ALBERT EINSTEIN

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INTRODUCTION

A HUNDRED YEARS ago an article with a modest title '*Zur Elektrodynamik bewegter Systeme*' (On the Electrodynamics of Moving Bodies) appeared in the sedate German Journal *Annalen der Physik*. Its author was Albert Einstein, an unknown young man of twenty-six, coming from outside the academic community, a mere clerk in the Patent Office, Berne, Switzerland. Yet this little paper brought about a revolution in physics, overthrew the ideas on space, time, mass and energy that had held sway for nearly 300 hundred years since Newton published his *Principia*. Einstein's name is to be ranked with those thinkers, philosophers and scientists who have brought about revolutionary changes in human thought.

We know that scientific investigations of mankind started with the very dawn of civilization through the endeavour of man to understand the natural phenomena, to comprehend their laws and comprehending them to act upon nature for betterment of human lives. Much of the history of early scientific activity of man and of his early inventions are still unknown to us. Thus we do not exactly know how fire was invented, wheels were invented, though these played vital roles in the advancement of human civilization. In many of the ancient civilizations, like the Indian, Chinese, Egyptian and Greek civilizations we notice that scientific thinking attained high levels. But what we journey from the 15th century. In the Middle Ages the spirit of scientific enquiry was stifled because of religious injunctions and stranglehold of the religious institutions. In the 16th century, going against the religious edicts, Copernicus emphasized the importance of observation and logical analysis for arriving at truth. It was a first step in bringing about a revolutionary change in how man should look at the world. This tradition of experiment, observation and analysis was greatly advanced by Galileo through his study of motion of bodies and motion of stars and planets. Galileo's work was a big blow against religious dogmatism and gave a tremendous boost to scientific enquiry. Then came the era of Newton, who collated all the observations of his predecessors and went many steps further. Clearly enunciating the laws of motion, perfecting the mathematical tools for scientific investigation, he built the edifice of modern physical sciences on a firm foundation. The 18th and 19th centuries were the heydays of Newtonian mechanics. In the 19th century the Newtonian concept of particulate existence of matter and its motion was supplemented by the concept of field, the existence of physical reality as a continuum, through the researches of Faraday, Maxwell, Hertz and others.

Copernicus, Galileo, Newton represent milestones in the advancement of science. Einstein is to be ranked with these giants of science. The period from 1830 to 1930 was the golden age of physics. A host of uncommonly talented scientists not only advanced the frontiers of classical physics but also brought in revolutionary new concepts. The brightest star in the firmament was Einstein. The scientific thinking on matter, space, time that

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existed towards the end of the nineteenth century based on two hundred years of research after Newton underwent a radical transformation as a result of Einstein's work. This was a type of change that the historian of science Thomas Kuhn has termed as a paradigm shift. Man's idea of the physical world acquired a new dimension and physics entered the modern age from the classical age. This was, in the truest sense of the term, a revolutionary transformation of human thought about the external world. During the last hundred years all the experiments have proved beyond any doubt the truth of Einstein's Theory of Relativity. Einstein's place is in the front rank among the scientists and philosophers of all ages.

Einstein was not just a front ranking scientist; he was a great human being. His contribution to the advancement of human civilization is as much for his science, as for his humanity, for his recognition of social obligation, his untiring effort for the betterment of mankind and uplift of the downtrodden.

PHYSICS BEFORE EINSTEIN

The common man knows Einstein as the propounder of the Theory of Relativity, who formulated the celebrated equation, $E = mc^2$. Let us consider the main propositions of the Theory of Relativity. All of us gain some notions of relativity from our life's experience. For example, we all know that when we talk of front and back, or left and right, these words have connotations only with respect to particular things or persons. There is no universal front direction or left direction. Similarly, in ancient days, when man thought that the world was flat, the vertical direction at every point on the earth was thought to be one and the same, in other words, the "up" direction pointed the same way at every place. Now we know that the "up" direction in Kolkata and that in Rio de Janeiro point to different directions in space.

Physicists have discussed relativity more precisely with reference to motion of bodies. Man realized long ago that one could describe the motion of a body only with reference to its change of position with respect to another body. Galileo first put it as a scientific proposition that if an observer is fixed to a moving body he will not realize its motion. For example, when we travel in a car we realize that we are moving only by considering our position with reference to an object on the ground. If another car travel next to us with the same speed and in the same direction, it would appear to us that with respect to the second car we are stationary. All of us have experienced during our train journey that when we are halting at a station, if another train going the other way standing on an adjacent platform starts moving it appears to us that our train has started its journey. In the language of science we say that motion of a body is change of its position in a reference frame or coordinate system. In the particular frame of reference in which we are considering the body, its motion will have a particular measure, a particular speed and a particular direction of motion, but with respect to another frame of reference the motion of the same body would show a different measure of motion, a different speed and a different direction of motion. Thus, when a person is travelling on a train he will appear to be stationary to his fellow traveler. But to an observer on the ground the passenger would appear to move with a certain velocity. To an observer on the moon or on another planet, the measure of motion of the passenger would appear to be still different. In scientific language we say that in the frame of reference fixed to the train the passenger is stationery, but with respect to a frame of reference fixed to the ground the passenger has a certain velocity, and with respect to a frame of reference fixed to the moon or another planet he would have a different velocity. Note that the three frames of reference are moving with respect to one another.

