Social Scientist

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Source: *Social Scientist*, Vol. 7, No. 1/2 (Aug. - Sep., 1978), pp. 33-58
Published by: Social Scientist
Stable URL: http://www.jstor.org/stable/3516766
Accessed: 28/06/2014 11:56

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Marxism and the Special Theory of Relativity

LIKE all the great theories of science in the twentieth century, Einstein's special theory of relativity has also suffered at the hands of bourgeois philosophers who have both limited the theory and made wrong extrapolations, injected it with idealist interpretations and used it to buttress their own philosophical positions. By interpreting relativity as an absolute relativism, and by extending it to the field of ethics, new foundations were sought to be given to that decadent view of morality which implies a relativism of men's duties and rights. In its worst form, the theory has been used to add strength to the anti-Soviet propaganda of the imperialists.

A curious book written by Arthur Koestler[1] to justify the so called extra sensory perception theories begins with a chapter entitled 'The Perversity of Physics'. In a chapter which covers nearly one third of the book the author sets forth what according to him are perverse facts in physics. Only on the solid foundation of the 'irrationality of science itself' could Koestler bring in arguments for a whole lot of other world phenomena. One such example he gives is of time flowing backwards from the future to the past. Relativity is one of the pegs on which such a proposition on time is supposed to hang.

The question of the direction of time comes up again and again.

Eddington and Russell try separately to bring out the paradox of time in relativity. Thus Eddington finds it convenient to move from this question to that of an inner monitor who tells us what is good and bad. "The direction of time's arrow could only be determined by that incongruous mixture of theology and statistics known as the second law of thermodynamics; or to be more explicit, the direction of the arrow could be determined by statistical rules, but its significance as a governing fact 'making sense of the world' could only be deduced on theleological assumptions. If physics cannot determine which way up its own world ought to be regarded, there is not much hope of guidance from it as to ethical orientation. We must trust to some inward sense of fitness when we orient the physical world with the future on top, and likewise we must trust to some inner monitor when we orient the spiritual world with the good on top."[2]

Russell makes much the same point, except that being an agnostic unlike Eddington who was a theologian, he sees no point in orienting the world in terms of good and bad. In his book 'A,B,C of Relativity' he says[3]: "The collapse of the notion of one all embracing time, in which all events throughout the universe can be dated, must in the long run affect our views as to cause and effect, evolution, and many other matters. For instance, the question whether, on the whole, there is progress in the universe, may depend upon our choice of a measure of time. If we choose one out of a number of equally good clocks, we may find that the universe is progressing as fast as the most optimistic American thinks it is; if we choose another equally good clock, we may find that the universe is going from bad to worse as fast as the most melancholy Slav could imagine. Thus optimism and pessimism are neither true nor false, but depend on our choice of clocks."

Philipp Frank says,[4] "Because of the close connection, which obviously exists between Einstein's theory of relativity and Mach's philosophy, Lenin feared that Einstein's theories might become a Trojan horse for the infiltration of idealist currents of thought among Russian scientists and among educated classes in general. This suspicion accounts for the bitter sweet reception which Einstein's theories frequently met in the first years of the Soviet regime in Russia."

We shall examine in this article the basic ideas of the special theory of relativity and draw out some of the philosophical consequences of the theory. I shall show how special relativity further confirms dialectics—the broadest generalisations about the forms of motion of matter and society and thought. As Engels pointed out, there is no question of building the laws of dialectics into nature but of discovering them in it and evolving them from it. Nature is the test of dialectics. We shall see what nature as revealed through relativity has to say about the laws of dialectics.

We shall see how the mechanistic limitation of the propositions of relativity lead to some of the perversities to which references are made by people like Koestler who aim at peddling fancies and religion. We shall also examine the alleged connection between Einstein's theories and the *philosophy* of Mach, so that the comments on the reception to relativity in the Soviet Union are understood in the proper light.

CONTRADICTIONS IN NINETEENTH CENTURY PHYSICS

Relativity arose out of the contradictions in the nineteenth century theories of electricity and magnetism and their inability to account for the empirical data which the highly developed techniques in experimentation threw up. Several ad hoc attempts were made to patch up the discrepancies but what was called for was the re-examination of the very foundations of physics and of our basic conceptions in science. Such a re-examination was started by Einstein through his first paper on relativity in 1905.

Two like electric charges repel each other with a force depending on the charges and the distance between them. Similarly two magnetic poles also exert forces on each other. Electric charges flowing in a wire constitute a current. A current has an effect on magnets and exerts forces on magnets;so also a magnet in motion produces a current in a conductor. Faraday and others studied the relationship between currents and magnets and summarised their studies in a set of laws. These laws describe the relation between electric fields and magnetic fields. Basing himself on these laws, Maxwell derived a set of equations showing how the electric and magnetic fields, connected with moving charges and magnetic poles, change with time and how these fields vary from point to point in space. These equations, called Maxwell's equations, are a special type of relations known technically as linear partial differential equations.

Maxwell's equations predicted that electric and magnetic fields would vary and spread like waves, and that these waves would have a certain fixed speed. The speed of the waves was obtained in Maxwell's theory by taking the two natural units of electric charge. This value turned out to be 300,000 km per second, which also happens to be the velocity of light. This equality suggested that light was a form of wave motion of electric and magnetic fields. Later, Hertz demonstrated through electrical experiments that electromagnetic waves could indeed be produced as predicted by Maxwell's equations. Light is only one of the forms of electro-magnetic wave motion. Radio waves, ultra violet rays and X'rays all belong to this class of wave motion. All these waves move with the same speed 300,000 km per second, which speed we may denote by the letter c.

If light is a wave motion, in what medium were the waves moving? Water waves are carried through water, sound is carried through air or other matter. What is light carried through? It was postulated that the whole of space was filled with a medium called the ether. The properties of this ether were deduced from the requirement that the speed of propagation had to be high, the planets should move through the ether without friction, and so on.

Detection of the Ether

If light and other electromagnetic waves propagate through a medium called the ether then it should be possible to detect this medium. Since the earth goes round the sun it is wading through the ether. Relative to the earth the ether is flowing and should be observed as an ether wind. What would be the effect of this ether wind on the propagation of light?

