Time; proper, laboratory and canonical?

A. F. Kracklauer

Which, what or whose time?

- absolute vs. emission and absorption time

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- proper time; canonical for a single particle?

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- No-interaction theorems?

Recognized pathologies in Relativity:

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- Self-field diverges

- Asymmetric aging

Common thread: TIME

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Where is the variable conjugate to the system (multi-body) Hamiltonian? I seek a structure that is based on topological considerations, or, what is the same: integrability conditions for trajectories over pregeometerized manifolds. That is, structure that obtains regardless of the specific nature of the metric, whether Euclidean or Pseudo Euclidean (Minkowski space).

Current Physics theories do not satisfy this structure; they are afflicted by what may be called:

TIME CONTORTIONS

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Non-locality (instantaneous interaction)

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Non-locality (instantaneous interaction)

Advanced interaction (i.e.: 1/2(Adv. + Ret.))

TIME CONTORTIONS

Non-locality (instantaneous interaction)

Advanced interaction (i.e.: 1/2(Adv. + Ret.))

Asymmetric aging (“twin paradox”)

Why worry?

Why worry?

Self consistent philosophy (syntax)

Why worry?

Self consistent philosophy (syntax)

Self consistent physics

Why worry?

Self consistent philosophy (syntax)

Self consistent physics

Self consistent math (well posed equations)

What to do?

What to do?

Tantrum (pitch baby & bath water)

What to do?

Tantrum (pitch baby & bath water)

Add another story (build up on weak foundation)

What to do?

Tantrum (pitch baby & bath water)

Add another story (build up on weak foundation)

Repair with minimal changes

What are the repair costs?

What are the repair costs?

- EPR correlations: Abandon mystical explanations

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- Advanced interaction: New model for radiation reaction

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- EPR correlations: Abandon mystical explanations

- Advanced interaction: New model for radiation reaction

- Asymmetric aging: Reconcile several (not all) experiments, i.e., muon decay

EPR Correlations; two measurements + HV:

$$P(a,b) = \int P(a,b,\lambda)d\lambda . \qquad (1)$$

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Bell's encoding of "locality":

$$P(a,b) = \int A(a,\lambda) B(b,\lambda) \rho(\lambda) d\lambda, \tag{3}$$

statistical implications:

$$B(b|a,\lambda) \equiv B(b|\lambda), \quad \forall a. \tag{4}$$

output is uncorrelated regards of λ, #

Is there “advanced interaction”? Fokker gives us:

$$L_F = \sum_{j}^{N} L_j = \sum_{j}^{N} m_j \left(\mathbf{v}_j \cdot \mathbf{v}_j\right)^{1/2} \quad -$$

$$2\sum_{k\neq j}^{2} e_j e_k \int_{-\infty}^{+\infty} \mathbf{v}_j(\tau_j)\cdot\mathbf{v}_k(\tau_k)\,\delta\left(\left(\mathbf{x}_j(\tau_j)-\mathbf{x}_k(\tau_k)\right)^2\right) d\tau_k, \tag{5}$$

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However, using the above, write:

$$
\begin{aligned}
L = \sum_{j=1}^{2} m_j \left(\mathbf{v}_j \cdot \mathbf{v}_j\right)^{1/2} \\
-2 \sum_{k \neq j}^{2} e_j e_k \int_{-\infty}^{\tau} \mathbf{v}_j(\tau) \cdot \mathbf{v}_k(\tau') \delta \left(\left(\mathbf{x}_j(\tau) - \mathbf{x}_k(\tau') \right)^2 \right) d\tau',
\end{aligned}
\tag{6}
$$

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which yields as eqs. of motion:

$$m_j (\ddot{\mathbf{x}}_j)^{\mu} = \frac{e_j}{c} \left(\sum_{k \neq j} F_k|_{\mathrm{ret}} \right)^{\mu\upsilon} (\dot{\mathbf{x}}_j)_{\upsilon}, \; j = 1, 2.. \tag{7}$$

