The Conventional Nature of Time, and Two Distinct Formulations of Special Relativity

It is generally assumed that the Minkowski four-spacetime formulation of the special theory of relativity is both natural and unique. As a consequence, the main focus of all research has been aimed at reconciling empirical science with this framework. Furthermore, in a recent paper Petkov has made a very clear and appealing case for the acceptance of the Minkowski world-view. This talk has two objectives: the first objective is to discuss a few of the difficult problems caused by the four-spacetime formulation; while the second objective is to introduce a mathematically, but not physically, equivalent formulation of Maxwell's equations that solves these problems.

There are at least two clocks available to any observer for the observation of a given system, the (proper) clock of the observer or the (proper) clock of the observed system. Thus, without physical justification, the choice of clocks is a true convention in the sense of Poincaré.

Using the Clock of the Observer

In the Minkowski world-view, the clock of the observer is used and the following problems arise:

1. There is no definition of simultaneity that is the same for all observers
2. The canonical center-of-mass for a many-particle system is not the vector part of a four-vector (see [GZL]). This is the reason that there is no consistent relativistic quantum many-particle theory.
3. The problems of the Lorentz-Dirac equation can be directly traced to the Minkowski world-view.
4. The self-energy (mass) divergence of CED can be directly traced to the Minkowski world-view.

Using the Clock of the Observed System

In order to see how we can use the clock of the observed system, first recall Minkowski's definition of the proper-time of a source:

$$d\tau^2 = dt^2 - \tfrac{1}{c^2} d\mathbf{x}^2 = dt^2\left[1 - \tfrac{\mathbf{w}^2}{c^2}\right], \ \mathbf{w} = d\mathbf{x}/dt,$$
$$d\tau^2 = dt'^2 - \tfrac{1}{c^2} d\mathbf{x}'^2 = dt'^2\left[1 - \tfrac{\mathbf{w}'^2}{c^2}\right], \ \mathbf{w}' = d\mathbf{x}'/dt',$$

He correctly noted that this variable is not an exact one-form. The reason is a physical one since the same particle can traverse many different paths (in space) during any given τ interval. This reflects the physical fact that the distance a particle can travel in a given time interval depends on the forces acting on it. To change our view, rewrite the above equations as

$$dt^2 = d\tau^2 + \tfrac{1}{c^2} d\mathbf{x}^2 = d\tau^2 \left[1 + \tfrac{\mathbf{u}^2}{c^2}\right], \mathbf{u} = d\mathbf{x}/d\tau,$$

$$dt'^2 = d\tau^2 + \tfrac{1}{c^2} d\mathbf{x}'^2 = d\tau^2 \left[1 + \tfrac{\mathbf{u}'^2}{c^2}\right], \mathbf{u}' = d\mathbf{x}'/d\tau.$$

Thus, another possibility appears (which does give an exact one-form).

In order to see how this approach allows us to solve the center-of-mass problem, use the fact that the proper-time of a "particle" of mass M can also be represented as

$$d\tau = \left(Mc^2/H\right)dt, \; H = \sqrt{c^2\mathbf{P}^2 + M^2c^4}.$$

This representation is independent of the number of particles, so we can use it to define the proper-time for the global system. Notice that (as expected) it cannot be used as the time component of a four-vector. However, we get something better because we also have in the primed frame,

$$d\tau = \left(M'c^2/H'\right)dt, \; H' = \sqrt{c^2\mathbf{P}'^2 + M'^2c^4}.$$

Thus, the global system proper-clock is available to all observers. *This is a very important result since it shows that, although a closed system of particles does not induce a preferred coordinate frame (in the traditional sense), it does have a preferred (invariant) clock. This global clock is intrinsically related to the clocks of the individual particles in the system and provides a unique definition of simultaneity for all events associated with the system.*

It is shown in [GZL] (Foundations of Physics, 31 (2001) 1299-1355) that the systematic use of the clock associated with the observed system allows us to construct a parallel image of the conventional Maxwell theory by replacing the observer-clock by the clock of the source. This formulation is mathematically, but not physically, equivalent to the conventional form. The change induces a new symmetry group which is distinct from, but closely related to, the Lorentz group, and fixes the clock of the source for all observers. The new wave equation contains an additional gauge-independent dissipative term, which arises instantaneously with acceleration. This shows that the origin of radiation reaction is not the action of a ‘‘charge’’ on itself, but arises instead from inertial resistance to changes in motion. This dissipative term is equivalent to an effective mass, so that classical radiation has both a massless and a massive part. It is further shown that, at the local level, the theory is one of particles and fields but *there is no self-energy divergence (nor any of the other problems)*. We also show that, for any closed system of particles, there is a global inertial frame (and unique, invariant global clock) for each observer from which to observe the system. Thus, we suggest that an alternate world-view is that the continuous becoming of physical reality is a three-dimensional movie directed along a global time-line (distinct fourth-dimension). This view is also supported by our constructive representation theory for the Feynman path-integral and operator calculus (J. Math. Phys. **43** (2002) 69-93).