J. Sci. Math. Res. (2008) vol. 2, pp. 1-11 Published by Centaurus Press
(Received 2008-06-27; revised 2008-08-07)

Ambiguities in Physical Theory

T. E. Phipps, Jr.
908 S. Busey Avenue, Urbana, Illinois 61801
tephipps@sbcglobal net

Wave equations exhibit a well-known advanced-retarded solution ambiguity. It is pointed out that a comparable ambiguity arises in special relativistic kinematics regarding relative motion. There, the ambiguity is between the concepts "moving" and "stationary," or the allocation of motion between two bodies participating in states of relative motion. Something must break the symmetry inherent in that ambiguity in order for physical theory to describe the observed asymmetry of timekeeping in such states. I point out that this has direct bearing on the issue that Herbert Dingle termed "The Question," concerning rates of clocks in relative motion. To resolve the motion allocation ambiguity, a generalized conception of kinematics is proposed. This brings in causation in order to allow closer conformity of the description to the timekeeping asymmetry inherent in the known physics, through invoking a concept of *produced motion*. That is, relative motion never occurs in nature without being "produced" through the expenditure of energy (kinetic or potential). That clock is most slowed on which the most energy is expended. The implications are briefly discussed, and similar reasonings are extended to the field-theoretical treatment of gravity.

Key words: Relative motion, produced motion, timekeeping asymmetry, physical kinematics, gravity theory, ambiguities.

1. Introduction

The equations of mathematical physics, viewed as expressing the laws of nature, often exhibit profound ambiguities when confronted with their primary task of describing physical observations. A classic example is Maxwell's equations, which describe radiation by means of a wave equation employing an operator $\partial^2/\partial t^2$ that treats $\pm t$ on an equal footing, so that advanced and retarded solutions are of equal mathematical status. Moreover, the mathematics supports solutions that are arbitrary linear combinations of these two cases, so the basic mathematical ambiguity can be characterized by the cardinal number of the continuum (denoting non-denumerable infinitude of values of the mixing parameter). There is a widespread opinion, however, that these many candidate solutions are not of equal physical status, but that only retarded solutions are relevant to observation. Such a choice may be specified by "convention," by "definition," by "stipulation," or by "assumption," depending on taste in terminology. The choice must generally be made before the theory can legitimately yield verifiable predictions. (The half-advanced-half-retarded solutions of the Wheeler-Feynman (1945, 1949) theory appear to mark an exception to the retarded-solution rule. But for physical significance these require supplementation by a distant "absorber condition," so this is not the same physical theory or world model as Maxwell's.) Note that *consistently with just the mathematics of Maxwell's field equations* there is no resolution of the issue: advanced or retarded.

One of the few physicists to address this matter of the fecundity of mathematics in producing excess "solutions" to physical problems, Herbert Dingle (1972), observed that, "in the language of mathematics we can tell lies as well as truths, and within the scope of mathematics itself there is no possible way of telling one from the other. We can distinguish them only by experience or by reasoning outside the mathematics, applied to the possible relation between the mathematical solution and its supposed physical correlate."

The above specific example of ambiguity is far from unique in physical theory. The purpose of the present paper is to call attention to two other noteworthy cases. The first concerns the effect of motion on clock rates in Special Relativity Theory (SRT), and bears on the famous unresolved issue raised by Dingle (1972), and termed by him "The Question." The other relates similarly to the effect of gravity fields.

2. Dingle's "Question"

In Dingle's words (1972 pp. 7, 45), according to SRT, "if you have two exactly similar clocks, A and B, and one is moving with respect to the other, they must work at different rates... *i.e.*, one works more slowly than the other. [This asymmetry effect is quantified by (1b) or (2b), below. It was disputed by McCrea (1967), who is generally thought to have "refuted" Dingle, but we shall confirm the effect below.] But the theory also requires that you cannot distinguish which clock is the 'moving' one; it is equally true to say that A rests while B moves and that B rests while A moves. The question therefore arises: how does one determine, consistently with the theory, which clock works the more slowly?"

I shall argue that the key words here are "consistently with the theory," referring to the purely mathematical theory, and that the choice of which clock works the more slowly in the physical world is closely analogous to the question of which solution (advanced or retarded) of Maxwell's equations describes the physical world. In both cases one can cope only "by reasoning outside the mathematics." To proceed, we shall need to deal first with McCrea's challenge to the assertion of an objective rate difference between A and B.

