# Why the Apple Falls

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## Fantastic Physics for Children

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juggernaut

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*To our late fathers Ajit Kumar Banerjee and Hrishikesh Deb, two men very different from each other but absolutely alike in their honesty, courage and affection*

# Contents

# 1

# What Is Physics?

In our universe, the smallest particle scientists have discovered is a quark, a little ball that lives inside the atom and whose radius is 43 billion-billionths of a centimetre ($0.43 \times 10^{-16}$ cm)! The largest thing found till now is a supercluster of galaxies, called the Hercules-Corona Borealis Great Wall. It is so wide that light, which travels at the speed of 300,000 kilometres per second, takes about 10 billion years to move across the entire structure. And the universe itself is only 13.8 billion years old!

Physics is the study of everything from quarks to supergalaxies. And almost none of the things that we see and use today, from ice cream and airplanes to

ceiling fans and cell phones, would have been possible without the work done by physicists.

The word 'physics' entered English in the fifteenth century, derived from the Latin word *physica*, which means 'study of nature' and the Greek *phusikē*, or 'knowledge of nature'. But till the beginning of the twentieth century, it was clubbed together with chemistry, biology, botany, geology and so on, under the broad term 'natural sciences'.

## Physics and Math

Physicists are thinkers and seekers of knowledge. They try to understand the workings of nature using mathematics, which is full of abstract ideas and equations. Physicists use higher mathematics as a tool to figure out how nature works. Indeed, a lot of higher mathematics was initially worked out to understand things that happen in the physical universe.

Take motion as an example. Motion is present everywhere in nature. From the movement of stars across the sky to the crashing of waves on the seashore and tree leaves fluttering in the wind – there is constant motion and constant change. Galileo Galilei and Sir Isaac Newton were the first scientists who tried to

quantify motion and eventually discovered the laws governing moving bodies. Based on their discoveries, they were also able to explain the movement of planets, how tides happen, why an apple falls instead of going up and a whole lot of other things.

Galileo and Newton found that they could describe motion using mathematical equations. And centuries later, people used these equations to design washing machines and send rockets into space!

## Who Invented Physics?

The answer to the question 'Who invented Physics?' would be 'No one in particular', or 'A great many people in general'. Human beings have always wondered why things happen and what would happen if they did something differently. The person who discovered that fire could be produced by rubbing stones together was a physicist. So was the person who invented the wheel.

Ancient philosophers who pondered on the workings of the universe were also physicists. They did not have the instruments that we have today, which can make very accurate measurements even at an atomic level. But through deep thought, they arrived at certain truths about the universe.

There is a lot of proof that ancient Indians made discoveries that were ahead of their times when it came to the sciences. Excavations at Harappa and Mohenjo Daro, major Indus Valley Civilization cities, have unearthed tools resembling rulers crafted from ivory and shell, used to take measurements. Taking measurements is an essential part of physics.

Some of our ancient rishis came to certain conclusions that Western scientists reached much later. For example, the Indian natural scientist and philosopher **Kanada**, who lived sometime between sixth century and second century BCE, introduced the concept of atoms. He suggested that everything can be divided into smaller and smaller particles, but this subdivision cannot go on endlessly. Ultimately, one would reach particles that cannot be divided any further. Kanada went on to say that these smallest entities (which he named '*parmanu*' – the ultimate smallest particle) are eternal and that they combine in various ways to produce complex substances. This is very similar to the atomic theory of matter that British chemist John Dalton developed, which was accepted only in the early nineteenth century.

In Hindi, the term for 'nuclear bomb' is 'parmanu bomb'.

Ancient Greek philosophers pondered on the nature of the universe. They came to believe that the universe was harmonious and perfect and was governed by elegant equations. However, in those times, physics was clubbed together with theology – the study of God, religion and supernatural forces – and philosophy – the study of general questions about existence. Modern physics, which we are familiar with today, rose out of theoretical mathematics, accurate astronomy – the study of stars and planets and what goes on in space – and experiments to prove or disprove ideas. Indeed, a theory becomes a 'law' only after it has been tested and verified through experiments.

### The Scientific Method

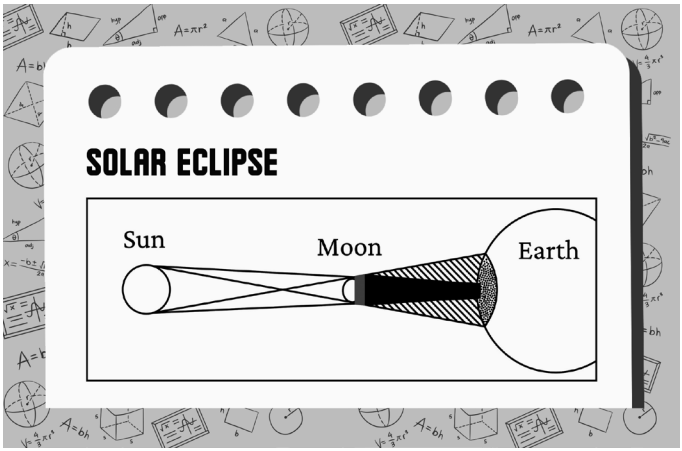
All physicists follow the 'scientific method', which involves four steps. They 'observe' something. Then they 'hypothesize', which is to develop an idea about why that something could be happening. They 'experiment' to check if the idea is correct. Finally, based on the results of the experiments, they 'conclude' whether the idea was right, half-right or completely wrong.

