The Philosophical Foundation of Einstein's Great Scientific Activity

Soumitro Banerjee *

WE OFTEN TEND to think that scientists solve the mysteries of nature with sheer intelligence. It is their extraordinary intelligence that helps them in steering through the labyrinths of mathematical intricacies, in finding way in the land of the unknown. This is the aspect that normally assumes centre-stage in the folklore about scientific legends.

That is why the intelligence of the legendary scientist Albert Einstein — and the brain that housed that intelligence — have aroused much curiosity. Since Einstein insisted that on his death his brain be made available for research, after his death in 1955, pathologist Thomas Harvey preserved the brain and made samples and sections. Brain physiologists have done detailed investigation on the size, weight, shape and fold-structure, trying to find the ways in which *that* brain is different from that of other common humans.

Surprise was in store there. Brain physiologists have found no aspect in which Einstein's brain can be said to be "extraordinary". The variations were within the range of normal human variations.

But how is that possible?

This is after all the brain that made original and path-finding contribution in five different areas of physics at the age of 26! It could attack the problems that occupied the great minds of the time from unexpected angles with simple and straightforward arguments that no one had thought before! And in the later years of his life? Today it is said that there is no area of physics that has not been enriched by the footprint of this great mind [1].

It is also true that there has been no dearth of exceptional minds at any age. During the Einstein's lifetime also, there were many scientists who had made quite important contributions in their own areas. Mach, Poincaré, Minkowsky, Planck, Bohr, Heisenberg, Schrödinger, Feynman, Gamow — none of them were any less brilliant. Yet, if we look at the horizon of physics, we see a Mount Everest standing tall among hills and mountains. Einstein looks like a giant among giants. While the genius of others was restricted to a narrow range of activities, Einstein could see the material world as a whole, could see the fundamental problems in our knowledge about it, and could show the way to solve them. Is it believable that such a person was not born with a brain different from the others?

Yes. That is what science says.

Else, how is it possible that nobody saw any spark of genius in his whole childhood? He never stood first or second in his student life. After a couple of years of unemployment and after scores of unsuccessful interviews, somehow he managed to find a job as a clerk in a patent office – that too with the help of a friend's father. If he were born a genius, its signatures would have been recognised right from the beginning!

*Dr. Banerjee is a member of the Editorial Board, *Breakthrough*, General Secretary of the Breakthrough Science Society, and a member of the faculty of I.I.T. Kharagpur.

Those who look for such things in exceptional personalities are actually missing the main point — that *man is the product of a process.* Every man's life, thoughts and abilities are determined by the *process* through which he builds himself. That is why it is futile to look for "special" folds in Einstein's brain. To understand the making of the great scientist, we have to look at the process through which he built himself.

The formative years

If one looks at Einstein's life from this angle, a few aspects attract attention. First among them is the fact of his undistinguished educational career. Many years later, when he was a world-famous scientist, a reporter asked him about it. Einstein said that he could never accept anything unless he was convinced about its truth after serious questioning from various angles. But during his school years, education in Germany was like a military "command system" — one had to accept whatever were written in the books as unquestionable truth. One had to learn them, memorise them, practise them, and write them in examinations. Einstein's mind used to question everything, and could not accept what was taught without critical judgement. That is why the teachers did not particularly like this student, and Einstein did not like the "bookish" education [2].

We are indeed fortunate that he paid very little attention to the grades and marks. Otherwise the great scientific mind would not be born.

As he grew into college and post-college life, he took another important step — to consciously choose the correct view-point in scientific investigation. Let us explain what that means.

We all obtain the ingredients of thought from the surrounding society. Right, wrong, good, bad – all sorts of thoughts are inherited this way. We come in contact with the thoughts of others through conversations with friends, relatives and strangers, through reading books and newspapers, through listening to songs, through watching films and TV. Through these interactions with the thoughts existing in the society, our own minds take shape. As we are exposed to the contradictions between cross-currents of various lines of thought, we decide which thoughts to adopt, which to reject, and thus we decide our position in the society. This concept in psychology was most precisely expressed by the Marxist thinker Shibdas Ghosh when he said "individual thinking is the personification of social thinking" [3].

But in most people it happens unconsciously. When one says that something is his own thought, his own opinion, his personal affair — he is actually taking to the side of one of the currents of thought existing in the society — only expressing it in his own style. But he has invariably obtained the elements of the thought from the society.

That is why most of the great men build their own individual thinking in a conscious manner. In the midst of various shades of thought existing in the society — good, bad, evil, correct, misguided, and plain wrong — they try to consciously recognise the correct thoughts. They then *practise* thinking in that way, making it their natural thought-habit. They put some effort to recognise the wrong lines of thought existing in the society, and consciously exclude these from their thought-habit. There is no short-cut to greatness without conducting this exercise. Nor for the scientists.

