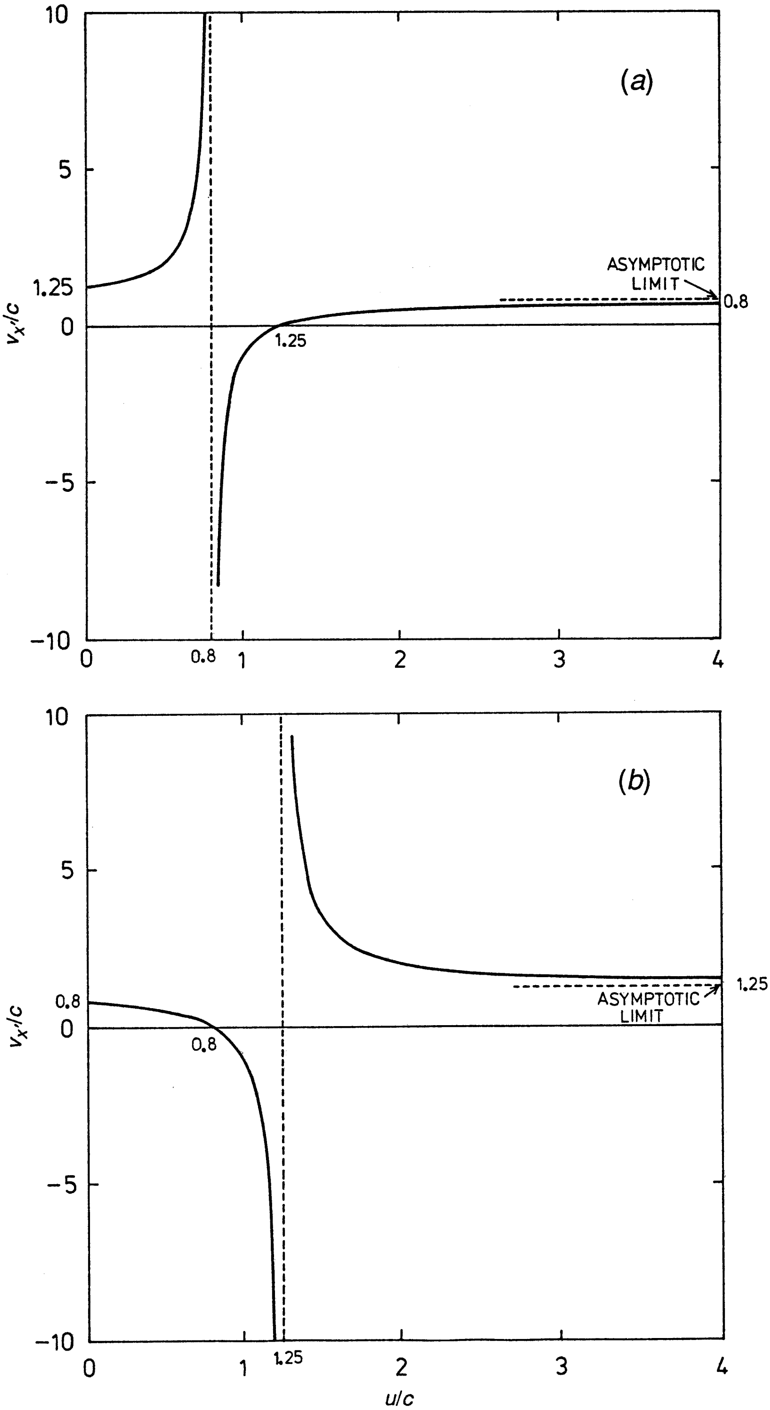

Fig. 6. Observed speed $v_{x'}$ as a function of the relative speed u/c between two inertial reference frames for a particle speed of (a) $v_x = 1\cdot 25c$ and (b) $v_x = 0\cdot 8c$.

tachyon. At $u = 0\cdot 8c$ the particle appears to be a tachyon with infinite speed. For $0\cdot 8c < u < c$ the observed speed $v_{x'}$ is negative, which indicates that the particle's apparent direction of motion has reversed and so it appears to Σ' as a switched tachyon. For $c < u < 1\cdot 25c$ the particle still appears to Σ' to have negative speed, but now $|v_{x'}| < c$ so that the particle appears to Σ' to be a bradyon. For $u = 1\cdot 25c$ the particle appears to Σ' to be a bradyon at rest, while for $u > 1\cdot 25c$ the particle appears to Σ' to be a bradyon with a positive relative speed. This indicates that an observer Σ', moving with speed $u > c$ relative to Σ, will see other particles moving with speeds greater than c (relative to Σ) as bradyons. This agrees with the discussion in Section 3, in which it was argued that tachyons would see other tachyons as bradyons, and illustrates in detail the general result given by Corben (1976). It also demonstrates how the velocity transformations automatically show the bradyonic frames in which the tachyon appears to the observer to have undergone switching, and that these frames are the ones obeying the condition $c > u > c^2/v_x$. This same condition was deduced in Section 5 using Minkowski diagrams, showing that these methods are consistent with each other in ER.