If the velocity of a body is specified in a particular coordinate system or frame of reference, then its velocity in another frame of reference or coordinate system can be easily calculated through a set of simple equations, provided we know the velocity of one reference system relative to the other. Let us consider a simple case, where in a three-dimensional reference system a body is moving with a velocity V in the x direction. If initially the position of the body is specified by the three coordinates, x_o, y_o and z_o, its coordinates after a time t in that reference system would be

$$x = x_o + Vt,$$
$$y = y_o,$$
$$z = z_o.$$

If two reference systems were initially coincident and then the second one started moving with respect to the first with a velocity v in the x direction, then the coordinates of the body with respect to the second reference system would be

$$x' = x_o + (V - v)\,t,$$
$$y' = y_o,$$
$$z' = z_o.$$

In other words, the velocity of the body in the second reference system is $(V - v)$. Such equations are known as Galilean transformation equations. The concept of relative velocity based on these ideas have gone into school level texts now and the students are easily solving the problems of relative velocity.

On the basis of the experiments conducted by Galileo, the Galilean principle of relativity can be formulated as stating that the laws of mechanics valid in one frame of reference are equally valid in another frame of reference if the latter has a uniform rectilinear motion with respect to the former. However, Galileo did not express the relativity principle in this language, though the essence was the same. Such frames of reference which move with uniform speed along a straight line with respect to one another are known as inertial frames of reference. All the inertial frames have equal status; one cannot be called better than or superior to another in any way. If the velocity of a body is 100 km per hour in a particular direction in one frame of reference, its velocity may be 200 km per hour in a different direction in another frame of reference. Both are equally true, one cannot be called true and the other false.

Newton went far ahead of Galileo in studying the motion of bodies and coordinating all observations enunciated the famous three laws of motion. In Newtonian mechanics the Galilean principle of relativity is fully recognized, that is, the laws of motion are equally valid in all inertial frames. If we throw a ball upwards with a certain velocity from the surface of the earth the ball will move upwards along a straight line and after reaching a certain height will start coming down along the same straight line and will reach the ground after a certain interval of time. If the same ball is thrown upward with the same velocity in a train that is moving with uniform velocity, the observer on the train will notice that the motion of the ball is the same as stated before. It will appear to him to have gone up and down moving in a straight line and to have reached the ground after the same interval of time as before, but to an observer on the ground the ball will have appeared to have travelled on a parabolic path. A corollary of Newton's laws of motion is that all inertial frames are equally valid. There is no absolute frame of reference, though we shall see later that physicists tried, albeit unsuccessfully, to define an absolute frame of reference. In Newtonian mechanics there is nothing called absolute rest, because from the viewpoint of the laws of mechanics there is no difference between rest and uniform rectilinear motion. Similarly there is no absolute motion, though Newton did try to describe an example of absolute motion. We shall not go into a discussion of Newton's example because it did not deal with uniform rectilinear motion.

Motion of a body means the change in its position in space over a certain length of time. Hence, concepts of space and time are closely linked with the concept of motion. Newton recognized position to be relative and motion to be relative in the sense that both are dependent on the choice of the frame of reference (see Galilean transformation equations). Yet he held on to the idea of absolute space and absolute time and he also provided definitions of them. "Absolute space in its own nature, without regard to anything external, remains always similar and immovable. Relative space is some movable dimension or measure of the absolute spaces, which our senses determine by its position to bodies, and which is commonly taken for immovable space…"[1] Thus, absolute space exists without relation to matter, without regard to anything external. Space is thought of as a receptacle filled with material bodies. However, it must be mentioned that this definition of absolute space lacks physical meaning. Newton himself recognized that absolute space does not come under the observation of our senses and in solution of real problems we apply only relative concepts. In a similar vein, he wrote about absolute time, "Absolute, true and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration: relative, apparent and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year."[1] Absolute time ever flows unidirectionally from past to future, and all events take place in this flowing time. Like absolute space, absolute time is in no way associated with matter. Absolute space and absolute time would exist even if there were no matter.

In Newtonian mechanics the position of any point in a given frame of reference is given by three numbers in three-dimensional space. The numbers would change if the frame of reference were changed. However, the distance between two points is invariant in the sense that it does not depend on the choice of frame of reference. Time also is not dependent on the choice of frame of reference. Hence, in classical relativity only the position of a body is dependent on the frame of reference, but the dimensions of a body as well as the time interval between two events are independent of the frame of reference.

The conceptual frame of Newtonian mechanics is built by combining the laws of motion with the theory of gravitation. According to Newton gravitational attraction between two bodies involve action at a distance and the force of attraction acts instantaneously. Some scientists felt uncomfortable with or were even doubtful about this idea of instantaneous action at a distance and about the concepts of absolute space and absolute time. But the spectacular successes of Newtonian mechanics in both practical and theoretical fields banished all doubts about its veracity.