How does it happen in case of scientific research?

When a scientist is conducting research, what is he actually doing? He is asking questions regarding a specific aspect of the

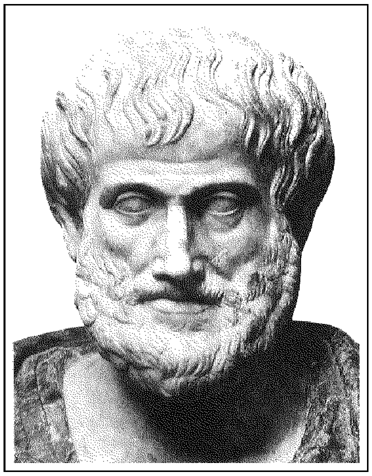
Breakthrough Archive

Friends of the Olympia Academy: Habicht, Solovine, Einstein. Photograph taken around 1903.

material world, and is looking for the answers. He is searching the truth about those issues. But many points of view exist in the society regarding how to search for the answer to a question, what is the nature of truth, how to distinguish between truth and falsehood, etc. Every scientist has to take a position as regards these issues. He has to adopt a specific approach, a well-defined methodology — without which he cannot take even a single step. Most people who practise science do that unconsciously, not knowing that he is actually making a choice between contradictory viewpoints existing in the society. If he adopts an erroneous viewpoint, that inevitably bears upon the success or failure of the research programme.

What Einstein did in his formative years was to carefully study the cross-currents of human thought regarding these issues – to consciously discard the wrong ones, to inherit the correct outlook, and to practise it to make it his natural thought-habit. Once he decided on his position as regards scientific thinking, he never wavered from it all through his scientific career.

To do this important work, Einstein and his friends Maurice Solovine and Conrad Habicht formed a science club named "Olympia Academy" [2,4]. There were weekly meetings in which the main subject of discussion was the philosophy of science. From a memoir by Solovine, it is now known that they did group-readings of the books by important philosophers, like *A System of Logic* by John Stuart Mill, *Critique of Pure Experience* by Richard Avenarius, *A Treatise of Human Nature* by David Hume, *The Analysis of Sensations and the Relation of the Physical to the Psychical* by Ernst Mach, *The Grammar of Science* by Karl Pearson and *Science and Hypothesis* by Henri Poincaré. They cross-examined these philosophical thoughts and discussed the new developments in science in the light of scientific philosophy. Through these discussions Einstein became exposed to the currents of philosophical thinking that are relevant in the pursuit of science, and that helped him decide on his own philosophical position.



Aristotle

Of course this was not his first acquaintance with philosophical thoughts. By the age of 16 he had already read the eminent philosopher Immanuel Kant's major works like *Critique of Pure Reason, Critique of Practical Reason* and *Critique of Judgement.* When in college and university, he continued the pursuit by studying Ernst Mach's philosophically oriented scientific books like *Mechanics* and *Principles of the Theory of Heat,* Ferdinand Rosenberger's *Isaac Newton and His Physical Principles,* and Friedrich Albert Lange's *History of Materialism* [4]. In his time some acquaintance with the philosophy of science was mandatory for all students of science at the university level, and it is on record that he enrolled for the course "Theory of Scientific Thought" in the winter session of 1897. But it seems the crucial decision regarding which side to take in his scientific pursuit was taken during his "Olympia Academy" years.

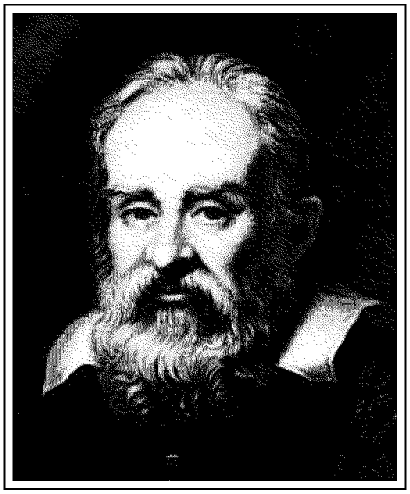
The philosophical cross-currents

In order to understand what "taking sides" means, let us first see which currents of philosophical thought influenced the scientific community during Einstein's formative years.

It is known that primitive man's thinking was nature-oriented. They could not think without reference to the material world. Then, with the advance of social evolution, man's philosophical speculation was divided into two broad camps: idealism and materialism, out of which the former became the dominant trend in the medieval period. But before the advent of the method of modern science, the way of seeking truth about any particular question, in both camps of thinking, was by reflection and personal realization. By thinking deeply about the question at hand, one would reach a realization which, to him, would constitute the truth about that question. A different person may reach a different conclusion by thinking on the same question. To him, *that* would be the truth. Common people would follow what wise men, sages, and saints would perceive and preach. If two wise men reach different perceptions on some issue, they will have their own set of followers — who will take the respective doctrines as unquestionable truth. Such was the thought process of the ancient and the medieval thinkers — what we today term as "subjective thinking."