In the second example an observer Σ sees a particle travelling along the x axis with speed $v_x = 0\cdot 8c$. Observer Σ' again travels along the common x, x' axes with speed u and sees the particle as having speed $v_{x'}$. A plot of $v_{x'}$ as a function of u for this system is given in Fig. 6*b*. For $0 < u < c$ it can be seen that $v_{x'}$ exhibits all the correct behaviour according to special relativity: $v_{x'}$ is positive for $u < 0\cdot 8c$, zero for $u = 0\cdot 8c$ and negative for $0\cdot 8c < u < c$. In each of these cases Σ' sees the particle as a bradyon. For $c < u < 1\cdot 25c$ (here $1\cdot 25c$ is the dual speed) observer Σ' sees the particle as a switched tachyon. At $u = 1\cdot 25c$ the particle appears to Σ' as a tachyon with infinite speed and zero energy, while for $u > 1\cdot 25c$ the particle appears to Σ' to be an unswitched tachyon. Hence an observer travelling faster than the speed of light sees bradyons as tachyons and, depending upon the relative speed, even sees some of the bradyons as switched tachyons.

These two examples have demonstrated the mathematical condition for switching. Here v_x is the speed of the particle in the initial frame Σ, while u is the speed of the final frame Σ' relative to Σ. The particle will appear to Σ' to be switched if

$$c > u > c^2/v_x \text{ for } v_x > c \text{ and } |u| < c, \text{ or} \tag{60}$$

$$c < u < c^2/v_x \text{ for } v_x < c \text{ and } |u| > c\,. \tag{61}$$

The velocity transformations automatically showed whether the particle is switched or unswitched relative to a particular observer. However, in both examples the particle had to appear to the observer as a tachyon to be switched, even though $v_x = 1\cdot 25c$ in the first example and $v_x = 0\cdot 8c$ in the second example. The particle appeared to behave normally according to SR when its apparent speed made it appear to the final observer as a bradyon.

The velocity transformations agree with the second postulate of ER given in Section 2. Putting $v_x = c$ into (56) gives $v_{x'} = c$, regardless of whether Σ' is a bradyonic or tachyonic observer. Thus tachyonic observers will measure the speed of photons in a vacuum as being c, even though those tachyonic observers are travelling at speeds far greater than c relative to bradyonic observers. The velocity transformations can also be used to prove Corben's (1975) result that for any three inertial reference frames, the relative speeds between them are either all less than c, or two are greater than c and one is less than c.

As a tachyon appears to have infinite speed in the dual frame of a bradyonic observer, then such a tachyon may instantaneously transfer momentum and charge between two objects. This is a distinct property of tachyons and so it would be a definitive test for their existence. Further discussion of how tachyons could possibly be involved in instantaneous transfers between particles can be found in the review paper by Recami (1986). Of course, in all other bradyonic frames the tachyon has a finite transit time between two objects.

7. Rods and Clocks

Introduction

Having developed the switching principle and the γ-rule, it is now possible to examine the behaviour of tachyonic rods and clocks. As the tachyonic transformations have a similar form to the Lorentz transformations, it is expected that contraction and dilation effects also apply to tachyonic rods and clocks. Time dilation effects are apparent in Fig. 4, in which it is clear that the measured time interval between the events involving the tachyon is different for each of the observers. However, the new range of speeds means that the magnitude of γ_u is greater than 1 for $u^2 < 2c^2$ and less than 1 for $u^2 > 2c^2$. Therefore it is anticipated that some apparent differences in behaviour between tachyonic and bradyonic rods and clocks will occur. There is of course a further complication due to the possibility that the tachyonic rod or clock appears to undergo switching in some reference frames.

