BYOD - Build Your Own Dynamometer

At-home Physics Activity

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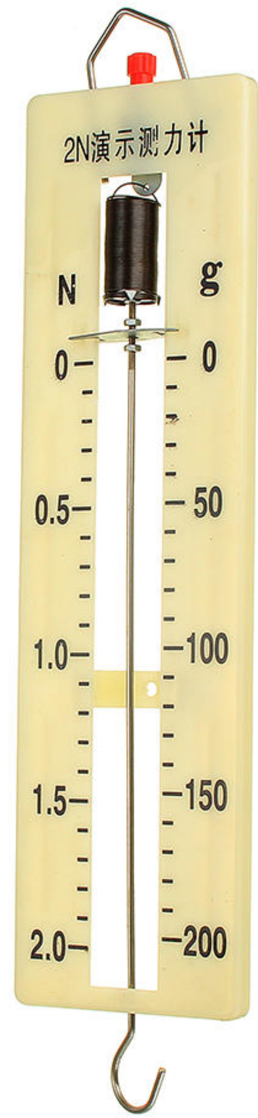
Dynamometer Theory



A dynamometer uses a spring to measure the force applied to an object. The extension of the spring past its normal resting point is proportional to the force applied.

You likely don't have a dynamometer at home.

If you have a luggage scale or a fish scale, you can adapt it to use as a dynamometer. The scale is calibrated in grams or kilograms, but it is actually the *weight* of the luggage or the fish that the scale measures. As you can see in this image, a scale and a dynamometer are the same tool, just calibrated in different units.

You can use the scale as a dynamometer by converting mass to weight by assuming that the scale is calibrated for an object subject to gravity at Earth's surface.

If you do not have a scale lying around, you can make a dynamometer using a spring or an elastic.

In all cases, you need to be able to attach one end of the spring/elastic to a fixed point, and you need to be able to measure how much the spring/elastic extends past its normal resting point. Just how to do this will depend on what kind and size of spring or elastic you can find.

Constructing a Dynamometer

The best choice for constructing a dynamometer is a spring. A spring will give a more accurate reading than an elastic, but springs might be harder to find. You might be able to find one if you have a garage with broken or unused mechanical equipment, or maybe in a toy owned by a little brother or sister. Ask first if you can borrow it. I tried the plastic spiral binding on a school agenda and it worked really well for measuring small forces.

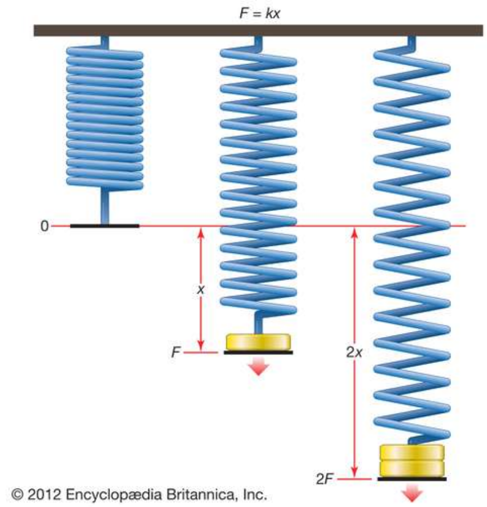
You can also try cutting an elastic band open so that it forms an elastic string (i.e. a straight line instead of a circle). This should act more like a spring in that the force applied to the end will cause only an extension of the elastic, rather than both a deformation and an extension.

If you are using a smaller spring or an office-type elastic band, you can try attaching it to thick cardboard as the base. You will be able to cut notches to hold the spring/elastic in place, and you can write directly on the cardboard as you calibrate your dynamometer.

If the cardboard is too thin, it will fold or buckle instead of resisting the pulling forces on the spring/elastic. If you can't find any thick cardboard, try gluing several layers of thinner cardboard together to reinforce it.

If you are using a more robust spring or elastic, like an exercise resistance band, you may need a more robust base to attach it to; think wood or metal. You will need to firmly attach one end of the spring or band to the base; duct tape might be a good choice here. As you calibrate your dynamometer, you might want to consider if the base will be reused, like a broom handle. In this case, you could calibrate it by writing the force values on a piece of masking tape stuck on the base.

Calibrating your Dynamometer



How many Newtons are you applying to make the spring/elastic stretch out? The idea behind a dynamometer is that we can convert between force applied and length of stretch and vice versa.