3. Does Relative Motion Alter Clock Rates Asymmetrically?

The mathematics of SRT's kinematics boils down to the Lorentz transformation (Møller 1972),

$$\boldsymbol{r}' = \boldsymbol{r} + \boldsymbol{v}\left[\frac{(\boldsymbol{r}\cdot\boldsymbol{v})}{v^2}(\gamma - 1) - \gamma t\right], \quad \gamma \equiv 1 \,/\, \sqrt{1 - v^2 \,/\, c^2}\ , \tag{1a}$$

$$t' = \gamma\left(t - \boldsymbol{r}\cdot\boldsymbol{v} \,/\, c^2\right), \tag{1b}$$

and its inverse

$$\boldsymbol{r} = \boldsymbol{r}' - \boldsymbol{v}\left[-\frac{(\boldsymbol{r}'\cdot\boldsymbol{v})}{v^2}(\gamma - 1) - \gamma t'\right], \tag{2a}$$

$$t = \gamma\left(t' + \boldsymbol{r}'\cdot\boldsymbol{v} \,/\, c^2\right). \tag{2b}$$

Note the mathematical symmetry − a symmetry of clock rate ratios, such that primed and unprimed inertial observers each measure the other's clock as running slower than their own. [McCrea (1967) says, "Manifestly the parameters t, t' do not have the same meanings in" (1b) and (2b). This is incorrect. If it were true it would destroy algebraic consistency − since the rules of algebra forbid changing the meanings of algebraic symbols. McCrea would be right if the parameters t, t' alone were present in (1b) and (2b); but the parameters $\boldsymbol{r}, \boldsymbol{r}'$ also enter and restore consistency without change of symbol definitions.] This physically (though not algebraically) baffling symmetry of the Lorentz transformation is thought to be demanded by the Relativity Principle. However, to the contrary, I have argued (Phipps 2006) that the qualitatively different Selleri time transformation (1996, 2004),

$$t' = t/\gamma, \quad t = \gamma t'\ , \tag{3}$$

which is both algebraically and physically consistent (describing an objective clock rate *asymmetry* with no change of symbol meanings), is likewise compatible with a weak form of the Relativity Principle. [In fact, it is compatible with the original form referring to symmetry (invariance) of *laws of nature* – a criterion much less stringent than the demand for symmetry of clock rate ratios, as implied by the Lorentz transformation.] I shall not digress further into that topic here.

Dingle (1972 p. 85) observed "Einstein's proof from his theory that the readings of a clock P, passing along a row of relatively stationary synchronized clocks Q, fell steadily more and more behind those of the Q clocks as it went along." Dingle then inverted this, noting "in exactly the same way, that if P also was one of a row of relatively stationary synchronized clocks, each Q clock also must fall steadily behind the P clocks as it went along. Hence, as the motion progressed, every P clock was losing steadily with respect to the Q clocks, and *vice versa*." This immediate logical consequence of the Lorentz symmetry is of course physically impossible. To this, McCrea (1969) objected that Einstein had never compared the rates of two individual relatively-moving clocks – he had considered only the case of one clock passing along a row of clocks. However, this overlooks the meaning of synchronization of the row of clocks. Being all in the same state of motion, they are *rate* synchronized by definition, quite independently of the Einstein clock-phasing convention. So, given two rows of clocks in relative motion, any one of the P clocks bears a given rate ratio to any one of the Q clocks, and *vice versa*. If that ratio is not unity, the "*vice versa*" produces a contradiction, as would in logic the proposition that $P > Q$ and $Q > P$. A referee has objected that P is behind Q if P is compared to Q in terms of the simultaneity in Q's rest frame, and that Q is behind P if Q is compared to P in terms of P's simultaneity. He concludes that "these two statements are consistent as can easily be proved." But is their symmetry consistent with physical observation? The referee's answer: SRT's "symmetry is empirically well confirmed."