Both bradyonic and tachyonic observers must still use light signals to perform synchronisation of clocks and calibration of rods. This is a direct consequence of the second postulate, which states that the speed of light in free space is constant for all inertial observers. These observers cannot use tachyons to synchronise clocks for the same reason that bradyons cannot be used: the apparent velocity of the particle depends upon the velocity of the observer relative to a fixed inertial reference frame. As tachyonic observers consider themselves and each other to be bradyons which travel more slowly than the speed of light, they can use photons to communicate information to each other (Corben 1976). This means that a pair of tachyonic observers investigating tachyonic rods and clocks is equivalent to a pair of bradyonic observers investigating bradyonic rods and clocks. Therefore it only remains to determine what happens when a bradyonic observer investigates tachyonic rods and clocks.

Rods

Imagine a rod lying at rest along the x' axis of frame Σ'. The ends of the rod are at x_1' and x_2' so that its rest length is $x_2' - x_1' > 0$. Now suppose that the rod is moving with speed $u > c$ along the x-axis relative to an observer in frame Σ, so that Σ considers the rod to be a tachyonic object. The SLTs give $x_1' = i\gamma_u(x_1 - ut_1)$, $x_2' = i\gamma_u(x_2 - ut_2)$, so that $x_2' - x_1' = i\gamma_u(x_2 - x_1)$, where it is assumed that the clocks in frame Σ are synchronised so that $t_1 = t_2$ when x_1 and x_2 are measured. In the complex plane the distance between any two points z and a is $|z - a|$ (Kreyszig 1983). The modulus signs are necessary as length is always a positive quantity, regardless of the actual coordinates (real or imaginary) of the points being measured. Hence the apparent length of the tachyonic rod as viewed in bradyonic frame Σ must be $|x_2 - x_1|$, so that

$$|x_2 - x_1| = |(u^2/c^2 - 1)^{1/2}|(x_2' - x_1')\,. \tag{62}$$

The SR equivalent for a bradyonic rod is

$$x_2 - x_1 = (1 - u^2/c^2)^{1/2}(x_2' - x_1')\,. \tag{63}$$

For $c^2 < u^2 < 2c^2$ the length of the rod measured in frame Σ is shorter than its rest length in Σ', so the rod is contracted, just as it is for $u^2 < c^2$. For $u^2 = 2c^2$ the rod appears to have the same length in both frames, while for $u^2 > 2c^2$ the length of the rod appears to be dilated so that the rod is longer in Σ than it is in Σ'.

If the rod is at rest along one of the transverse axes in Σ', i.e. the y' or z' axes, then the rod's apparent length in frame Σ is the same as in Σ'. For example, if the rod is at rest along the y' axis then its length as measured by Σ' is $y_2' - y_1' > 0$. (Remember that Σ' considers the y' and z' axes to be real, even though they are imaginary for Σ.) The apparent length of the rod as measured by Σ is $y_2 - y_1 = |iy_2' - iy_1'| = y_2' - y_1'$.

Fig. 7 contains worldlines representing a rod moving with speed $v > c$ relative to a bradyonic observer Σ_o who uses axes (x_o, ict_o). The rest frame of the tachyonic rod is Σ_T'' who uses axes (x_T'', ict_T''). In such a frame the end of the rod

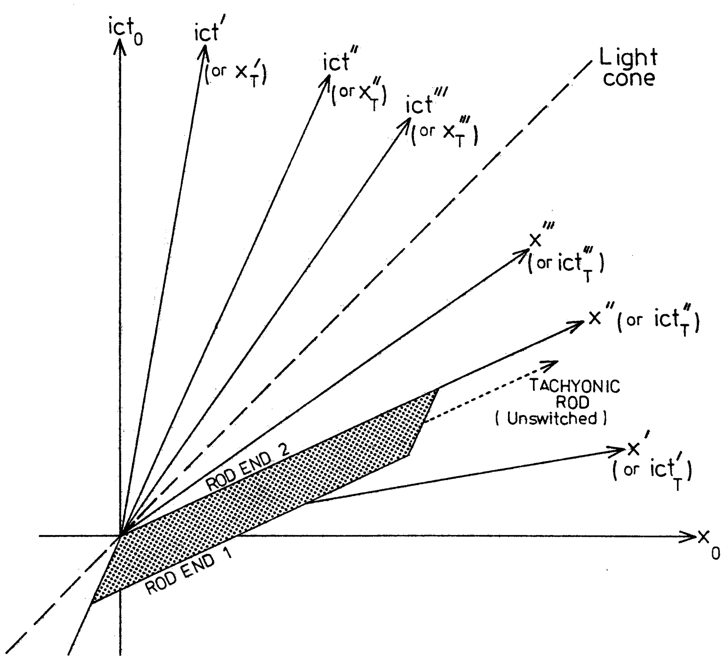

Fig. 7. Minkowski diagram showing the axes used by various observers and the worldlines of a tachyonic rod, whose rest frame is Σ_T'' in which the rod's proper length is $x_{T_2}'' - x_{T_1}'' > 0$.

