Modern theories of fundamental interactions describe strong, electromagnetic and weak interactions as quantum field theories with certain kinds of embedded internal symmetries called ‘gauge symmetries’. This article introduces quantum field theories and gauge symmetries to the uninitiated.

1. Things Behind the Things We See

The reader looking at this page must be establishing some sort of interaction with the marks of ink that define the letters on the page. How is this interaction being established? Well, if it is evening, I assume that there is an electric lamp glowing in the room. Light coming out of that is hitting the page, getting reflected, and entering the reader’s eyes. In short, the interaction is being established through light.

Suppose we now ask, why is the lamp glowing? When the lamp was switched on, how did the lamp, sitting a few meters away from the switch, get that piece of information? We know the answer to this question. Here is a wire connecting the switch and the lamp, which carried an electric current. So in this case, the connection was established through electricity.

What happens when we turn on an electric fan? Here are coils of wires inside a fan. When an electric current flows through it, it generates a magnetic field around the coils. If we put a metallic ring within that magnetic field, the field induces a rotation on the ring. Once you have a rotating something, it is easy to fit a few blades on it so that it can send ripples in the air around it. So
here, it is the magnetic field which acts as an agent in establishing connections.

In the second half of the 19th century, James Clerk Maxwell taught us that these are not independent phenomena. Light, electricity, magnetism: they are all governed by a common set of laws. So we can summarize the statements made in the previous paragraphs by saying that two things can interact with each other through the electromagnetic field.

In the first half of the 20th century, we cracked the mystery of atoms. An atom has a nucleus in some central position, and electrons going around it. How do the electrons know that there is a nucleus somewhere there? Because the nucleus contains protons and neutrons, of which the protons carry positive electric charges. These charges create an electromagnetic field around them. The electrons hover around through this field. So in this case also, the electromagnetic field acts as the matchmaker.

Sometimes if two different substances are brought close together, they react chemically. What happens in a chemical reaction? In short, molecules break up owing to interactions between the atomic electrons, and the atoms reorganize themselves into new molecules. Thus, here also the interaction is electromagnetic.

While I write, I hold a pen in my hand. How do I do that? Here is something going on in the atoms and molecules that constitute the fingers of my hand which allows them to put a pressure on the atoms that constitute the pen. It would be hard for me to describe the details – firstly because the processes are complicated and secondly because I am no expert in physiology. What I can say for certain is that some kind of interaction between atoms is responsible for my holding the pen, and these interactions are electromagnetic. It is the same story behind most of the things we do – speaking, walking, sitting down, chewing our food – you name it!

But if my pen slips out of my hand and falls on the floor, that’s not due to electromagnetic interactions. Here the earth’s gravitation is responsible for the phenomenon. Just as a charged particle or a magnet sets up an electromagnetic field around it, a massive particle sets up a gravitational field around it. Because of the gravitational field that the earth creates, the pen in my hand came to know the presence of the earth near it. So, as soon it slipped out of my hand, it went down and hit the floor.