A little school mathematics would show that the speed of propagation of light would be different in different directions. The situation is like a swimmer in a river which is flowing. The swimmer here is a ray of light, and the river is the ether wind. It can be shown that the time taken for the swimmer to swim downstream and back through a distance of one km is not the same as the time required by him to swim straight across the stream and back through the same distance. If T is the time taken by the swimmer to go upstream and downstream through a distance of one km, and T' is the time taken to go an equal distance across and back, then it can be shown by elementary mathematics that

$\frac{T}{T'} = \frac{c}{\sqrt{c^2 - v^2}}$. Here v is the velocity of the stream and c is the velocity of the swimmer in still water. Let us denote this ratio by β.

The earth goes round the sun with a speed of about 30 km per second, and hence the speed of the ether wind can be expected to be 30 km per second. The speed of the swimmer is 300,000 km per second. Since v is very small compared to c, the value of the ratio β is close to one. In fact, for this value of v the ratio β turns out to be 1.000000005. This means that T and T' are almost equal, and their difference is extremely small.

But technology had progressed so much by the end of the nineteenth century that it was possible to detect the consequences of such small differences in time. Several experiments were performed to detect this predicted difference in time taken by light to travel to and fro in perpendicular directions. These experiments were carried out by Michelson and later by Morley and Miller. The Michelson-Morley apparatus consisted of two perpendicular arms along which a ray of light was sent with the help of mirrors.

The result of all these experiments was that no difference in time could be found. *The expected shift of fringes did not come about.* Though the apparatus was sensitive to detect the predicted shift, no shift occurred. The result was negative. This was the greatest null experiment of all time.

Attempts to Reconcile Theory with Experiment

The Michelson-Morley experiments were repeated several times between 1881 and 1904. While the ether hypothesis predicted a shift of fringes in the experiment all the experiments showed that there was no difference in the path of light and no shift. Several attempts were made to save the ether hypothesis.

It was postulated that the earth carried the ether with it in what may be called a drag. Sir Oliver Lodge tried a small scale experiment to test for such an effect by passing a beam of light by a rotating disc. The result was negative. Other experiments connected with the aberration of the images of stars also ruled out the possibility of an ether drag.

Another attempt at reconciling theory with the null results was made by H A Lorentz. This theory did lead to a reconciliation, but it raised deeper problems regarding the nature of space measurements and time measurements, and thus paved the way for Einstein's special theory of relativity.

Lorentz considered the atomic structure of matter. All matter was known to be composed of atoms, which in turn consisted of electrically charged particles like protons and electrons. The structure of matter was determined by the electrical forces between these particles. Lorentz accepted the ether hypothesis and assumed that electrical forces were stresses and strains in the ether. He also accepted Maxwell's equations on the electric and magnetic forces. Using these equations he showed that the distances between the atoms would depend on whether the body was stationary in the ether or moving in it. He showed that as a result of the ether wind the atoms get crowded together in the direction of the flow. As a result the length of a body gets shortened in the direction of motion by a factor $1/\beta$. The lengths in directions which are perpendicular to the motion would remain unaltered. This contraction of length on a body along the direction of motion is called Fitzgerald contraction after the scientist who proposed such a contraction on an ad hoc basis to make up for the results of the Michelson-Morley experiment.

The above theory of Lorentz fully explains the null results of Michelson and Morley. Why is it that the two times T and T' turn out to be the same when we expect them to be in the ratio $\beta : 1$? The Lorentz theory explains that this is because the arm of the Michelson-Morley apparatus along the direction of the ether wind *shrinks* by the factor $1/\beta$.

Further Consequences of Lorentz Theory

The Lorentz theory also developed formulae for the mass of an electron and proton in motion. An electron in motion, being a charge in motion, constitutes a current and has a magnetic field around it. If we try to increase the speed of the electron we shall have a changing magnetic field. A changing magnetic field produces an electric field and this will act back on the electron. Thus the electron will try to resist any attempt to change its speed. It was shown that the resistance behaves just like the resistance due to mass; the electron behaves sluggishly just as though its *mass had increased.*

Thus Lorentz was led to the concept of mass or inertia through a study of electromagnetism. He suggested that all mass had an electromagnetic origin. The mass of a body should increase with its speed in the ether.

If we consider a clock which is travelling in the ether and apply Lorentz' theory we shall see that its oscillations are slower as a result of this slight increase in mass and also because of the slight changes in the forces within the clock. Thus a clock goes slow by a certain factor if it is moving uniformly.

It was mentioned that measuring rods in motion would shrink. What is the net effect of this change in the unit of length and in the unit of time as envisaged in the Lorentz theory? The net effect is that the moving observer will measure the velocity of light to be exactly c, neither more nor less. All observers will get the same velocity of light irrespective of their state of motion. Hence by measuring the speed of light it cannot be hoped to detect the motion of an observer through the ether.

Lorentz' theory starts with the firm assumption of the existence of the ether, and ends up by saying that everything conspires in such a way that the ether cannot be observed. Like other attempts to reconcile theory with experiment, this theory also raised questions for which the answers could only be given by making a complete break with old ideas. What was needed was a new synthesis. Einstein's theory provided such a synthesis.

SPECIAL THEORY OF RELATIVITY

With this introduction, Einstein's contribution seems natural and expected. However, writing in 1905, Einstein was not aware of Lorentz' paper of 1904 or his arguments. In particular, Lorentz had given certain equations relating the measurements of distance and time obtained by different observers in motion. These equations were re-derived by Einstein in his paper. It was Einstein who gave a proper justification for these equations which are called Lorentz transformation equations.

Einstein started with what everyone was trying to explain, namely, the null results of Michelson and Morley. Einstein took it as a law of nature that the velocity of light is the same for all observers (for whom the equations of mechanics hold good). In special relativity we are dealing with observers and frames of reference which are moving uniformly without acceleration or change in speed. Accelerated motions are considered in general relativity. The frames of reference we shall consider are what are called inertial frames.

Einstein also took it as a law of nature that it is impossible to distinguish by any experiment whatsoever between two frames of reference which are in uniform motion with respect to each other. Thus if a man is in a smoothly sailing ship, no experiment performed within the ship will show that it is in motion. If he drops a ball it will fall backwards just because the ship is in motion. If he measures the speed of light within the ship, it will turn out to be c. Thus he can as well assume that he is at rest and it is the land which is moving backwards. This principle that we cannot distinguish between two frames of reference in uniform motion is called the principle of relativity.

Einstein examined the implications of these two simple assumtions, namely, of the constancy of the velocity of light and the principle of relativity. The first implication of these assumptions was that our earlier concepts of time and space have to be modified.

Simultaneity

Light and the electromagnetic radiations are the fastest signals available to us. The speed of light is great, yet it is finite. This finiteness of the speed of the fastest signals has to be taken into account when we are dealing with distant events. Thus it takes several years for light to reach us from the nearest stars.