In Newtonian mechanics matter is conceived as particles, micro or macro, that is, it is portrayed as discrete particulate matter. Later researches of Faraday, Maxwell, Hertz and others led to the development of the theory of field as an independent physical form of matter existing as a continuum. The scientists recognized the existence of electrical, magnetic and electromagnetic fields as distinct entities extending over space. Einstein placed great importance on the development of the field concept and commented that the "theory of relativity arises from the field problems". Faraday not only unravelled the interconnection between electrical and magnetic phenomena, he also realized the link between electromagnetic and optical phenomena. Maxwell's equations brought to the fore the existence of electromagnetic waves and showed that light can be considered as electromagnetic waves. In the words of Maxwell, "…… light itself…is an electromagnetic disturbance in the form of waves propagated through the electromagnetic field according to electromagnetic laws."[2]

According to the ideas prevalent at the time, if light is considered wave, a medium is required for its propagation, and thus arose the idea of the all-pervasive luminiferous ether which is the carrier of electromagnetic waves. The ether was conceived as a stationary medium and all moving bodies go through this stationary medium. From the philosophical point of view the idea of stationary ether was very important because it would provide an absolute frame of reference, and thus absolute space, and absolute rest and absolute motion could be defined in this frame of reference. However, many scientists were not happy with the ether hypothesis, because there is artificiality in it. Moreover if it is to be the carrier of electromagnetic waves it must have some amazing and bizarre properties. The ether hypothesis could provide satisfactory explanations of some phenomena observed in connection with the propagation of light, but certain other experimental data contradicted it. Finally, the experiment of Michelson in 1881 and of Michelson and Morley in 1887 conclusively proved the untenability of the stationary ether hypothesis.

EINSTEIN AND RELATIVITY

All contradictions between the phenomenon of light propagation and ether hypothesis were resolved in 1905 with the publication of Einstein's Special Theory of Relativity. To arrive at this theory Einstein made some postulates based on experimental facts. These are:

1. All laws of nature are the same in all inertial reference systems moving uniformly in a straight line relative to each other. Note that the only difference between this postulate and the Galilean principle of relativity is that it speaks of "the laws of nature" instead of "the laws of mechanics". Thus Einstein extends the relativity principle to a much wider physical domain. All the inertial systems have equal status; none of them can be called an absolute system.
2 The velocity of light in vacuum is the same in all inertial frames and does not depend on the motion of the source or the observer.

The idea of ether is dispensed with. Einstein wrote, "The introduction of luminiferous ether will prove to be superfluous inasmuch as the view to be developed will not require an 'absolute stationary space' provided with special properties". The Special Theory of Relativity that he developed on these simple postulates, which were firmly rooted in experimental facts, could provide a satisfactory explanation of all the phenomena associated with the propagation of light waves. But at the same time he showed that if we accept these, we have to radically change the classical ideas of space, time, simultaneity etc. That is why Einstein's theory brought about a revolutionary change, not only in the domain of physics, but also on how man thinks about space, time and the external world. This is the revolutionary significance of Einstein's research.

Einstein showed that unlike in classical mechanics time is also dependent on the frame of reference. If two events appear to be simultaneous in one frame of reference, they might not be simultaneous in another frame of reference. He illustrated this with a very simple example. Einstein starts with defining simultaneity in the following way. Two events taking place at points A and B of an inertial reference system are simultaneous if the light signals (or any other signals of finite velocity) sent from points A and B at the instants of the events reach a point at the middle of line AB at the same time. Let us now imagine a train several million kilometers long travelling with a uniform velocity of about 250,000 km/sec.

