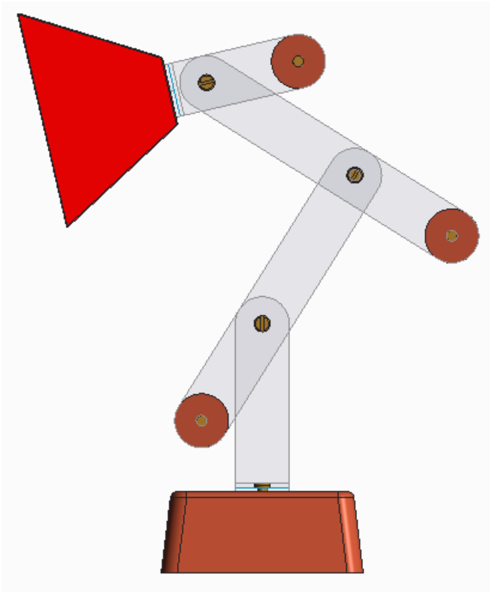
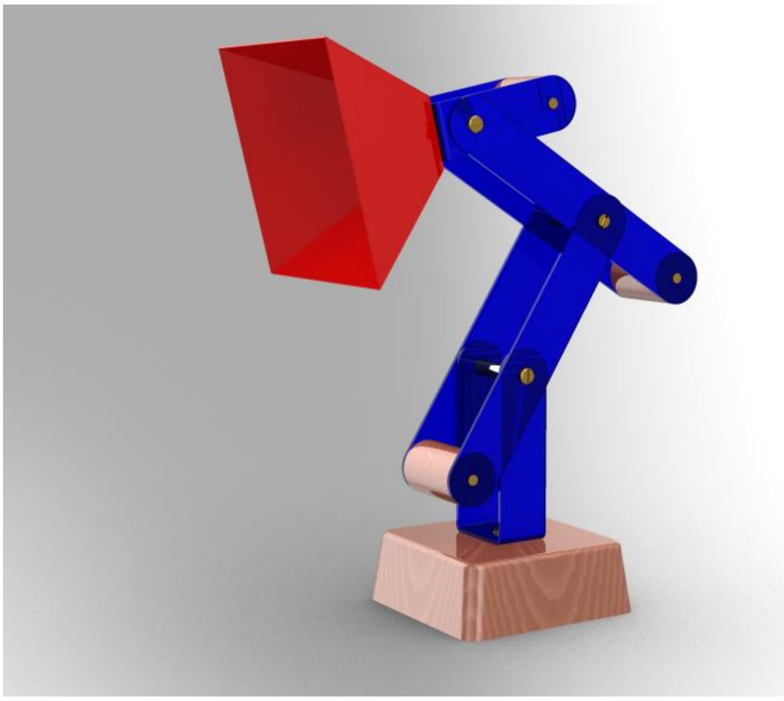
Articulating lamps - STEM into Action





timbdesign

Context

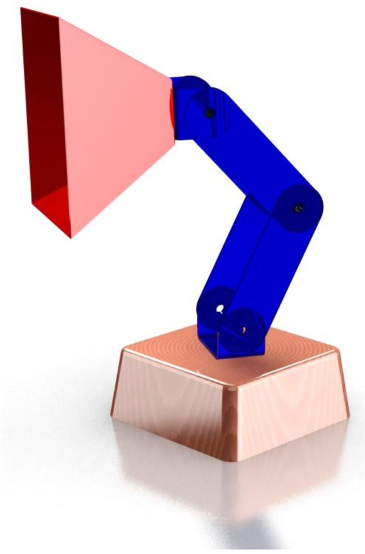
Many high school engineering courses include lighting projects and a desk lamp is a popular focus.

The purpose of this guide is to 'articulate' the mechanical design which is often overlooked.

This guide does not consider the equally important aesthetics of desk lamps

Designs similar to this are very common and suffer from the following shortcomings.

- Unstable.
- Poor balance.
- Difficult to adjust.

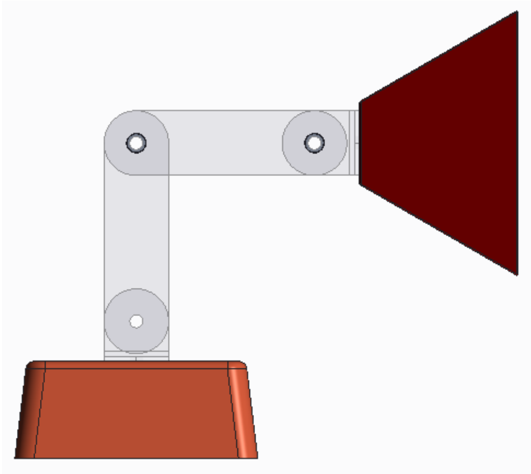


To understand these problems it's important to understand the forces in the structure and to show this can be done let's analyse one of the moving sections.