labelled '2' leads the end of the rod labelled '1' so that $x''_{T_2} - x''_{T_1} > 0$. Another tachyonic observer Σ'_T using axes (x'_T, ict'_T) sees end 2 lead end 1 in the apparent direction of motion, which in this frame is in the positive x'_T direction. A third tachyonic observer Σ'''_T using axes (x'''_T, ict'''_T) considers the rod to be moving in the negative x'''_T direction, as the rod has a negative velocity in this frame due to the observer's relative speed. Observer Σ'''_T still measures $x'''_{T_2} - x'''_{T_1} > 0$, but now end 1 leads end 2 in the apparent direction of motion.

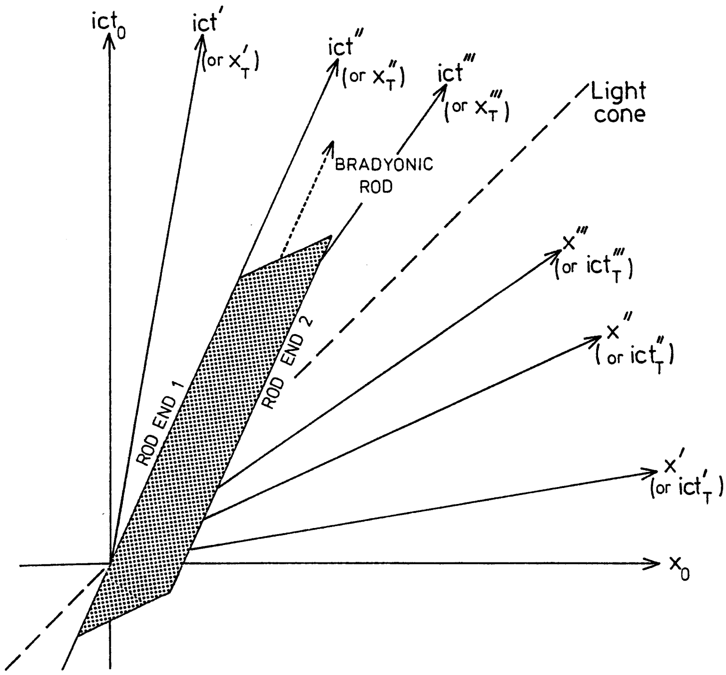

Fig. 8. Minkowski diagram showing the axes used by various observers and the worldlines of a bradyonic rod, whose rest frame is Σ''.

Now consider the bradyonic reference frames used by observers Σ', Σ'' and Σ''', who use the coordinate axes (x', ict'), (x'', ict'') and (x''', ict''') respectively. Observers Σ_o and Σ' view the tachyonic rod such that end 1 leads end 2 in the apparent direction of motion, and so $x_{o_2} - x_{o_1} < 0$ and $x'_2 - x'_1 < 0$. For observer Σ'' the length $|x''_2 - x''_1|$ is indeterminate, while observer Σ''' measures $x'''_2 - x'''_1 > 0$. Note that the tachyonic rod is unswitched in frames Σ_o and Σ', but appears to be switched in frame Σ'''. The rod appears to observers Σ_o and Σ' to be travelling with positive velocity and with end 1 leading end 2, but for the switched frame used by observer Σ''' the rod appears to be travelling in the negative x''' direction and so has negative velocity, but with $x'''_2 - x'''_1 > 0$. Hence for all bradyonic observers end 1 appears to be leading end 2 in the apparent direction of motion. Combining this result with the discussion of the apparent behaviour of the rod in tachyonic frames leads to the following conclusion: end 1 appears to lead end 2 in the apparent direction of motion in all reference frames in which the observer has a relative speed less than that of the tachyonic rod. In all frames in which the observer has a greater relative speed than that of the rod, end 2 appears to lead end 1 in the apparent direction of motion.

If the rod in Fig. 7 were travelling such that its worldlines appeared in the fourth octant of the Minkowski diagram, then the relevant observer's axes should be reflected about the ict_o axis. This gives the same results as for the tachyonic rod travelling through the first octant. If the modulus signs are removed from (62) it can be seen that the resultant sign is opposite to what one would expect from the above discussion of the tachyonic rod. This means that the SLTs should not be used just to determine which end leads the other one in any particular reference frame: a Minkowski diagram is adequate for this task.