To probe this, let us examine a more realistic case, that of circular motion comparable with that of the muon "clocks" in the CERN experiment Bailey *et al.* (1977). This will allow comparison of SRT's prediction with actual observations. To be sure, non-inertial motion lies outside the purview of SRT, strictly interpreted with reference to the Lorentz group, but Einstein himself considered it (in respect to a clock at the pole and one at the equator of a spinning "earth") in his original 1905 paper, and the theory would be useless without the extension to curvilinear relative motion. (Such an extension is implicit in the recognition of $d\tau$, the differential of proper time, as inexact, *i.e.*, as path dependent.) Consider the clock P to move in a circle, and consider a row of clocks Q just outside the circle at rest in the laboratory. By the same argument given above, the clock P progressively loses time compared to the Q-clocks it passes, and thus runs at a slower rate than any of the "stationary" Q-clocks. This is confirmed by the muon observations Bailey *et al.* (1977), which confirm, after a number of circlings, that the muons in motion have decayed much less than if they had remained at rest in the laboratory. There is no doubt of this decay asymmetry as an objective fact having nothing to do with any observer's idea of "simultaneity." Next, apply the Relativity Principle and hold the clock P at rest, while the set of Q-clocks rotate around it, so that the *relative motion* is unaltered. The Principle, as embodied in the (instantaneously applied) Lorentz transformation, asserts a symmetry such that what was true before must be true with the roles of P and Q interchanged. Thus the Q clocks progressively lose time relative to the P clock. This translates to a rate difference such that the laboratory Q-clocks now run slower than the muon P-clock. The circling P-muon therefore is predicted (by the same reasoning that just predicted the opposite) to decay more rapidly than its notional counterpart, the lab-stationary Q-muon. This is contrary to observed fact – what Dingle accurately termed a "lie." The Relativity Principle, incautiously interpreted, tells lies. As the muons are informing us, in nature timekeeping asymmetry works in only one direction. This needs to be recognized as a physical fact that trumps the mathematical symmetry.

There are several ways, more or less consistently with SRT, that a relativist might go about refuting this unwanted conclusion. First, it could be objected that non-linear motion has been introduced; hence the strictest form of the theory is inapplicable. That would deny SRT its claimed agreement with the CERN observations, and would have to be viewed as a Pyrrhic victory for the theory. Alternatively, since the muon circle in the problem can in principle be made of arbitrarily large radius, the departure of motion from inertiality can be made arbitrarily small (though in the actual experiment the muon acceleration was about $10^{18} g$), so the issue of SRT's applicability or inapplicability can be reduced to epsilon-delta logic chopping. As still another alternative, the *accelerative* aspect of "travel" can be identified as itself responsible for the crucial asymmetry. This was Feynman's approach (Feynman, Leighton, & Sands 1966). Such tacit recognition of the need to invoke a physical asymmetry inconsistent with (and over-riding) the mathematical symmetry of the Lorentz transformation takes us halfway to the main topic of this paper, to which we next turn. Our aim will be to make this recognition explicit and to find a consistent way of expressing the physics in it.

In sum: If McCrea were correct in challenging the objective reality of the rate asymmetry of Dingle's clocks (A and B or P and Q), doubt would justly fall upon the ability of SRT to describe the CERN observations Bailey *et al.* (1977).

4. Ambiguity in the Apportionment of Relative Motion

A different approach, which I favor, recognizes that we encounter in this problem another example of ambiguity in fundamental theory, analogous to that between advanced and retarded solutions in electromagnetism. In this case the ambiguity is kinematic; it is between the concepts "stationary" and "moving." Like the electromagnetic, this kinematic ambiguity is characterized by the cardinal number of the continuum, since degree of motion can be arbitrarily apportioned between any two objects in relative motion. In some theories, such as the Lorentz ether theory, it is easy to resolve the ambiguity, because an absolute standard of "rest" is postulated. But, if we insist (quite reasonably) on maintaining some form of Relativity Principle, that simplest of all solutions is unavailable to us. To cope with the above-mentioned fact of timekeeping asymmetry, we must look for a different criterion of asymmetry affecting nominally "relative" motion… one that does not appeal to a concept of "absolute" rest. I suggest the missing concept may be spoken of as "produced motion."

In the real world motions are created, but are not all created equal. In Einstein's conceptualization of kinematics relative motion is not created at all, nor produced, but is *hypothesized*. That is, Einstein simply presents us with a set of imagined inertial systems, all in relative motion. Such relative motions are neither initiated nor terminated, but are *perpetual*. They exist and have always existed "in eternity." This is decidedly a mathematician's approach. A physicist must recognize that no relative motion occurs without being *produced* through performance of work or expenditure of energy. In the muon experiment, work was done on the muon clocks and not on the laboratory clocks – a clear distinction that can provide the clue we need. If we supplement SRT with the convention, definition, stipulation, or assumption that *those clocks are rate-slowed that have work done on them* – the more work the greater the rate change – then we seem to glimpse the possibility of resolving the ambiguity and extracting from the hazy theory (tarnished by its operationally meaningless flirting with "eternity") a shiny, clean-cut prediction.