In the fourteenth and fifteenth centuries, changes of far-reaching implication took place in the economic and social structure, which provided the material basis for a change in social thinking — the "renaissance." There was renewed interest in studying natural phenomena, and a change in man's approach to the material world. The changed mode of thinking found the most wholesome and forceful expression in the thoughts of Galileo Galilei, whose approach, method of investigation, and ways of arriving at conclusions represented the true spirit of the time.

It was Galileo who struck at the base



Galileo Galilei

of the subjective mode of thinking. He showed that the thoughts of a wise man like Aristotle — whose opinion about various things were held as unquestionable truth for nearly two thousand years — also needed to be tested. He argued that all thoughts – even his own – needed to be tested through experiment and observation. His refutation of one of Aristotle's assertions (that heavy bodies fall faster than lighter ones) by actually doing the experiment at the leaning tower of Pisa has reached the status of a scientific folklore. He showed, in essence, that the ultimate test of truth of any line of thought has to be obtained from nature.

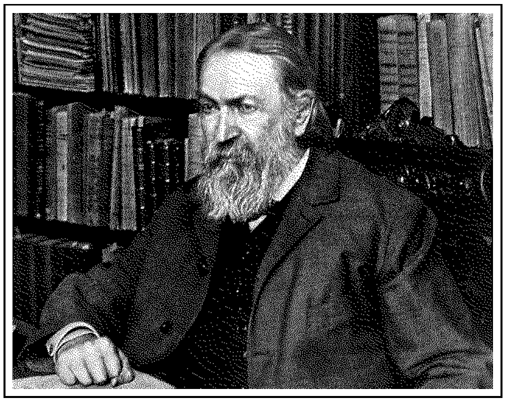
Through this he established a new method called *objective* thinking. Slowly, and through arduous struggle by generations of scientists, the new viewpoint established itself. It was recognized that no theory is acceptable without proper tests through experiment and observation. Since then the objective approach is considered to be the basis of any scientific endeavour.

But was the subjective thought process uprooted altogether? Far from it. It remained as a hangover of the past, and manifested in the thoughts and expressions of many scientists. Even today we see fanciful and unscientific ideas expressed by many scientists, most notably in the opinions about issues outside the ambit of scientific research.

The struggle between the two lines of thought — subjective and objective — was very much alive at Einstein's time. Young Einstein had to choose the correct one to be followed in his scientific pursuit. He firmly took to the side of objective thinking. That is why the search for objectivity is at the base of all his theories. Not only that, he had to learn to recognize the hidden signatures of subjective thinking in a scientific discourse, and to consciously expel such thoughts from his own mind.

But the problem of choosing the correct line does not end there. There were serious differences of opinion even among those who called themselves adherents of objective thinking. When Einstein was a student, one line of thought was very influential in the scientific community, called *positivism*. The Austrian scientist and philosopher Ernst Mach was a prominent proponent of this viewpoint. The positivists opined that science should concern itself only with the "observables," for, in their opinion, what cannot be observed are not real. This point of view emerged out of attempts to free the pursuit of knowledge of subjective imagination. Apparently the position seems to be right. If one asks whether witches can fly on broomsticks, it is quite right to ask back: "Have you ever observed one? Has anybody observed? If not, you should understand that witches do not exist."

But when applied to scientific endeavour, it becomes a different story altogether. The reader must have come across Dalton's atomic theory in school. Dalton said that if we continue breaking up any piece of mat-



Ernst Mach

ter into smaller and smaller pieces, in the end we will get tiny particles called atoms (in his time the distinction between atoms and molecules was not clear), and there are only a few "species" of atoms. This theory helped chemists understand chemical reactions — especially the fact that reactants always take part in a definite proportion. That is why the chemists started using the theory out of practical necessity.

But most physicists did not recognize the existence of atoms and molecules. From the positivist viewpoint they asked: Have you ever seen a molecule or an atom? Has anybody ever observed one? If not, there is no reason to believe that atoms and molecules actually exist. True, that concept helps chemists in their calculation of proportions. But it should not be taken as anything more than a convenient tool of imagination.