Fig. 8 shows the worldlines of the ends of a bradyonic rod, along with the axes used by the same set of observers as in the previous figure. In this case the bradyonic observers Σ_o and Σ' see that end 2 leads end 1 such that $x_{o_2} - x_{o_1} > 0$ and $x_2' - x_1' > 0$, and that the rod moves in the positive x_o and x' directions. In frame Σ'' the rod is at rest with $x_2'' - x_1'' > 0$. In frame Σ''', which moves faster than the rod relative to frame Σ_o, the rod has negative relative speed but still has $x_2''' - x_1''' > 0$. In this frame the relative speed causes end 1 to appear to lead end 2 in the motion along the negative x''' direction.

Now consider the motion of the rod in Fig. 8 as viewed by the tachyonic observers Σ_T', Σ_T'' and Σ_T'''. In frame Σ_T' the rod appears to have positive speed, end 1 leads end 2 and $x_{T_2}' - x_{T_1}' < 0$. In frame Σ_T'' the rod appears to have infinite speed and so its length is indeterminate. In the tachyonic frame Σ_T''' the rod has undergone switching and appears to move in the negative x_T''' direction. In this case $x_{T_2}''' - x_{T_1}''' > 0$ and end 1 leads end 2 in the apparent direction of motion. Hence for all frames with a relative speed greater than that of the bradyonic rod, it appears to the observer that end 1 leads end 2 in the apparent direction of motion. Conversely, in all frames in which the observer has relative speed less than that of the bradyonic rod, end 2 appears to lead end 1 in the apparent direction of motion.

Clocks

Now suppose there is a clock at rest in frame Σ', and that Σ' moves with speed $u > c$ relative to frame Σ. The time interval in Σ' is $t_2' - t_1' > 0$. Using the SLTs gives the corresponding times recorded in Σ as $t_1 = -i\gamma_u(t_1' + ux_1'/c^2)$ and $t_2 = -i\gamma_u(t_2' + ux_2'/c^2)$ so that $t_2 - t_1 = -i\gamma_u(t_2' - t_1')$, where the clocks have been arranged so that $x_1' = x_2'$. All observers move forwards in time along their respective time axes: ict' for observer Σ', ict for observer Σ. Therefore the time interval between two events must be positive for each observer. However, due to switching the apparent order of the two events may be reversed. Hence the elapsed time interval as measured by Σ is given by

$$|t_2 - t_1| = |-i\gamma_u|(t_2' - t_1') = (t_2' - t_1')|(u^2/c^2 - 1)^{-1/2}|\,. \tag{64}$$

The equivalent expression in SR for the time interval is

$$t_2 - t_1 = (t_2' - t_1')(1 - u^2/c^2)^{-1/2}\,. \tag{65}$$

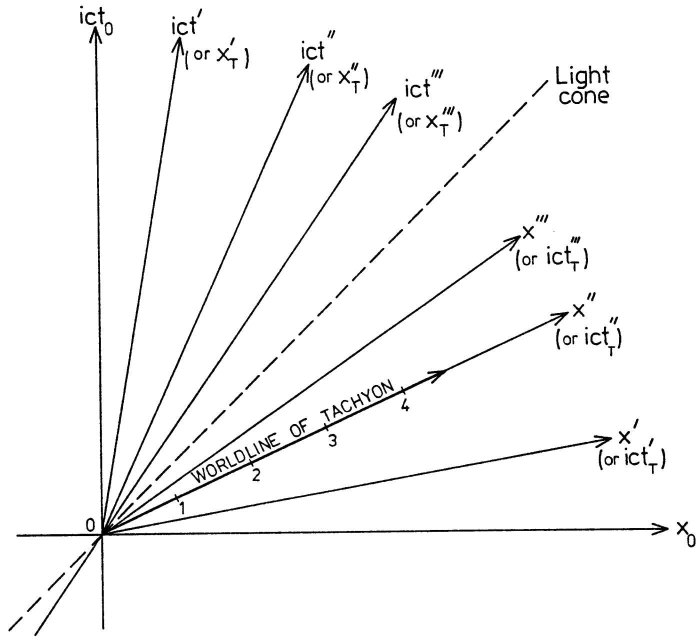

Fig. 9. A tachyonic clock is at rest in frame Σ_T'', with the points marked 0, 1, 2, 3 and 4 representing ticks of the clock. In tachyonic frames Σ_T' and Σ_T''' and bradyonic frames Σ_o and Σ' the clock appears to tick in the sequence 0, 1, 2, 3, 4. In bradyonic frame Σ'' the ticks occur at the same t''-time, while in bradyonic frame Σ''' the ticks occur in the sequence 4, 3, 2, 1, 0.

