Prelab: Solids and structural integrity

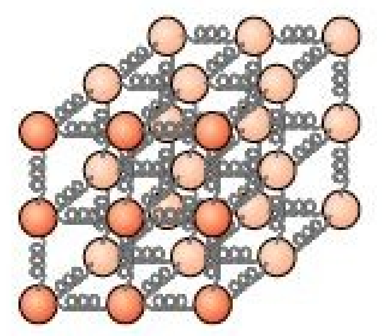
Everyday thing: buildings and bridges do not usually collapse, our bones can support our weight and all kinds of activity while being lightweight.

It is physics: these rely on the strength of solids to resist or absorb huge forces and clever shapes and arrangements which distribute these forces in a smart way.

Solids

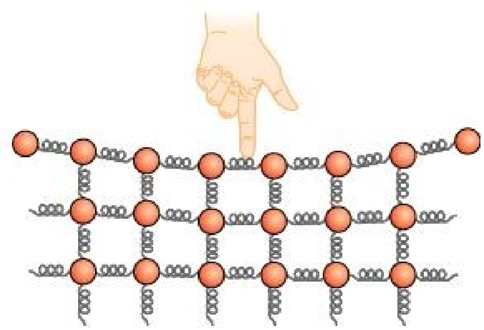
In the last lab, we discussed **gases** and **liquids**, this time we will study the third of the three non-exotic phases of matter: **solids**. In contrast to gases and liquids, solids are, well, *solid*, i. e., they do not "flow" and resist changes in its shape or volume.

In other words, we cannot just put our hand through the armrest of our chair the same way we can run our hand through a bath or waive it though air.



This is because the atoms that make up the solid are much more tightly arranged than in a liquid or gas; they form strong **bonds** with most of the other atoms around, tightening it to single cluster of atoms which we then call a solid.

These bonds between atoms are actually formed by the electrons. However, in order to understand the mechanical properties of solid, one can think of a solid as made of **tiny balls connected by tiny, very rigid springs** (see picture on the right).



Following this model, it is clear why we cannot put our finger though a solid (see right, obviously not to scale!): as we push against some of the atoms, we compress the springs and they push back against our fingers.

That analogy may seem a little ridiculous, but it turns out to be incredibly accurate in practice, so accurate in fact that physicists, chemists and engineers use it on an everyday basis when predicting the properties of materials. (More sciency, on can say electronic bonds respond to small displacements like springs do.)

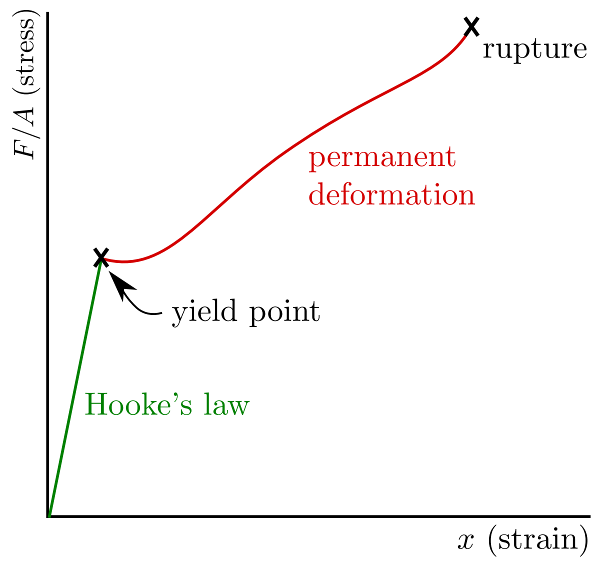
But if solids can be modelled by a set of springs, and we know from the springs lab that springs in parallel or series again behave like a spring, shouldn't that mean that the *whole* solid should behave like a spring?

It does! When one stretches a material (one applies **tension**) by a small distance x (called **strain**) the material will respond with an opposing force F:

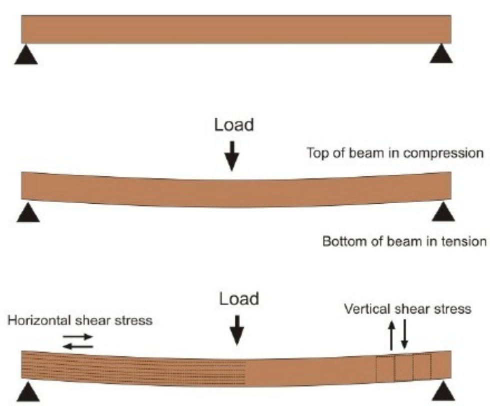
$$F = kx$$

called **stress**. This is nothing but Hooke's law, which you found in the springs lab. A similar thing happens when **compressing** the material (the spring constant might be different). One can thus say that a spring behaves like a spring because it's made up of tiny springs (it's like *Inception* all over again).

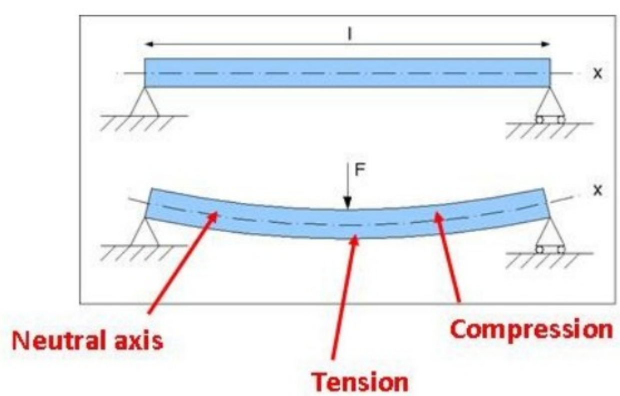
When we put more and more strain on the material (stretch it more and more), we will reach what is known as the yield point. At this point, instead of stretching, we will start *breaking* the bonds and we will permanently deform the material. Because the bonds have given way, the material is now easier to stretch (red region on the right). If we strain the material even more, at some point it will rupture. The force we need to apply to rupture the material is known as the **ultimate tensile strength**.



A beam with a load is an interesting example of the material's response to stress. As shown in the diagram, the upper surface of the beam is squeezed (compression) and the lower part isstretched (tension). As a consequence the "layers" of the material are subject to shear forces (second picture).



http://fet.uwe.ac.uk/conweb/commercial/ironandsteel/section1.htm



http://theconstructor.org/structural-engg/beam-design/beam-characteristics/1534/

--> Solve the first three levels of "Bridge Builder":

http://www.physicsgames.net/game/Bridge_Builder.html