The Greek philosopher Thales of Miletus, who lived in the seventh century BCE, was the first physicist in the modern sense of the word, because his explanations of nature did not involve supernatural forces. He believed that although there were many kinds of materials, the basic element present everywhere was water. The interactions of the various phases of water – solid, liquid and gas, i.e., ice, water and vapour – gave materials different properties.

He was followed by Leucippus in the fourth century BCE. He, too, opposed the idea that the gods were interfering in the universe and proposed that natural phenomena had natural causes.

Archimedes, the Greek mathematician, scientist and engineer who lived in the third century BCE, is one of the most outstanding characters in the story of physics. He is best known for his 'Eureka' moment while having a bath, when he discovered the principles of density and flotation – why some solids (like a stone) sink in water and others (like leaves) float. Although this is his most popular story, Archimedes didn't stop there. He made many other important contributions to physics. He improved upon the mechanism of pulleys and levers, and laid down mathematical principles that enabled the construction of complex machines.


Mathematicians of ancient India often used their knowledge to make accurate astronomical predictions. Aryabhata was a renowned mathematician and astronomer who lived during the fifth–sixth century CE. He correctly proposed that the earth is round, rotates around its own axis and revolves around the sun. European physicists came to the same conclusions hundreds of years later and were persecuted and almost killed for saying so. Aryabhata explained how solar and lunar eclipses occur and gave an accurate measurement of the length of a day which is amazingly close to the modern estimates. Other Indian greats included Bhaskara, Brahmagupta, Varahamihira and Madhava.




Source: From 'LIDAR and Ground Ozone Measurements in the PBL during the August 11, 1999, Solar Eclipse' via researchgate.net

*The moon comes between the sun and the earth, and casts a shadow over the earth. Where the moon does not fully block off the sun, there is a partial solar eclipse. Where the sun is fully obscured by the moon, there is a total solar eclipse.*

We will look at some of these great minds later in the book.

## The Earth Moves around the Sun

Copernicus was a Polish astronomer who lived in the fifteenth century. He was the first European to propose the 'Heliocentric Theory', which states that the sun is at the centre of the solar system and that the earth and all the other planets revolve around it. This was a revolutionary idea at that time, because people believed

that the earth was at the centre of the universe, and it was the sun that revolved around it. Copernicus' 'Heliocentric Theory' laid the foundation upon which Galileo and Newton could develop physics further.

Nearly a thousand years before Copernicus, Aryabhata had proposed the same theory, but by the time of Copernicus, Aryabhata's work had been forgotten outside India. In Chapter 4, we'll see why that happened. Even in India, hardly anyone remembered him.

So these are the early physicists, some of the heroes in our story. This is a story filled with many twists and turns, featuring brilliant men and women whose ideas have changed the way we look at the world. It is also closely linked to the story of technology and innovation. While physics tries to explain the workings of the universe, technology uses this knowledge for practical purposes. At the same time, physics experiments today use a lot of technology, so progress in one field has led to progress in the other.

This book is about the evolution of one of the most fascinating fields of study, from the earliest days several thousands of years ago to the latest puzzles that scientists are now trying to solve. It is also the story of

some of the greatest scientists ever born – both those who have become legends and those who never got their due recognition in their lifetimes for the great discoveries they made.

**A warning: As we progress through the book, the universe will become more and more mysterious and weird!**

### The Laws of Physics

Physics is the science of matter, motion and energy. Its laws are expressed as mathematical equations. The most famous equation of all time, of course, is Albert Einstein's $E=MC^2$.

Physics can be divided into two parts: classical and quantum. Classical physics is about the movement of macroscopic objects – roughly, stuff that we can see around us – and other phenomena like heat, sound, electricity, magnetism and light. Quantum physics looks at the basic building blocks of matter, such as electrons, protons and neutrons – particles that live inside an atom.

The ultimate aim of physics is to find one set of laws that governs matter, motion and energy – from sub-

atomic levels too tiny to even imagine to the extragalactic scale so vast that the mind boggles. This will be the one Grand Unified Theory that would explain everything in the universe. But it has not yet been found. Perhaps it never will be.

Even if a unified 'Law of Physics' is discovered, in science, all laws are open to being tested and re-tested based on new data and observations. This means such laws are open to be improved upon or disproved in the future. This is a basic principle of science. So the journey for knowledge never ends. And that is a beautiful thing.