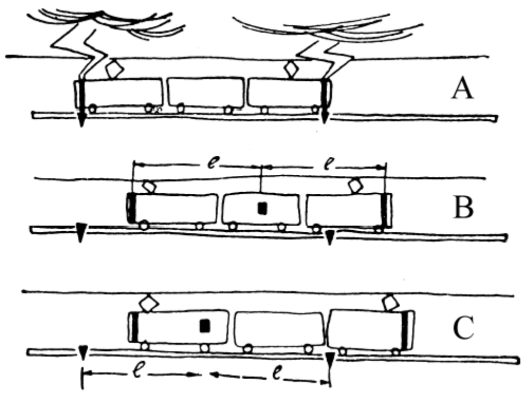

Fig.1

Lightning strikes the front and rear ends of the train and passes into the ground (Fig. 1 A). We want to check whether the lightning strikes were simultaneous or not. An observer on the train would conclude that the lightning strikes were simultaneous if a detector placed exactly at the middle of the train receives the two light signals at precisely the same instant (Fig. 1B). On the other hand an observer on the ground would conclude that the lightning strikes were simultaneous if the light signals reach at precisely the same instant a detector located exactly halfway between the marks left by lightning on the ground. Fig. 1B shows that the signals reach the detector in the middle of the train at the same instant and hence the lightning strikes appear to be simultaneous to an observer on the train. But the light signals took some time to reach the instrument and the train has travelled some distance. Hence the position of the detector is not at the halfway point between the lightning marks on the ground, but closer to the "front mark". Hence to an observer on the ground the lightning strikes would not appear to be simultaneous; he would say that the rear of the train was struck by lightning first. On the contrary if the signals reach at the same instant a detector closer to the rear of the train as in Fig. 1C, it would appear to the observer on the ground that the lightning strikes were simultaneous, but to the observer on the train the lightning would appear to have hit the front first. This conclusion that two events which appear to be simultaneous in one frame of reference are seen to have taken place at different instants in another frame of reference violates our common sense and goes against the experience of our everyday life. But according to the Special Theory of Relativity this is the physical reality and both the simultaneity and non-simultaneity are real in the two frames of reference. We cannot talk of simultaneity without specifying the frame of reference. We shall see later that these strange phenomena become apparent only when we travel at very high speeds comparable to that of light.

Through such simple examples Einstein also demonstrated that the passage of time is also dependent on the frame of reference. Let us think about a passenger traveling by the Einstein train. Let us assume that all the clocks in the different stations are perfectly synchronized.* A passenger boards the train at a station after synchronizing his watch with the station clock (Fig. 2A). After traveling for an hour at a speed of

* Einstein had given a precisely defined procedure for verifying the synchronization of clocks in an inertial reference system.

250,000 km/sec, when he arrives at the next station he is surprised to find that his watch is running slow with respect to the station clock, though there is nothing wrong with his watch (Fig. 2B). At the third station he finds that his watch has further slowed down (Fig. 2C). To the passenger it would seem that if one hour has elapsed according to the station clocks, according to his watch less time has elapsed. The greater the speed of the train the greater is the time lag difference.

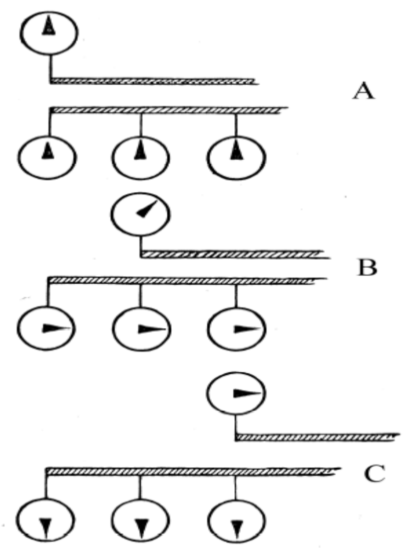

Fig.2

On the other hand, if an observer on the station compares the station clock with the clocks on the train as it flashes by he would discover that the station clock is behind. Einstein showed that simple deductions from the basic postulates of the Theory of Relativity prove that each and every observer who is motionless in relation to his clock will notice that it is the other clocks moving relative to him which are fast and the clocks go faster as the rate of their motion increases. Time passes more slowly in an inertial reference system that is moving with reference to another. This is not a defect of the clock or a measurement error; this is a fundamental law of nature. The clocks in the two reference systems give equally true measure of time valid for that particular system.

We had mentioned earlier that in Newtonian mechanics the distance between two points or length of an object is an invariant quantity, it does not depend on the reference system. This is not so in Einstein's relativity. Let us imagine a passenger boarding the Einstein train with a 1 km ruler. The stationmaster has also a ruler of the same length. As the train gets a speed of 250,000 km/sec the stationmaster would notice that the ruler of the passenger is somewhat shorter than his own ruler. And the passenger would likewise see that compared to his ruler the stationmaster's ruler seems shorter. Let us imagine that the Einstein train rushes past a station platform which is 2,500,000 km long (in the reference system fixed to the earth). The train travels from one end of the platform to another in 10 seconds according to the station clock. We have already mentioned that if it is 10 seconds by the Station clock it would be less, say 5 seconds, by the passenger's clock. So the passenger would conclude that the platform is only 1,250,000 km long, that is, the platform has contracted. By applying similar logic it can be shown that for the observer on the platform the train would have appeared to be shortened. Length is a relative quantity depending on the reference system in which it is measured. All moving bodies contract in the direction of their motion. Of course this motion has to be considered in a particular reference system. This contraction is not an optical illusion, but an objective reality. However, there is no absolute reference system in which the length has a maximum "true" value, relative to which there is a contraction in length of a moving body.

In Newtonian mechanics time and length are not dependent on the frame of reference, but according to Einstein's

Theory of Relativity both time and length are relative and depend on the frame of reference. In Newtonian mechanics Galilean transformation equations give the relations between the space and time coordinates in different inertial systems, Similarly in relativistic mechanics Lorentz transformation equations give the relation between the space and time coordinates in different inertial systems. The Galilean and Lorenz transformations are:

Galilean	*Lorentz*
$x' = x - vt$	$x' = \dfrac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$
$y' = y$	$y' = y$
$z' = z$	$z' = z$
$t' = t$	$t' = \dfrac{t - \frac{v}{c^2}x'}{\sqrt{1 - \frac{v^2}{c^2}}}$

where v is the velocity of one inertial system relative to the other and c is the velocity of light.