Asymmetric aging:

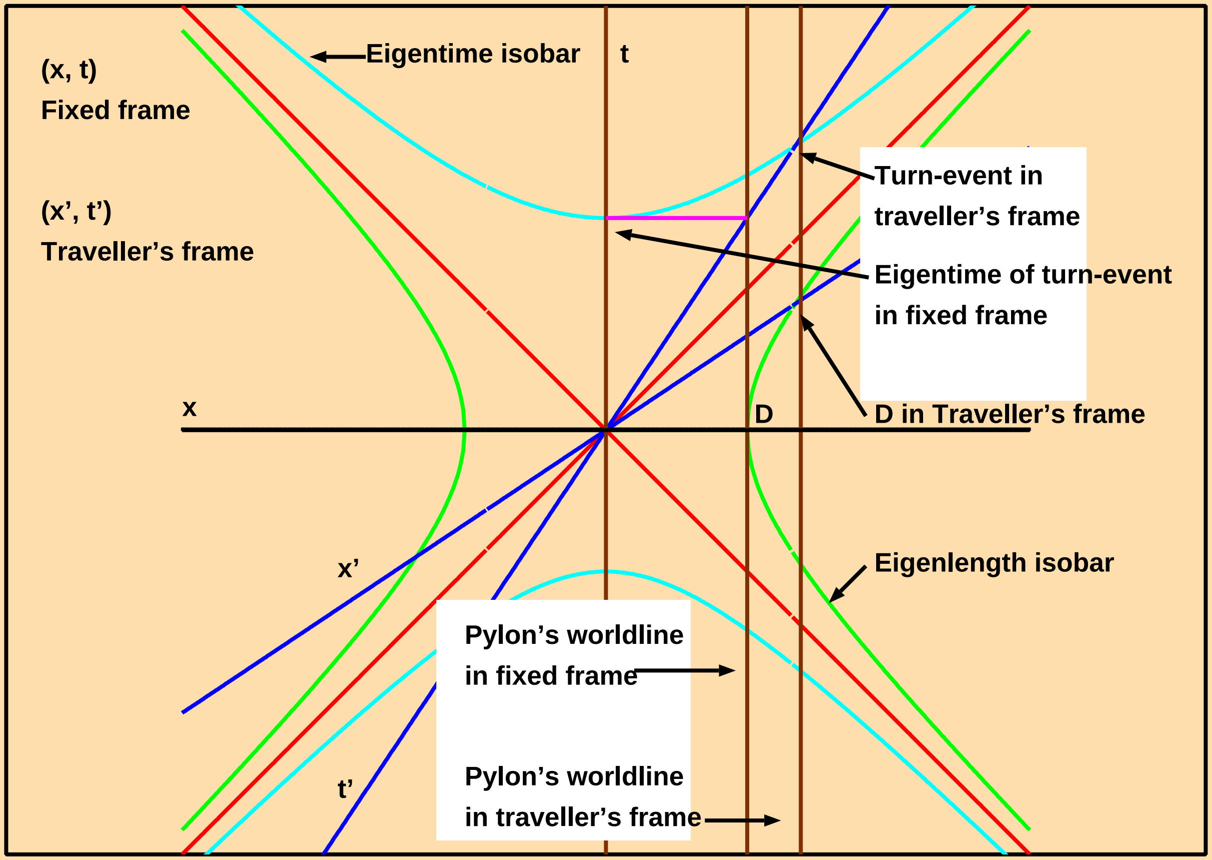
If $v = dx/d\tau$, then $v \cdot v = c^2$. Thus, whenever: $a \cdot v = 0$, one may write:

$$cd\tau_i = (dx_i \cdot dx_i)^{1/2} = ... = (dx_j \cdot dx_j)^{1/2} = cd\tau_j \tag{8}$$

which can be rearranged so:

$$d\tau = dt_j \gamma_j^{-1} = dt_k \gamma_k^{-1}. \tag{9}$$

MINKOWSKI CHARTS FOR RELATIVE MOTION



Palacios (1891-1970), relativity without asymmetric aging

Motivation

One gets to this 'clock' absurdity inevitably by using the Lorentz transformations—a circumstance that suggests that one might be able to make an alteration just there that could serve as a basis for relativity without its current logical problems. We shall examine, therefore, the fundamentals in search of altered transformations meeting this requirement, and then describe our results involving nothing more that the introduction of a factor to the Lorentz transformations that permits one simultaneously to derive two theories, Einstein's and an alternate, by setting this factor as an exponent to either 1 *or* 0*.*

Lorentz Transformations

The postulates of Einstein's theory of relativity.

1. Galileo's postulate:*Given any inertial system, S, another system which moves at a constant velocity with respect to it, is also an inertial system.*

2. Invariance of the speed of light: *Light propagates with the same speed in all inertial frames.*

3. Relativity principle:*No experiment can distinguish between a stationary system and one moving with a constant velocity.*

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3. Relativity principle:*No experiment can distinguish between a stationary system and one moving with a constant velocity.*

The problem becomes then of determining the coefficients of the following transformation formulas:

$$
\begin{aligned}
x &= a_{11}x' + a_{12}y' + a_{13}z' + a_{14}t' + k_1 \\
y &= a_{21}x' + a_{22}y' + a_{23}z' + a_{24}t' + k_2 \\
z &= a_{31}x' + a_{32}y' + a_{33}z' + a_{34}t' + k_3 \\
t &= a_{41}x' + a_{42}y' + a_{43}z' + a_{44}t' + k_4.
\end{aligned} \tag{10}
$$

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t &= a_{41}x' + a_{42}y' + a_{43}z' + a_{44}t' + k_4.
\end{aligned} \tag{10}
$$

Let us, to begin, impose the condition $t = t' = 0$ when the origins of both systems coincide, which leads to $k_1 = k_2 = k_3 = k_4 = 0$.

Since movement is along the axis $X \equiv X'$, the coordinates y, z corresponding to $P(x', y' z')$ must be independent of time; thus

$$a_{24} = a_{34} = 0.$$

The conservation of parallelism implies that if $x'_1 = x'_2$, then also $x_1 = x_2$ for $t = \mathrm{const.}$, likewise for the other coordinates. This same consideration evaluated on the other axes gives

$$a_{12} = a_{13} = a_{21} = a_{23} = a_{31} = a_{32} = 0.$$

Evidentially, the axis $X \equiv X'$ is an axis of symmetry, for which whatever holds between y and y', is also true for z and z'. As a consequence

$$a_{22} = a_{33} = a.$$

Let $-v$ be the velocity with which points of S move with relation to S', that is

$$\left(\frac{\partial x'}{\partial t'}\right)_x \equiv -v,$$

and this, with the first of Eqs. (10) and, as shown above, that $a_{12} = a_{13} = 0$, also leads to

$$\frac{a_{14}}{a_{11}} = v.$$

The considerations above imply, therefore, that by virtue of the first postulate and the way the axes as well as the origin of time were chosen, it has to be true that

$$\begin{aligned} x &= a_{11}(x' + vt'); \\ y &= ay'; \\ z &= az'; \\ t &= a_{41}x' + a_{42}y' + a_{43} + a_{44}t'. \end{aligned} \tag{11}$$

Passing now to the second postulate, we see immediately that if the equation

$$x^2 + y^2 + z^2 = c^2 t^2$$

must convert to

$$x'^2 + y'^2 + z'^2 = c^2 t'^2,$$

then the coefficients of the terms $x'y'$, $y'z'$, $z'x'$ must be nullified, so that

$$a_{41}a_{42} = 0; \quad a_{42}a_{43} = 0; \quad a_{43}a_{41} = 0;$$

and; by virtue of symmetry about the axis $X \equiv X'$, the second of these equations implies that

$$a_{42} = a_{43} = 0,$$

which satisfies all these stipulations.