While dealing with events on the earth we can ignore the time taken by light to reach us. On earth we can directly see whether two events are simultaneous or not because the distances are small and the time interval is negligible. But if we want to know whether two distant events like the explosion of two stars are simultaneous or not, we shall have to know the distances. We shall have to *infer* whether the events were simultaneous. Even if we see the two explosions at the same time, we shall have to check the distances to infer simultaneity. Since what is important is not the distances at the moment of receiving the signals, but the distances when the signals were emitted by the stars, we shall also need to know the state of motion of these stars.

But the state of motion of the stars depends on the state of motion of the observer himself, because each observer can with equal right say that he was at rest. Thus simultaneity is bound up with the motion of the observer. Einstein gave an example of two events which were inferred as simultaneous by one observer, and which were inferred to be not simultaneous by another observer who was relatively in motion. Einstein showed that simultaneity was not an absolute concept, but depended on the state of motion of the observer.

Lorentz Transformation

We specify the positions of objects by means of coordinates. There are several ways of doing this. We can specify the position of a town by giving the latitude and longitude (which are two numbers) and we can specify the position of an aeroplane by giving its altitude in addition to the latitude and longitude of the place above which it is flying. We say that space is three dimensional because three numbers are required to specify a point in space.

To describe an *event*, such as the explosion of a plane, we need to give in addition to the three coordinates the time at which the explosion took place. A simple way of giving coordinates is used in school mathematics. This is done by taking three lines at right angles (called axes) and measuring distances along these directions. These distances can be denoted as x, y and z. Thus the coordinates of an *event* can be given by four numbers x, y, z and t.

Different observers will have different values of coordinates for the same event. Whereas a man at Churchgate station will give the distance of Bandra as 13 km, a man in a train will give the distance as 13 km, 12 km, 11 km,...depending on the time and his speed. How are the coordinates of a man A to be related to the coordinates of a man B, when both are observing the same event? Matters are simplified if we consider that B is moving along the x axis of A with speed v, and that both have parallel axes. Such transformation equations relating the coordinates were first given by Galileo.

We can write for any event E the coordinates as x, y, z, t observed by A and x', y', z', t' as observed by B. Then the Galilean transformation equations are $x' = x - vt$, $y' = y$, $z' = z$, and $t' = t$. By using the two basic principles stated earlier, Einstein showed that these equations are not exact but need to be corrected. He derived the following equations called Lorentz transformation equations:

$$x' = \beta (x - vt),\ y' = y,\ z' = z, \text{ and } t' = \beta (t - vx/c^2)$$

Since β is very close to one for velocities we come across in daily life which are very small compared to c, these equations are almost the same as Galileo's equations. For velocities that are large and comparable to c the transformation equations imply consequences that are observable.

From the Lorentz transformation we can derive the so called Fitzgerald contraction, as also the fact that clocks in motion go slow and produce what may be called time dilatation. Time measurements and space measurements depend on the state of motion of the observer.

Space-Time

For inertial observers A and B distance measurements and time measurements are not the same though they are observing the same event. What then is invariant? What is it that both observers measure as the same? Minkowski showed that if we mix up the space measurements and time measurements in a special way we get an invariant quantity.

This quantity is called the interval between two events. The interval between two events is calculated by taking all four coordinates of both the events. For two inertial observers the coordinates, distances and time spans will be different, but both will get the same value for the interval between two events.

Minkowski showed that it was neither space measurement nor time measurement which was invariant, but this quantity obtained by mixing these measurements. Space and time are not to be treated separately but as one entity, space-time. The world is not three dimensional, but four dimensional *in this sense.*

Mass-Energy

Another consequence of the Lorentz transformation is that when two observers A and B moving relatively to each measure the mass of a body they do not get the same value. If a train is running at a speed of 30 km per second and observer A in the train measures the mass of a body in the train as one gram, then observer B on the station would observe its mass to be 1.000000005 gram. This corresponds again to the ratio β which is close to one for small velocities of the observer.

Einstein showed that if the mass of the body at rest in the train is m, then its mass measured by an observer on the station is m' where $m' = \beta m$. By writing β in full and expanding with the help of the Bino. mial theorem in algebra, we get approximately $m' = m + \frac{1}{2} m v^2/c^2$.

This means that the increase in mass, which is m'—m, is given by $\frac{1}{2} m v^2/c^2$. Thus a mass m at rest will appear to be more massive by an observer who is moving. Conversely, a body which has mass m at rest will have mass m' when it is in motion with a velocity v. The increase in mass due to the body possessing speed is $\frac{1}{2}m v^2/c^2$.

But we know that the expression $\frac{1}{2} m v^2$ gives the kinetic energy of the body. It denotes the capacity of the body to do work or produce motion. If we denote this kinetic energy by E and the increase in mass by M, we have $M = E/c^2$. We can rewrite this in the form $E = Mc^2$.

This is Einstein's famous equation showing that mass and energy are interconnected, an increase in energy showing itself up as an increase in mass. The equation suggests that mass itself is convertible into energy. Since M is multiplied by c^2, and c is a very large number, this suggests that the energy corresponding to any change in mass is very large. This is the equation which explains the release of energy in atomic bombs. It also explains the large quantities of energy released in the stars.

This relation $m' = \beta$ m has been verified to high levels of accuracy by experiments. Though ordinary bodies are not found having velocities close to the velocity of light, we can find electrons in the laboratory with very high velocities. By studying the behaviour of such electrons it has been verified that the masses do obey Einstein's law.

The slowing down of life processes in a fast moving object as envisaged by the Lorentz transformation equations is also observed. Elementary particles called mesons which have a very short life time are observed to live longer when they are in fast motion. They do not decay as fast as slow particles of the same kind.

The predictions of the special theory of relativity have been indeed very well confirmed within the limits of accuracy given by modern technology and science.

A REVOLUTIONARY THEORY

The theory of relativity represents a revolutionary step in the development of man's understanding of the world. It makes a clean: break with the notions of Newtonian (classical) physics. It nevertheless retains within itself the rational core of classical mechanics, and by showing the limits within which classical mechanics holds it increases our confidence in the use of the results and propositions of the old theory.

The idealists take up the position that a new theory totally negates an earlier theory and since every theory eventually gets negated in this fashion there is no objectivity to scientific theories. Max Born[5] says "the rise, acceptance and fall of theories is an everyday occurrence; what today is valuable knowledge will tomorrow be so much junk, hardly worth a historical backward glance".