The equations show that when the velocity v is very small compared to the velocity of light (c), the Lorenz transformation formulas turn into the formulas of the Galilean transformation. Only at velocities approaching that of light the difference between relativistic mechanics and Newtonian mechanics becomes apparent. At commonly encountered low and high velocities Newtonian mechanics is applicable. Einstein's theory incorporates Newtonian mechanics as a limiting case.

In Newtonian mechanics dimensions of the bodies are invariant. Bodies occupy a position in space, and time is independent of space. According to Theory of Relativity space and time are linked together to form a space-time continuum. Events happen in this continuum; each event has space and time coordinates whose values depend on the choice of reference system. The dimensions of bodies are relative and depend on the frame of reference, but the space-time separation of events is invariant and does not change in passing from one inertial system to another. Though for problems of everyday life it is not necessary to apply the relativistic formulations and Newtonian mechanics provides more or less the correct answers, from a philosophical point of view there is a sharp and fundamental difference between the two. Absolute time and absolute space of Newtonian mechanics have no place in relativistic mechanics. Theory of Relativity reaffirms that space and time do not exist independently of matter. Existence of space and time means existence of matter. This is a fundamental law of nature — the objective reality.

Another important proposition of the Special Theory of Relativity relates to mass and energy. In classical mechanics the mass of a body does not depend on its velocity. It remains the same in all inertial systems irrespective of its velocity. However, according to the Theory of Relativity if a body has a certain mass (rest mass) when it is stationary in any inertial system, its mass will increase when it starts moving with a velocity, though the increase will be appreciable only when the velocity approaches the velocity of light. In classical mechanics matter has mass, and energy has no mass; from the viewpoint of physical reality mass and energy represent two distinct entities. Hence, in classical mechanics, there are two separate laws, conservation of mass and conservation of energy. Einstein showed that mss and energy are intimately linked together, and his celebrated equation proclaims the equivalence of mass and energy, $E = mc^2$. What has mass has also energy, and energy has mass associated with it. Thus, philosophically it may be enunciated that matter encompasses both mass and energy. Though in dialectical materialism such a concept had already appeared on the philosophical plane, Einstein's research scientifically established this dialectical concept of matter.

Hundred years have passed since Einstein propounded his Special Theory of Relativity. Countless experimental results have confirmed its propositions, and the results of many complex experiments have been elegantly explained by this theory. Over these hundred years not a single experimental result has contradicted the Theory of Relativity.

In 1915 Einstein propounded the General Theory of Relativity. Here he discussed how the principle of relativity operates in a non-inertial system; he delved deep into the geometry of space-time continuum, discussed the curvature of the four dimensional continuum and proposed a revolutionary new idea on gravitation. A new vista was opened for mankind's conception of the universe. Einstein's theory laid the foundation of modern cosmology. However, it is not possible to discuss the General Theory of Relativity without taking the help of complex mathematical tools.

OTHER CONTRIBUTIONS OF EINSTEIN

Apart from relativity, Einstein made path-breaking contribution in other fields too. In the same year as the Special Theory of Relativity, Einstein published a paper on photo-electricity. Though Newton had proposed the corpuscular theory of light, by the end of the nineteenth century the physicists had come to generally accept the wave theory of light. In 1900 Planck had proposed the theory of light quanta as a hypothesis to explain the observed character of radiation from a black body. Einstein supported the theory and showed that if we assume light to have a discrete character not just when radiated but also when absorbed by a substance and when propagating through space, then one has a very natural explanation of the phenomenon of photo-electricity. In his own words, "Light…is not propagated continuously over an increasingly greater space, but continues to consist of a finite number of energy quanta localized at a point in space, which can move without dividing and are only generated and absorbed as a whole."[3] This revolutionary idea about particle-wave duality of light presaged the particle-wave duality of matter in general and opened the road for future quantum mechanics. Louis de Broglie, stressing the immense importance of this discovery of Einstein, remarked that the brief but brilliant paper, quite apart from the question of the nature of light itself, was like thunder from an almost clear sky, and that the crisis created by it had still not been eliminated 50 years later. In 1905 itself, Einstein published another paper on the Brownian motion which laid the groundwork for proving the real existence of molecules and the kinetic theory of fluids proposed by Boltzman.

EINSTEIN'S PHILOSOPHICAL THOUGHTS

Some scientists, for example, James Jeans, and partly Arthur Eddington also, used to think that the objective character of matter and of the physical laws governing it are negated in the Theory of Relativity. Eddington said, [Space and time] "…are not things inherent in the external world."[4]. And in the words of Jeans, [The theory of relativity led to the notion that] "…matter as ordinarily understood, the matter of solid objects and hard particles, has no existence in reality."[5] According to him the theory of relativity reflected a certain general picture of matter "which must be more mental in character". But this is a false understanding of the philosophical implication of Einstein's theory. Rather, the concept of absolute space and absolute time independent of matter, which existed in Newtonian mechanics, has no place in the Theory of Relativity.