In addition, the second postulate demands satisfaction of the identity

$$
\begin{aligned}
a_{11}^2(x'+vt')^2 + & \quad a^2(y'^2+z'^{2)} - c^2(a_{41}x'+a_{44}t')^2 \\
\equiv & \quad \rho^2(x'^2+y'^2+z'^2-c^2t'^2),
\end{aligned}
$$

where ρ^2 is an arbitrary constant. The final result is:

$$
a_{11}^2 - c^2a_{41}^2 = \rho^2; \quad a = \rho; \quad v^2a_{11}^2 - c^2a_{44}^2 = -c^2\rho^2;
$$

$$
va_{11}^2 - c^2a_{41}a_{44} = 0. \tag{12}
$$

These four equations permit determination of all coefficients of the transformation equations as a function of an arbitrary constant $\rho = a$. To do so, solve the fourth equation for a_{44} and substitute it in the third equation:

$$
v^2a_{11}^2 - \frac{v^2a_{11}^4}{c^2a_{41}^2} = -c^2\rho^2.
$$

From this result solve for $c^2 a_{41}^2$ and substitute it in the first equation, giving, where $\rho = a$:

$$a_{11} = \pm\frac{\rho}{\sqrt{(1 - v^2/c^2)}}.$$

In so far as we supposed that the axes X and X' are oriented in the same sense, we have to take for x and x' the same sign at $t = t' = 0$, let it be "$+$".

The third equation then gives:

$$a_{44} = \pm\frac{\rho}{\sqrt{(1 - v^2/c^2)}},$$

and as $t' > 0$ if $t > 0$, it also has a positive sign.

Finally, the last equation of the set Eq. (12) gives:

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so that the final transformation set is:

$$\begin{aligned} x &= \rho \frac{x' + vt'}{\alpha} \\ y &= \rho y' \\ z &= \rho z' \\ t &= \rho \frac{t' + \frac{v}{c^2} x'}{\alpha} \end{aligned} \tag{13}$$

where:

$$\alpha = \sqrt{1 - v/c^2}.$$

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Einstein's principle of relativity serves to fix the value of the magnitude of ρ such that it has the exponent: zero; then, in order that the systems S and S' be equivalent, it is necessary that one can pass back and forth by changing v to $-v$ and primed symbols can be replaced by unprimed ones.

The results then are such, as is easily seen, that $\rho = 1$, and we get the usual Lorentz formulas:

$$x = \frac{x' + vt'}{\alpha}; \quad y = y'; \quad z = z'; \quad t = \frac{t' - \frac{v}{c^2}x'}{\alpha} \tag{14}$$

and their inverses:

$$x' = \frac{x - vt}{\alpha}; \quad y' = y; \quad z' = z; \quad t' = \frac{t - \frac{v}{c^2}x}{\alpha} \tag{15}$$

From the first of the inverses one deduces that the velocity of S' with respect to S is:

$$\left(\frac{\partial x}{\partial t}\right)_{x'} = v.$$

This shows that relative velocity has the same absolute value in both systems.

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The clock paradox

The station master could reason so: let the traveler's clock be retarded, by reason of the $(1-\alpha)$ per hour factor, then one may write:

$$2T' = 2\alpha T + \triangle t', \tag{16}$$

where $\triangle t'$ is an advancement to the hands of his clock to take the reversal into account.

