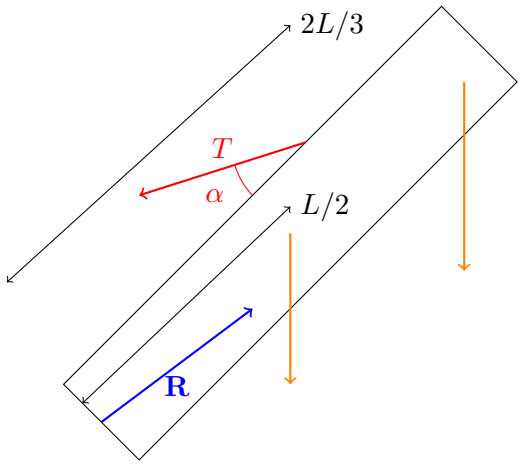
Large Forces in Back Muscles

Many people will at some point in their lives deal with back pain. This is caused from, over long periods of time, having too much tension in the muscles in your back. In this problem, we will estimate the forces present in these back muscles. We can model someone's spine as a rigid rod of length L. Typically, the torso, supported by the spine, weighs about $2/5$ of a person's total weight Mg. The head and arms, which are connected at the top of the rod, weigh about $Mg/5$. However, a person might be carrying some object, which has weight mg, so we'll need to add that in to the force at the top of the spine. Where the spine connects to the pelvis, there is a reactionary force $\mathbf{R}$. Finally, the back muscles have a tension T, and are oriented at a very shallow angle α to the spine. You should estimate for this problem that $\sin\alpha \approx 1/5$, and that the force from these muscles is applied a distance $2L/3$ from the pelvis:



(a) As shown in the free body diagram above, suppose someone is bending over so that their torso is oriented at angle θ, relative to the horizontal. Use the equations of static equilibrium to determine $\mathbf{R}$ and T.

(b) Suppose someone of mass $M = 60$ kg has bent over fully ($\theta = 0$) to pick up an object which is heavy, of mass $m = 20$ kg. What is the tension in their back muscles? Express your answer as a dimensionless number T/Mg, and comment on the result. Also comment why this dimensionless number is the appropriate way to think about these tension forces.

(c) How should one carry heavy objects to minimize T, and correspondingly the long term risks for back pain?