The theory states that space and time has no existence independent of matter. Space and time exist means that matter exists in that particular space and time. In all his research and philosophical writings Einstein had stressed time and again that physical laws have a real existence independent of human consciousness. The external world exists independently of human consciousness, but is knowable. He himself posed the question, "There are two different conceptions about the nature of the Universe: (1) The world as a unity dependent on humanity. (2) The world as a reality independent of the human factor."[6] Elsewhere he clarified his own position, "The belief in an external world… is the basis of all natural science."[7] In his conversation with Rabindranath Tagore he said, "I cannot prove that scientific truth must be conceived as a truth that is valid independent of humanity; but I believe it firmly. I believe, for instance, that the Pythagorean theorem in geometry states something that is approximately true, independent of the existence of man. Anyway, if there is a *reality* independent of man, there is also a truth relative to this reality."… "Even in our everyday life, we feel compelled to ascribe a reality independent of man to the objects we use."[6] The belief in the objective reality of nature and natural laws was the cornerstone of Einstein's scientific endeavour. He believed that, "Sense perception only gives information of this external world…indirectly."[7] But he was not an empiricist who considered knowledge to be obtainable directly from experimental data without resorting to mental activity. According to Einstein, scientific concepts are the result of the work of the brain and not of the sense organs. We get knowledge through mental processing of sense data. We do not grasp reality through activity of unrestricted free thinking. He wrote, "The theoretical idea… does not arise from and independent of experience by a purely logical procedure. It is produced by a creative act."[8] In Einstein's view scientific concepts, principles, and theories were historical categories. From time to time they had to be reexamined, and adjusted to fit reality. Einstein was not like the positivists either who find no place for philosophy in scientific endeavour, who maintain that only our sensations and perceptions are immediately given to us, and we should limit ourselves to the study of them. In sharp contrast to such positivists, Einstein stressed that, "the present difficulties of his science force the physicist to come to grips with philosophical problems in a greater degree than was the case with earlier generations."[9] He was always concerned with the relation between epistemology and science, "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."[10] Criticizing the positivist outlook on atomic theory he wrote, "This is an interesting example of the fact that even scholars of audacious spirit and fine instinct can be obstructed in the interpretation of facts by philosophical prejudices. The prejudice – which has by no means died out in the meantime – consists in the faith that facts themselves can and should yield scientific knowledge without free conceptual construction."[11] Einstein believed in the power of human reason and had a profound faith in its capacity to reveal the hidden secrets of the Universe, to know the essence of the objects of the external world on the basis of scientific concepts.

He was a firm believer in causality and determinism, and this belief brought him in philosophical conflict with the propositions of quantum mechanics even though it was his own work, which in a way led to quantum interpretation of matter. The statistical character of the quantum mechanical laws, the philosophy of the Uncertainty Principle violated his philosophical view of causally determined natural phenomena. His debates with Niels Bohr on these issues have the epic character of the battle of titans. Einstein did not disregard the phenomenal success of quantum mechanics in its applications, but he was of the view that it did not give the complete picture of reality. He wrote, "Quantum mechanics is very impressive. But an inner voice tells me it is not yet the real thing."[12] "I still believe in the possibility of giving a model of reality which shall represent events themselves and not the probability of their occurrence."[13] Einstein believed that the Universe and its workings should be comprehensible to man. Therefore, these workings must conform to discoverable laws; thus there was no room for chance and indeterminacy. To the end of his days he held on to this belief.

Some argue that though Einstein reflected materialist outlook in his scientific work, his philosophical thoughts were influenced by idealism – he was a believer in God and religion. One of his comments is oft quoted in this context, "Science without religion is lame, religion without science is blind."[14] However, it would be an oversimplification to label Einstein in this way. We should critically judge Einstein's thoughts on religion. It can certainly be said that he was not a believer in religion in the crude sense; he did not have faith in organized religion and in overt religious practices. He himself wrote that at a quite young age he "reached the conviction that much in the stories of the Bible could not be true."[11] He categorized religion as a historical phenomenon that arose at a certain stage of human development and passed through a number of stages on its way. About the origin of religious thoughts and practices he wrote, "Since at this stage of existence understanding of causal connections is usually poorly developed, the human mind creates illusory beings more or less analogous to itself on whose wills and actions these fearful happenings depend. Thus one tries to secure the favour of these beings by carrying out actions and offering sacrifices, which, according to the tradition handed down from generation to generation, propitiate them or make them well disposed toward a mortal."[14] He also came close to an understanding of the class character of religion. "In many cases a leader or ruler or a privileged class whose position rests on other factors combines priestly functions with its secular authority in order to make the latter more secure; or the political rulers and the priestly caste make common cause in their own interests."[14] He was also aware of the contradiction between religion and science: "When one views the matter historically, one is inclined to look upon science and religion as irreconcilable antagonists."[14] In a letter to a school-going child he wrote, "Scientific research is based on the idea that everything is determined by laws of nature, and therefore this holds for the action of people. For this reason, a research scientist will be hardly inclined to believe that events could be influenced by a prayer, i.e., by a wish addressed to a supernatural Being."[15] We can form an idea of Einstein's religion from his various writings. "…science can only be created by those who are thoroughly imbued with aspiration toward truth and understanding. This source of feeling, however, springs from the sphere of religion."[14] When asked whether he believes in God or not, he replied, "I believe in Spinoza's God who reveals himself in the harmony of all beings, not in a God who concerns himself with the fate and actions of man."[16] In the letter mentioned above, he further wrote, "Everyone who is seriously involved in the pursuit of science becomes convinced that a spirit is manifested in the laws of the Universe – a spirit vastly superior to that of man and one in the face of which we with our modest powers must feel humble. In this way the pursuit of science leads to religious feeling of a special sort, which is indeed quite different from the religiosity of someone more naïve."[15] Belief in the existence of a law-governed ordered Universe, and faith in the power of human reason to unravel the laws of nature together act as the source of what he calls "cosmic religious feeling". "A knowledge of the existence of something which we cannot penetrate, our perceptions of the profoundest reason, and the most radiant beauty, which only in their most primitive forms are accessible to our minds – it is this knowledge and this emotion that constitute true religiosity; in this sense and in this alone, I am a deeply religious man. I cannot conceive of a God who rewards and punishes his creatures, or has a will of the kind that we experience in ourselves."[17] He also said that cosmic religious feeling "can give rise to no definite notion of a God and no theology."[14] Critical analysis of Einstein's thoughts show that in his scientific philosophy he was consistently materialistic, and he went a long way in reflecting materialistic outlook on general philosophical issues, but in a subtle way an idealist trait did exist in his thinking. This, of course, is not unexpected because without being a dialectical materialist one cannot carry materialist thinking covering all spheres. Einstein was certainly not a dialectical materialist, but this is not so important in correctly evaluating Einstein. Einstein's scientific research strengthened the materialist philosophy and has revealed the dialectical nature of the existence of matter in space-time framework.

