And about time too!

by Alan Sturt

If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts he shall end in certainties.

Francis Bacon The Advancement of Learning I.v.8

Summary

There is no such thing as time in physics, nor is there any such thing as distance. These terms are figurative descriptions of concepts which everybody understands in principle, but leave us wondering what time actually is. Is time a silken thread running through the ages? Is distance a long stiff rod stretching out across the landscape? In fact neither is true. What we call time is the intervals between events, or time-intervals, and what we call distance is the interval between particles or objects, or distance-intervals. These are necessary to the transport of the dimensions of Newton's mathematical physics into algebra, and hence calculus. The reason is that algebra deals in numbers, and only in numbers, even if they are disguised as symbols for the purposes of manipulation. The numbers in question are numbers of intervals of different species of variable such as the *x*-species and the *y*-species, and the operations available in algebra are limited by this segregation into species. However, if these species are not differentiated into numbers of intervals, the basic hypotheses of algebra are not met.

Intervals of a species must be identical, sequential, contiguous and orthogonal. Given this, it is certainly acceptable to transport any variable of physics into algebra, even in terms which make no literal sense, such as $(\text{time})^2$ or $(\text{temperature})^4$, because the intervals are simply numbers, and these terms are acceptable with numbers. It is just that they are numbers assigned to a particular species, namely time or temperature. The same concept also justifies the role of constants in which species of variable are measured, such as a constant to transform feet into metres, and so they can be rationalised with other numbers as such, because they have to stay within their species until both constant and interval are substituted by numbers. Since algebra works with this methodology, so does calculus. The resulting mathematical physics also agrees with what happens in practice, which is encouraging!

It may be surprising enough to conclude that time and distance do not exist except conceptually, but the corollaries for physics are quite startling. Intervals are marked by points at the beginning and the end, but there is nothing in between. 'Nothing' cannot dilate, and so the algebraic basis of Relativity is flawed. This is in addition to the misinterpretation of observations which led to the formulation of Relativity in the first place, as described in my previous analysis. Nor are there minimum sizes of intervals, a fact that allows the increments to tend to zero, which is an essential requirement of calculus, but which also means that the time and distance species of variable are not

quantised. There are no quanta along the time or distance axes, because we can choose any length of interval we want, which undermines two pillars of quantum theory. This reinforces the fact that quanta of distance are not consistent with the physical distortion of atoms in materials under stress, and the force of restitution to their former state when stress is removed.

Mass is different, because fundamental particles are certainly quanta of mass. Mass is a term invented by Newton as a constant of proportionality in equations which describe force. The existence of quanta of force ought to disrupt the transition of the mass-species into algebra and hence calculus. What has in fact happened is that physics has taken the pragmatic solution of using different mathematics at different levels. For 'everyday' masses the algebra and the calculus can be said to work, provided it does not venture down into the subatomic regions. For subatomic particles a different approach is required because it is no longer true that pieces of materials can simply be lumped together to make a larger mass. Fundamental particles tend not to aggregate but to orbit each other, behaviour that is complicated not just by their size range but by electric charges which are much more significant at this level in proportion to their mass e.g. the charges on electrons and protons, compared with those on much heavier neutral atoms or ions.

It may be that quantum theory is one way of describing these systems which are too small to observe and model directly. However, it would be better still to recognise the interactions of particles for what they are: orbits.

Finally, outside the 'everyday' environment of the Solar System there are indications from ever more sophisticated measurements that the behaviour of mass may be complicated by the immense magnitudes of masses and distances which are the norm in space. Not least is the fact that only 4% of the mass which Newtonian physics calculates should exist in the Universe is actually observed; hence dark matter etc. Gravitational forces must still exist, anything else is unthinkable, but its relation to mass-intervals and distance-intervals may be different, which indicates some more fundamental phenomenon that causes gravitational attraction, yet to be discovered.

A. Introduction

There is no such thing as time. There is no silken thread running through history from the past into the future. However poetic or philosophical it may be to think of time in this way, and however puzzling it was for St Augustine amongst others, there really is no such thing. It is not clear whether Newton thought of time as a thing in the sense of a physical phenomenon in its own right, but his would-be successors certainly have tried to treat it in this way, and fallen into considerable confusion as a result.

At the beginning of the 20th century, physics branched out from its classical foundations as laid by Newton and formed two new, additional, main streams: Relativity and quantum physics. Newton's physics gave, and continues to give, excellent predictions of the everyday world, if you can call the orbits of planets in the Solar System and the trajectories of rockets 'everyday', but it had no explanation for the extraordinary behaviour of light which was always found to travel at the same velocity of $3x10^8$ ms^{-1} in vacuo, irrespective of the velocity of the source or the receptor i.e. it appeared not to obey the mechanical laws of relative velocities. Nor did it explain the equally puzzling behaviour of newly discovered fundamental particles, which refused to obey his basic laws and went their own way probabilistically, apparently with a mind of their own.

The analysis of my recent series of papers suggests that Newton's laws can in fact be applied to these new phenomena by reconsidering the observations which led to misinterpretations. The constant speed of light in vacuo is a fact, but there is no reason why the velocity of the source or receptor should be related to it, because the phenomenon depends on the mechanism of emission and absorption at the electronic level of atoms. It is the changes of the velocity of electrons orbiting the nucleus close to the speed of light which generates electromagnetic radiation, rather than the velocity of these atoms as a whole through space. In short the conclusion of mystical behaviour is a misapplication of Newtonian mechanics. Similarly the probabilistic behaviour of fundamental particles can be explained as their orbital interactions with other particles, leading to apparently inexplicable deviations from straight-line mechanics. However, on a scale at which we can see them, the 'deviations' of satellites and comets in the Solar System seem perfectly calculable using Newtonian mechanics.

Mathematics compounded the problems for physics in two ways. First it was forgotten that mathematical equations describe models of how the physical world works; they can be no better than the models on which they are based. Algebraic equations generalise a physical model, so that any behaviour within the parameters in which it has been tested can be predicted; such predictions validate the model within those limits. Occasionally such predictions point to anomalies in the model, and may lead to modifications which may count as discoveries, but they are not the means of discovery. Measurements are the means of discovery.

Furthermore, it was forgotten that the manipulations of algebra require orthogonality between variables, because this expresses their own distinct character. If they are not orthogonal, the operation of equations is invalid. In simple terms, if every value of y contains a proportion of x, and if every value of x contains a proportion of y, the relationship between x and y is hopelessly confounded in any observation; it is impossible to unravel it by treating x and y as separate variables. In graphic terms, if the variables are not different species, then the x and y axes are not rectangular with respect to each other, and so it is impossible to tell whether any change in the value of a point lying between them is caused by a change in the value of x or a change in the value of y. The corollary is that time and distance, for instance, cannot both be variables of different species subject to the laws of algebra and at the same time form a new variable called space-time; Relativity and algebraic equations do not go together, a conclusion which may shock some.