For his part, the traveler reasons as follows: a clock at the stations is retarded with respect to mine, because when it shows $2T$, mine shows:

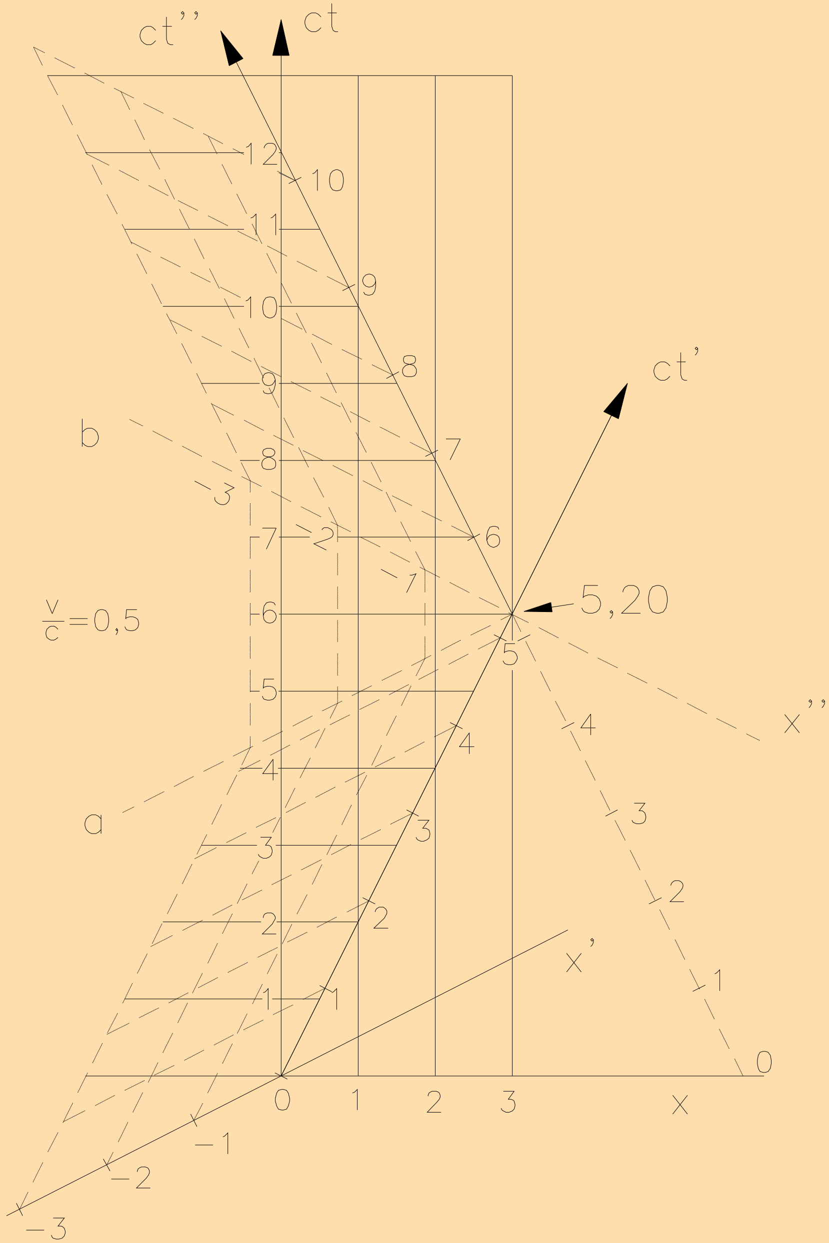
$$2T' = 2T/\alpha + \triangle t'. \tag{17}$$

The paradox consists in that these two solutions, each apparently legitimate, are incompatible, as a comparison between Eq. (16) and (17) results in an absurd equation

$$\alpha = 1/\alpha. \tag{18}$$

After these two contradictory solutions, a position that seems logical is that of Professor Dingle (*loc. cit*.), which asserts that both are incorrect, and that it must be that $2T' = 2T$, as if clocks in S and S' run parallel. Let us proceed now to examine this question.