The dialectical materialist sees that the proposition regarding the inexhaustibility of the properties of matter in depth is daily being confirmed by science and practical experience. He therefore recognises that the cognition of these properties is an infinite process as well. The dialectic of absolute and relative truth is an important methodological principle of cognition.

The development of science involves not only the appearance of new knowledge but the retention of knowledge obtained earlier. Relativity theory reaffirms the results of Newtonian mechanics for velocities that are small in comparison to the velocity of light. Since most of the speeds we come across, including the speeds of interplanetary rockets and missiles, are small in relation to the velocity of light, the theory shows us that we are justified in using classical mechanics within these limits. Relativity, while extending and correcting the results of classical mechanics, carries forward the kernel of truth contained in it and prescribes the limits within which it holds.

However, "every truth, if overdone, if exaggerated, if carried beyond the limits of its actual applicability, can be reduced to absurdity and is even bound to become an absurdity under these conditions"[6] Apparently while writing Materialism and Empiriocriticism in 1908 Lenin was not aware of Einstein's paper of 1905. But he was aware of the ideas of Lorentz and the electrical theory of matter. These ideas were not acceptable to many physicists. Abel Rey criticised these notions of the new physics. Rey's criticism was countered by Lenin who pointed out that classical mechanics mirrored motions which were slow but the new physics gave a correct picture of fast motions. He said,[7] "But however much both Rey and the physicists of whom he speaks abjure materialism, it is nevertheless beyond question that mechanics was a copy of real motions of moderate velocity, while the new physics is a copy of real motions of enormous velocities". Haldane[8] speaks of an article Lenin wrote subsequently in which he accepted relativity but rejected idealistic interpretations of it.

What relativity has to say about phenomena outside the above prescribed limits of classical mechanics is very important. We shall see the implications of the theory to our understanding of matter in motion. I have said that relativity is a wider theory than classical mechanics and introduces a correction into its results. But the philosophical implications of relativity are much deeper than is suggested by the word 'correction'. For relativity makes a total break with the older ideas of matter, energy, time, space and motion which were a part of the absolute notions of classical physics.

The Concept of Matter Widened

It was stated earlier that relativity arose out of the experiments designed to check on the existence of the ether. All attempts to measure the velocity of the ether wind had failed. However, relativity theory did not *disprove* the existence of the ether as some people suppose. What Einstein did was to skirt around the problem and explain matters in terms of electric and magnetic fields in space *without reference to the ether.*

The field concept is much older than relativity. As early as the eighteenth century, the concept density and velocity fields had been used in hydrodynamics. Faraday and Maxwell had also used the concept of electric and magnetic fields as states of stress in the ether. However, it was only with the coming of the theory of relativity that this concept was accepted as representing physical reality in its own right.

Einstein showed that electric and magnetic fields were bounded together into one entity called the electromagnetic field. How much of the electric aspect and how much of magnetic aspect a person would see depended on his state of motion. A station master sitting with an electric charge would observe a purely electric field around him. But a man in a train running past would observe this as a moving charge, or a current, and would therefore see a magnetic field as well. Thus the same point in space would be for one a scene of electric activity and for another a region with a magnetic field. By the principle of relativity these are equivalent. It is the joint field that is the physical reality.

In Newtonian mechanics one considered things as made up of bodies interacting with each other. In the nineteenth century we found that new causal factors like the electric and magnetic fields had to be added to our conceptual structure. Bodies are separated in space and localised in different regions. But fields are spread continuously in space. By showing that a wide range of phenomena could be explained by taking the fields themselves without reference to an underlying ether Einstein firmly established the existence of the field as a new category in physics.

The introduction of the fields involves a fundamental modification of our concept of matter. In Lenin's definition, as distinct from the ideas of pre-Marxist materialism, matter is not identified with the concrete, historically limited forms of matter known at a given time, "...the sole property of matter with whose recognition philosophical materialism is bound up is the property of *being an objective reality*, of existing outside the mind".[9]

Fields are one more form of existence of matter. Mechanical materialism even now attempts to fly away from the concept of the field, and tries to explain everything in terms of particles and interparticle actions. It is of course possible to avoid the field concept and use what are called retarded potentials in electromagnetic theory. But the resistance to the field concept arises essentially from a mechanistic outlook, which tries to explain phenomena through *mechanisms*, through particles and forces acting between them.

Dialectics recognises the inexhaustibility of the forms of matter in motion. Lenin said,[10] "It is, of course, sheer nonsense to say that materialism ever maintained that consciousness is 'less' real, or necessarily professed a 'mechanical', and not an electromagnetic, or some other, immeasurably complex picture of the world of moving matter". By including the field as a material reality, relativity prepared the way for a non-mechanistic picture of the world. This suggested non-mechanistic picture was, however, not accepted by most physicists.

The recognition that fields constitute one more form of existence of matter also led to the recognition of new *forms of motion* of matter. Thus in addition to the mechanical motion of displacement of *bodies*, one had to take into account changes in the intensity or strength of the electromagnetic field as a new form of motion of matter.

The Equivalence of Mass and Energy

The equation $E = Mc^2$ states a relation between mass and energy. It states that a mass of M grams is equivalent to a huge quantity of energy Mc^2. The equation states that in addition to what is called kinetic energy or energy of motion, a body also possesses *rest energy*. To understand the meaning of this rest energy we must go into the meanings of the terms mass and energy.

The common sense notion of the mass of an object is that mass measures the quantity of permanent substance in the body. This is a very rough idea and it reflects the relative invariance we observe in th objects around us. If we break a piece of chalk into two the sum of the weights of the pieces is equal to the weight of the original stick. It is this idea of permanence that is reflected in this sense of the term mass.

However, there are two aspects of mass that are considered by physics in order to make this concept precise. The first aspect is what is called the inertial mass, or the property of *laziness* or inertness that bodies exhibit. To change the speed of a body a force is required; without a force the body either remains at rest or keeps going at a fixed speed. According to Newton's law, Force=mass x acceleration. Thus mass appears as a coefficient in the equation. If we can measure the force and the acceleration, we can work out the value of the mass. This mass is called the inertial mass of the body.

Though it was never stated explicitly by Newton, he always assumed that this mass is an invariant and does not change from experiment to experiment for the same body. This is an *observed fact* in experiments in the domain of Newtonian mechanics. We must note that this is not a matter of definition, or convention, as described by some idealist philosophers, but is an observed relationship which leads to the definition of inertial mass.