EINSTEIN'S SOCIAL THOUGHTS

Einstein was not a scientist residing in an ivory tower. As a scientist he was acutely conscious of his social obligations. His personal life was simple, unostentatious. "I never strove for the fleshpots and luxury, and even have a good deal of disdain for them. My passion for social justice brought me in conflict with people". In a very moving piece he wrote, "A hundred times everyday I remind myself that my inner and outer life are based on the labour of other men, living and dead, and that I must exert myself in order to give in the same measure as I have received and am still receiving. I am strongly driven to frugal life and am often oppressively aware that I am engrossing an undue amount of the labour of my fellow men."[17] From this urge to give back to the society in some measure what he had received from it, Einstein actively involved himself with social movements, took up the cause of the exploited and the downtrodden. He had a deep compassion for people who were politically or economically oppressed. In his message to the students of the California Institute of Technology he said, "It is not enough you should understand about applied science in order that your work may increase man's blessings. Concern for man himself and his fate must always form the chief interest of all technical endeavours…. Never forget this in the midst of your diagrams and equations."[18] Just as he realized the law-governed character of the natural phenomena, he accepted the law-governed link and causal dependence of social events. At least partly he could grasp the causes of social inequity, and throughout his life he registered his protest against oppression and injustice in whichever way he could. With deep pain and anguish he noted that advances of science and technology have created enormous wealth for mankind, have made it possible to emancipate man from monotonous physical labour, but the fruits of these advances have not reached the common man. On the contrary, tyranny, exploitation and human misery have increased many times. “Our time is rich in inventive minds, the inventions of which could facilitate our lives considerably. We are crossing the seas by power and utilize power also in order to relieve humanity from all tiring muscular work. We have learned to fly and we are able to send messages and news without any difficulty over the entire world through electric waves. However, the production and distribution of commodities is entirely unorganized, so that everybody must live in fear of being eliminated from the economic cycle, in this way suffering for the want of everything.”[19] He perceived that the production relations in the society in which he was living, the capitalist society, were the progenitors of the miseries. In the essay ‘Why Socialism?’ he wrote, “The economic anarchy of capitalist society as it exists today is, in my opinion, the real source of the evil. We see before us a huge community of producers the members of which are unceasingly striving to deprive each other of the fruits of their collective labour – not by force, but on the whole in faithful compliance with legally established rules. In this respect, it is important to realize that the means of production – that is to say, the entire productive capacity that is needed for producing consumer goods as well as additional capital goods – may legally be, and for the most part are, the private property of individuals.”[20] In his writings we find even the defense of the theory of surplus value which Marx had formulated many years earlier. “The owner of the means of production is in a position to purchase the labour power of the worker. By using the means of production, the worker produces new goods which become the property of the capitalists. The essential point about this process is the relation between what the worker produces and what he is paid, both measured in terms of real value. Insofar as the labour contract is ‘free’, what the worker receives is determined not by the real value of the goods he produces, but by his minimum needs and by the capitalists’ requirements for labour power in relation to the number of workers competing for jobs. It is important to understand that even in theory the payment of the worker is not determined by the value of his product.”[20] He mentioned, “Private capital tends to become concentrated in few hands, partly because of competition arising among the capitalists, and partly because technological development and the increasing division of labour encourage the formation of larger units of production at the expense of the smaller ones. The result of these developments is an oligarchy of private capital the enormous power of which cannot be effectively checked even by a democratically organized political society.”[20] Further, “Production is carried on for profit, not for use. There is no provision that all those able and willing to work will always be in a position to find employment; an “army of unemployed” almost always exist…The profit motive, in conjunction with competition among capitalists, is responsible for an instability in the accumulation and utilization of capital which leads to increasingly severe depressions.”[20] So he got attracted to socialism. “I am convinced there is only *one* way to eliminate these grave evils, namely through the establishment of a socialist economy, accompanied by an educational system which would be oriented toward social goals. In such an economy, the means of production are owned by society itself and are utilized in a planned fashion. A planned economy, which adjusts production to the needs of the community, would distribute the work to be done among all those able to work and would guarantee a livelihood to every man, woman and child. The education of the individual, in addition to promoting his own innate abilities, would attempt to develop in him a sense of responsibility for his fellow-men in place of the glorification of power and success in our present society."[20]