Unfortunately, it is not quite that simple. The "work" done on a clock to slow it has to be of a special, reversible kind. For when a muon clock is speeded up relative to the laboratory, and then brought back to rest there, its running rate must be precisely restored to the original value, so that, if the clock's rate was *slowed* when its motion was speeded up, its rate must be *speeded-up* when its motion is slowed back down. This is actually not so difficult or complicated as it sounds. At all times and in all states of motion relative to a fiducial "rest" state (an arbitrary inertial state), the clock's rate is directly and simply controlled by SRT's familiar rate factor,

$$\frac{\mathrm{d}\tau}{\mathrm{d}t} = \sqrt{1 - \frac{v^2}{c^2}}\,. \tag{4}$$

Here, $\mathrm{d}\tau$ is an increment of proper time of the "moving" clock on which work is done, $\mathrm{d}t$ is the same for the "stationary" fiducial clock on which *no work* is done, and v^2 is the squared-velocity of the moving clock relative to the stationary one. Equation (4) applies at every moment throughout the motion.

Thus we have what would appear to be a practical criterion by which ambiguity can be resolved as to how "relative motion" is to be apportioned between any two clocks or objects in relative motion. In effect, the "motion" is to be treated not as relative but as if it were absolute, with all of it being assigned to the object that has acquired its motion through having had work done on it. If work is done on both objects under consideration, a third clock-object must be introduced that has had no work done on it, to serve as fiducial reference standard for $\mathrm{d}t$ definition in the above formula. In particular, if two clocks have equal work done on them to put them into states of oppositely-directed motion, each is equally rate-slowed relative to a third fiducial clock on which no work has been done, so both run at the same (slowed) rate. This idea of introducing a third (work-free, hence motionless) clock to act as fiducial reference has occurred to other investigators. For instance, Stedman (1973) observed, "The feature of the situation for which Dingle is searching is that the two events he considers define a third inertial frame, C say, in which the two events occur at the same position. My one sentence answer to Dingle's question is: the time interval calculated by A is greater (less) than that calculated by B if the relative speed of C and A is greater (less) than the relative speed of C and B." This expresses the traditional purely-kinematic view, with no attention paid to the physics of how relative speeds are acquired. In the absence of such attention, the role of frame C in Stedman's (kinematically valid) resolution is physically mysterious and logically *ad hoc*. Moreover, it offers no clue as to how to modify it for the variable-gravity case.

I have chosen energy change or work here as the causal agent of relative motion, rather than, say, force or acceleration (vector quantities, less appropriate to v^2-controlled timekeeping). But there may be still better criteria. For instance, I have suggested "action" (which, like the Lagrangian, resembles total energy but with altered sign of potential energy) as the best criterion for codifying timekeeping phenomena, including those affected by gravitational potential energy changes (Phipps 2006). Details of this sort are not essential to get exactly right at this stage, where concepts are not entirely agreed on. Most physicists do not as yet recognize the existence of any ambiguity in SRT, much less the need to do something about it.

As a practical realization, consider clocks in earth satellites. To get such clocks into orbit, work has to be done on them (or action state has to be changed). The fiducial reference clock on which no work has been done (the one that tells $\mathrm{d}t$ time) could be a clock left at rest on the earth's surface. Alternatively, we might choose to recognize that such a clock at rest deep in a gravity field has its rate slowed as a result of that location – so might elect to refer both surface and orbiting clocks to a clock on which truly zero work has been done – namely, one at rest outside the gravity field at "infinity." Either analysis, consistently carried out, would be acceptable. [I believe the Global Positioning System (GPS) uses still a different system, referring to an imaginary clock at rest on the axis of a hypothetical non-rotating earth.] The choice of fiducial reference is evidently not critical (it affects only the rate of measured "time flow," hence can be compensated by an arbitrary change of time units) – but does require some knowledge of the relevant physics.

This is a very important point: The choice of fiducial reference system is not dictated by any inherent physical uniqueness, but is basically a matter of convenience. The "no work" criterion, though convenient, is not in itself essential, nor even uniquely defined. Actually, any inertial system will serve as the fiducial one. In the muon problem the fiducial system could be the quasi-inertial one in which the circling muons are at rest. In this case it would have to be recognized that the fiducial system's motion is "produced," hence clocks native to that system are slowed, hence clocks native to the lab are (relatively) speeded. This is of course not a natural or "convenient" way to look at it; but it fits with all that is observable.

The present resolution of the twin paradox (Dingle 1972) will be recognized as rather close to that of Feynman *et al.* (1966). Like him, we acknowledge that the mathematical symmetry demands to be over-ridden by physically asymmetrical considerations, in order that the theory not make a fool of itself as physics. He chose "acceleration" as the physical symmetry-breaker; we have chosen energy or action expenditure for that role. In nature, none of these physical factors can change without concomitant changes of the others. So the resolutions amount to much the same thing, with different verbalisms.

