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1. The second law is the one that tells you how to calculate the value of a force. Force (measured in Newtons) is one of the fundamental physical properties of a system and comes in many forms. You might feel it as a push or pull (a mechanical force), while it is the value of your weight (the gravitational force of the Earth pulling on you) and can be seen in the repulsion or attraction of magnets or electric charges (electromagnetic force). A force might be the result of any number of fundamental physical interactions between bits of matter but Newton's second law allows you to work out how a force, when it is present, will affect the motion of an object.

In the form pictured, above, it says that force (F) is equal to the rate of change of momentum (p) with respect to time (t). The small "d"s are differential notation, another Newtonian invention that appears in countless physical equations and that allows you to mathematically predict how something will change as another related parameter is incrementally altered – in this case, time.

Momentum is the mass (kilograms) of an object multiplied by its velocity (metres per second). In most situations, the mass of something does not change as it moves so the equation can be simplified to mass (m) multiplied by the rate of change of velocity, which we know as acceleration (a). That gives us the more familiar school textbook version of the second law: F=ma.

Like the rest of Newton's physics, the second law of motion holds up for a staggering array of everyday situations and is a workhorse in modern science and engineering. The way almost anything moves can be worked out using his laws of motion – how much force it will take to accelerate a train, whether a cannon ball will reach its target, how air and ocean currents move or whether a plane will fly are all applications of Newton's second law. He even used the laws of motion, combined with his universal law of gravitation, to explain why planets move the way they do.

Weight is a force, equal to an object's mass multiplied by the gravitational acceleration caused by the Earth (equal to 10 metres per second per second), in the direction of the centre of the planet. The reason you don't fall through the ground, of course, is explained by Newton's third law of motion, which says that the surface of the Earth is pushing up against your feet at a force equal but opposite to your weight.

A modified version of the second law applies when the mass of an object is changing, such as a rocket, which burns up fuel and becomes lighter as it climbs through the atmosphere.

We all know the second law in practice, if not in mathematics. You need to exert more force (and therefore more energy) to move a heavy grand piano than to slide a small stool across the floor. When you catch a fast-moving cricket ball, you know it will hurt less if you move your arm back as you catch it – by giving the moving ball more time to slow down your hand has to exert less opposing force on the ball.

The cricket ball example demonstrates that forces not only have a size but act in a particular direction. Forces belong to a category of physical properties, which includes momentum and velocity, known as vectors. These contrast with scalars, which have a size but no direction, for example temperature or mass.

The F in Newton's second law refers to the net force acting on an object. Working out what happens to an object that has several forces acting on it, therefore, requires you to take account of both the directions and sizes of each force. Two forces might have the same sizes but, if they are pointed directly opposite one another, they will cancel to zero.

A game of tug-of-war is a good way to think about this. When two teams are pulling in opposite directions, the movement of the rope (as calculated by Newton's second law) will be determined by the net force on the rope. The size of that net force is the difference in the sizes of the forces being exerted by the two teams. The direction of the net force will be in the direction of whichever team is pulling harder.

To describe atoms, and even smaller things, physicists use versions of force and momentum in the equations that include quantum-mechanical descriptions of time as well as space. At this scale, forces are the mathematical by-products arising when fundamental particles of matter, such as electrons and quarks, exchange particles such as photons, gluons or W or Z particles, that "carry" forces and are collectively known as gauge bosons.

Newton's second law works as a way to describe the motion of everything in a quantum mechanical system as long as the particles are not moving near the speed of light.

When an object is moving close to the speed of light, we get into the realm of special relativity, which tells us that the mass of an object will increase as it moves faster. You need to take this into account when calculating forces at these speeds.

Indeed, most of Newton's classical physics needs to be modified in extreme situations – the second law is not accurate when immense gravitational forces are present, around a black hole or in the context of the huge masses of entire galaxies for example, where general relativity takes over as the best way to describe the movement within a system.

1. **An electric field** is the [physical field](https://en.m.wikipedia.org/wiki/Field_%28physics%29) that surrounds each [electric charge](https://en.m.wikipedia.org/wiki/Electric_charge) and exerts force on all other charges in the field, either attracting or repelling them. Electric fields originate from electric charges, or from time-varying [magnetic fields](https://en.m.wikipedia.org/wiki/Magnetic_fields). Electric fields and magnetic fields are both manifestations of the [electromagnetic force](https://en.m.wikipedia.org/wiki/Electromagnetism), one of the four [fundamental forces](https://en.m.wikipedia.org/wiki/Fundamental_interaction) (or interactions) of nature.

**A** **magnetic field** is a [vector field](https://en.m.wikipedia.org/wiki/Vector_field) that describes the magnetic influence on moving [electric charges](https://en.m.wikipedia.org/wiki/Electric_charge), [electric currents](https://en.m.wikipedia.org/wiki/Electric_currents), and magnetized materials. A charge that is moving in a magnetic field experiences a force perpendicular to its own velocity and to the magnetic field. The effects of magnetic fields are commonly seen in [permanent magnets](https://en.m.wikipedia.org/wiki/Permanent_magnet), which pull on [magnetic materials](https://en.m.wikipedia.org/wiki/Ferromagnetic_material) such as [iron](https://en.m.wikipedia.org/wiki/Iron), and attract or repel other magnets.

The basic concept of current is that it is the movement of electrons within a substance. Electrons are minute particles that exist as part of the molecular structure of materials. Sometimes these electrons are held tightly within the molecules and other times they are held loosely and they are able to move around the structure relatively freely.

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