Einstein was an ardent pacifist, fiercely opposed to war and militarism. During the First World War and its aftermath, even at the risk of being branded as anti-national, he joined the anti-war struggles and even worked to organize scientists and intelligentsia for protest against war and militarism. After the Nazis came to power in Germany he condemned their attacks on democracy and on the Jews, and ultimately renounced the German citizenship as a sign of protest. He resigned from the Prussian and Bavarian Academies of Sciences. In an open letter to the Prussian Academy he wrote, "…[I would] resign my position in the Academy and renounce my Prussian citizenship; I gave as my reason for these steps that I did not wish to live in a country where the individual does not enjoy equality before the law, and freedom of speech and teaching."[21] Even after emigrating to the United States he was fully aware of the danger of Nazism. So when the news came that the German scientists were continuing their research on uranium and that the Germans had got control over the Czech uranium mines and had actually stopped the sale of uranium from these mines, he became immediately concerned that if the Nazis came to acquire an atomic bomb, it would be a disaster for human civilization. He wrote his famous letter to President Roosevelt, as a consequence of which the US Government stepped up the effort to manufacture the atomic bomb. It culminated in the tragedy of Hiroshima and Nagasaki, followed by the nuclear arms race and the Cold War. Einstein did not foresee this, but he immediately realized the menace of atomic war and the danger of self-annihilation of mankind. After the Second World War, as long as he was alive, he took a leading role in the anti-war movement. It became the mission of his life to stop arms race, to bring about nuclear disarmament and to ensure world peace. To avert the possibility of the arms race between USA and Soviet Union culminating in atomic war, he appealed to the leaders of both the countries to settle their differences through negotiations. He talked of a world government as the only way to ensure world peace. He insisted that peace among nations could be maintained in the atomic age only by bringing all men together under a system of world law. The Russel-Einstein manifesto played a big role in mobilizing scientists for peace. It was his last appeal to the reason and conscience of humanity.

But in spite of the fervent attempts of Einstein and all the other concerned people, arms race among nations is still continuing unabated, the world could not be made free of war. Today there is no Soviet Union, no Cold War between the socialist and the capitalist camps, but war has not been ended, imperialist aggression has not stopped, rather it has become more violent and ruthless. In Iraq, Afghanistan, Africa and Latin America wars are going on either through direct aggression of the imperialist powers or being fomented by them. It is a tragedy of Einstein's life that in spite of his whole-hearted sincerity and passionate attempts he did not succeed in the anti-war struggle and the struggle for world peace. Moreover Einstein could not comprehend the politics that the capitalist-imperialists conduct from their class interest. He failed to realize that as long as capitalism-imperialism exists aggression will continue, wars will be waged and peace hampered. From the same lack of comprehension of the imperialist class interest he became a victim of the Zionist conspiracy. Anti-semitism in European society and social-cultural oppression of the Jews made Einstein sympathetic to the Zionist cause for a separate homeland for the Jews. He did not visualize this as a conventional nation state, but more as a cultural centre where Arabs and Jews would peacefully live together. But he did not discern the imperialist class design underlying the formation of Israel. Einstein who was always a champion of the underdog did not perceive the gross injustice of uprooting the Palestinian people from their homeland. But we should not make an overall evaluation of Einstein on this basis alone. The great tragedy of this noble scientist is that he, who through his researches brought about revolutionary change in how man thinks about the external world, who throughout his life showed acute consciousness of his social obligation, who always did what he thought was the right thing to do, without paying any heed to petty considerations or personal or professional gains, died without seeing any sign heralding the society of his dream, based on justice and equity and free from exploitation, and without being able to influence the world politics in any significant way.

If we look at the scientific scene in our country, we sadly find that the tradition of combining commitment to science with obligation to society which Einstein epitomized is lost today. Thousands of people have taken up science as a profession, but how many us are truly committed to seek for the truth and to discharge our duty to the society? Unconcern about the society is on the increase, and the common tendency is to look upon scientific work as a career building activity. Remembering Einstein can have only one objective, to redeem our pledge to direct our scientific activity for finding the truth, for betterment of the life of the people, for fulfilling our obligation to the society.

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