In summary, we have perceived that SRT, a purely postulational construct or mathematical entity, based on the Relativity Principle as expressed uncritically in the Lorentz transformation, asserts such ludicrously strong kinematic symmetry that it is completely ambiguous as to whether high-speed muons age faster or slower than stationary ones – 'high-speed' and 'stationary' being rigorously interchangeable concepts. Predictively, the pure theory – as it stands – is useless for choosing between these two physical alternatives. Dingle vainly wore himself to a frazzle directing attention to this obvious point. For his pains he was ridiculed and labeled as demented. A permanent fix will, I opine, require the recognition of reduced mathematical symmetry, as in the asymmetrical formulation of (3). When the physics is plainly asymmetrical, the mathematics should reflect that fact. But at least a temporary fix seems to be offered, whereby ambiguity of the existing SRT formalism can be recognized and patched-up, by introducing a concept of "produced motion," such that *all 'relative' motions* are stipulated to be *produced* by energy or action expenditures affecting observable timekeeping.

For this fix to work, it must be recognized as basic to "relativity" that relative motions never arise spontaneously; they are always caused or produced, always in association with an energy cost. To say it again: relative motions are not *hypothesized*, as in Einstein's original formulation of kinematics, but are *produced* through greater or lesser energy, work, or action investments. An arbitrary curvilinear trajectory is produced by continuous evolution of action. The resulting relative v^2 measure of (kinetic) work or action change is quantitatively related [Eq. (4)] to the influence of "relative motion" on timekeeping, and may be considered also responsible for the inexactness of the moving clock's proper-time differential (path dependence). Similarly for gravity field work (Phipps 2006). What is proposed here is a basic *reform* of kinematics at the level of conceptualizing "relative motion." The physics in this resides in the proposition that to change the energy or action state of a clock (whether by motion or by location in a gravity field) is to change its natural running rate. Kinematics cannot be separated from timekeeping – that was Einstein's great perception. It means that the physics of kinematics cannot be separated from the physics of timekeeping. And it also means there is physics in *both*. This is radical news, surely, that there is physics in kinematics.

In this way we take the sting out of the existing mathematical formalism's excessive (and physically outrageous) formal symmetry by supplementing the mathematics with a symmetry-spoiling interpretive side condition or convention, based on the idea of *produced motion*. (The analogy with the symmetry-spoiling causality condition, by which retarded solutions of Maxwell's equation are selected, needs no elaboration.) Personally, I see this as at best a stopgap on the way to better basic theory. But I recognize that my contemporaries have been schooled to accept SRT as an Immaculate Conception. My present proposal enables them to leave the "core" mathematical formalism sacrosanct and just to fiddle with peripheral aspects: "interpretation," "convention," etc. But even that may start a tiny crack in the polished façade of myth currently protecting SRT from a comprehensive re-examination as physics. Does really healthy theory need Band-Aids?

5. Physical Kinematics

Ultimately at stake here is the meaning we wish to attach to "kinematics." As currently understood (its dictionary definition), kinematics is the science of pure (relative) motion *considered apart from causes*. That is a legitimate science for mathematicians to study. But physicists need to supplement this view. In speaking of "motion" they must acknowledge that "time flow" is implicit in motion's very conception. They must also acknowledge the empiricism that physical time does not "flow" at a rate independent of state of motion. This is a deep complication – that the measure of motion itself depends on state of motion – something requiring a halt to automatic thinking and even a possible about-face. If all that were involved in the science of motion were what can be considered apart from causes, then such science would be an adequate basis for treating one (limited) aspect of physics. But, when more is involved, "causes" cannot safely be left out. To be most useful to physicists, "kinematics" must have its meaning augmented. Indeed, the science of *pure kinematics* needs to be supplemented by a *physical kinematics* – wherein causes *are* considered to the extent that they *produce* states of motion and therefore govern time flow or aging rates. It is from this trend of thought that the primacy of the concept of "produced motion" arises and becomes recognizable as pivotal for the type of kinematics concerned with individual particle aging rates. Complementary to the motion "produced" by a cause is the motion "acquired" by the clock on which the cause acts.