The existence of fundamental particles introduces a further complication. Most physics concerns bulk properties such as heat, light, sound and electricity. Relationships in these phenomena have been evaluated in systems which contain very large numbers of particles, whether atoms, or particles of light or electrons. Equations and constants are established which relate to the behaviour of particles in large numbers. However, the behaviour of individual particles may not simply be a proportionate contribution to the property of the bulk. A single electron may appear to react aberrantly, but for the reasons mentioned above, a stream which is composed of a very large number of electrons nevertheless gives an exactly reproducible spectrum of deflections. Likewise a single particle of light may seem to fly off at a tangent, whereas a beam of light produces a characteristic diffraction pattern.

This paper shows how the use of mathematical methods, Newton's *Principia mathematica*, can be reconciled with the concept of dimensions in physics, provided they are orthogonal and infinitely variable. The fact that mass as a property is not infinitely variable, because fundamental particles are the lowest limit, helps explain why it cannot be handled in the same way. Hence it may need a different approach.

There is one consolation for mathematics in all this: at least the phenomena of the natural world are homogeneous through time. That is the fundamental concept which underlies all scientific investigation. This is Lyell's principle writ large; the physics which shaped the Earth in the past is the same as we observe at its present state of evolution, and the chemistry of the stars is what we observe on Earth, with due allowance for temperatures and pressures which are extraordinary for us. Nothing else would make sense, and the fact is that it does make sense, progressively more so as the pursuit of scientific knowledge continues. By contrast in the discipline of economics, for example, more properly described as political economy, there are no processes that can be considered as homogeneous through time, any more than people are homogeneous through time either as individuals or en masse, which makes forecasting difficult and prediction impossible.

The fundamental dimensions on which Newton founded his mathematical physics are those which we can sense. The following analysis shows how they fit with the mathematics, some of which Newton had to invent himself to make any headway, and highlights his circular argument about mass. Time is fundamental to any analysis because clocks are inherent in every process, but nevertheless it is a difficult concept to handle. Best to start with distance, because everybody knows what distance is, at least notionally. Our understanding of distance may give us clues about the nature of time too.

B. Distance

We recognise distance by using our senses of seeing, touching, hearing or listening. Imagine a line of trees along a straight road as in a landscape by Hobbema. We stand by one tree and look into the distance towards the last tree in the line which we can see. We can estimate the distance to the end of the line by counting the number of trees in between the position where we are standing and the last tree, because they are evenly spaced. We can do better still by walking along the line and counting the number of paces needed to reach the last tree, especially if we have standard Roman paces, which seems unlikely because they seem to have taken unusually long strides for people who were fairly short by today's standards. We could measure the distance literally in feet by walking heel to toe along the line. We might construct a wheel with a circumference of a known number of feet or paces, and push it along the road from beginning to end while counting the number of revolutions, which is what the Romans in fact did when measuring their ‘miles’ of a thousand ‘paces’.

In our more sophisticated times those units seem rather rough and ready, but it should be remembered that in many places cloth is still measured in yards gauged from shoulder to finger tip, and it is not long since the Anglo-Saxon rods, poles or perches were part of the curriculum. These archaic units of length were certainly practical under the ridge and furrow field system of medieval times, because they were the length of pole (literally) needed to tap an ox on the shoulder during ploughing in order to make the team turn at the end of a row. That is all gone now, but, as far as I am aware, we still do not hear of horses competing over the 5,000 metres, and races are still lost or won in the last furlong.

These are distances which we all experience through our senses, and even if we reach the limit of our powers of observation, we invent proxies to do it for us by the use of technology. The description brings out the essential features of distance for us. First, there has to be an origin, a point from which measurement begins. This provides the degree of freedom to which the whole framework relates. Then there has to be a direction in which distance is to be measured; any direction will do, but it is chosen to be of most use. The direction is a straight line, by which we mean that the line preceding any chosen point is at 180° relative to the line which comes after. This can be measured using our senses by drawing a circle on a piece of paper and folding it in two across a diameter i.e. making a protractor. We use a unit of measurement, say a foot, yard or metre, to estimate how far along the line is the particular point in which we are interested. It helps to communicate the length to others if we use an agreed unit, say a metre stick. The units of length along the line must be identical, sequential and contiguous to be useful. There is no long, rigid rod for us to follow. What we measure is the distance-interval from the point of origin along the chosen direction, gauged in the number of standard units.
The term distance-interval is used rather than length, because length already implies a short distance and the term length-interval may appear to be tautologous. It is a question of perspective. To illustrate the point, however far along the line we go into the distance, there is still just as far left to travel, which is as good a definition of infinity as any.

We draw a mathematical model to abstract the argument from specific applications, and make it applicable more generally. The point which we chose as the origin is conceptual, because it has no length, width or height; if it had, it would take a bite out of the distance-interval to be measured. The line from the origin in the chosen direction is also conceptual because it has only one dimension i.e. no width or height to lend it substance, rather like an infinitely thin laser beam. But even if we looked back along its length, the line would still be no more than conceptual, because we would be looking at a point identical to the origin.

We may have dispensed with the tangibles for analytical purposes, but the same procedures still apply. The distance to a point is still measured by counting the number of standard contiguous intervals in the desired direction until the point is reached. If the point was on exactly the opposite side of the origin, we would count in the same way, but we would give a negative sign to the number of distance-intervals for mathematical purposes.

We can extend the argument to the measurement of area and volume. To measure area we count the number of distance-intervals from the origin to a point in a desired direction which we can call the x-axis, and then we count the number of distance-intervals from the origin to a point in a direction which is at 90° to the x-axis, called the y-axis. We then draw lines parallel to the axes from the two points to meet in another point, which completes a rectangle. All the points and lines are conceptual, and the rectangle itself is conceptual without depth. The area of the rectangle is the number of distance-intervals along the x-axis multiplied by the number of distance-intervals along the y-axis.

The distance-intervals on the x-axis do not have to be the same as the distance-intervals on the y-axis. The one might be a metre while the other is a foot. If both intervals were a metre, say d, and the number of distance-intervals along each axis was 2, the rectangle would be a square and the area would be $2d$ by $2d$, which is $4d^2$. However, if the distance-interval on the x-axis was a foot, the arithmetic would be the same i.e. 2 x 2 which equals 4, but the area of each unit would be a metre by a foot or a ft.metre. The rectangle would have an area of 4 ft.metres.