To account for a returning train, change from the inertial system S' into another S'' and, although with it one does not change the rate of the clocks, proceed to determine the arbitrary constants that appear in Lorentz transformations applied to new initial conditions. To facilitate considerations, suppose that an interval $\triangle t$ needed to reverse course is negligible, and take $v/c = 0.5$.


ct''
ct
ct'
x''
x'
x
b
a
$\frac{v}{c}$=0,5
5,20

The clock problem resulting from supposing that motion reversal is effected with simultaneity in S'. All events between lines a and b are simultaneous in S'. Travelers age slower than those staying in an unaccelerated system.

The traveler who is located always at $x' = 0$, takes as initial conditions for a return trip (See: Fig.) the values $x = vT$, $t = T$, and a value of t' given by the Lorentz formula:

$$t = \frac{1}{\alpha}\left(t' + \frac{v}{c^2}x'\right),$$

which, with reference to Fig. **??**, are $t' = \alpha T = 5.20$ for $x' = 0$; $t = T = 6$. The initial conditions would be then:

$$x'' = 0,\ t'' = \alpha T \ \text{ for } \ x = vT,\ t = T;$$

so that one has $T'' = \alpha T$; and, the transformation formulas for the traveler's return, supposing that the reversal is carried out simultaneously in S', where, in the traveler's terms:

$$
\begin{aligned}
x &= \frac{1}{\alpha}(x'' - vt'' + 2vT''), \\
t &= \frac{1}{\alpha}\left(t'' - \frac{v}{c^2}x''\right); \\
x'' &= \frac{1}{\alpha}(x + vt - 2\frac{v}{\alpha}T''), \\
t'' &= \frac{1}{\alpha}\left(t + \frac{v}{c^2}x - 2\frac{v^2}{\alpha c^2}\right)
\end{aligned} \tag{19}
$$

and when both clocks return to be isotopic at $x - x'' = 0$, each's reading respectively would be:

- Station clock:.....................$t_0 = 2T = 12$

- Traveler's clock..............$t_r'' = 2\alpha T = 10.4$

with the final result:

$$t_v'' = \alpha t_0. \tag{20}$$

So far so good, but the station master rejects this result, adducing that his clock, which just before the train changed direction, indicated a time t_1 satisfying the equation:

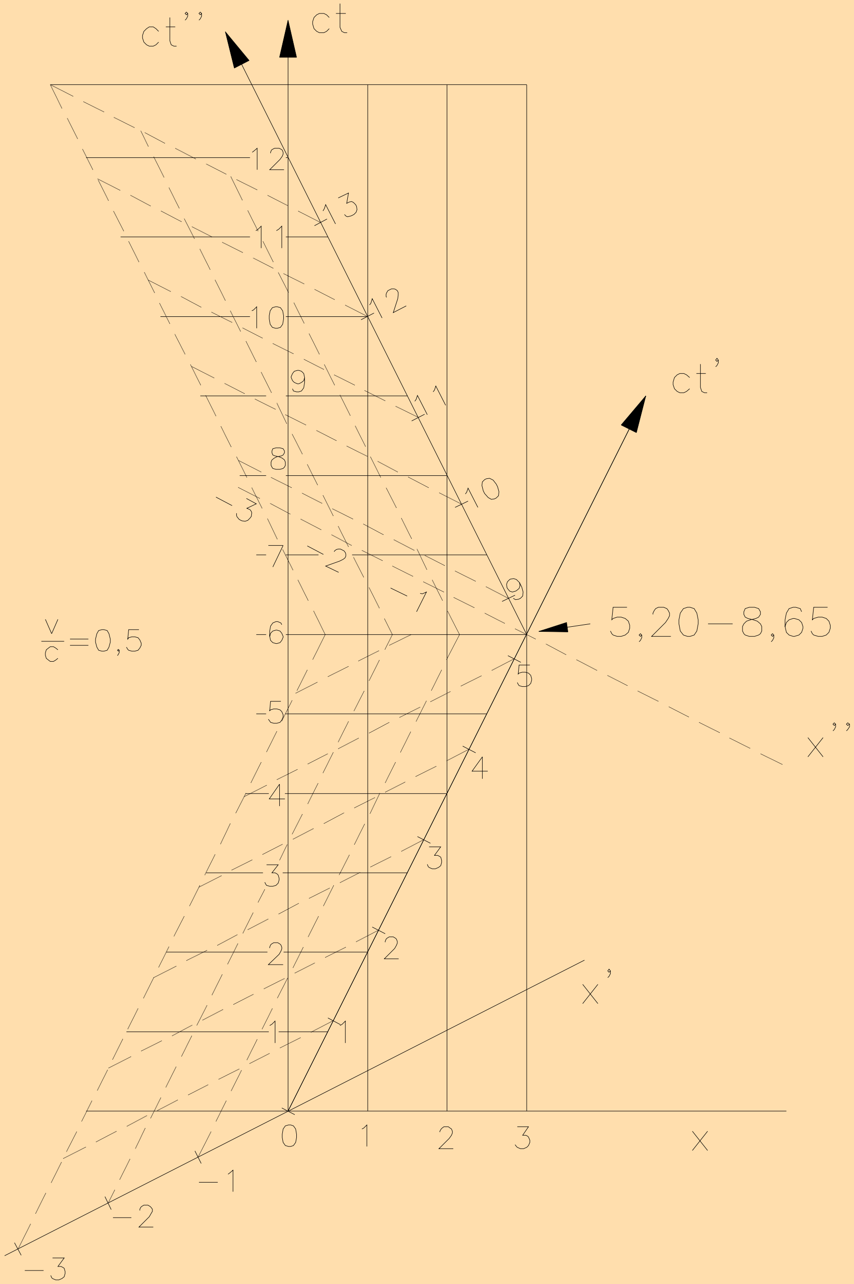
$$t' = \frac{1}{\alpha}\left(t_1 - \frac{v}{c^2}x\right) \;\; \text{for} \;\; x = 0,\; t' = \alpha T,$$