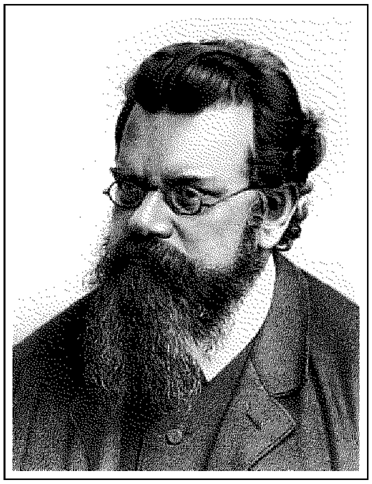
The small group of physicists who were trying to build theory assuming atoms and molecules as real, faced intense opposition. Take the example of Ludwig Boltzmann. He assumed that gases were made of innumerable small molecules moving randomly at high speed, and then argued that the behaviour of the gas in terms of the relationships between pressure, temperature and volume could be explained on the basis of the average motion of molecules. Thus he laid the foundation of statistical mechanics. He also explained the concept of entropy in terms of the theory of probability. These were works of pathbreaking importance, as shown by the later developments in physics. But during Boltzmann's lifetime the physics community did not accept his theory. Why? Because molecules were treated only as figs of imagination. Boltzmann had committed the "error" of basing his theory on something that are not observable. The ageing scientist was so heartbroken at this rejection of the work of his lifetime, that he committed suicide. Such was the influence of the positivist doctrine on physicists during Einstein's formative years.

On the other hand, the materialist school of thought – which was subdued during the middle ages – had also advanced considerably since the time of Galileo. Materialists hold that the universe is composed of matter, the material world exists independently of our consciousness, and there is nothing supra-matter in this material world[1]. The multitude of phenomena which science investigates is nothing but different forms of matter in motion. That is why all truths are to be found in the properties of matter and the interactions between its different forms.

The sharp line of difference between the positivists and materialists was that the first group refused to treat anything as real unless it is observable, while the second group argued that since matter exists as independent of our consciousness, the reality of any concept does not depend on our ability to observe it. The way to reach the underlying reality of phenomena is through theory-building, and testing the theories objectively.

Einstein later said that in early life he was quite influenced by the positivist phi-

[1]Here the philosophical term "matter" also encompasses energy and radiation.



Ludwig Boltzmann

losophy. During the university years and afterwards, when he was consciously seeking the correct philosophy to guide his scientific pursuits, he realised that positivism and other existing shades of empiricism did not provide the correct approach to reach truth. Since then he embraced materialism as his guiding philosophy.

Citing some of his comments on religion, some people question if he really pursued a materialist philosophy. If one probes this question deeply, one finds that all those comments are dated at times before the advent of fascism in Germany. No comment on such issues can be found in the later periods. Moreover, according to Einstein, his idea of God is like that of Spinoza — who identified God with the material world [5]. This is far from the usual religious conception of a personal God who rewards the virtuous and punishes the sinners. Actually Einstein followed the materialist line of thinking in his philosophical approach (as we will see shortly) but did not or could not break with the pantheistic approach to religion. His defence of objective reality and causality in scientific research was, however, in strict accordance with the materialist school.

The reality of molecules

He looked at the issue of the reality of molecules from this perspective. He argued that if molecules and atoms really exist, their existence would not depend on our consciousness, and hence on our ability to observe them. But if they exist, and if our theory about them is correct, we should be able to deduce certain manifestations which can be tested.

Many people do not know that Einstein's first scientific work was on this issue. He wrote some half a dozen papers to prove the reality of molecules from different angles, out of which two deserve special mention here.

One is his Ph.D. thesis [6], entitled "A new determination of molecular dimensions," submitted to the University of Zürich on 20 July 1905. He forwarded a new line of reasoning to prove the reality of molecules. He argued that if molecules exist, they must have some dimension – however small. The question is, can we measure the dimension? Of course we cannot directly observe molecules and hence cannot use the usual measuring instruments. But can we measure it indirectly?

He said, suppose you take some amount of water. If you assume that molecules exist, you would say the body of water is composed of millions of molecules jostling in thermal motion. Now suppose you dissolve a bit of sugar in it, which means another breed of molecules is now mixed with the water molecules. For the sake of simplicity, assume that both species of molecules are spherical, only the sugar molecules are much larger than the water molecules. With only this much assumption, Einstein showed that the viscosity and coefficient of diffusion of the liquid will change due to the mixing of sugar, and the extent of change

Box-1: Einstein's approach to finding the dimension of molecules

In his Ph.D. thesis Einstein showed that for a sugar solution, the relationship between N (the number of molecules in a mole of water) and P (the average radius of the sugar molecules) is

$$NP^3 = \frac{3m}{4\pi\rho}\left(\frac{k^*}{k} - 1\right) \quad (1)$$

where k is the coefficient of viscosity of pure water, k^* is the coefficient of viscosity of the solution, ρ is the mass of the dissolved substance per unit volume, and m its molecular weight. All the quantities in the right hand side can be measured. But one needs another relation to determine N and P separately.
He then showed that the coefficient of diffusion D of the solution is also dependent on N and P, and the relationship is

$$NP = \frac{RT}{4\pi kD} \quad (2)$$

where T is the absolute temperature and R is the gas constant (whose value is 8.31×10^7). The terms in the right hand side of this equation also can be measured. Thus equations (1) and (2) enable one to determine N and P individually, and both are proofs of the reality of molecules. Einstein even used the available experimental measurements and determined the values $P = 9.9 \times 10^{-8}$ cm and $N = 2.1 \times 10^{23}$.

is dependent on the radius of the solute molecules (see Box-1). Since viscosity and the coefficient of diffusion are measurable, the radius of the sugar molecule can be obtained by measuring these quantities before and after mixing with sugar.