Note that (64) only gives the elapsed time between events in frame Σ: it does not indicate which event appears to occur first in that particular frame. For $c^2 < u^2 < 2c^2$ the clock appears to Σ to be slowed down, just as it would be for $u^2 < c^2$. For $u^2 = 2c^2$ the clock appears to run at the same rate in both frames, while for $u^2 > 2c^2$ the clock as seen by Σ will appear to run fast.

Fig. 9 shows a Minkowski diagram of a tachyonic clock passing successively through the points 0, 1, 2, 3 and 4. The coordinate axes used by bradyonic observers Σ_o, Σ', Σ'' and Σ''' and tachyonic observers Σ_T', Σ_T'' and Σ_T''' are the same as those in the previous figure. In all of the tachyonic frames Σ_T', Σ_T'' and Σ_T''' the clock appears to travel forwards in time via the sequence 0, 1, 2, 3, 4. The bradyonic observers Σ_o and Σ' also see the clock travel through the sequence 0, 1, 2, 3, 4 and so $t_{o_2} - t_{o_1} > 0$ and $t_2' - t_1' > 0$. For observer Σ'' the clock appears to have infinite speed and the points 0, 1, 2, 3, 4 all occur at the same t''-time. As Σ'' is the dual frame to Σ_T'' the apparent time interval between the points is zero. For observer Σ''' the tachyonic clock appears to have undergone switching, so that it travels forwards along the ict'''-axis via the sequence 4, 3, 2, 1, 0. (see also Fig. 4). Hence the correct time ordering and the apparent time interval in any bradyonic frame is given by

$$t_2 - t_1 = (t_2' - t_1')(u^2/c^2 - 1)^{-1/2}, \tag{66}$$

where $u^2 > c^2$ and the sign of the square root indicates whether the tachyonic clock is unswitched (+ root) or switched (− root). For $t_2' - t_1' > 0$ in the tachyonic clock's rest frame, equation (66) gives $t_2 > t_1$ for unswitched frames and $t_2 < t_1$ for switched frames.

8. Conservation of Electric Charge

The first postulate of ER that tachyons must obey the laws of physics means that in a given inertial reference frame there must be conservation of electric charge. While a detailed discussion of this topic will be given in the third paper of this series, a derivation will be given here to show how the γ-rule automatically allows charge to be conserved in each frame.

Consider what happens to the electric charge carried by the exchanged tachyon in Fig. 5. Observer Σ sees T_+ carry charge $+Q$ from X to Y, while conservation of charge in frame Σ' however, indicates that T_- must carry charge $-Q$ from Y to X. As T_+ and T_- are in fact the same particle viewed from two separate bradyonic reference frames, then the apparent disparity in the electric charge they carry disagrees with the result of SR, according to which electric charge is an invariant. In order to resolve this difficulty, it is necessary to digress briefly and discuss the volume of a tachyon.

Consider a cube which has sides of length l_o in its own rest frame. If the cube has speed $|u| < c$ relative to the observer, it will appear to have a volume of $(l_o/\gamma_u)(l_o)(l_o) = l_o^3/\gamma_u$, where γ_u is real. The volume of the cube when $|u| > c$ and γ is imaginary is given by

$$|il_o/\gamma_u| . |il_o| . |il_o| = l_o^3/|i\gamma_u| , \tag{67}$$

where each side has a length which is positive and real, even though the transverse dimensions are imaginary. Therefore by extension all tachyonic objects will have real, positive volumes, regardless of the observer's reference frame.

Let $d\omega_o$ be the volume of a small element of charge as measured from an inertial frame Σ_o, relative to which the charge is instantaneously at rest. The total charge within the element is equal to $\rho_o d\omega_o$, where ρ_o is the proper density of proper charge. In a second frame Σ' travelling with speed $v' > c$ with respect to Σ_o the charge density is $\rho' = i\gamma_{v'}\rho_o$. The factor i has appeared because both charge and volume are always real regardless of the observer's inertial reference frame, and so the charge density must also be real: this will be proved in Paper III. The volume of this element as measured by Σ' is $d\omega' = d\omega_o/|i\gamma_{v'}|$, which is real and positive. Therefore the total charge within the element as measured by Σ' is

$$\rho' d\omega' = \frac{i\gamma_{v'}\rho_o d\omega_o}{|i\gamma_{v'}|} = \pm\rho_o d\omega_o , \tag{68}$$

where the + sign applies if the positive root of $\gamma_{v'}$ is used (tachyon is unswitched) and the − sign applies if the negative root of $\gamma_{v'}$ is used (tachyon is switched). As the positive root of $\gamma_{v'}$ is always used for bradyons, then the standard result from SR is obtained: electric charge is an invariant for bradyons viewed by bradyonic observers.

