Prelab: Weights and springs

Everyday thing: Springs are built into almost every piece of technology. They are the central part of a scale that allows you to measure weight, they are built into most keyboards to push your keys back up once you pressed them, they are used in cars to smoothen out bumps against the wheels.

It is physics: springs are one of the most fundamental objects in physics, because they respond to a force in a particular way (which we will explore in this lab). Even if they don't involve real springs, many phenomena in physics can be well described using springs: a piece of solid, for instance, can be extremly well approximated by atoms connected by tiny, very rigid springs.

1. Mass and weight

Mass and weight are often used synonymously, however, in physics they are two different concepts.

Mass is just the amount of matter in an object. Its SI unit is the **kilogram** (**kg**). We have two main ways we can observe mass:

- **inertia**: the resitance of an object against a change in velocity when a force is applied.
- **weight**: the force the object feels from the gravity of another body (say, the Earth).

(Remarkably, these two effects always go together, that is, the inertial mass is as far as we can tell exactly equal to the gravitational mass. This is more surprising than you might think: we could imagine an object that feels gravity very strongly yet is easy to move and vice-versa.)

Weight, as mentioned, is the gravitational force an object feels by the presence of another object. Its SI unit is the **Newton** (**N**). The weight of an object is given by:

$$\begin{aligned} \text{weight} &= (\text{mass}) \times (\text{strength of gravity}) \\ F_w &= m\,g \end{aligned} \tag{1}$$

On the surface of the Earth, the strength of gravity is about:

$$g \approx 10\,\frac{\mathrm{N}}{\mathrm{kg}} \tag{2}$$

This means that we can compute the weight of an object with a mass of 50 kg by:

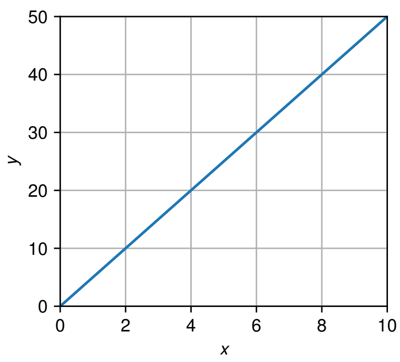
$$F_w = m\,g \approx 50\,\mathrm{kg} \cdot 10\,\frac{\mathrm{N}}{\mathrm{kg}} = 500\,\mathrm{N} \tag{3}$$

On the moon, on the other hand, $g \approx 1.6\,\mathrm{N/kg}$, so even though our mass is the same whether we are on the Earth or the moon, our weight (the force we actually feel) is reduced by a factor of 6 on the moon.

Thinking of weight this way gives us ideas about how to measure weight: measure the force needed to support an object. Most useful devices make use of springs to provide the force. What you will learn in this lab is that the amount a spring stretches is connected to the force it provides.

2. Laws and proportionality

You will be asked to find the relationship between two quantities, for instance the length of the spring and the weight pulling on the spring.



Linear behavior (direct proportionality):

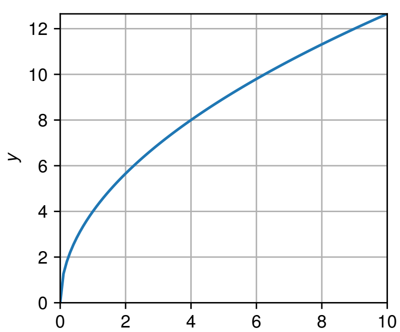
Formula: $y = kx$

Observations (e.g.):

- 2 x → 2 y
  (read: if I double the value of x, I observe twice the value of y)
- 3 x → 3 y

Coefficient of proportionality:

$$k = \Delta y / \Delta x$$

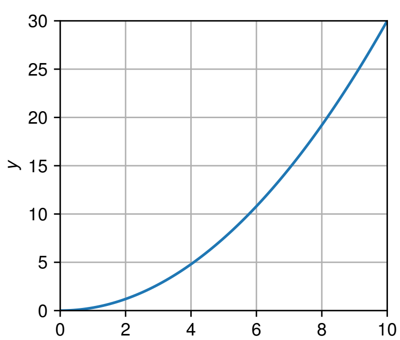


Square root behavior:

$$y = k\sqrt{x}$$

Observations (e.g.):

- 2 x → $\sqrt{2}y \approx 1.4y$
- 4 x → 2 y

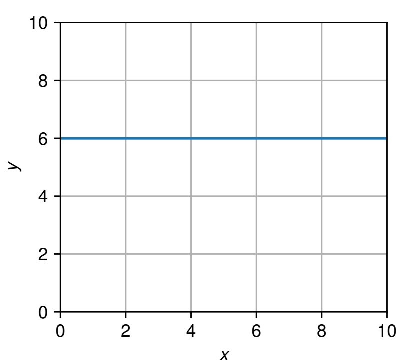


Quadratic behavior:

$$y = kx^2$$

Observations (e.g.):

- 2 x → 4 y
- 3 x → 9 y



Constant behavior:

$$y = k$$

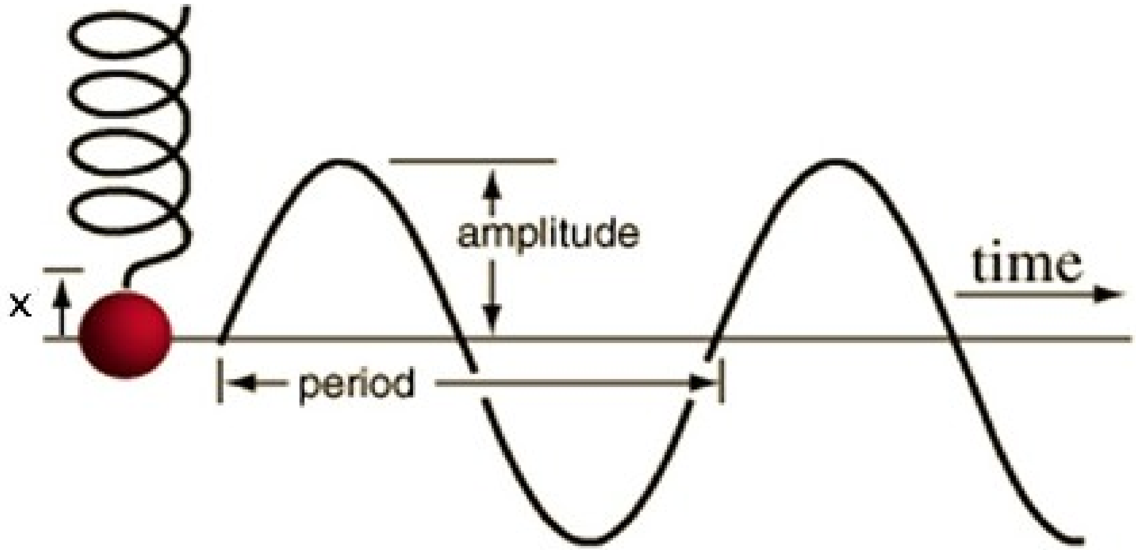
Observations:

- 2 x → y
- 3 x → y

3. Periodic motion

An object is in a periodic motion if the potion repeats after a certain time, called the period *T*. Periodic motions are ubiquitous in physics, they form the basis of waves, pendulums. A particularly simple periodic motion, called **harmonic oscillation**, can be observed with springs and weights.

Here is how such a motion looks over time:



Note that the weight goes through the equilibrium postition (the middle position) twice per period – once moving upwards, and once moving downwards.