A very unconventional argument. The examiner of the Ph.D. thesis could not digest such drastic deviation from commonplace science, and returned the thesis as "unacceptable" [2]. The thesis was however accepted later after some minor amendments. And by virtue of this work, Einstein became Dr. Einstein.

The second research paper [6] proving the existence of molecules was published in the same year in the German journal *Annalen der Physik*, with the title "On the motion of small particles suspended in liquids at rest required by the molecular-kinetic theory of heat." In the second decade of the nineteenth century, a botanist named John Brown had noticed that pollen particles placed in a drop of water can be seen as moving about in a random fashion when observed with a microscope. At first, people thought that the pollens are alive, and they swim about in water. But soon it was clear that the pattern of motion is not like swimming at all, for the pollens move in small straight line segments. The cause behind this peculiar type of motion remained a mystery.

Einstein showed that this particular zigzag motion of the pollen was an important evidence of the existence of the molecules. If the apparently stagnant drop of water was composed of millions of molecules, the kinetic theory of heat would require that the molecules should move about at high speeds due to thermal motion. If a pollen particle with size and mass much larger than those of water molecules was placed in the drop, it would be subjected to innumerable collisions with the

[2]The same examiner later recommended Einstein's name for the Nobel Prize.

Box-2: The reality of molecules from Brownian motion

Suppose a pollen particle starts from the origin of a suitably defined coordinate system and undergoes random collision with water molecules. Einstein showed that the average distance travelled along the x direction in time t is given by

$$\lambda_x = \sqrt{2Dt} \tag{3}$$

where D is the diffusion coefficient. The value of D is given by equation (2) given in Box-1. Only, the term P will now represent the radius of the pollen particle. Eliminating D from equations (3) and (2) we get

$$\lambda_x = \sqrt{t}\,\sqrt{\frac{RT}{N}\frac{1}{3\pi kP}} \tag{4}$$

He then made a simple calculation assuming (a) that the fluid is water at 17°C for which k was measured to be 1.35×10^{-2}, (b) that the Avogadro number N is 6×10^{23}, and (c) that the diameter of the pollen is 0.001 mm, and predicted that the pollen would move about 6 microns per minute.

Einstein argued that this displacement can be objectively measured, and if the rate of displacement turns out to be as per prediction from the theory, that itself will be a firm proof of the existence of molecules. He even proposed that this measurement can be used for estimating the value of the Avogadro number.

water molecules – which would impart kinetic energy. Since the water molecules would strike from all directions, the resultant effect would be a random motion of the pollen particle. It would traverse in a straight path as a result of one collision, and successive collisions would change the direction of motion. If molecules are real, this is what is naturally expected to happen. Since the motion of the pollen particle had been observed, Einstein argued that we had in effect observed molecules in action.

But this is a qualitative argument. In order to establish a theory – a controversial one at that – it is necessary to talk in terms of quantities on the basis of which it can be objectively tested. So Einstein asked: If the motion of the pollen is completely random, is it possible to say what distance the particle will traverse from the starting position after, say, a thousand impacts? Einstein showed that even though the motion is random, it is possible to work out a probabilistic estimate of the distance traversed. This means that if one measured the distance traversed (keeping track of the number of impacts), then the average distance over a number of trials will be approximately equal to that obtained from Einstein's theory. This is something that can be objectively tested. People did the test, and found that the motion of the pollen did indeed follow Einstein's equation (see Box-2).

After such objective proof, it is impossible to question the existence of molecules.

The reality of the quantum nature of radiation

Next, he took up another issue to fight the positivists' position from a materialist standpoint. The nature of heat radiation from a body had intrigued scientists for a long time. After Maxwell's discovery it was known that heat radiation is also electromagnetic wave, which means it is defined by frequency and wavelength, which are measurable quantities. It was found that the radiation emitted by a heated body does not have a single wavelength, rather, it is a mixture of waves of many wavelengths. The natural question was: Is there any law that tells us which frequency component will be emitted in what proportion?