Since a foot is a known proportion of a metre, say expressed by k i.e. the distance-interval on the x-axis becomes kd, the mixture of units could be reconciled by introducing k as a constant. Constants are numbers associated with particular variables to bring them into line with other units, and so the answer then becomes $4\mathrm{k}d^2$ metres. If the constant k is associated with the x-axis, it cannot generally be treated as if it were associated with the y-axis and vice versa, though in this particular case it does not affect the result. The only condition is that the two axes must be orthogonal for the arithmetic to hold.

The definition of the distance-interval was developed above first in tangible terms as the interval between two objects (trees etc), and then mathematically as the interval between two conceptual points. The simplest definition for physics may be the interval between two particles, where a particle is something small but potentially tangible, such as a fundamental particle, but still far enough from reality to permit detachment in the analysis.

Whatever choice we make, the unavoidable corollary of the argument is that between the two particles there is nothing. There is no stiff rod linking them which could expand or shrink. Thus distance is not a physical phenomenon in the sense of an object or process to be managed, but a useful concept for communication. The two particles may be further apart or closer together, but that is nothing to do with dilation or shrinking of distance per se. What must have happened is that some physical process has moved them closer together or further apart by the use of energy, and this is the process to investigate. In physics there is no such thing as distance as an invisible, infinitely long rod, but only distance-intervals.

The next stage in the argument is to show how this matches, and indeed is vital to, Newton's mathematical physics. But first it is necessary to spell out the assumptions which are inherent in the mathematics themselves.

C. Arithmetic, Algebra and Calculus

Numbers are necessary to physics as the results of measurements. The manipulation of numbers therefore, which is arithmetic, is necessary to assemble the measurements into a conclusion. We showed above in the discussion of area that the arithmetic can be separated from distance-intervals in the manipulation of variables. This is because numbers have no dimensions in themselves. They can be added, subtracted, multiplied and divided, as everybody knows, and they can be raised to higher powers as in squares and cubes, so that 2 can become 2^3. They can also cancel out in fractions in which they appear in both numerator and denominator. Thus 2 in a numerator is exactly cancelled out by 2 in the denominator, because they are the same universal species i.e. numbers.

Algebra uses symbols such as x and y in equations as substitutes for numbers in mathematical manipulation on the express condition that they can be re-substituted by numbers at any time. These symbols are called variables. They can be associated with numbers e.g. $2x$ or $3y$, and these can be added, subtracted, multiplied, divided and raised to higher powers such as x^3. However, the variables can be cancelled out only with themselves, because x represents not only a number, but also a number which is a member of a particular species; it is a number of the x kind or the y kind. Thus $4x$ divided by $2x$ can be cancelled out to give 2, because x in the numerator cancels out x in the denominator. By contrast, if a fraction contains mixed 'species', say $4x$ divided by $2y$, the numerals can be cancelled out to give 2 but the separate species x and y remain, and so the result has to be left as $2x$ divided by y.

Describing the variables x and y as different species of numbers is another way of saying that they are separate or orthogonal, to use graphical terminology. This means that an interval of the x species contains no part of an interval of the y species and vice versa. The only relationship between the two species is contained within the equation which links them. Furthermore the symbols x and y have to be substitutable by numbers when moving from general manipulation to specific solutions. So if the value of y is a function of x, each x can be replaced by a number every time it occurs in an equation. The results can then be simplified arithmetically to give the numerical value of y for that particular value of x.

Reducing algebraic symbols to numbers is exactly compatible with the analysis developed above that x and y in physics mean numbers of identical, contiguous distance-intervals. This was shown to be a requirement of the physics, and now it is seen to be necessary condition of the algebra. If intervals of distance cannot be assigned a number, which is what measuring in standard, contiguous distance-intervals does, then the assumptions of algebra are violated. However convenient it is to ignore it for some purposes, if the symbols do not result in numbers, there can be no algebra.

This ceases to be a pedantic argument when a theory decides for the basis of analysis that ‘axes’, which are purely notional, have some mysterious property of being elastically expandable or shrinkable in the same model. The length of distance-intervals may be chosen to suit the analysis, because as shown above, there is nothing within the interval, but just the ‘particles’ at beginning and end of the interval. But what is not permissible is to assert that the ‘nothing’ in the interval should cause the ‘particles’ to move apart, especially in a variable way during the same operation. This is equivalent in algebraic terms to saying that you can choose any number you like at a particular stage of a process to suit the model.

There is a further requirement for distance-intervals in the mathematical technique of calculus, which is used for describing changing systems. If you have an equation that relates the value of a variable y to the value of a variable x, it is useful to derive a further equation which describes the way in which it varies, rather than draw it out as a graph or calculate the value of y point by point. The mathematical method for approaching the problem is to evaluate the change in the value of the variable y which results from a change in the value of x at any point on the curve.

The change in the value of the variable y is designated Δy. The change in the value of the variable x is designated Δx. The required result is the ratio of these two, which is normally written as $\mathrm{d}y/\mathrm{d}x$. If the change in the value of x is large, it gives a change in the value of y that is only an average of the change around the centre point, because it bridges the curve, which disguises its eventual trend. This is resolved by letting the change in x, which is Δx, tend to zero, which in effect evaluates the change at a point. The term Δx cannot be reduced to zero, or there will be no change in y, which makes the exercise pointless, but if the value of Δx only tends to zero without actually becoming zero, the ratio of Δy to Δx is meaningful at that point. In effect the standard contiguous distance-interval along the x-axis is reduced so much that the notional points at each end tend to become one point, but not quite. This is not a procedure which can be carried out on conceptual axes on which the ‘nothing’ between points dilates or shrinks during a process to suit the model.

The result of this analysis is that both algebra and the differential calculus are seen to require that measurements along the x and y axes must be treated as numbers of distance-intervals. The terms x and y simply designate species of distance-interval to which the numbers refer. If distance-intervals vary in any particular direction with velocity, for instance, we may have to have a new velocity-based algebra to describe it! Moreover, intervals have to be able to take any size we choose, and so there is no minimum distance-interval; if there were, it could not tend to zero. In other words, there is no quantum of distance.

D. Time

The preceding analysis prepares the way for the discussion of time. All life on Earth is affected by the passage of time. There seems to be a clock built into all life forms which runs on diurnal timekeeping i.e. we recognise day and night even if we cannot see it. If we measure the time which elapses between successive mid-days, we find that it varies systematically from day to day throughout the year. There was a time when this would have been ascribed to Apollo's chariot of fire speeding up or slowing down across the sky, which one might think would be quite a good definition of time-dilation.