Another aspect of mass is the gravitational aspect. Bodies produce gravitational attraction. This is an active aspect of mass. By measuring the gravitational pull exerted by a body we can arrive at a measure of its mass. This is called the gravitational mass of the body. Experiments have shown to great accuracy that these two masses of a body, inertial and gravitational, are the same. This result of experiment is incorporated in the general theory of relativity. What we are at present interested in is the relation between the three notions of permanence, inertial mass and gravitational mass which *are bound together as one in the realm of Newtonian mechanics.*

We now come to energy. Energy was originally defined in physics as the quantity of motion. However, there were two different mathematical expressions which were taken to measure the quantity of motion. If a body has mass m and velocity v then the two expressions taken were $m.v$ and $m.v^2$. Both these are important expressions. If we are studying the impact of elastic bodies, the sum of the expressions $m.v$ for all the bodies remains the same before and after the impact. The sum of the expressions $m.v^2$ also remains the same. For a long time there was a dispute as to which quantity actually measured the quantity of motion.

Engels[11] gives a good account of this history, and makes his own original contribution towards arriving at a proper definition of energy. It had been shown that the quantity $m.v$ is conserved when there are purely mechanical transfers like elastic impacts and also when some mechanical motion vanishes as a result of friction. However, the quantity

$m.v^2$ is not conserved when mechanical motion vanishes. "Therefore, m.v appears here as the measure of simply transferred, hence lasting mechanical motion, and mv^2 as the measure of the vanished mechanical motion."

Engels pointed out that so long as it was not known what becomes of the apparently annihilated mechanical motion absence of clarity was inevitable. He said,[12] "In short, mv is mechanical motion measured by mechanical motion; $mv^2/2$ is mechanical motion measured by its capacity to become converted into a definite amount of another form of motion." Thus in the context of conversion of mechanical motion into heat, which is a form of internal molecular motion, and various other forms of motion it was demonstrated that $\frac{1}{2}mv^2$ was the more appropriate expression. This is what is called the kinetic energy of the body.

Thus the kinetic energy of a body is a measure of its capacity to produce different forms of motion. Heat, sound, light and other electromagnetic vibrations are all different forms of energy[13]. "Because the total energy in an isolated system is conserved, there is the tendency for us to think of it as a permanent substance, like a fluid that flows from one part of the system to another. But such a fluid has never been observed. Energy appears as an invariant but transformable aspect and function of some kind of movement and never appears as an independently existing substance." This is a very important point: *energy is an aspect of the movement of matter.*

With this understanding of the meaning of the terms mass and energy we can bring out the proper significance of the equivalence in special relativity of these two concepts. According to the theory of relativity mass can be annihilated to give out an equivalent amount of energy, and energy can be absorbed by matter so that its mass increases. Hence the notion of mass representing something permanent has to be given up.

Einstein showed that an increase E in the energy of a body contributes the same quantity E/c^2 to both its inertial mass and gravitional mass. Thus in Einstein's theory mass and energy are not regarded as originating in essentially different ways; but are thought of as two different aspects of a single process of movement. They are different aspects of matter in motion.

A system like a moving body has a relatively invariant capacity to do work, to interact with other systems and set them in motion at the expense of its own original movement. This capacity is called energy. Following Bohm,[14] we can separate energy into energy of outward movement and energy of inward movement. Thus a body moving with a velocity v has energy of outward movement $\frac{1}{2}mv^2$, which is its kinetic energy, and inward movement corresponding to the thermal motion of the molecules, movement of the atoms and nuclei. This inward movement also contributes to its inertial and gravitational properties. Rest mass is the equivalent of the energy of inward movement.

Since the electron has rest mass, the above argument shows that the electron too has inner movements. "The electron is inexhaustible..."[15] An object which appears to be at rest, like a stone, also possesses energy mc^2 where m is its mass. This signifies its internal movement. Matter without motion is impossible.

However, the terms inward and outward are relative. In relation to large scale motion, say the motion of a stone, the movements at the molecular level are to be considered as inward movement since they cancel out in their overall effects. But if we take motions at a microscopic level, say the Brownian motion of pollen grains suspended in water the molecular movements of water belong to the outward movements, and the electronic and nuclear movements are still inward movement.

Mechanical materialism always looks for external agencies as causes for change or motion of matter. Machanical materialism looks at the world as a complicated mechanism. If we take a watch and consider the movements of its parts, each movement depends on the movement of some other part, the balance wheel is kept going by a gear, the gear is driven by yet another gear, and so on until we come to the wound spring. The spring itself was wound by an external hand. Thus mechanical materialism needs an external First Cause to set the whole world in motion.

Dialectics teaches us to look for inner causes. Dialectical materialism has no need for a First Cause, for within matter itself are the agencies for its development. The concept of rest energy in relativity points to this inner movement at every level of matter. The equation $E = Mc^2$ shows that though mass can be destroyed and converted into energy, together mass and energy are conserved. What is conserved is matter in motion. Matter in motion is inexhaustible and indestructible.

The Nature of Space and Time

In Newtonian mechanics space is considered to be some sort of receptacle in which all bodies exist and move. Time is an ever moving stream that flows at the same rate for all. All observers measure time and space to get identical results. In this sense space and time are absolute.

According to Kant, the eighteenth century philosopher 'who attempted to weld in one system the achievements of science and the inner light of conscience',[16] space and time were not given by experience. All objects were given to us through experience. But space and time were given *a priori* to the human mind. He denied the reality of space and time and regarded these categories as forms of visualisation by means of which the human observer combines his perceptions into an orderly system. Space and time were the preconditions for the observation of matter. Matter presupposed space and time.

Engels[17] criticised this view from the standpoint of dialectical materialism. "It is the old story. First of all one makes sensuous things into abstractions and then one wants to know them through the senses, to see time and to smell space". While he recognised that space and time are universal forms of existence of matter, he said "The two forms of existence of matter are naturally nothing without matter, empty concepts, abstractions which exist only in our minds."

Does the relativity of the measurements of space and time imply non-objectivity? Some idealist philosophers were quick to jump to this conclusion. Dingle, for instance, maintained that the dependence of a body's length and of the time interval on the frame of reference meant that relations of space and time were not inherent in matter at all. He said that relativity "declines all attempts to assign to matter any properties whatsoever". This is a total misrepresentation of the propositions of relativity.