There were issues that diverted attention from the central question. For example, the heated body could be made of iron, copper, wood, or for that matter of any material. The radiation would not be the same in these cases. Moreover the radiation would not be the same for a body of iron coloured red and another coloured black. So scientists needed to keep these differences among the radiating bodies out of attention, at least to investigate the basic question. So they brought in the concept of an ideal emitter – the so-called "black body" – which can absorb all the radiation falling on it and whose thermal radiation depends only on its temperature. Experimental results obtained from a close approximation to the ideal black body showed a definite relationship between the intensity of radiation and the frequency. For any given temperature of the radiating body, the radiation has a maximum value at a specific frequency, which falls off following well defined curves for higher and lower frequencies (see Fig.1).

Come next stage, the scientists faced the problem of explaining why black body radiation follows this specific curve. This is where the crucial problem occurred. Physicists found that if the existing theory is followed, that is, if one assumes that energy is emitted in continuous stream in a wavelike fashion, the predicted graph does not match that obtained from experiment.

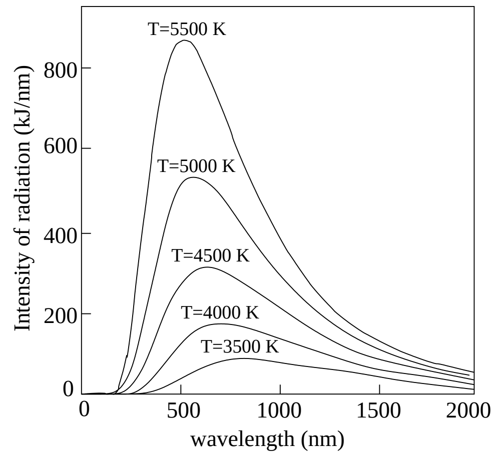


Figure 1: The graph of the intensity versus wavelength at various temperatures.

When physicists were groping in dark for an answer to the problem, Max Planck showed that if we assume, *ad hoc*, that energy is not radiated continuously, rather it is emitted in distinct "packets," then one obtains exactly the same curve from theory as is obtained from experiment. People were not happy at all: What is this *ad hoc* assumption that has no basis? Has anybody observed the packets of energy? Has anybody measured? If one assumes for the time being that Planck is right, the quantity of energy in each packet is very small — so small that they would never be observable individually. According to the positivist philosophy, what is not observable is not real. The opposition was so intense that Planck's calculation was not accepted by the main body of scientists. Planck also could not forcefully defend his own theory[3].

In this situation Einstein looked at the problem from a materialist standpoint. If

[3]Planck was not a positivist, and the reason behind his unwillingness to defend his own theory lay elsewhere. He saw that he had to assume something without theoretical ground just to satisfy the empirical observations. And so his own calculation, to him, looked like blind empiricism. [7]

the quanta of radiation exist, their reality would not depend on our consciousness, that is, on our ability to observe them individually. It is true that the quanta are so small that they may never be directly observable. But the fact that Planck's calculation did tally with experimental observation was, to Einstein, an indirect evidence of their reality.

But more direct evidence is needed. He did not have to look very far. Many experimental observations had accumulated over the years that were yet unexplained. The phenomenon of fluorescence and Stoke's rule relating the incident and emitted radiations was not properly understood. It had been observed that gases ionise if radiated with ultraviolet light, and this also was not properly explained. Then there was the photoelectric effect. Einstein solved all these apparent mysteries in another paper published in the same year in *Annalen der Physik*, and showed that all these were evidences that quanta of radiation were not just convenient assumption; they were real [6].

The case of photoelectric effect has earned some fame, as the Nobel Committee cited this as *the contribution* for which the Nobel prize was awarded to him (even though it was a small part, Section 8, of his original paper where his main contention was to prove that quanta are real). So let us explain it in some detail.

It had been observed some years earlier that when light falls on plates made of some metals, electrons are emitted. At first nothing seemed unusual about it, because light has energy, and when light is absorbed by an electron, the energy goes into it. If the energy is sufficient to overcome the electrical attraction of the nucleus, it is natural that the electron will be ejected.

Only, it should take some time to accumulate sufficient amount of energy to overcome the electrical attraction, and so it was expected that the electrons would be emitted after some delay. But the experiments showed that the electron flow starts the moment light falls on the metal plate.

Scientists now looked at the situation carefully. If the incident light is monochromatic, it has a specific frequency (or colour), which can be varied. It can also have a specific intensity which can be varied. In the output side also there are two measurable quantities: the number of electrons emitted and the average kinetic energy of the electrons. It was found that no electrons are emitted below a certain frequency (not intensity). If we choose the frequency above this minimum value and vary the intensity, the number of emitted electrons vary but the energy of each electron remains fixed. If we keep the amplitude constant and vary the frequency, the number of emitted electrons remains fixed but the kinetic energy of the electrons vary.