For most of man's time on Earth this hardly mattered; indeed it might scarcely have been noticed. Things began to change when mechanical clocks were used to wake monks so that they could say their prayers at the correct time in the early morning. All the clocks kept different times from east to west and from day to day when they were calibrated against the sundial, but it still did not much matter.

Change came when navigators on the high seas needed to know their longitude with precision. The source of the systematic variation was identified by Flamsteed: the Earth's orbit is an ellipse, not a circle, which means its speed in orbit varies; and the Earth's axis is not perpendicular to the orbit. Combining these two effects gives a curve that predicts the time when the Sun is at its highest on each day which matches the observations. This enabled mariners to correct their measurements with an equation called the Equation of Time, still given in recent Reeds Nautical Almanacs. But the real crunch came with the invention of the railway and its thermodynamic steam engines. Their timetables had to be consistent across the country if trains were not to be missed, and so time was redefined on the basis of the year to eliminate diurnal variation. Later even greater precision was obtained with atomic clocks, which showed that years too varied slightly but systematically in length because of precession of the Earth's orbit. So we feel that we know quite a lot about time.

However, all the above concerns not time in the sense of the nature of time, but time-intervals. Days and years are time-intervals. When we divide days into hours, minutes and seconds by the Babylon system of reckoning in 60s, we arrive at the scientists' time-interval which is the second. But all the different methods of time-keeping described above would have given different lengths of second, sometimes differing from day to day because the day varied in length. In fact the standard time-interval, the second, varies with the natural phenomenon used to measure it. If the phenomenon is electromagnetic, it may even vary from place to place in the Universe. So which is correct, and does it tell us anything about time? The preceding analysis of distance showed that intervals along an axis say nothing about the nature of the axis. We need to move to a general mathematical model.

As living creatures we sense time passing and observe changes in the environment around us, but we cannot see forward into the future, only back along the time-line to log what happened and when it happened i.e. the series of events. We start at a particular time in the past and count forward from it, day by day, which is in effect the calendar. This provides us with a degree of freedom, exactly analogous to the point of origin which we discussed with respect to distance. The number of years since that time is simply the number of orbits of the Earth around the Sun, and the number of days is a matter of counting the times the Sun has risen and set. It is the varying length of seconds within days which is the problem, because we need to be able to measure constant, universal time-periods for our modern way of life.

We have solved this by making clocks, which produce regular time-intervals based on specific physical phenomena, like the swing of a pendulum or the tick of a watch, but each new advance has shown the deficiencies of the technology that went before. Most recently the atomic clock has superseded all the others for timekeeping, but it too shows variation, though the cause is a matter of some dispute. All of this sheds light on time-intervals but none on time itself, which takes us back to the beginning again.

The problem of the nature of time has been addressed in my previous analysis by making a clock based on radioactive decay. This uses a material containing radioactive nuclei which decay in what are called decay-events or more simply ‘sparks’, from the method of detection. As far as is known, the phenomenon of radioactive decay in bulk material is not influenced by any of the usual conditions such as heat and pressure. Each radioactive nucleus of the same species has the same probability of decaying and emitting a spark, and it may decay while being observed, but it may not. The rate of decay of the bulk material therefore depends only on the number of radioactive nuclei present. Since each decay-event leaves one less radioactive nucleus, the number of radioactive nuclei in the material, and hence the number of sparks emitted, decreases exponentially. This has been verified experimentally by following the progress of decay of radioactive materials.

This phenomenon can be used as the basis of a radioactive clock. The parameters of exponential decay can be determined by observing the number of sparks emitted over a period. An interval of time may be chosen by counting a suitable number of sparks, say a million, from the time at which the clock is deemed to start. The number of sparks which will be emitted in the next time-interval of the same length and contiguous with the first can be calculated from the parameters of the exponential curve. In fact the decreasing spark count at all the subsequent, equal, contiguous time-intervals throughout the decay process can be calculated in advance i.e. predicted. This is an example of predicting the future that really works.

The relevance of the radioactive clock to the argument is not in the performance of the clock, but in what it reveals about the nature of time. A decay-event is an instantaneous event; it takes no time because either the spark is emitted or it is not. The decay-event is therefore no more than a point on the time-axis. Since each radioactive nucleus decays when it is ready, independently of the other radioactive nuclei around it, and therefore independently of what has gone before, decay-events must be independent events, similarly unassociated with each other. Thus between any two decay-events there is nothing.

Dilation of time on this clock would require the intervals between sparks, which are ‘nothing’, to expand or shrink. Time-dilation by this clock is therefore impossible, and the time -intervals in which it is calibrated are immutable; they may be called absolute intervals of time.

The corollary is that time, like distance, does not exist as a physical phenomenon. Time is a convenient concept not a silken thread. What we observe is events, between which are time-intervals, and it is the length of these intervals which can be measured. In the radioactive clock the events are randomly generated by decay, and the numbers are handled statistically. Clocks based on other physical phenomena provide a continuous series of events or ‘ticks’ with equal time-intervals between them against which the event of interest may be matched. Time-intervals on the clock can be added arithmetically, but the intervals are numbers of the time sort rather than phenomena in their own right. The events are the phenomena, both the ‘ticks’ of the clock and the event being timed.

There is no reason why numbers of the time species should not be added, subtracted, multiplied, divided, raised to powers etc, just like any other algebraic variable and with the same caveats, because they are removed from the physical world. It is the processes that they help to describe which are the physical world.

Time-intervals can be of any length of our choosing for analytical purposes. We cannot choose the length of years or days; that has already been decided for us. However, we can choose the length of time-intervals by which to describe them, say, hours, minutes or seconds. Alternatively we can choose some other length of time-interval for a specific purpose, like the million sparks for the first time-interval of the radioactive clock described above.

The corollary is that there is no minimum length of time-interval. There is no quantum of time-interval, because there is nothing in the interval, and the requirement of the calculus that Δt tend to zero is met. Neither is there a quantum of time; in view of the above analysis, that would be meaningless.

E. Mass

Mass is different in kind from distance and time. Mass is in fact a term invented by Newton as a constant of proportionality to link two different phenomena: the force of gravity and the force which causes acceleration. We cannot experience mass in the same way that we experience time and distance. Indeed we shall see that time and distance are used to define mass in the absence of something tangible. What we experience is weight, which is the gravitational attraction between bodies and the Earth, and force, which is applied by one body to another and involves a change of momentum.