To make this clearer we give the following example suggested by Max Born. "Let us suppose that we cannot for some reason directly observe a cardboard circle but can see the shadows it casts on some screens placed at different angles to it. All the shadows will be different save that they will all be elliptical. On studying the axes of the elliptical shadows, we shall have enough evidence to show that they have been cast by a circle and to find its radius. The projections of the properties of the object concerned (the cardboard circle) relative to other objects, which play the part of reference systems (the screens), differ. But in each case the real properties of the objects concerned (the circle) remain identical. Shadows of different size and shape are relative expressions of the absolute size and shape of the cardboard circle. Similarly, the length of bodies and time intervals are relative expressions of the absolute length of the space-time interval, which is independent of the reference system. The shadows cast by the circle are as real as the circle and the screens. The different lengths of the bodies and time intervals in different reference systems are as real, as independent of consciousness, as the space-time interval (whose expressions they are) and the corresponding reference systems."[18]

Apart from showing that space and time are not absolute, Einstein showed in his general theory of relativity that the space-time relations in a region depended on the distribution of matter. Kant and all thinkers prior to him believed that the geometry of Euclid (which we learn in school) gave an accurate description of the relations in space. Einstein showed that this is an approximate description of space. Euclidean geometry is true in empty space, or if there is very little matter. The sum of the angles of a triangle is 180 degrees in Euclidean geometry.

However, in the presence of matter, like in the neighbourhood of the sun, geometry is non-Euclidean. The sum of the angles of a triangle is slightly different from 180 degrees. Thus geometry depends on the distribution of matter. Space and time are joined into a four dimensional structure and the geometry of this depends on the distribution of matter.

Space and time depend on matter in motion. The dialectical materialist stand is that space and time are abstracted from matter in motion. To quote Lenin again,[19] "Although man has abstracted space and time from special and temporal things, nevertheless he presupposes those as the primary grounds and conditions for the latter's existence. Hence he thinks of the world, that is the sum total of real things, matter, the content of the world, as having its origin *in* space and time. Even Hegel makes matter arise not only in, but out of, space and time ... In reality, exactly the opposite holds good, . it is not things that presuppose space and time, but space and time that presuppose things, for space or extension presupposes something that extends, and time, movement, for time is indeed only a concept derived from movement, presupposes something that moves."

About the relativity of the concepts of space and time and their objectivity Lenin said:[20] "Human conceptions of space and time are relative, but these relative conceptions go to compound absolute truth. These relative conceptions, in their development, move towards absolute truth and approach nearer and nearer to it. The mutability of human conceptions of space and time no more refutes the objective reality of space and time than the mutability of scientific knowledge of the structure and forms of matter in motion refutes the objective reality of the external world." This was written in 1908.

MACH, EINSTEIN AND LENIN

Einstein acknowledged his indebtedness to Mach—Lenin launched a determined attack on Mach—Lenin was suspicious of the work of Einstein—relativity met with a bitter sweet reception in the Soviet Union. This is how Frank argues. If this interpretation of the history of relativity helps anyone, it helps the imperialists in their propaganda that under socialism science is muzzled by political authority.

The insinuation that relativity was banned in the Soviet Union does not merit any serious rebuttal. Not only was relativity studied seriously in the Soviet Union, but the first non-static, evolutionary model of the universe based on the general theory of relativity was given by the Soviet scientist Friedman in 1922. This was much before the so called red shift of distant nebulae was observed which suggested an expanding universe. Einstein was impressed by this work. He wrote:[21] "The mathematician Friedman found a way out of this dilemma. His result then found a surprising confirmation by Hubble's discovery of the expansion of the stellar system."

Mach was a philosopher and a scientist. This must not be forgotten. As a philosopher he was a positivist and believed that the world was made up of sense impressions alone, complexes of sensations, and the task of science was to order and describe these sense impressions in the most economical way so as to predict other sense impressions. All theories of science should deal with concepts that are directly formed from sense impressions. Lenin demolished this philosophy of the logical positivist Mach. While doing this Lenin showed how Mach the positivist contradicted Mach the scientist. Lenin said:[22] "Mach forgets his own theory (positivism) and, when treating of various problems of physics, speaks plainly, without idealist twists, that is materialistically. All the complexes of sensations and the entire stock of Berkeleian wisdom vanish. The physicists' theory proves to be a reflection of bodies, liquids, gases existing outside and independently of us, a reflection which is, of course approximate; but to call this approximation or simplification 'arbitrary' is wrong. *In fact,* sensation is here regarded by Mach just as it is regarded by all science which has not been 'purified' by the discipleity of Berkeley and Hume, namely, as an *image of the external world.* Mach's own theory is subjective idealism; but when the factor of objectivity is required, Mach unceremoniously inserts into his arguments the premises of the opposite, that is, the materialist theory of knowledge."

Lenin was not opposed to Mach's technical-scientific propositions but was opposed to his epistemology. Thus he defended Mach's position regarding 'n' dimensional spaces much before Minkowski came up with the idea of a four dimensional space-time continuum. He wrote[23] "In his Mechanics, Mach defends the mathematicians who are investigating the problem of conceivable spaces with dimensions; he defends them against the charge of drawing 'preposterous' conclusions from their investigations. *The defence is absolutely and undoubtedly just,* but see the epistemological position which Mach takes up in this defence." (emphasis added)

Mach's Influence on Einstein

The same book History of Mechanics exercised a profound influence on Einstein while he was a student. In this book Mach criticised Newton's views on mass, time, space and motion. On the notion of mass he stated that Newton's definition was unsatisfactory and suggested that the definition of mass be linked up with force and acceleration. He further pointed out that the significance of weight acting as a measure of mass should not be forgotten. He sharply brought out the difference between the pull of gravity and the pull of a magnet by showing that mass connot be measured by considering the pull of a magnet.

Mach criticised Newton's idea of the uniform flow of absolute time. He pointed out that the concept of time involved the comparison of different processes. He suggested that time could flow at different rates for different observers. Regarding space he had similar comments to make. Motion in absolute space did not mean anything to him. Space and motion are to be defined in terms of other bodies. Motion is relative.

Mach considered Newton's bucket experiment in which a bucket of water is made to turn about its axis by means of a rope and the surface of water is studied. The surface becomes curved as a result of the turning. Mach said that the centrifugal forces acting on the water are due to the turning with respect to the fixed stars. Absolute turning has no meaning. The forces arise because the water is turning with respect to the distant parts of the universe. The universe as a whole exerts its influence in this way. This is what is called Mach's principle.

These were the seminal ideas of Mach the scientist which influenced Einstein. These ideas Mach put forward *"without idealist twists, materialistically."* We can easily see how close Mach was to the ideas of special and general relativity. It was this debt that Einstein acknowledged.

