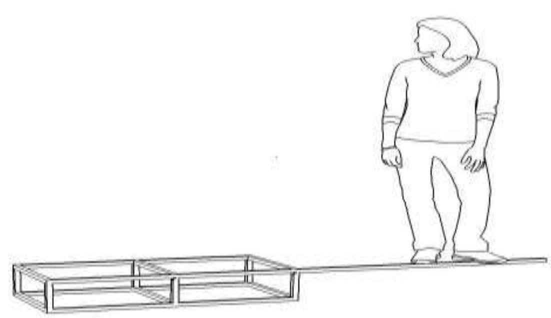
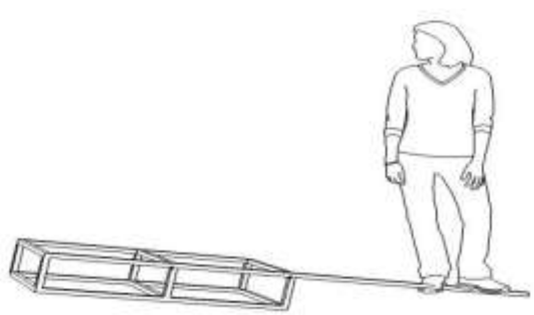
CALCULATING THE POINT AT WHICH A PIECE OF BOX SECTION STEEL WILL BEND AND NOT RECOVER

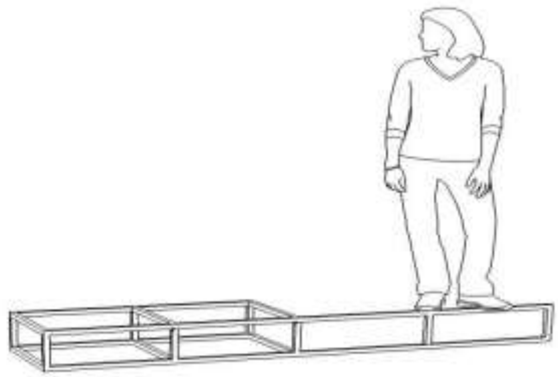
It’s often the case in the metal workshop that the laws of physics are challenged in order to pursue a design aesthetic. Luckily, with some knowledge of physics and a little common sense we can employ these laws and prevent a lot of wasted time and effort.

In the case below, a square section tubular steel construction is required to support the weight of a person. It’s quite clear that if a person stands on the extended tube the rest of the frame will tip up. See below

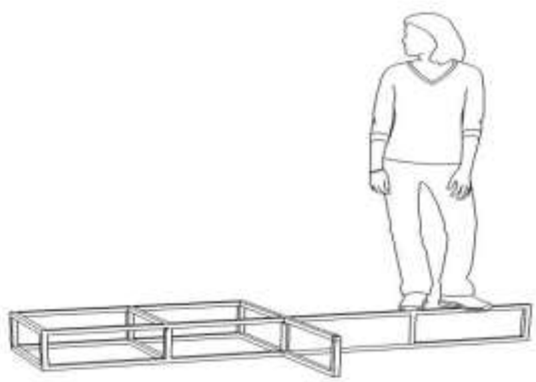




We will need to support the tube under her weight to prevent this from happening

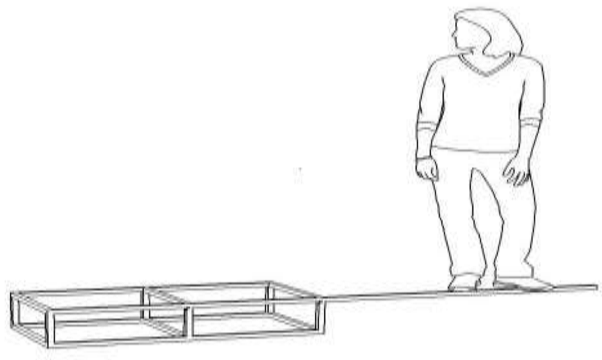


I know what you’re thinking; that the frame could still tip up from the back and she could fall forwards. Yes; do you see how our basic understanding of the laws of physics, are deeply routed within us?



So we have now arrived the design above, a long way from the original, but one that will prevent the frame from tipping and be able to support the load.

However, this is not acceptable from the designer’s perspective and only the design below will do.



We will need to prevent the frame from tipping and this can be done in a number of ways; by either counterbalancing the frame or bolting the it to the floor (as shown above although fixings cannot be seen) this being the most acceptable from the designers point of view and leads us to our next problem:

What is the maximum distance the unsupported steel tube can extend from the rest of the frame before it will bend under the weight of the person standing on it?

And I suppose now we come to the essence of the document, as this simple question is not easy to answer and one that requires a much greater appreciation of the laws of physics and a determination in employing them to our advantage.

First we must understand turning forces as it is clear that this is what we are referring to. The extended tube (acting as a lever) can no longer turn the frame and tip it up as it is bolted to the floor. However, when the woman stands on the tube the force to turn the frame is still there.

This turning force is called a ‘moment’ and is measured in Newtons per metre squared or $Nm^{2.}$ ‘Moments’ are calculated by multiplying the length of the lever (here the extended tube) by the amount or force applied to it (represented by the weight of the woman). However, weight is not the same as force. Weight is static, it has magnitude (measured in Kilograms) but it is going nowhere, whereas force (measured in newtons) has both magnitude and direction.

Fortunately, Isaac Newton can help us here: he states that 1kg falling to Earth has a force of 9.81N

Because the woman is raised up, she has a downwards force acting on the tube. Lets say she weighs 70kg (the average weight of a person) she has a force of 70 X 9.81 = 686.7N

If she stands ½ a meter away from the fixed point she exerts 0.5 x 686.7 = 343.35N/m^2 of turning force

This helps us find the moment of turning force along any given point on the extended tube she stands on, but it doesn’t help us find out if this moment of turning force exceeds that of which the tube is capable of withstanding.

Source: http://process.arts.ac.uk/content/calculating-point-which-piece-box-section-steel-will-bend-and-not-recover