Newton observed that different weights, when dropped from the same height, reached the ground at the same time. They fell because of their gravitational attraction to the Earth. They arrived at the same time because the gravitational attraction was proportional to their weight i.e. the more they weighed, the greater the gravitational attraction, which is something of a tautology. However, he also observed that the acceleration of bodies to Earth was independent of their bulk; a bag of feathers fell at the same rate as a cannonball of the same weight, as compared directly in a balance. He concluded from this that there was some underlying property of bodies which he called mass; the force of gravitational attraction between bodies was proportional to their mass.

The next step in his analysis was to observe that bodies experience forces apparently independently of gravitational attraction, for instance when we push a cart, and the result of the application of force was acceleration of the body to which it was applied. This was force transmitted by contact rather than at a distance through space. In line with his previous analysis the cart had mass, and the magnitude of the force pushing it needed to be proportional to the mass i.e. the greater the mass, the more push it required. However, in the case of the cart it was also possible to produce different levels of acceleration, depending on how hard you pushed, unlike the experiment with gravity where acceleration was fixed by the mass of the Earth. His conclusion was that the acceleration produced was proportional to the force applied, which can equally be stated as force was proportional to acceleration. Thus force was equal to mass multiplied by acceleration in suitable units, which is now his Second Law of Motion. As stated above, mass as such cannot be experienced, but acceleration is measured in terms of distance-intervals and time-intervals, which can certainly be measured directly. Mass is therefore being defined in terms of distance-intervals and time-intervals.

What was ignored was that weight can be experienced without any motion at all, let alone acceleration, as for instance when you sit on a chair. This has been accommodated in physics by the term ‘rest mass’, though why the rest mass is identical to the mass defined by acceleration has been more difficult to explain. It also ignores the question of inertia. If a cart needs pushing to cause it to accelerate, what is the force which is restraining it, leave aside friction in the bearings, air resistance etc, or more specifically, what is the origin of its inertia? There has to be a force to overcome, or the cart would simply glide away at increasing velocity untouched.

Thus the analysis of mass is complicated by the way it evolved. In some ways the term mass is a proxy for what we feel, which is force. There is force acting at a distance caused by gravitational attraction; we do not know what gravity is, but we describe it by its effect. Then there is force caused by collision of masses, which is more comprehensible because it involves physical contact which we can experience for ourselves. Finally there is force which we experience as weight when there is direct contact of the two masses but no motion, like the weight of a body on the surface of the Earth. Newton lumped all these forces together and attributed them to the property of mass.

Then there is the complication that we live in a particulate Universe. According to my previous analyses, the unique property of particles is that they have mass (and the unique property of mass is that it is always associated with particles!). When large numbers of particles come together, they form what we call bodies. The particles of which bodies are composed are atoms, consisting of positive nuclei surrounded by negative electrons which bind the whole together. These are also particles, and if other entities are found at a still more fundamental level, they will certainly be particles too. Thus bodies always have a sheath of electrons, which is the point of contact between atoms, even though they may be electrically neutral overall. Bodies which are large agglomerates of atoms, such as the materials of the world which we see around us, behave quite differently from the particles of which they are composed when these are separate individuals, not least because the electric charges in these particles are not neutralised, and so they become much more significant in relation to their mass. This is the difference between bulk materials and fundamental particles. The corollary is that there is a size of agglomerate at which bulk behaviour gives way to particle behaviour.

Gravitational attraction exists between all pairs of bodies in the Universe. There is no reason to believe that gravitational attraction between two bodies ceases to exist beyond a certain distance, though it is certainly diminished. If gravity did cease to operate, the Solar System and the Milky Way would not exist. Thus every body is attracted gravitationally by every other body in the Universe, though obviously not to the same extent. Nor is there is any reason to believe that the presence of a third body affects the force of gravitational attraction between the other two. As a result there is no shielding from gravitational attraction; you cannot interpose a third body as a gravity-shield between two bodies and nullify their gravitational attraction for each other. Gravitational attraction is all from one body to one body. Every body is gravitationally attracted to varying extents to every other body in the Universe on a one to one basis, which means that no body can travel in the straight line beloved of textbooks. Forces of gravitational attraction changing en route mean that all bodies waltz around each other, though their partners may be a long way off. The straight line of orthogonal axes of distance is necessary to detect any deviation from it. The one to one relationship indicates something significant about the underlying nature of the phenomenon. For instance, energy cannot be at the root of the phenomenon, because no body could have that much energy,. Finally, all forces which are applied in the processes of the Universe, whether natural or manmade, operate in the presence of and in addition to these omnipresent gravitational forces. Gravitational forces cannot be switched off.

Measurements in the laboratory showed that the force of gravitational attraction between two objects decreased with the square of the distance between them. Newton and perhaps others calculated that the orbits of planets around the Sun were compatible with an inverse square law, and so his model made good predictions at least up to the boundaries of the Solar System. He then went on to assert that it was in fact Universal, though of course his concept of the Universe was rather different from our own today.

Thus Newton's basic assumption was that the gravitational attraction between an apple and the Earth was the same phenomenon as the force of attraction between the Earth and the Moon, and between the Earth and the Sun. In each case his model was that the force acting at a distance was proportional to the masses of the pair of bodies, whatever their magnitude. He also assumed that force generally was proportional to mass when one body collided with another, and when one mass impinged on another by physical contact without movement, and the whole of physics vindicated his hypothesis up to the discovery of fundamental particles, even though its basis was not fully understood.

The place to start the analysis of mass in this paper is with the sort of bodies of matter which Newton had in mind in his mechanics. First we need a degree of freedom to do for mass what the origin does for distance and the calendar does for time. We cannot choose a point of no mass, in the same way that we can choose a point of zero distance i.e. the origin from which we can the count distance-intervals, or a zero time at which we start the stopwatch. The point of zero mass would be irrelevant, and the first meaningful quantity of mass is that of the smallest fundamental particle, a quantum of mass, if you like. Analysis has to be done by comparison with this mass or some more convenient multiple of it. Moreover, gravitational attraction by definition involves two bodies; it is a two-sided force, and so we have to agree a standard for two masses simultaneously. In fact all forces are two-sided except in textbooks, because any body which applies a force to another must simultaneously receive an equal and opposite force itself. To coin a phrase, for every action there is an equal and opposite reaction.

The first of the standard units of mass has been chosen for convenience and durability as a kilogramme of platinum, where the kilogramme is a quantity selected arbitrarily. The weight of the kilogramme in a particular location in Paris was designated the standard of mass, and it was then used to provided a standard for comparison from which all other kilogrammes of mass could be made. But there had to be a second standard mass to complete the gravitational couple, and that was in effect the mass of the Earth as detected at this particular location. The effective mass of the Earth is influenced by unusually large masses in the vicinity, such as a large mountain or mass of rock below the surface. This means that the weight of the standard kilogramme would vary slightly in different locations on the surface of the Earth, and it would certainly be quite different if it were transported to the Moon, even though the kilogramme of mass remained constant. That is the whole point of mass.

