Weight and Mass

In case you didn't think there was any difference...

Mass

What it measures:
Basically, the amount of stuff (as opposed to volume, which is the amount of space the stuff takes up).

What it's measured in:
SI units are kilograms (kg), although it can also be measured in grams, tonnes, etc, or even in imperial units.

How it can be experienced:
Through inertia/momentum (it takes a lot more work to get something moving if it has a large mass), or through the effect it has on weight (see opposite).

Food for thought:
Imagine rugby tackling someone on the moon – the impact of tackling someone much bigger (more 'massive') than you would be pretty much the same as on Earth. Because you're tackling horizontally, you're not having to work against gravity either on Earth or on the Moon, just inertia.

Weight

What it measures:
The force that gravity exerts on anything with mass – the more the mass, the greater the weight.

What it's measured in:
SI units are Newtons (N) (it is a force, after all), although using $F = ma$ we can see that this is equivalent to $kgms^{-2}$.

How it can be experienced:
Only indirectly – generally what we think of as our weight is actually the normal reaction forces that act on us as a result of our weight. A feeling of 'weightlessness' is essentially a feeling of no forces working against the weight (ie, in freefall).

Food for thought:
When going up in a lift, you feel heavy at first not because your weight has changed but because the normal reaction acting on you from the floor of the lift has increased (to accelerate you upwards). And you feel lighter as the lift decelerates because your normal reaction is then lower than usual.

On Earth, your weight is directly proportional to your mass (always $9.8m$), but on the Moon, since the acceleration due to gravity is lower, while weight is still directly proportional to mass, the constant of proportionality is lower (so we get about $1.6m$).

Recall that the acceleration due to gravity is the same for any object (close to the surface of the Earth), and is written as $g = 9.8ms^{-2}$. This means any object, neglecting air resistance, should fall at the same rate.

Some extra info...

Gravity is a force which acts on everything which has mass. In fact, the greater the mass of the objects, the greater the force of gravity attracting them to each other. So, technically, even people are gravitationally attracted to one another (a force of around $0.000001N$ if you're at arm's length – enough to pull you together in something over an hour if you were isolated in space, for instance). However, in general gravity is an extremely weak force *unless* one or both of the objects in question are massive (have a huge mass). Eg, the Earth.

Gravitational force is calculated using:

$$F = \frac{GMm}{r^2}$$

Where M and m are the masses of the two objects, r is the distance between their centres of mass, and G is the gravitational constant, 6.67×10^{-11} (a very, very small number).

It's only when we can factor in a huge mass like that of our planet (5.97×10^{24}) that we get enough of a number to worry about, even taking into account a relatively large distance from us to the centre of the planet ($r = 6371km = 6.371 \times 10^6 m$). Since the mass of the Earth doesn't really change, and our distance from the centre is more or less fixed (at the poles around $6357km$ and at the equator $6378km$), the only variable left in the force equation is our own mass. We could write it as:

$$F = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} m}{(6.371 \times 10^6)^2} \approx 9.8m$$

Since force is always related to acceleration through mass ($F = ma$), because the force of gravity is directly proportional to mass, we have $9.8m = ma$, which means $a = 9.8$. That is, the *acceleration due to gravity* is completely independent of mass. So any object falling freely under gravity will fall at the same rate. This is why the number $9.8ms^{-2}$ is referred to with its own special letter, g. g is an acceleration, and mg is the weight (the force exerted on a particle of mass m by gravity).

Physics vs. Maths – why do they use 9.81 *and we use* 9.8*?*

The actual acceleration due to gravity, because of the variation in the Earth's radius, does in fact vary between around 9.78 and 9.82. Although 9.81 is more accurate (technically, closer to the true average value), since the value itself varies so much, 9.8 is probably a more sensible level of precision to use.