

Chapter-1: Physical World

1.1: Some of the most profound statements on the nature of science have come from Albert Einstein, one of the greatest scientists of all time. What do you think Einstein meant when he said: “The most incomprehensible thing about the world is that it is comprehensible”?

Solution: The physical world around us is composed of various complex natural occurrences, making it difficult to comprehend. However, it has been discovered via research and observations that all of these events are founded on certain fundamental physical rules, making them understandable.

1.2: “Every great physical theory starts as a heresy and ends as a dogma”. Give some examples from the history of science of the validity of this incisive remark.

Solution: The above statement is correct. The validity of this astute observation can be demonstrated using the example of a moment of inertia. It states that a body's moment of inertia is determined by its energy. However, according to Einstein's mass-energy ratio, energy is proportional to the body's speed.

1.3: Politics is the art of the possible”. Similarly, "Science is the art of the soluble ". Explain this beautiful aphorism on the nature and practice of science.

Solution: It is commonly known that, to gain votes, politicians would go to any length, even if they are unsure of the outcome. Likewise, in science, numerous natural occurrences can be explained using a few basic laws. Similarly, to how 'Politics is the art of the possible,' 'Science is the art of the solvable.'

1.4: Though India now has a large base in science and technology, which is fast expanding, it's still a long way from realizing its potential of becoming a world leader in science. Name some important factors that, in your view have hindered the advancement of science in India.

Solution: Some significant elements, in our opinion, that has hampered India's scientific progress:

- For the development of scientific activities and laboratories, adequate funding is not available. The laboratories and scientific tools are ancient and obsolete.
- The majority of Indians are uneducated and adhere to strict traditions. They are unaware of the significance of science.
- In India, there are no suitable job opportunities for scientific graduates.
- In India, there are no adequate facilities for science education in schools and institutions.

1.5: No physicist has ever “seen” an electron. Yet, all physicists believe in the existence of electrons. An intelligent but superstitious man advances this analogy to argue that ‘ghosts exist even though no one has ‘seen’ one. How will you refute his argument?

Solution: Although no physicist has ever observed an atom, there are practical proofs that an electron exists. Even powerful microscopes struggle to measure their sizes since they are so minuscule.

However, its impacts could be investigated. On the other hand, no phenomenon can be explained only by the existence of ghosts.

1.6: The shells of crabs found around a particular coastal location in Japan seem mostly to resemble the legendary face of a Samurai. Given below are two explanations of this observed fact. Which of these strikes you as a scientific explanation?

a. A tragic sea accident several centuries ago drowned a young Samurai. As a tribute to his bravery, nature through its inscrutable ways immortalized his face by imprinting it on the crab shells in that area.

b. After the sea tragedy, fishermen in that area, in a gesture of honors to their dead hero, let free any crab shell caught by them which accidentally had a shape resembling the face of a samurai. Consequently, the particular shape of the crab shell survived longer, and therefore in course of time, the shape was genetically propagated. This is an example of evolution by artificial selection.

[Note: This interesting illustration is taken from Carl Sagan's 'The Cosmos' highlights the fact that often strange and inexplicable facts which at the first sight appear 'supernatural' actually turn out to have simple scientific explanations. Try to think of other examples of this kind].

Solution: Explanation (b) is correct is a scientific explanation of the observed fact.

1.7: The industrial revolution in England and Western Europe more than two centuries ago was triggered by some key scientific and technological advances. What were these advances?

Solution: England and Western Europe invented the steam engine, electricity, gravitational theory, and explosives more than two centuries ago. Steam engines aided them in the fields of heat and thermodynamics, the theory of gravitation in motion, and the manufacture of firearms. In England and Western Europe, these advancements ushered in the industrial revolution.

1.8: It is often said that the world is now witnessing a second industrial revolution, which will transform society as radically as did the first. List some key contemporary areas of science and technology, which are responsible for this revolution.

Solution: Some of the most important contemporary areas of science and technology that have the potential to drastically alter civilization include:

- Computers that are extremely fast are being developed.
- The internet, as well as an enormous progress in information technology,
- Development in Biotechnology.
- At room temperature, superconducting materials are being developed.
- Robotics development.
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1.9: Write in about 1000 words a fiction piece based on your speculation on the science and technology of the twenty-second century.

Solution: Assume you and your companions are aboard a spaceship heading for Mars. The spaceship's body is composed of a specially created material that gets harder as it gets older.

The temperature rises. The spaceship runs on nuclear power, and there are three nuclear reactors on board. Two of them alternate shifts, while the third is only used in an emergency. The spaceship is traveling at a breakneck speed, and you're all ecstatic. The energy produced in power plants are turned into electric energy which operates the motors of the spaceship. You and your companions arrive on Mars safely, collect data, snap photos, and then return to Earth. On the way back, the spaceship collides with an object in space, causing two power plants to shut down. Only one power plant is operational at the moment, and its efficiency is steadily declining owing to overheating.