Mass must be additive. If you add a mass to the standard kilogramme in the shape of another piece of platinum, its mass must increase in proportion, as must its force of attraction for another body. So also must its weight at any particular location. The corollary is that it could also be divided into a thousand smaller units i.e. grammes, and so on until you reached a single fundamental particle, which cannot be divided because it is a fundamental building block; that is what fundamental means.

We know that the standard kilogramme of mass must contain a specific number of platinum atoms, and so it is tempting to use that number as a definition of the kilogram of mass everywhere else. However, that does nothing to help the reconciliation of rest mass and what is called inertial mass, and so it needs a deeper understanding.

When the inverse-square law is applied to calculate the force of gravitational attraction, we need to measure the distance between masses. The question then is: the distance between what and what, because bodies come in all shapes and sizes? Large masses are considered to have a centre of gravity which provides a point from which to measure. It becomes less obvious when the mass under consideration is an atom, where the nucleus contains almost all the mass, the point of contact between atoms is the electric shell far away from the nucleus and the rest of the atom is void. This is the problem in getting down to fundamentals. According to the equation, the force of gravitational attraction becomes infinite when the distance between masses is zero i.e. when they are in contact. This cannot be valid, because after all this time in the existence of the Universe, it would consist of one large lump as free particles came into contact and became stuck to each other for ever after. The inverse-square law clearly applies to the sort of size of mass which Newton intended. Somewhere between that and the size of fundamental particles some other mechanism must begin to operate. This is not surprising in a phenomenon which has to rely on comparison for its characterisation, because that in itself indicates incomplete understanding.

Everything written above in this section forms the backdrop for mathematical analysis. First we can reconcile the variable which we call mass with the requirements of algebra for Newton’s sort of mass, the bodies which we come across at the human level of observation from very small grains of sand up to planets. We should think carefully before going beyond planets, because the model has not been validated for the motion of bodies outside the Solar System. It was shown above that the algebraic treatment of a variable in Newton’s mathematical physics requires that it should be composed of numbers of intervals which are identical, sequential and of a distinct species i.e. mass. In the case of mass the intervals can range down to fundamental particle level, provided we agree not to use them for such particles as a self-imposed limit. Thus the mass-axis can start at very nearly zero for the purposes of Newtonian mathematical physics.

Intervals of mass can then be chosen along the axis at whatever level of mass suits our purpose, say kilogrammes, grammes, microgrammes etc. Provided everybody agrees on the definition of the kilogramme given above, the axis can then be considered as numbers of intervals of the mass kind i.e. mass-intervals. All the manipulations of algebra described previously are then open to us.

There is a further complication in the form of the speed of light. Not only does this constant apply to light in vacuo, but it also constitutes a barrier to the velocity of mass. The Theory of Relativity proposes that the reason for this is that mass actually increases with velocity according to a curve with the shape of a hyperbola, so that it becomes very much greater as the speed of light is approached. The speed of light is in effect an asymptote which cannot be exceeded. This is part of Einstein’s attempt to maintain the same form of equations at velocities near the speed of light as apply under what might be called Newtonian conditions. However, the other facets of his model also require that time also slows down eventually to a standstill and distances lengthen until they become infinite. This is a use of the axes and variables of algebra which we have disproved in this paper. The axes of Newton’s mathematical physics are not phenomena but convenient concepts. Intervals along the axes are by numbers of a particular species. There is nothing in the intervals to dilate. Algebra requires numbers of intervals, in this case numbers of the mass-sort.

However, the observation remains that mass becomes increasingly difficult to accelerate as the speed of light is approached, and so an explanation is required. My alternative to Relativity, which I proposed in previous papers, is to modify Newton’s Second Law of Motion by inserting into the equation a factor R, the Inertial Resistance Factor. This factor describes the increasing force which has to be overcome in accelerating mass through the medium of space. An increasing fraction of the energy required to cause acceleration of the mass is dissipated in the form of electromagnetic radiation as the speed of light is approached, until at the speed of light it is all dissipated in this way, so that no further acceleration is possible. The shape of this parameter R is also a hyperbola with respect to velocity, and its parameters have been calculated in the previous papers.

Introduction of the Inertial Resistance Factor R into Newton's Second Law obviates the need to postulate dilation of time, distance and mass. The algebra of Newton's mathematical physics stands. Furthermore it explains why rest mass is identical to inertial mass, which must be a relief to physicists everywhere!

However, use of the mathematical technique of calculus is a different matter. If the interval of a variable cannot tend to zero on principle, which is what we have postulated, a good deal of circumspection is required before applying differentiation if it is to give meaningful results. The least one can say is that the range must be well away from the particle region, which was the condition imposed above. Particles require a different treatment.

The combined masses of particles are not simply additions, which is what the Newtonian analysis of mass implies. Particles do not attach themselves to one another in the way that lumps of platinum may be fused together. Their tendency is to go into orbit around each other. This might be true of particles of 'pure' mass, if they could be observed, but in fact particles at this level carry electric charges; it might be expected that charges would repel if they were like, but particles do not fuse even if their charges are opposite, which one would have thought would promote the process.

Thus electrons are negatively charged particles with mass, and protons are positively charged particles with much greater mass, about 1870 times greater. When they come together the electron goes into orbit around the proton to form an atom, in this case a hydrogen atom. It does not stick to the surface of the proton. If adhesion of this sort were the rule, there would be no free electrons and no free protons in the Universe and very little of what we know as hydrogen. In fact what we have is very large proportion of hydrogen, a substantial proportion of helium and small proportions of heavier atoms.

One reason may be that electrons, being lighter, have much greater velocities than protons and other positively charged particles in the form of nuclei. In effect they are kept separate by their momentum i.e. their mass, and so they never actually land, though it is not clear how we would know if they did. Electrons are thought to orbit nuclei in the 'chemical' orbits at about a third of the speed of light. When on an entirely different scale manmade and natural satellites enter into orbit around much larger bodies like the planets including Earth, this is thought to be a simple example of Newtonian mechanics.

Fundamental particles of like charge may simply avoid each other while finding their way into orbit. My previous paper on the structure of the atom proposes that successive electrons do just this around nuclei of increasing atomic mass. The first electron finds its own orbit. Since electrons are all identical, the second electron finds the same orbit, but in a diametrically opposite position i.e. as far as away as possible from the first at all times, because of the mutual repulsion of their negative charges. The same may be true of electrons within the nucleus, which I propose as an alternative explanation of the phenomenon of intranuclear neutrons. These are in fact intranuclear electrons in close orbit around protons, and in order to form stable structures they must be orbiting at close to the speed of light, even faster than extranuclear or ‘chemical bonding’ electrons.

