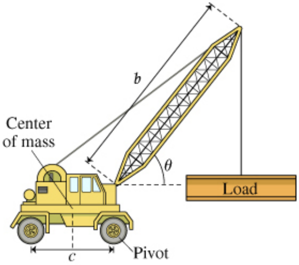


2. A different observer mentions to you that there is a maximum load the crane can lit without tipping, and you can find that maximum load by observing the minimum angle $\theta_{min}$ that the crane makes with the horizontal. Is this correct?

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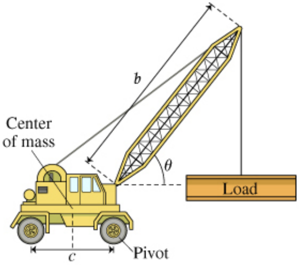
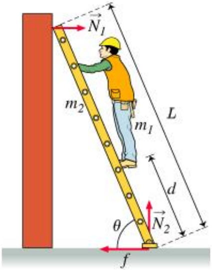


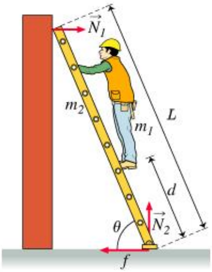

3. Given the angle $\theta_{min}$ what is the maximum load $W_{L,max}$ that this crane can lift without tipping forward?. Express your answer in terms of $\theta_{min}$ and other quantities given in the problem introduction.

# Person Standing on a Leaning Ladder




A uniform ladder with mass $m_2$ and length $L$ rests against a smooth wall. A person of mass $m_1$ stands on the ladder a distance $d$ from the bottom. The ladder makes an angle $\theta$ from the ground. There is no friction between the wall and the ladder, but there is a frictional force of magnitude $f$ between the floor and the ladder. $N_1$ is the magnitude of the normal force exerted by the wall on the ladder, and $N_2$ is the magnitude of the normal force exerted by the ground on the ladder.

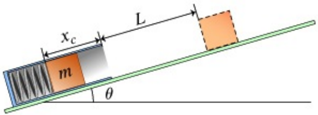
# Person Standing on a Leaning Ladder




Question:

What is the minimum coefficient of static friction $\mu_{min}$ required between the ladder and the ground so that the ladder does not slip? Express answer in terms of $m_1,\ m_2,\ d,\ L$ and $\theta$.

# Block and incline

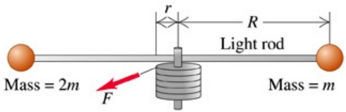



A block of mass $m$ is placed in a smooth-bored spring gun at the bottom of the incline so that it compresses the spring by an amount $x_c$. The spring has spring constant $k$. The incline makes an angle $\theta$ with the horizontal and the coefficient of kinetic friction between the block and the incline is $\mu$. The block is released, exits the muzzle of the gun, and slides up an incline a total distance $L$.

Question: Find $L$. Ignore friction when the block is inside the gun. Also, assume that the uncompressed spring is just at the top of the gun (i.e., the block moves a distance $x_c$ while inside of the gun). Use $g$ for the magnitude of acceleration due to gravity.

Express the distance $L$ in terms of $x_c$, $k$, $m$, $g$, $\mu$ and $\theta$.

# Rotating Spheres

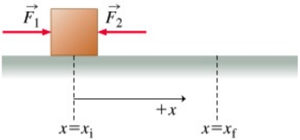



Two massive spheres are mounted on a light rod that can be rotated by a string wrapped around a central cylinder, forming a winch as shown in the figure. A force of magnitude $F$ is applied to the string to turn the system. With respect to the variables given in the figure, the equation for the magnitude of the angular acceleration $\alpha$ is

$$\alpha = \frac{rF}{3mR^2}$$

Question: If the sphere on the left is moved closer to the central cylinder and placed at a distance $R/2$ from the axis of rotation, what is the magnitude of the angular acceleration $\alpha$ of the modified system? Assume that the rest of the system doesn't change.

# Work




Two forces of magnitudes $F_1 = 90.0N$ and $F_2 = 20.0N$, act in opposite directions on a block which sits atop a frictionless suface as shown. Initially the center of the block is at position $x_i = -3.00cm$. At some late time the block has moved to the right and its center is at a new position $x_f = 2.00cm$.

1. Find the work $W_1$ done on the block by $F_1$ as the block moves from $x_i$ to $x_f$.
2. Find the work $W_2$ done on the block by $F_2$ as the block moves from $x_i$ to $x_f$.
3. What is the net work $W_{net}$ done on the block by the two forces?
4. Determine the change $K_f - K_i$ in the kinetic energy of the blocks as it moves from $x_i$ to $x_f$.