As long as, and to the extent that, physics can rely on an essentially Newtonian conception of time (*i.e.*, time flows independently of state of motion), the mathematicians' form and definition of "pure kinematics" can serve physics perfectly well. This covers an important sub-class of physical problems, including all of strictly dynamical character (for a justification of this claim employing the quasi-Newtonian concept of "collective time," see Phipps 2006). But to the extent that *proper time flow* (particle "aging rate"), dependent on state of motion, requires quantification, a "physical kinematics" is called for that admits a distinction among motions as to their degree of "production" by "causes." This is no more than a capitulation to nature – an acceptance that clock-rates are relevant to kinematics and that clocks run at different rates depending on physical factors invisible to those philosophers who admit about *motion* only that it is "relative." Physical kinematics defines a different sub-class of physical problems, distinct from those of purely Newtonian character, responding to different questions put to nature.

Two principles govern the quantification of clock rates in the presence of produced motion:

(1) As with potential, clock rate exhibits no absolute level; only changes are subject to verifiable quantification.

(2) All clocks at rest in a given inertial system – or, in general, all clocks occupying the same state of motion – run at the same rate, regardless of location or motional history.

The second of these implies a reversibility of the "work" done on a clock (Phipps 2006), such that, when a clock (initially at rest in an arbitrary inertial system S) acquires a net velocity *increment* of magnitude v_{acq} relative to S, its running rate is *slowed* by a γ-factor of the form indicated by (4),

$$\gamma = \frac{1}{\sqrt{1 - v_{acq}^2 \ / \ c^2}}. \tag{5}$$

If subsequently the same clock has its speed relative to S reduced to zero, as a result of acquiring a net velocity *decrement* of magnitude v_{acq}, then its rate is *speeded* by the same γ-factor. [Mathematically, speeding and slowing are reciprocal operations, in agreement with (3).] Consequently, on recovering a state of rest in S the clock recovers its original running rate, in agreement with principle (2). This recovered rate is identical to that of clocks permanently at rest in S.

These considerations assume gravity to be absent or its effects to be held constant. As discussed elsewhere (Phipps 2006), if a change $\Delta\Phi$ of gravity potential accompanies an acquired net velocity increment v_{acq}, then the effect on clock rate, to first order in c^{-2}, can be described as above, with the use of a modified γ-factor,

$$\gamma_{\text{generalized}} = \frac{\mathrm{d}t}{\mathrm{d}\tau} = \frac{1}{\sqrt{1 - v_{acq}^2/c^2 + 2\Delta\Phi/c^2 + O\left(c^{-4}\right)}}, \tag{6a}$$

where the higher-order correction term can be derived from the Schwarzschild metric (Matolcsi and Matolcsi 2007), $\mathrm{d}t$ is measured by a clock at rest outside the gravity field, and $\mathrm{d}\tau$ by a moving clock inside the field. An alternative theoretical approach (Phipps 2006) employing *action* yields

$$\gamma_{\text{generalized}} = \gamma - \frac{\Delta\Phi}{c^2}, \tag{6b}$$

which agrees with (6a) to first order – the only order presently subject to observational confirmation.

6. Ambiguities of Gravity Theory

Newton's gravity, statically produced by massive point sources, was simple and unambiguous. When it was reformulated in the language of field theory, employing Poisson's equation, all the ambiguities of field theory at once crept in. Field theory can be formulated in any number of dimensions, but it seems most natural to employ the four-space balanced arguments (x, y, z, t) characteristic of traditional field variables. Thus a four-dimensional counterpart of Poisson's equation, with "gravity waves" and the $\partial^2/\partial t^2$ operator, at once seizes the analyst's imagination – with the associated $\pm t$ ambiguities. That is, our minds become occupied with "incoming" as well as "outgoing" gravity waves and actions, and with arbitrary linear combinations of such contributions. No longer does the simple Newtonian point source suffice to model what we are forced to imagine must be "out there." Now, in addition to local point sources, we are invited to think of distributions of source matter at infinity – such distant sources of the incoming waves being easily confused with distant "absorbers," which are rightly sinks of the outgoing waves.

In addition to ambiguity as to whether gravity fields propagate in advanced fashion from distant sources or in retarded fashion from local ones, there is the question of the effect of "depth" in a gravity field on timekeeping. Supposedly, clocks deeper in the field run more slowly. But a clock deep in a retarded field is high in an advanced one. So, maybe the clock is speeded, instead of slowed, by being placed "deep" in the field. The mathematics is not helping us on this point. It needs to be supplemented "by reasoning outside the mathematics," guided by empiricism.