What about Mach's positivism? Did this play a part in the development of relativity? Einstein was not a professional philosopher. It is possible from his copious writings to pick out passages which emphasise the importance of sense perceptions, or which refer to complexes of sensations. Attempts have been made to demonstrate from these that Einstein was, if not a logical positivist, at least a logical empiricist. It has been made out that in his analysis of simultaneity Einstein was heuristically helped by the positivist requirement of Mach that every statement of physics must state relations between observable quantities. This is a far fetched argument.

Every scientist tries to build up his concepts from the results of observations and tries to link up concepts and theories in such a way that they lead to empirical verification. In doing this he throws overboard unnecessary hypotheses. By minimising hypotheses, the scientist tries to simplify his arguments and presentation. This is a part of scientific methodology.

This has been reflected incorrectly in the writings of various idealist philosophers. Thus Leibniz spoke of the identity of indiscernibles, and much earlier, William of Occam gave his famous razor to shave away unnecessary hypotheses. Occam's principle can be stated as "Entities should not be multiplied without reason", or more authentically, "It is vain to do with more what can be done with fewer". When Einstein explained electromagnetic phenomena without using the concept of the ether, we can with equal justification say that he was helped by Occam. Einstein's analysis of simultaneity can equally well be stretched to give credit to Leibniz or Occam.

It is true that Mach's philosophy influenced Einstein as a student. But he quickly grew out of this. Mach required that every statement of physics should deal with directly observable quantities. This is essentially a sterile principle, for it disallows all concepts of statements, like the many statements in general relativity about the nature of space-time, which are not directly verifiable. In fact, Einstein has been criticised on the ground that his general theory of relativity did not conform to the "operational principle that only such symbols should be introduced into the theory as could be defined in terms of observations which could in principle be carried out."

About Mach's philosophy Einstein said:[25] "... in my younger years, however, Mach's epistemological position also influenced me greatly, a position which today appears to me to be essentially untenable. For he did not place in the correct light the essentially constructive and speculative nature of thought and more especially of scientific thought-in consequence of which he condemned theory on precisely those points where its constructive-speculative character unconcealably comes to light, as for example in the kinetic atomic theory."

Mach's positivism is a brand of philosophical idealism. Did Einstein belong to the class of idealists? The stand he took in the face of the rise of the Copenhagen school of quantum theory shows how he stood on the side of materialism.[26] The distinction between an idealist and a materialist is that a materialist uncompromisingly asserts the primacy of matter, and the existence of the external world independent of his consciousness. In an article entitled *Maxwell's Influence* he wrote:[27] "The belief in an external world independent of the percipient subject is the foundation of all science. But sense perceptions inform us only indirectly of this external world, of Physical Reality, it is only by speculation that it can become comprehensible to us". Certainly, Einstein was no positivist.

THE ARROW OF TIME

Relativity welded time to space and obtained a four-dimensional continuum. It was a formal welding, in the sense that the formulae for space measurement and time measurement indicated that mixing up these measurements in a certain way would give an invariant. However, this gave a picture that was rich in suggestions for a conceptual structure for studying general motions.

But mankind sets up against the world the pictures that are abstracted from it and suppose them to have a reality of their own independent of the world. Along the x-axis one can move to the left or to the right, to positive values of x or to negative values. If time is one more axis of coordinates, is it possible to 'move' along the time axis in the same way? Thus is it possible to move from positive values of t to negative values? The question of time moving backwards is suggested by this placing of time and space on an equal level.

To this was added a new circumstance. Special relativity pointed out to the existence of pairs of events about whose priority in time different observers would disagree. If the Pole star and the Sirius are seen to explode simultaneously by us on earth, there would be two observers A and B such that A would infer that the Pole star exploded before Sirius, and B would infer that Sirius exploded first. Thus the time order for this pair of events is reversed depending on the observer. It is to this that Russell refers when he tries to make out that progress is a matter of clocks and observers.

This interpretation arises from a wrong reading of the results of relativity. The special events for which time reversals are possible are only pairs of events which occur far away in space and yet so close together in time that either event cannot be the cause of the other. In the above example the explosion of the Pole star cannot be the cause of the explosion of Sirius since the fastest influence travelling from the Pole star to the Sirius takes several years to reach Sirius, and the explosion of Sirius takes place before this. These are causally unconnected events. Special relativity allows time reversals for such events, but *for all causally connected events* relativity forbids time reversal.

This situation has a philosophical meaning. Mario Bunge[28] says: "One of the severest blows suffered by the empiricist reduction of causation to uniform succession came from relativity physics. In fact, relativity introduces a radical difference between time series of genetically unconnected events (which are reversible) and causal series (which are irreversible). Moreover, it suggests that it is the flow of time (relative to every reference system) that can be regarded as rooted to genetic sequences or if preferred, as measuring their tempo. Change is thereby regarded as primordial and time as derivative. The time theory of causation, defended by Hume and his followers, is thereby reversed and a *causal theory of time* is established."

The Symmetry of the Laws of Physics

It is said that the laws of physics are time symmetric. This means that in the various equations of physics if we substitute the value of time, t, by its opposite,—t, the laws remain unchanged. It was supposed that this is a property of all the basic laws of physics at the level of elementary particles. The laws of mechanical motion are time symmetric. If we look at Maxwell's equations, they too have this property, namely, we can replace t by —t without changing the laws.

The implication of this mathematical property of equations is that if a system traverses a sequence of states 1,2,3,...10, the reversal of the time sign signifies that the same sequence may be traversed in the reverse direction: 10,..4,3,2,1. If the earth goes around the sun in one direction, the equations of mechanics show that it can as well go in the opposite direction.

The only exception to this property of time symmetry is the so-called second law of thermodynamics. This law states that in any system the amount of 'disorder' goes on increasing with time, and if we bring two gases together the extent to which they are mixed increases with time. But physicists argued that this is not a law of nature in the same sense as Maxwell's equations or the equations of mechanics, quantum theory, and so on. This was a statistical law which reflected our ignorance of the details of the individual particles of the gases. It was argued that if we had sufficient knowledge of the individual velocities of the molecules of the gases and if we could by some magic reverse the velocity of each molecule, then the system would go backwards and eventually the two gases would automatically get separated and disorder would get reduced.

If all the laws of physics are time symmetric, how is it that the universe as a whole is not time symmetric? The past is certainly different from the future. Where does the arrow of time come from? Is there an arrow, or is it, as Russell suggests, an illusion?