The corollary of this is that the algebra of Newtonian physics is not appropriate to describe these dynamic systems, because of difficulties of characterisation on this subatomic scale. They must be described by mathematical methods which are appropriate for orbits in systems which can be observed only indirectly.

Quanta of mass are implicit in the whole concept of fundamental particles, both for particles which are known and for any which may be discovered in future, and it is true that integers are appropriate to label orbits in the absence of direct observations, since they are complete circuits. Different integers may also be required to describe orbits of successive additions of particles to the same orbit, because the particles interact with each other as well as the central mass. However, these are mathematical devices; there is no reason to think that they describe what is actually happening, especially if they postulate that one electron is in some way different from the next. Any difference is one of successive additions to a system, not of kind.

Finally it must be observed that fundamental particles are charged in a way that larger masses are not. Large masses are neutral because the opposite charges on protons and electrons of which atoms are composed cancel each other out, although bodies must have a skin of electrons, because they form the outside of atoms. By contrast, the electric charge on an individual proton or electron is much more significant in relation to the particle’s mass, assuming that the distinction makes sense.

This distinction may have some bearing on the phenomenon of mass defects, which according to Einstein’s equation represents an energy difference in nuclei compared with their individual nucleons. Much analysis is of necessity carried out by indirect means; no one has weighed a bottle of separated nucleons and compared the results with a bottle containing the same number of nucleons combined in the form of nuclei. Such a technique is mass spectrometry, in which charged particles are accelerated, and deflected by a magnet. The mass of the particle is calculated from the magnitude of the deflection, and the resolution is so good that even the smallest differences of mass can be detected. However, the technique is basically comparative; turning these comparisons into absolute rest masses, which the mass defect relationship requires, begs many of the questions raised above concerning the interaction of the properties of mass and charge of a particle.

At the other end of the scale there is what happens beyond the limits of the Solar System. It is not self-evident that Newton’s model should apply homogeneously across the entire Universe, in spite of his claim to an equation for Universal Gravitation. Astronomical mass-intervals are well outside the ‘tangible’ range, and possibly outside the range at which his model can be tested by predictions. In fact calculations using his equation suggest that as much as 96% of the mass of the Universe is not accounted for by what can be 'seen'; hence the theories of dark matter and dark energy. Stellar orbits may be observed directly and translated into gravitational attraction and from that into mass, but it cannot be ruled out that there may be other phenomena which we are not at present able to detect. Other methods of estimating mass rely on measurements of luminosity in the empirical mass-luminosity relation, or on the types of spectra from stars. However, such methods depend ultimately on the quality of light received after its journey through space for a long time, and it is possible that it may have been affected en route, not its velocity but its other properties such as frequency, polarisation and direction. These may affect the translation of measurements of electromagnetic radiation into intervals of mass. They would be extremely difficult to detect because it all happens at a great distance, and the only means of covering the distance is light, which is therefore both the solution and the problem.

F. Bulk electrons

Reference has been made in the paper to the difference between the bulk properties of mass which we call bodies, and mass in the form of individual particles. The transition from one to the other needs an alternative model, and therefore a change from the mathematics of algebraic variables to the dynamics of orbital interactions.

The negative charge of the electron gives a particularly vivid illustration of this. Electrons orbit the nucleus of an atom, which requires a form of mathematics that can describe orbits, whether algebra or quantum mechanics, as argued above. However, going back to the early days of electricity, it is known that an ebonite rod rubbed with fur is left with a negative charge i.e. a surplus of electrons which is called 'static' electricity. When the charged rod is brought close to one end of an insulated metal rod, electrons on the metal surface are chased down to the opposite end, leaving the end close to the ebonite positive i.e. with a deficiency of electrons. This phenomenon occurs with one electron or many individual electrons, resulting in regions of static electricity on the surface. Everyone has experience of static electricity on synthetic materials, on insulated vehicles such as cars etc. Everyone is familiar with spark-producing Van der Graaff machines. There seems to be a certain unpredictability about electrons because of their very mobility; they move to a position which suits them best, speeding around a nucleus in one case and stationary or static at the pole of a conductor in another etc. The same sort of unpredictability is observed when an electron is fired into a matrix of atoms in the form of a thin metallic sheet. You cannot be quite sure of the direction in which it will travel after it hits the surface. My previous analysis suggests that this unpredictability arises from the vagaries of orbital interactions.

Contrast this with electric current. What we normally describe as electricity is very large numbers of electrons moving along a conductor in the same direction under the influence of a potential difference i.e. a bulk phenomenon. As every student knows, the equation which describes the system is that the quantity of electricity which passes along the conductor in unit time is proportional to the applied potential difference, or voltage, and inversely proportional to the resistance of the conductor. It is all perfectly predictable by a very simple equation. The mathematics is chosen to suit the scale of the model.

One final example concerns the force of restitution when a bar of material is compressed by just enough applied force to permit full recovery of its shape. The result of compression is a squashing of the electron shells of the atoms of which the bar is composed; they are no longer spheres but ellipsoids. The force of restitution which limits the distortion is the attraction of individual electrons to their parent nuclei, and the repulsion of individual electrons for each other, and yet they behave as a shell. When the compressive force is removed, the electrons pull the atom back into shape in the reverse process so as to reform their spherical shell. The same mechanism must apply to weight.

It is a matter of conjecture how the distortion of the orbits of fifty or more individual electrons could take place in quantum steps, while retaining their integrity as a shell. It is no less conjectural how they could each find their way back again in quantum steps when the stress is removed.

G. Conclusions

The dimensions of Newtonian physics are concepts, not phenomena. Time and distance are the elemental dimensions which we can verify by our senses. Mass is more difficult because it was Newton's way of representing force, which we can also feel, starting with the force of gravitational attraction. Postulating the property of mass enabled him to describe the mechanics of the world around him and extend it up into the heavens so well that the motion of the planets around the Sun could be accurately predicted.

It is not obvious why the variables of his physics could be imported wholesale into algebraic equations which were themselves a subject of debate at the time, because it can lead to terms such as 'time to the power 2', or t^2, and later to 'temperature to the power 4', or T^4. Distance squared or cubed is reasonable: we can conceive of areas and volumes, even if they are no more than that i.e. conceptual. But higher algebraic powers of time and temperature offend against common sense. Nevertheless they work! But why?

This is the sort of 'philosophical' question which irritates most physicists considerably, but it is important to think it through as clearly as possible, because the next step has been extension onto areas in which it is unwarranted, and to coin a phrase has led men into absurdity.