Moments

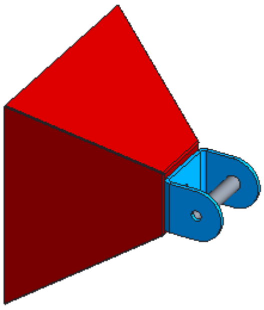
Here, the horizontal arm is supporting the lamp holder, shade and swivel components at the right hand end.

In turn, the horizontal arm is being supported by the lower arm which is upright in this illustration.



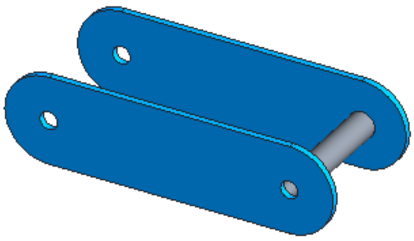
First we find the mass of the lampshade sub assembly.

= **0.6 Kg**



...and the mass of the top arm.

= **0.2 Kg**



The forces, or moments, acting on the arm are drawn on the right.

Taking moments about the left pivot...

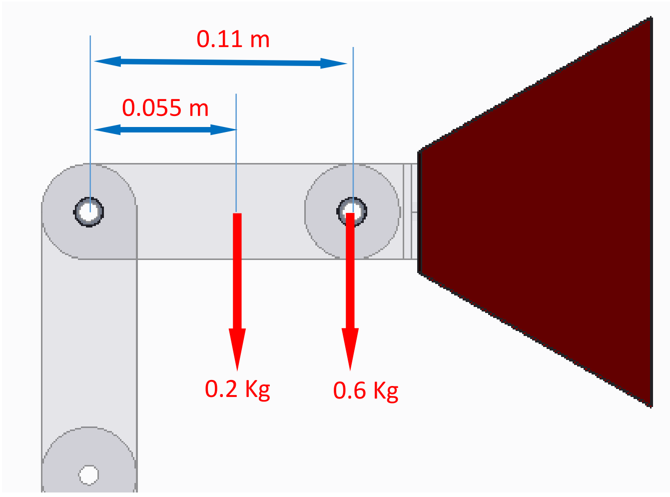
= (0.2 x 0.055) + (0.6 x 0.11)

= 0.011 + 0.066

= **0.077 Kg metres**

In this design, the only thing stopping the arm dropping is friction in the joint.

How large is this friction force?



Imaging a mass hanging from a rope.

The radius of the friction area is 0.02 m so the mass needed would be:

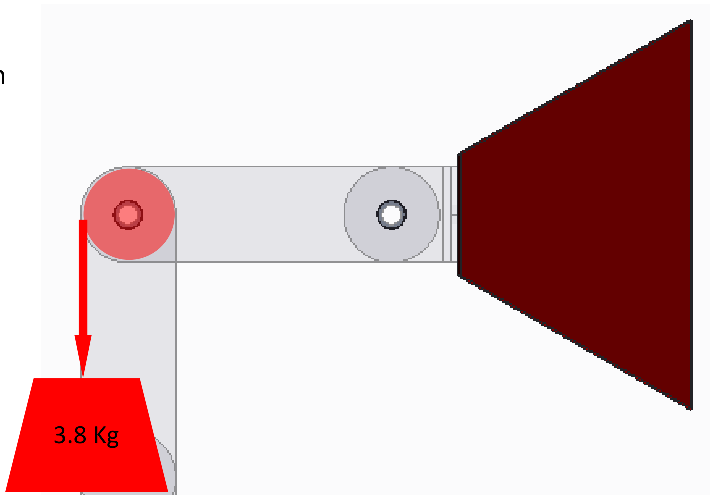
0.077 = 0.02 x mass

$\frac{0.077}{0.02}$ = **3.85 Kg**

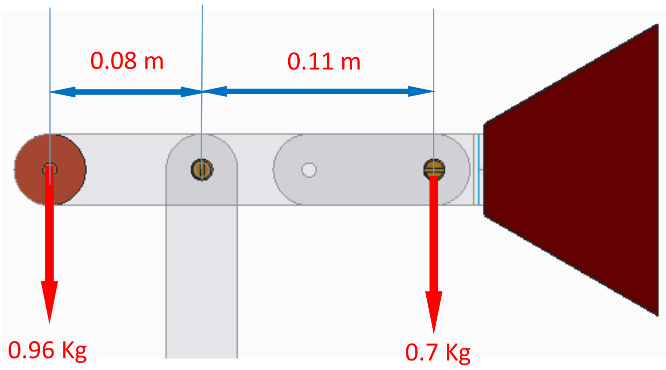
This is a large mass and explains why you need to be a gorilla to tighten the hinge bolts to stop the arm dropping!