FORCE APPLIED ⇔ LENGTH OF STRETCH

These two values should be proportional to one another, forming a straight line that passes through zero when we graph them.

We don't have objects labeled in Newtons lying around the house, but we can use objects of known mass to calibrate our dynamometer, because we know how to convert mass to weight when an object is on the surface of the Earth.

$$F_g = mg$$

If you have a kitchen scale like the one pictured, you won't be able to use it as a dynamometer, but you can use it to find the mass of household items.

If you hang an item of known mass off the end of the spring/elastic, you will be able to calculate the weight of that item. You can therefore find the force applied to the spring/elastic to make it stretch a certain amount.

What if you don't have a kitchen scale? We can use objects of known mass, like a block of butter or a can of tuna. But, be careful, a can of tuna lists the mass of the tuna inside, but doesn't include the mass of the container itself, which is not negligible in the same way as that of the mass of the wrapper on a block of butter.

Another way to measure a mass of a known value is to remember that we know the density of water is 1 g/ml. If we use a lightweight plastic cup, then the mass of the cup will be negligible with respect to the mass of the water inside. Most houses have measuring cups with known volumes, which can then be used to find mass, which can then be used to find weight:

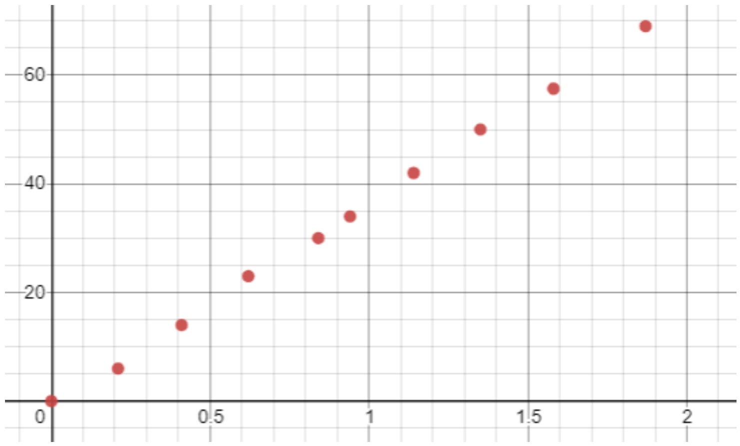
VOLUME ⇒ MASS ⇒ WEIGHT

No matter how you do it, your dynamometer should have markings down its length that show how many Newtons cause the spring/elastic to stretch to that point.

Creating a Calibration Curve

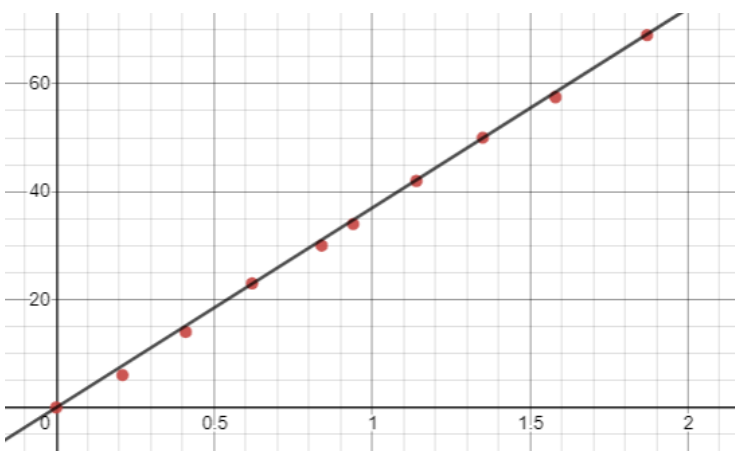
Because there is always some uncertainty in how to measure the stretch, as well as in how to measure the force applied, it makes sense to create a calibration curve in order to increase the accuracy of our force measurements.

A calibration curve is made using a scatter plot of spring extension vs. force applied.



It is unlikely all of the points will lie on a perfectly straight line, but they can be *modelled by* a linear function. The linear trend-line of the scatter plot is the calibration curve, and it will help us account for the fact that each individual point might be slightly imprecise.

Overall, the trend-line will be more accurate than any one point because the errors associated with each point will tend to cancel one another out.



For this dynamometer:
Extension (mm) = 37 × Force (N)

Knowing the equation of the trend-line, you can then calculate the force applied if you know how far the spring was extended.

Your dynamometer is now calibrated and ready to use in a physics experiment.

Examples of a BYOD