In the example above of tachyon exchange, observer Σ sees the unswitched tachyon T_+ carry charge $+Q$ from X to Y as Σ uses the positive root of γ_u. Observer Σ' however must use the negative root of γ_u as he sees a switched tachyon T_-, and so (68) indicates that Σ' sees T_- carry charge $-Q$ from Y to X.

Switching is purely an artefact of the observer's motion relative to the viewed object. The object itself does not change in any way because of switching, only the observer's perception of the object changes. For example, a tachyonic electron will always be an electron, even though observers in switched frames will measure it as having a positive charge. Hence the Feynman picture of a positron as being an electron going backwards in time is not immediately applicable to the case of a switched tachyon.

The sign change due to switching will have subtle but far reaching effects in any tachyonic system. For example, the sign change on the electric charge will carry through any calculations involving electromagnetism, which will be considered in detail in Paper III. Examples in that paper will include a calculation of the electric and magnetic fields generated by a charged tachyon, as well as investigations of the tachyonic Doppler effect and retarded potentials.

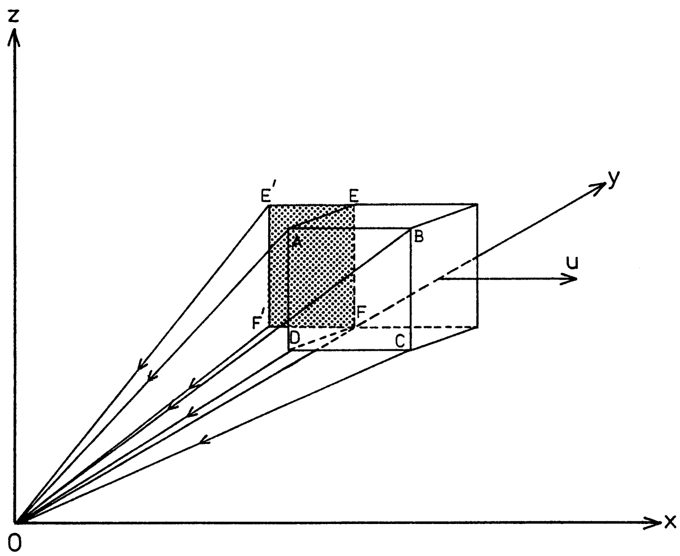

Fig. 10. A demonstration of the apparent rotation of a tachyonic cube as seen by an observer at O.

9. Visual Appearance of a Tachyonic Cube

Any object which is moving at a relativistic speed relative to the observer appears to undergo a rotation, and so a tachyonic object should also appear to be rotated. The following discussion is adapted from the relativistic case given by Rosser (1964).

Consider a cube which has edge length l_o in its rest frame. The cube is moving with a uniform velocity v relative to an inertial frame Σ, as shown in Fig. 10. Let the cube be viewed from a large distance in a direction perpendicular to its direction of motion, so that the angle subtended by the cube at the position of the observer situated at O, the origin of Σ, is very small. When the cube is moving the light quanta from the four corners A, B, C and D, which reach the observer's eye at the same time, form a rectangle of height l_o and apparent length l given by

$$l = l_o(1 - v^2/c^2)^{1/2} \quad \text{for } v^2 < c^2\,, \tag{69}$$

$$l = l_o|(v^2/c^2 - 1)^{1/2}| \quad \text{for } v^2 > c^2\,. \tag{70}$$

The apparent length along the x-axis is contracted for $v^2 < c^2$ and $c^2 < v^2 < 2c^2$, but is dilated for $v^2 > 2c^2$.

When the cube is moving relative to the observer, light quanta from the corners E and F can also reach the observer's eye at the same time as the quanta from A, B, C and D, as shown in Fig. 10. The light quanta from these corners leave the cube at an earlier time, when the corners E and F are at the positions E$'$ and F$'$ respectively. Therefore the side ADFE of the moving cube is visible to the observer and appears to be a rectangle. If the observer is far away from the cube then, to a first approximation, the light from E travels the extra distance l_o in the time that E$'$ goes to E. Hence the distance EE$'$ is equal to $l_o v/c$, so that for $c^2 < v^2 < 2c^2$ the face ABCD appears to be contracted and the face ADFE is dilated. For $v^2 > 2c^2$ both faces ABCD and ADFE are dilated, and so as $v \to \infty$ the cube appears to become enormously elongated. (The tachyonic rod discussed in Section 7 had an infinite apparent length in the frame in which it appeared to have infinite speed.) Of course, for speeds such that $v \gg c$ the approximation that the distance EE$'$ is given by $l_o v/c$ is no longer valid, as the observed angle subtended by the face of the cube is then quite large. In this case a far more detailed analysis is required, which will not be attempted here.