I have tackled the problem by going back to the assumptions which are inherent in the mathematics. It is easy to gloss over the fundamentals of algebra and Cartesian co-ordinate geometry which are so engrained in our thinking. We begin by substituting symbols for numbers in mathematical processes, so that writing them down in equations allows much more facility in handling problems conceptually. Algebra allows generalisation of relationships between variables, which frees the reasoning from specific systems, and permits problems of a new level of complexity to be solved. It also allowed the development of differential calculus, not necessarily by Newton but certainly by Leibniz, which later made it possible to deal with the dynamics of systems, from engineering to space flight.

Variables in algebra have no limits unless specified and this carries over into co-ordinate geometry, where the *x*-axis and *y*-axis may be drawn without scales to differentiate them, and so they appear infinitely long by implication. However, the basic assumption of algebra which has been forgotten is that symbols are a substitute for number, and so numbers must be substitutable for symbols at every point, if required. Assigning numbers to variables is possible only if the variables or axes are marked out in intervals. We may choose any intervals we need for a particular purpose, but they must be identical, sequential, contiguous and orthogonal to be meaningful. They cannot carelessly drift off into infinity.

The processes of algebra may then be construed as handling numbers of intervals of a particular species or along a particular axis i.e. *x* or *y* etc. In this form they are not interchangeable with numbers of a different species, because this signifies different intervals in kind. They are subject to the rules of manipulation of algebra, which are the rules of arithmetic with constraints added to take account of this. In similar vein it might be considered that the numbers used in arithmetic are also intervals of the same species, but without specifying which, so that you can add your own: bushels of wheat etc. We call these arithmetic intervals units.

The point about intervals designated by points on an axis is that they have a point at the beginning and a point at the end but nothing in between. We may be deceived into thinking that there is a bit of *x* inside the *x*-interval, but we must remember that the term *x* is no more than the description of a species of interval. There is no *x*-axis in the sense of a line; this is no more than a visual aid. If we want to refer to points inside the interval which we first selected, we choose a new interval. There is nothing inside an interval which represents a phenomenon.

From this unlikely observation we can begin to resolve the problem of reconciling mathematical physics with algebra, and with some unexpected conclusions. We can use the symbol *t* in equations raised to the power 2, because it represents a number of intervals of the time-sort. Since it is merely a number, it can be used in any form consistent with algebraic manipulation. The same is true of all the variables used in physics, say mass, length, temperature etc. These are intervals of the mass-species, length-species, temperature-species etc. This is in complete accord with the rule in physics that dimensions must be consistent. It is also compatible with the use of constants in equations to enable variables to be stated in consistent terms. The proviso with constants is that they must represent numbers relating to specific species of variable. They may be numbers, but they do not have the anonymity of arithmetic until both they and the variables to which they refer are substituted by numbers. As long as the rules are kept, it all works theoretically (philosophically?), and we know it works in practice.

However, the startling conclusion that comes out of all this is that there is no such thing as time. Nor is there any such thing as distance. The emphasis is on the word ‘thing’. They are general concepts that we all use for our convenience, but they are not phenomena, and so they cannot be manipulated by the methods of algebra. What algebra manipulates is in fact numbers or proxies for numbers of particular species: the *x*-sort, the *y*-sort, the *t*-sort, the *m*-sort etc. There is no silken thread of time running through the ages; time in physics is the number of time-intervals between events. Neither is there some infinitely long rod of distance; distance in physics is the number of distance-intervals between bodies or particles. And so on for all variables.

In this case there is no time or distance. Nor does the dilation of intervals make sense, because there is nothing inside an interval; that is the whole point of intervals. 'Nothing' cannot be postulated to dilate. Furthermore we can pick any size of intervals we choose to suit our purpose in any analysis; there is no minimum size or 'quantum' of time or distance. These conclusions are totally at odds with the Theory of Relativity which is therefore founded on a misuse of the mathematics as well as a misinterpretation of the observations reported previously. They are also totally at odds with quantum theory, which is an attempt to characterise systems that are far below our abilities to observe directly; what is needed is orbital mechanics. In fact it comes down to Newtonian behaviour after all, if only we could see the workings more clearly. The fact that there are no quanta of time or distance is vital to the theory of differential calculus, a technique of such wide and fundamental application.

Mass is in a different class. If we believe that all the 'tangible' world is made from particles in various sizes, according to the degree of aggregation, then there must be at least one minimum size of particle at the level of fundamental particles. In other words this decides the minimum mass-interval which is possible. We are no longer free to choose the interval we want under every circumstance.

The result is that physics has adopted an essentially a pragmatic solution. In the world in which Newtonian mechanics is applicable, we use his mathematical physics and its variables as described above. We can use differential calculus by choosing suitably large mass-intervals which cannot tend to zero, but smooth over the theoretical constraints by agreeing not to use it at the smallest mass-intervals, which are subatomic particles.

Subatomic particles need a different treatment for a number of reasons. They do not agglomerate together like larger masses in which bulk disguises the underlying reality. Instead we have to look to the mathematics of orbital systems, often without being able to model the systems themselves, because we cannot observe them directly. This may in effect be a rationalisation of the quantum approach, but it does not alter the fact that the fundamental particles are in orbits. Moreover, at this level it is not possible to separate out the effect of electric charge without recourse to observations made on bulk material, which may not be relevant to subatomic particles.

Beyond the space in which Newtonian mechanics has been tested, which is the Solar System, increasingly sophisticated measurements suggest that there is much more to be found. There are not necessarily new phenomena e.g. not a substitute for gravity, which according to some interpretations the theory of dark matter may seem to imply, but a possibility that the mathematical expression which describes gravitational attraction in the Solar System may need modifying for environments outside, because of some underlying gravitational mechanism which has not yet been discovered. This may involve all terms in the equation e.g. the inverse-square law for the decrease of gravitational attraction with distance-intervals, the linear addition of mass-intervals (or units of mass) for very large masses and the gravitational interaction between pairs of very large masses, because the distances and masses are of magnitudes so far beyond our experience.

It may be painful to apply the Socratic method of inquiry to physical science (… so you think you know what time is? … and what about distance?), but ultimately it is necessary, and may be revealing, because errors of definition lead men into absurdities, even in the pursuit of truth. There can be no theories of everything. Science develops through a process of what has been described as provisionality; present models may be good, and predict outcomes in the physical world quite well, but they will be even better later as new measurements are possible, in a never ending process.

For of one thing we may be sure: there are more things in heaven and Earth than are dreamt of in our philosophies!

A C Sturt

23 December 2007