Suffice it to say that the pure mathematics of field theory, applied to the problem of describing gravity, affords no resolution of the timekeeping ambiguity, nor of the ambiguity regarding whether gravity emanates from local point sources or from distant distributions of matter. One can resolve the latter ambiguity empirically by noting that no such distant matter distributions are *observed*. (One must acknowledge, however, that since physicists have begun to believe in the by-definition unobservable – *e.g.*, dark matter, dark energy, etc. – theory's kite is no longer tethered to empiricism.) Although inappropriate for resolving issues in purely mathematical theory, empirical evidence is appropriate in physical theory (of the old-fashioned or tethered sort) as the basis for extra-mathematical side conditions or "conventions" of the kind we have already found effective in dealing with comparable ambiguities in electromagnetic and special relativity theory. Just as empiricism (*i.e.*, the fact that advanced radiation has never been observed) can be used to resolve the radiative advanced-retarded ambiguity, so we can use the above-noted empiricism as a side condition to remove the field-created ambiguity of our gravity source model and restore the simple Newtonian source picture from which gravity theory started. That also takes care of the timekeeping matter, since "depth" in the gravity field becomes a clearly-defined concept once the field sources lose their ambiguity of location. Our excursion into field theory thus leads us back essentially to where we started, in Newtonian non-field theory.

As for the treatment of gravity by General Relativity Theory (GRT), that theory is of field theoretical pedigree (loosely speaking), hence it inherits the full gamut of field theoretical problems – what fields are, where they come from, where they go, how they relate to quantum physics, etc. GRT supplies no new intellectual content to cope with these problems except "geometry," which proves (according to Einstein himself) to be nothing but new verbalism for a "relativistic ether" (Kostro 2000) – which is to say (unkindly) a non-physical, supra-physical, or metaphysical recycling of ideas supposedly discredited by SRT.

7. Residual and Irresolvable Ambiguities

When all is said, our dictum that produced motion is "knowable" cannot fit the facts in all practical cases. Clock rates on distant astronomical objects cannot be precisely known from Doppler data alone, for these are insufficient in themselves to constitute a true measurement, rather than an inference, of relative speed of approach or recession. The net running rate of clocks native to any sufficiently distant astronomical object thus remains permanently ambiguous, since what is measured is an unresolved combination of Doppler speed effect and inherent clock rate effect, the latter being the quantitative residual evidence of earlier "produced" motion. Thus, not all ambiguities of physical description are necessarily resolvable.

Where an object approaches close enough to allow radar ranging, as in planetary astronomy, an independent measurement of relative speed becomes possible. In this case the Doppler Effect can be filtered out. Any discrepancies between the radar data and the Doppler data might thus be attributed to our hypothesized produced-motion effect. In the case of the planet Venus, it is my understanding that such discrepancies do exist. These may provide a novel method of inferring the way in which the solar system was formed. (Alternatively, if that is considered known, a method may be provided for testing the validity of the present "produced motion" hypothesis.) Thus, if the planets were originally hurled outward from the Sun, the Earth was manifestly hurled farther and more vigorously than Venus; consequently, more energy was expended in that process, greater v^2 motion was "produced," and all native Earth-based clocks (atomic processes, as measured spectroscopically) should subsequently run more slowly than those on Venus. In case the solar system was formed by the opposite process, *viz.*, an inward-gathering of material, the opposite conclusion might be reached. Therefore a study of the Doppler and radar data discrepancy could provide a basis for resolving timekeeping ambiguities among the planets associated with their relative motions, and for making an inference about the formation method of the solar system independent of past inferences. The speculative nature of the remarks in this Section will be evident.

8. Summary

The ambiguity of apportionment of advancement and retardation to solutions of the wave equation finds its counterpart in an ambiguity of apportionment of "motion" to any two objects in "relative motion." Such ambiguities need to be resolved before physical theory can make definite predictions – that is, before mathematical or kinematic theory can claim utility as physical theory. The resolution, as Dingle pointed out, can come only "by reasoning outside the mathematics." As an example of such reasoning, I have suggested that relative motion never occurs spontaneously in nature, but always is "produced" by knowable-in-principle apportionments of energy among the participating components. Through this recognition or Ansatz, it becomes possible to quantify relative clock rates, as affected by (produced) motion, using the basic timekeeping relation, (4). The identification of a fiducial clock to serve as dt-timekeeping reference for all motions is viewed as a matter of convenience. The ultimate reference of this sort (the fastest-running of all clocks) is a clock uninfluenced by either motion or gravity – *i.e.*, one situated outside the gravity field, "at rest at infinity." Such a clock can be said to have *no work* done on it, either by gravity or other causes. Any other clock, having some quantifiable degree of work done on it, is slowed thereby in accordance with known laws.