Einstein showed that these characteristics of the photoelectric effect actually proved the reality of the quantum. If radiation is emitted in packets, it must also be absorbed in packets. Therefore if electrons absorb radiation, the increase in energy will be exactly the same as that contained in one packet. It is not possible to absorb radiation slowly, with continuous increase of energy. If the energy of the electron is to increase, it must happen in one jolt, and if that is sufficient to overcome the attraction, the electron will be emitted. That is why electrons start flowing the moment light falls on the metal plate.

Moreover, as per Planck's assumption, the energy in the packet is proportional to the frequency. Therefore if the frequency is increased keeping the intensity fixed, the number of packets remain fixed but the energy in each packet goes up. On the other hand, if the frequency is kept fixed and the intensity is increased, the energy in each packet remains fixed and the number of emitted electrons goes up. It is clear that if one assumes the quantum nature of light, the whole picture fits in like a jig-saw puzzle. Einstein presented this natural explanation of the photoelectric effect, and thus proved that light quanta are not just figs of imagination. The concept actually reflects the underlying reality, irrespective of our ability to observe individual quanta.

The theory of relativity

His most famous work — the theory of relativity — does not need an elaborate discussion here since a lucid exposition was included in the last issue of *Breakthrough*. We only note here that on this issue also, Einstein's position was strictly objective. His main assertion was that truth must be independent of the observer. Therefore if one observer is static (in some frame of reference) and another moving, the laws of nature should be the same with respect to both of them.

Now, Maxwell's theory of electromagnetism had shown that the speed of light is dependent only on the character of the medium, given by

$$c = \frac{1}{\sqrt{\epsilon\mu}}, \tag{5}$$

where ϵ is the permittivity and μ is the permeability of the medium, and c is the velocity of light; and it does not depend on the speeds of the emitter and the receiver. This implies that in vacuum the velocity of light should have a constant value, which should not depend on the motion of the light source and that of the observer. But the Newtonian concept of relative velocity would demand that if a light ray is moving with speed c and an observer is moving with a speed v in the opposite direction, then the velocity of light *relative to the observer* should be $c+v$. Thus the two well-established theories made two contradictory assertions. This problem had troubled scientists for a long time.

Einstein realized that Maxwell's theory rests on objectively tested premise, namely, the experimental observations of scientists like Faraday, Ampere and Ohm on the relationship between electricity and magnetism. This implies that the equation (5) should be a law of nature. If that is so, objectivity would demand that the validity of this equation (and therefore the velocity of light) should be independent of the observer's motion. Therefore the error must be hiding somewhere in the framework of Newton's theory.

It is hard to imagine the audacity of a 26 year old unknown patent office clerk to question the correctness of Newton's theory — which stood unchallenged for more than two centuries as the ultimate triumph of the human mind in unravelling the secrets of nature. Scores of tests had supported it. Astronomers had been able to predict the orbits of the planets to astonishing precision, so that the mystery shrouding the motion of planets was finally removed, giving a death-blow to the superstitions harboured by the mystery – including astrology. The occurrence of solar and lunar eclipses could also be predicted with accuracy. Even during Newton's lifetime, his friend Edmund Halley made observations on the position and momentum of a bright comet, and applying Newton's theory predicted that it will come back 74 years later. It did come, and has been coming every 74 years ever since. It really takes quite a bit of scientific audacity to say such a successful theory had a flaw in it.

And where! Where nobody had suspected. In a statement which nobody ever thought could be flawed. Newton had stated in his *Principia Mathematica* that time flows equitably for every object in this universe, without being affected by anything. Well, isn't that our common experience? Had anybody ever encountered anything that could indicate that the statement could be flawed? Yet, Einstein saw that while Newton treated space as relative; velocity, acceleration etc. as relative; by the above statement he placed time in a position of the absolute. While materialist philosophers had brought the concept that truth is relative, the above statement of Newton made one component of truth absolute. *That* was the flaw.

Starting from this premise, Einstein first made the point that we measure and compare time through simultaneity of events, then showed that simultaneity is relative, and then quantitatively worked out by how much the time as observed by two observers in relative motion with respect to each other would differ. The moment this roadblock was removed, it easily followed that the other quantities that were so far tacitly assumed as absolute – like a body's length and mass – are also relative. It was established beyond doubt – in the arena of physics – that truth is objective but relative.