You and your friends try to cool the power plant down by blowing air through it, as well as trying to fix the other power plants' fuses. Finally, before the first plant surpasses the danger limit of an excessive temperature, the fuse of another plant is fixed and it begins to work. Finally, you and your companions return to Earth safely.

1.10: Attempt to formulate your 'moral' views on the practice of science. Imagine yourself stumbling upon a discovery, which has great academic interest but is certain to have nothing but dangerous consequences for human society. How, if at all, will you resolve your dilemma?

Solution: A type of finding that is of tremendous academic interest but destructive to human society, in our opinion, should not be made public because science is for society, not society.

1.11: Science, like any knowledge, can be put to good or bad use, depending on the user. Below are some of the applications of science. Formulate your views on whether the particular application is good, bad, or something that cannot be so clearly categorized:

- a. Mass vaccination against smallpox to curb and finally eradicate this disease from the population. (This has already been successfully done in India).
- b. Television for eradication of illiteracy and for mass communication of news and ideas.
- c. Prenatal sex determination
- d. Computers for an increase in work efficiency
- e. Putting artificial satellites into orbits around the Earth
- f. Development of nuclear weapons
- g. Development of new and powerful techniques of chemical and biological warfare.
- h. Purification of water for drinking
- i. Plastic surgery
- j. Cloning

Solution:

- a. Good
- b. Good
- c. Bad
- d. Good
- e. Good
- f. Bad
- g. Bad
- h. Good
- i. Good
- j. Good

1.12: India has had a long and unbroken tradition of great scholarship - in mathematics, astronomy, linguistics, logic, and ethics. Yet, in parallel with this, several superstitious and obscurantist attitudes and practices flourished in our society and unfortunately continue even today -among many educated people too. How will you use your knowledge of science to develop strategies to counter these attitudes?

Solution: In India, poverty and illiteracy are the two key causes that cause people to be superstitious. So, to eradicate superstition and obscurantism, we must first conquer these causes.

Everyone should be educated to extremely fast computers gain notes science textbook scientific mindset. Science knowledge can be used to disprove people's superstitions by demonstrating the logical reasoning underlying everything that happens in our world.

1.13: Though the law gives women equal status in India, many people hold unscientific views on a woman's innate nature, capacity, and intelligence, and in practice give them a secondary status and role. Demolish this view using scientific arguments, and by quoting examples of great women in science and other spheres; and persuade yourself and others that, given equal opportunity, women are on par with men.

Solution: Some people in our society believe that women lack the innate nature, capacity, and intelligence that males possess.

To dispel this notion, there are numerous examples of women who have demonstrated their ability in a variety of fields. Science as well as other subjects

Some examples are Marie Curie, Mother Teresa, Indira Gandhi, Margaret Thatcher, Rani Laxmi Bai, and Florence Nightingale. So, in our day and age, women are not lagging behind males in any sector.

1.14: "It is more important to have beauty in the equations of physics than to have them agree with experiments". The great British physicist P. A. M. Dirac held this view. Criticize this statement. Look out for some equations and results in this book that strike you as beautiful.

Solution: An equation that agrees with the experiment must also be simple and hence pleasing to the eye. In physics, we have some simple and beautiful equations like: $E = mc^2$ (Energy of light)

$$E = hv \text{ (Energy of a photon)}$$

$$KE = 1/2mv^2 \text{ (Kinetic energy of a moving particle)}$$

$$PE = mgh \text{ (Potential energy of a body at rest)}$$

$$W = F \cdot d \text{ (Work done)}$$

All of them are the same dimensions. One experiment reveals that energy is dependent on speed, whereas the other shows that it is dependent on frequency and displacement. That is the beauty of equations in Physics coming from different experiments.

1.15: Though the statement quoted above may be disputed, most physicists do have a feeling that the great laws of physics are at once simple and beautiful. Some of the notable physicists,

besides Dirac, who have articulated this feeling, are Einstein, Bohr, Heisenberg, Chandrasekhar, and Feynman. You are urged to make special efforts to get access to the general books and writings by these and other great masters of physics. (See the Bibliography at the end of this book.) Their writings are truly inspiring!

Solution: It is undeniably true that outstanding physical laws are both simple and attractive. Below are a few instances:

- I. Einstein's mass-energy equivalence relation $E = mc^2$
- II. According to Max Planck's quantum, the energy of a photon is $E = h\nu$
- III. The de-Broglie wavelength associated with a particle of mass m is given by $\lambda = h / mv$

1.16: Textbooks on science may give you a wrong impression that studying science is dry and all too serious and that scientists are absent-minded introverts who never laugh or grin. This image of science and scientists is patently false. Scientists, like any other group of humans, have their share of humorists, and many have led their lives with a great sense of fun and adventure, even as they seriously pursued their scientific work. Two great physicists of this genre are Gamow and Feynman. You will enjoy reading their books listed in the bibliography.

Solution: True, scientists, like any other group of people, have their share of witty individuals. Gamow and Feynman are two notable physicists in this genre. CV Raman, Einstein, and Niels Bohr, a former Indian president, are a few other scientists who might be added to this list. For example APJ Abdul Kalam.