The above reference to "rest" at infinity or elsewhere does not necessarily imply *absoluteness* of rest, nor is it incompatible with the original form of the Relativity Principle. In fact, one way of stating that Principle is that any inertial state of motion can be considered the state of rest (hence the fiducial state). That fact reflects the irreducible ambiguity of "time flow rate" that is inherent in the concept. Choice of an altered inertial state as the fiducial state of rest – allowable if the new state represents measurably "produced" motion – merely causes all clocks in the universe to run at a rate altered (relatively) by a constant factor. That is equivalent to redefining the "second," which is allowed by the arbitrariness of time units. Changing physical units of any kind does not alter the *laws of nature*, by Newton's Principle of Similitude. The laws of nature thus remain rigorously invariant under changes of the fiducial state. (Such invariance need have nothing to do with the mathematical contrivance known as "covariance," as I have been at pains to show elsewhere (Phipps 2006); but the present "produced motion" convention is compatible with either invariance or covariance as the mathematical expression of the Relativity Principle.)

In this way, compatibly with the original Relativity Principle (invariance of laws of nature), one introduces a "physical kinematics," based upon a supplementary condition or convention specifying greater apportionment of "relative motion" to that object which has had more work done on it. Thus in the clock paradox the stay-at-home clock, having had no work done on it, is treated as if absolutely at rest, whereas the traveling clock is treated as moving (in absolutely "produced" motion) as a result of rocket fuel expenditure. By this convention a physical asymmetry is established, spoiling the purely "relative motion" symmetry – recognized as physically false or misleading – and SRT as a result can be seen as making definite predictions of relative *aging-rate asymmetry* that accord with observation. Such predictions cannot be extracted from the un-supplemented covariant formalism of the Lorentz transformation, whose symmetry is unbreakable within the strict bounds of rigorous mathematics. The latter was Dingle's point, which has never been refuted, but has been successfully missed by generational battalions of physicists.

Physicists must decide what they desire of their "physical" theories. Do they want right predictions or do they want beautiful mathematics? As things presently stand, they are living in a dream world if they think they are entitled to both. Perhaps when the underlying mathematical formalism has been improved… But present practitioners have not earned improvement in that department because they have not only never sought it but have systematically fought it (Dingle 1972), with a success the endurance of which must become one of the wonders of future history of science. It will be compared with the success of Ptolemaic astronomy, a showpiece for the thousand-year persistence of a postulated mathematical beauty never surpassed – that of the perfect circle.

References

Bailey, J. *et al.*, "Measurements of relativistic time dilatation for positive and negative muons in a circular orbit," *Nature* **268**, pp. 301-305 (1977).

Dingle, H., *Science at the Crossroads*, Martin Brian & O'Keeffe, London (1972).

Einstein, A., "Zur Elektrodynamik bewegter Körper," *Annalen der Physik* **17**, pp. 891-921 (1905); English translation in *The Principle of Relativity*, Dover, NY (1952).

Feynman, R. P., Leighton, R. B., & Sands, M., *The Feynman Lectures on Physics Definitive Edition*, Addison-Wesley, San Francisco, p. 16-3 (1966).

Kostro, L., *Einstein and the Ether*, Apeiron, Montreal (2000).

Matolcsi, T. & Matolcsi, M., "Coordinate time and proper time in the GPS," *European Journal of Physics* **29**, pp. 1147-1151 (2007).

McCrea, W. H., "Why the Special Theory of Relativity is Correct," *Nature* **216**, pp. 122-124 (1967).

McCrea, W. H., "Definitions and Realities," *The Listener* **82**, p. 315 (1969).

Møller, C., *The Theory of Relativity*, Oxford, London, 2nd ed., p. 40 (1972).

Phipps, Jr., T. E., *Old Physics for New*, Apeiron, Montreal (2006).

Selleri, F., "Noninvariant one-way velocity of light," *Foundations of Physics* **26**, pp. 641-664 (1996).

Selleri, F., "Sagnac effect: end of the mystery," in *Relativity in Rotating Frames*, Rizzi, G. & Ruggiero, M. L., eds., Kluwer, Dordrecht, pp. 57-77 (2004).

Stedman, G. E., "Stedman's Answer," *Nature* **244**, p. 27 (1973).

Wheeler, J. A. & Feynman, R. P., "Interaction with the Absorber as the Mechanism of Radiation," *Rev. Mod. Phys.* **17**, pp. 157-181 (1945).

Wheeler, J. A. & Feynman, R. P., "Classical Electrodynamics in Terms of Direct Interparticle Action," *Rev. Mod. Phys.* **21**, pp. 425-433 (1949).