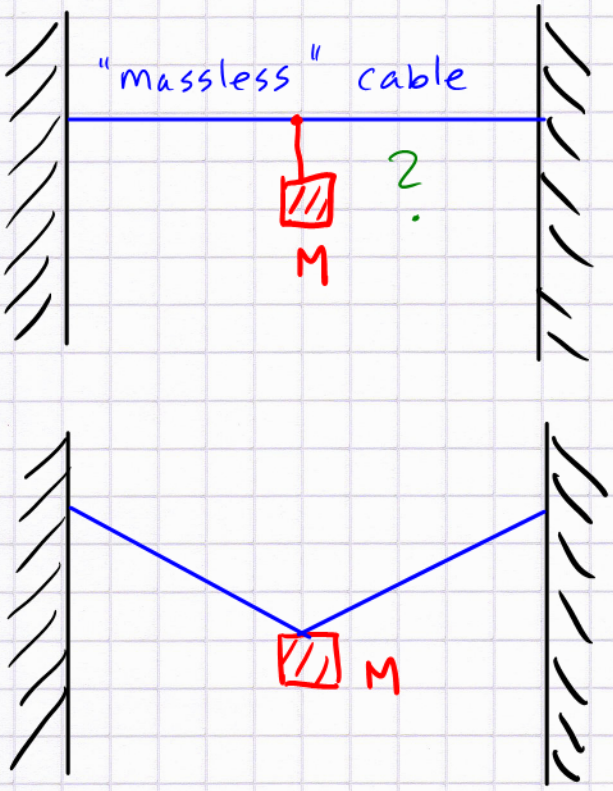
Statics

Newton's 2nd law $\vec{F} = m\vec{a}$ takes care of dynamics (determining motion from the net force)

Special case: $a = 0$, or $F_{net} = 0$

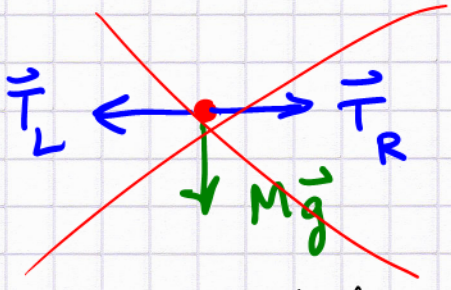
or $\boxed{F_{net,x} = 0}$ and $\boxed{F_{net,y} = 0}$

Example: cable suspended at both ends with a weight hanging from the middle



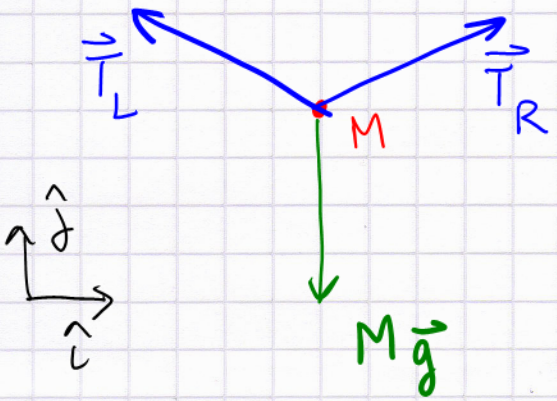
Can this work?

→ free-body diagram



No!

Downward force has to be compensated by a vertical up!



Principle:

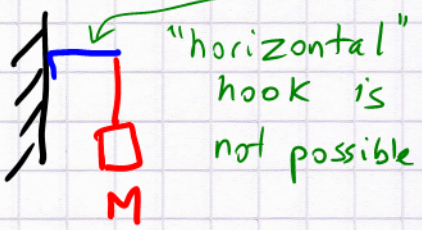
1) $T_{L,y} + T_{R,y} - Mg = 0$ (why "−"?)

2) $T_{L,x} + T_{R,x} = 0$

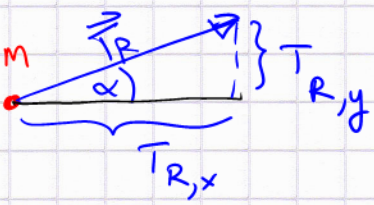
Now apply trigonometry.

Note: $\vec{T}_L$, $\vec{T}_R$ have to be aligned with the cable (or a rod)

↳ bending occurs



The magnitudes $T_L = T_R$ (for a symmetric set-up) depend on the angle of the cable with the horizontal / vertical:



$$\frac{T_{R,y}}{T_R} = \sin\alpha$$

$$T_{R,y} = \frac{1}{2}Mg$$

$$\frac{1}{2}Mg = T_R \sin\alpha$$

$$\therefore \boxed{T_R = \frac{Mg}{2\sin\alpha}}$$

Note: we can also write

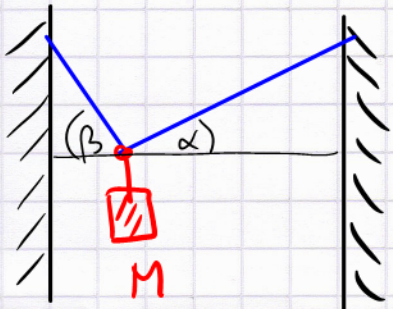
$$\vec{T}_R = \vec{T}_{R,x} + \vec{T}_{R,y}$$

$$= \rightarrow + \uparrow$$

↳ Consequence: if $\alpha \to 0$ $T_R \to \infty$!

∴ it is impossible to hang something from a perfectly horizontal cable!

Generalize the problem: hanging M not at the middle between the walls, but using α, β angles



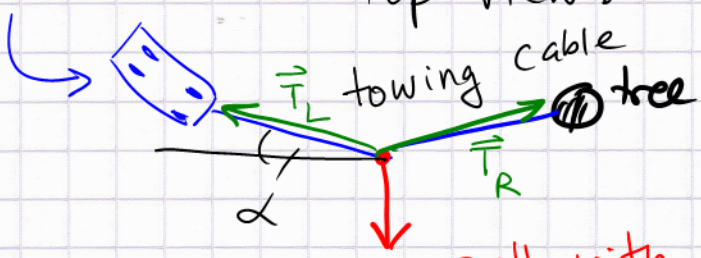
$T_L \neq T_R$ now

$T_{Ly} + T_{Ry} = Mg$ $\quad T_{L,x} + T_{L,x} = 0$

Application "magnify" your pull

stuck car

top view:



pull with $\vec{F}$, where $|\vec{F}|$ is not sufficient to get the car moving

Note: $T_L > F$ when α is small

$$T_{Ly} = \frac{1}{2} F$$

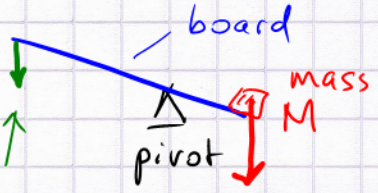
$$T_L \sin\alpha = \frac{1}{2} F$$

$$T_L = \frac{F}{2\sin\alpha} \qquad \frac{1}{2\sin\alpha} = \text{amplification factor}$$

Of course, we need the tree to be in the right position and strong enough to withstand $T_R = T_L$!

"Force magnification" is not a crazy idea:

we use it in the lever principle



In our example the knot where $\vec{F}$ applies travels a longer distance than the towed car.

Note: α will not remain constant.