Einstein on quantum mechanics

Even though Einstein was one of the founders of the quantum theory, it is true that he did not agree with many concepts that were brought in by the later developments in quantum mechanics in the 1920s and 1930s. In the scope of this article it is not possible to elaborate the grounds of the difference. So let me quote the famous physicist and mathematician Roger Penrose who wrote in the foreword of the book *Einstein's miraculous year* [6]: "Why, when Einstein started from a vantage point so much in the lead of his contemporaries with regard to understanding quantum phenomena, was he nevertheless left behind by them in the subsequent development of quantum theory? $\cdots$ Many would hold that Einstein was hampered by his "outdated" *realist* standpoint, whereas Niels Bohr, in particular, was able to move forward simply by denying the very existence of such a thing as "physical reality" at the quantum level of molecules, atoms, and elementary particles. Yet it is clear that the fundamental advances that Einstein was able to achieve in 1905 depended crucially on his robust adherence to a belief in the *actual* reality of physical entities at the molecular and sub-molecular levels." Penrose continues to add "Can it really be true that Einstein, in any significant sense, was as profoundly 'wrong' as the followers of Bohr might maintain? I do not believe so. I would, myself, side strongly with Einstein in his belief in a submicroscopic reality, and with his conviction that present-day quantum mechanics is fundamentally incomplete." Penrose is not alone in this conviction, evidenced by the fact that the foundations of quantum mechanics is still an active area of research that draws inspiration from Einstein's philosophical arguments.

Conclusion

One point is noteworthy here. Be it Brownian motion or photoelectric effect, the experimental observations were already there. Many scientists were trying to find explanation. But it was only Einstein who could see light in the midst of darkness.

A few years before Einstein's miraculous year of 1905, Michelson and Morley had ingeniously used the Earth's rotation to show experimentally that the velocity of light in the direction of Earth's motion is exactly equal to that opposite to the direction of Earth's motion. Most historians of science now believe that Einstein was not fully aware of these experiments at the time. Apparently he did not know that experiments had already indicated that the speed of light through vacuum is independent of the velocity of the observer. Yet, based on the sound logic he could see that a revolution in physics was imminent, and could take the lead in ushering the revolution.

How could he do it? Where did he get this deep insight? This is the question that should take centre-stage in the seminars and symposia being organized on the occasion of the World Year of Physics. Yet, this is the question that is receiving the least attention. Einstein could become the century's greatest scientist by adopting the correct materialist world-outlook, and by making it his natural thought habit.

In a recent article published in *Physics Today* [4], Don A. Howard narrates an interesting story. In 1944, a young professor of physics at the University of Puerto Rico was trying to introduce the philosophy of science into the physics curriculum. When he faced opposition from his colleagues, he wrote to Einstein for help in persuading his colleagues. Einstein replied: "I fully agree with you about the significance and educational value of methodology as well as history and philosophy of science. So many people today—and even professional scientists—seem to me like someone who has seen thousands of trees but has never seen a forest. A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering. This independence created by philosophical insight is—in my opinion—the mark of distinction between a mere artisan and a real seeker after truth."

In 1949, a book was published with the title "Albert Einstein: philosopher-scientist" [8]. Interestingly, Einstein himself was invited to contribute an article to this volume. He wrote "The reciprocal relationship of epistemology and science is of noteworthy kind. They are dependent upon each other. Epistemology without contact with science becomes an empty scheme. Science without epistemology is — insofar as it is thinkable at all — primitive and muddled."

Today the world of scientific research has moved away from the path shown by the great scientist, as most scientists do not feel the necessity to study the philosophy and methodology of science. We have placed Einstein in the position of a cult figure, a scientific celebrity. But we did not tread his path. We have looked for shortcut ways of success. Today there are many more people who call themselves scientists, who have taken science as a profession. But if we try to identify the most far-reaching change that has taken place in the world of science since Einstein's miraculous year of 1905, the practicing scientists' lack of interest in philosophy would top the list. This is bound to have a telling effect on the progress of science.

Today, in the World Year of Physics, let us take a pledge to overcome this shortcoming, to follow the path of Einstein. □

References

[1] Abraham Pais, "Subtle is the Lord — The Science and the Life of Albert Einstein," Oxford University Press, Oxford, 1983.

[2] B. Kuznetsov, "Einstein," Progress Publishers, Moscow, 1965.

[3] Shibdas Ghosh, "Selected Works," Vol.II, SUCI publication, Calcutta, 1988.

[4] Don A. Howard, "Albert Einstein as a Philosopher of Science," *Physics Today*, December 2005.

[5] Albert Einstein, "Ideas and Opinions," Rupa & Co. Calcutta, 1984.

[6] John Stachel (editor), "Einstein's Miraculous Year: Five Papers that Changed the Face of Physics," Scientia, Delhi and Princeton Univ. Press, USA, 1998.

[7] Max Planck, "The Philosophy of Physics," George Allen & Unwin Ltd., London, 1936.

[8] P. A. Schilpp (Editor), "Albert Einstein: philosopher-scientist", The library of Living Philosophers, Evanston, Illinois, USA, 1949.