Take Maxwell's equations. If a charge oscillates, it produces waves that go on increasing in radius and proceed to infinity. This is like the ripples in water that are produced when a stone is dropped. Now Maxwell's equations are time symmetric and t can be replaced by —t. This means that the equations also *allow* waves coming from infinity, and becoming smaller and smaller until they reach the charge. What is surprising is that these waves start *before* the charge has started oscillating. Technically,this is called the advanced solution. Maxwell's equations allow both situations. But in nature we never observe such 'premonitory' waves. The advanced solution does not correspond to physical reality. What is the reason?

To understand the origin of such symmetry, let us consider a simple problem from school algebra. We are told that a father is nine times as old as his son and that the product of their ages is 81. How do we find the ages? We set up the equation $x. 9x = 81$. From this equation we immediately get the solution $x = 3$. The son is aged 3 and the father is aged 27. Now the quadratic equation $9x^2 = 81$ has another solution, namely $x = -3$. This is because of the basic symmetry of the quadratic equation. We naturally reject this solution $x = -3$ on physical grounds. How did we get an extra solution? This is because the original quadratic equation did not fully reflect the physical fact that the ages have to be positive, or that the father has to be older than the son. The quadratic equation reflected the situation only partially, and therefore further reasoning is required to reject the extra solution.

Time symmetry in the laws of physics arises from the same basic fact that the laws only reflect nature partially. Mechanical motion, like change of place, is reversible. Hence the laws abstracted from such motions have time symmetry. This explains the time symmetry of the laws of classical mechanics. But even for mechanical motions reversibility is only approximate. Behind symmetry lurks asymmetry. Thus the earth can go backwards in its motion around the sun, but the flattening at the poles or the bulging at the equator cannot be negated. Strict reversibility is not available.

But mechanistic and metaphysical ways of thinking die hard. When classical mechanics is the model for all theories, it is natural to transfer the symmetries of mechanics to such theories as well. The example of Maxwell's equations serves to illustrate this hold that mechanistic philosophy has on contemporary physicists.

The advanced solution of Maxwell's equations were for a long time considered as some sort of skeleton in the cupboard of electrodynamics. Then in the late 1940's Wheeler and Feynman took this out and tried to give life to it. They *postulated* that both the advanced and retarded solutions of Maxwell's equations represented physical reality. A charge in motion gives waves into the future and into the past, according to this theory. If we light a match this causes waves to proceed and reach the sun eight minutes later. But further, according to this theory, this causes the production of waves coming to the match starting from the sun eight minutes *before* the match is lit !

But such a conclusion cannot be accepted. They linked this up with absorption of radiation by other particles in the universe in such a way that these advanced waves (premonitory waves) are all absorbed so that only the usual waves are observed. Waves going into the past are produced, but no one can observe them because they are also absorbed! I cannot resist quoting the White Knight's scheme which Eddington quoted many years ago in a different connection:

> But I was thinking of a plan
> To dye one's whiskers green
> And always use so large a fan
> That they could not be seen.

This idea of the symmetry of the two solutions was taken further by Hogarth, Hoyle and Narlikar who tried to link this up with the nature of the universe. In an expanding universe, the waves going into the past would all be absorbed. In a contracting universe the waves going into the future would all be absorbed. But the arrow of thermodynamics also will point in the same way. Narlikar and Hoyle linked up the three arrows suggested by thermodynamics, Maxwell's equations and the expansion of the universe and said that all three pointed to the same direction, or at least, a *random observer* would see them in the same direction. They could however not solve the problem of the arrow of time.

The Character of Laws in Science

The special theory of relativity makes drastic changes in most of the results of classical mechanics. However, it leaves Maxwell's equations in tact. This should not surprise us if we consider the genesis of the problem. The problem was to adjust theory with experiment. The most accurate experiments were in the domain of light and other electromagnetic phenomena. The velocity of light being the same for all observers suggested that the equations of Maxwell were valid for all observers. Hence the programme of relativity could not have been said to be complete if the invariance of Maxwell's equations had not been shown.

This however should not mean that Maxwell's equations are a description of reality under all conditions. It is characteristic of mechanical materialism to look for laws that are absolute and final. Mechanical materialism believes in the finality of laws. Dialectical materialism, on the contrary, recognises that[29] "the measure of truth about anything which we can achieve at any time—in what terms and how adequately we express it—depends on the means which are available at that time for discovering and expressing truth." Truth is correspondence between ideas and objective reality. But such correspondence is generally only partial and approximate. "The laws which science gives certainly reflect objective processes; they correspond to the real motion and interconnection of things in the external world. Yet science has established few laws which can claim to be absolute truth."

Einstein himself considered that Maxwell's equations would have to be corrected in the future:[30] "These are formulations which coincide with the experiences of infinitely weak electromagnetic fields. The empirical origin already determines their linear form: it has however, already been emphasised above that the true laws cannot be linear. Such linear laws fulfil the superposition principle for their solutions, but contain no assertions concerning the interaction of elementary bodies."

Leaving aside Maxwell's equations, we see that already elementary processes in the atomic domain have been discovered which are not time-symmetric. Time symmetry is particularly absent in the so called weak interactions. All interactions in which neutrinos are given out are asymmetric with respect to time. The decay of K mesons also show time asymmetry. Regarding the linking up of the arrow of time to such processes, Hoyle and Narlikar say that this[31] is "a possible, but not a promising, approach to the problem". I think that this resistance to accept the time-asymmetry of the basic processes, like the resistance to accepting the field as a category of matter, arises from a basic mechanistic philosophy.

Space and time are abstracted from matter in motion. Motion or change is the form of existence of matter. With the help of slow and secular changes we coordinate ourselves in space. Thus we say that a house is between the hill and the lake, though both hill and lake are subject to change. With the help of regular and recurring changes we orient ourselves in time. The rising of the sun, or the coming of the rains are changes which give us the notion of time.

But there is a sense in which space and time are differently abstracted. While space is abstracted from mechanical motions of displacement, time is abstracted from a wider form of motion. Time is abstracted from *process* itself. Process includes mechanical motions which are reversible as well as *development* which is irreversible. Changes which arise from inner contradictions, like the growth of a seed into a plant or the evolution of a star or the transformation of capitalist society into socialist society, are irreversible. It is this irreversibility of the basic process of nature that is reflected in the arrow of time. The problem of the arrow of time has its root in the inability of mechanistic materialism to grasp the dialectical nature of the universe and all its processes.

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