10. Conclusion

The overall framework of special relativity can be extended to include particles having speeds greater than c, simply by using the postulates of special relativity and allowing the existence of inertial reference frames travelling at a constant speed greater than c. The only other requirements necessary to allow tachyons to behave in a logical and consistent manner are the *switching principle* developed in Section 5 (expressed mathematically as the γ-rule), a standard convention for decomposing imaginary square roots, and the minor modification of some familiar definitions. Even so, the results and modified definitions in ER automatically reduce to the standard ones of SR as soon as the objects appear to the observer to be bradyons. This formulation does not change SR in any way and automatically accounts for familiar results, such as sources and detectors being fixed due to bradyons never appearing to be switched relative to a bradyonic observer.

The switching principle may appear to be a mere mathematical artifice, but the fact that it automatically allows tachyons to obey the laws of conservation of energy, momentum and electric charge in a given reference frame shows that it has deep physical significance. In the third paper of this series it will be shown that the theory of tachyons as described here is completely consistent with electromagnetism, to the point where Maxwell's equations in a vacuum apply for all speeds from 0 to ∞. It is not necessary to make any changes to Maxwell's equations to accommodate charged tachyons as has been done by Recami and Mignani (1974) and by Mignani and Recami (1975).

As stated by Imaeda (1979) it is not possible to retain all three of the following: (i) the Minkowskian (in our case Euclidean) nature of space–time, (ii) the reality of the extended transformation (i.e. in four dimensions) and (iii) the group character of the transformations for all particles. Clearly the present formulation falls into Imaeda's case A in which the transformation formulae contain imaginary quantities as well as real ones. The appearance of imaginary factors in the SLTs does not lead to any major problems, except that of interpretation of intermediate steps in calculations. The fact that the imaginary factors cancelled out when necessary, as demonstrated in the numerical example of Section 5, means that tachyons will have real and detectable properties such as energy, momentum and electric charge.

Imaeda suggests that the introduction of either a complex space–time or an increase in the number of dimensions of space–time would enable the coordinates of an event to be maintained as real quantities. He goes on to formulate for tachyons a quarternionic approach. We have not yet investigated the implications of this sort of approach to our own work.

In this paper there is no detailed discussion of tachyons and their consequences for causality. The reader is referred to an excellent review of these considerations by Recami (1987).

Switching has been discussed from a different point of view in an interesting paper by Schwartz (1982). By studying in detail the integration of the four-divergence of a conserved quantity over the three-dimensional surface bounding a region of interaction containing both bradyons and tachyons, he comes to the conclusion that the momentum of a particle and the question of whether it enters or leaves the interaction region are not to be treated as separate aspects if the particle is a tachyon. It is the 'product' of these two concepts or what Schwartz refers to as the 'momentum flow' which is significant. The new ideas of Schwartz seem of particular importance in a quantum formulation of tachyon properties, although they do result in the switching entering in an automatic way. A later paper in the present series will investigate the implications of Schwartz's approach for our own work based upon the Klein–Gordon equation.

Further discussion of such quantum aspects is not appropriate for the present paper where purely classical considerations are involved. Thus at no stage in this work has ER indicated how to create a tachyon: this is equivalent to the fact that SR does not say exactly how to create a bradyon. An attempt to determine how to create tachyons must be made at the quantum level and would require the development of a tachyonic analogue of relativistic quantum mechanics.

Corben (1978) has argued that tachyons, should they exist, 'are basically the same objects as ordinary particles (they just look different because they are moving so fast).' This is certainly the case in the present formulation, where the emphasis is on rigorous derivations of tachyonic transformations with worked examples used to check for internal consistency and the sensibleness of results. All of the tachyonic transformations and expressions for various quantities given in this series of papers can be derived using similar steps to the corresponding relativistic analogue. Finally, one of our referees has drawn our attention to an unpublished paper by Finch (1990) in which the result for the tachyonic transformations (equation 26) in this paper is studied carefully in the light of the group properties of the transformations.

Acknowledgments

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