Even with high friction materials in the hinge there are stability problems and a danger the light will collapse or topple over and break.

Surely there is a better way?



Counterbalance

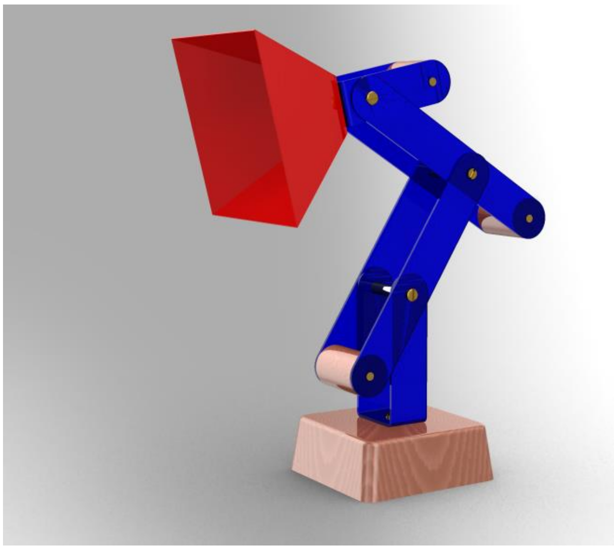


In this example the top arm has been extended and a mass inserted as a counterbalance. The moments look like this:

0.96 x 0.08 = 0.7 x 0.11

So, because the counterbalance is further away from the pivot, it only needs to be 0.96 Kg.

The top arm is now balanced so the hinges don’t need to provide much friction. The bolts can be finger tight making it easy to move the arm into any position.



Repeating the analysis and calculation for the lamp swivel and the lower moving arm leads to a modified design like this.

The mass counterbalances are heavier as they get lower and this could be achieved in different ways including:

- The same material but changing the diameter.
- The same diameter but using more dense materials lower down.

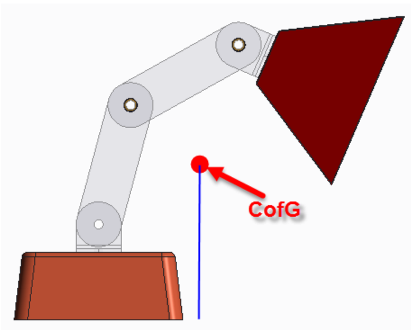
With each of the arms nicely balanced, adjustment is easy and the lamp will stay in any position.

Are there any other benefits from this modified design?

Stability

Below left is a **Mass Properties** analysis of the lamp parts above the base in the original design showing the location of the **centre of gravity** (CofG).

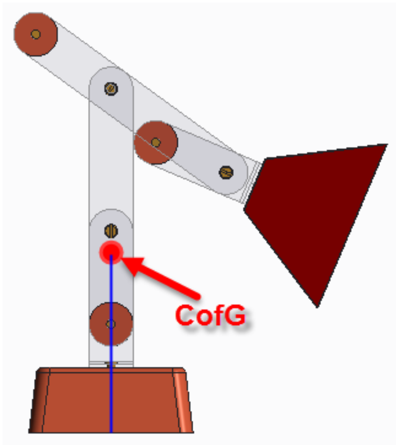
Notice where the CofG lands relative to the base.



A lamp which is difficult to adjust, unstable and probably unsafe!

A **Mass Properties** analysis of the upper parts in the modifed design has the centre of gravity directly over the middle of the base.

This applies no matter what postion the lamp is placed in.



A stable design which is user friendly and safe.

Further support

This is one of many resources written by Tim Brotherhood who has nearly forty years of experience providing guidance, training and support to D&T teachers, subject leaders and managers.

If you would like to develop this project further or would like to discuss strengthening STEM in your own projects, please contact:

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Acknowledgements

Feedback

In order to ensure these materials are of the highest quality, users are asked to report errors to the author.

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Suggestions for improvements and other activities would be very welcome.

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