so that, $t_1 = \alpha^2 T = 4.5$, suddenly passes by the station again at time t_2, the value of which is obtained from the last of Eq. (19) with $x = 0$ and $t'' = T''$, i.e.,

$$t_2 = \frac{1}{\alpha}\left(1 + \frac{v^2}{c^2}\right) T'' = 7.5,$$

which means that its hands have been advanced, without justifiable cause, by an interval

$$t_2 - t_1 = \frac{2v^2}{\alpha c^2} T'' = 2(1-\alpha^2)T = 3. \tag{21}$$



ct''
ct
ct'
5,20−8,65
x''
x'
x
v/c=0,5
0
1
2
3
−1
−2
−3

The clock problem resulting from supposing that motion reversal is effected with simultaneity in S. The hands of the clock jump from $ct = 5.20$ to $ct = 8.65$. Travelers age quicker than those remaining in a non accelerated frame.

To recast the problem from the viewpoint of a station master who is located at $x = 0$ (See: Fig.), one has to take as the initial situation that which results from a proper concept of simultaneity, following which, a reversal of the train is an event which occurs when its clock shows $t = T$, and such that a clock in S', which then passes by $x = 0$, indicates

$$t' = \frac{1}{\alpha}\left(t - \frac{v}{c^2}x\right) = T/\alpha = 6.93,$$

with the value of x' given by

$$x' = \frac{1}{\alpha}(x - vt) = -vT/\alpha.$$

The initial conditions would be, then,

$$x'' = -vT/\alpha, \;\; t'' = T/\alpha \;\text{ for }\; (x = 0,\, t = T),$$

with which transformation formulas for a return trip become:

$$\begin{aligned}
x'' &= \frac{1}{\alpha}(x + vt - 2vT), \\
t'' &= \frac{1}{\alpha}\left(t + \frac{v}{c^2}x\right); \\
x &= \frac{1}{\alpha}\left(x'' - vt'' + 2\frac{v}{\alpha}T\right), \\
t &= \frac{1}{\alpha}\left(t'' - \frac{v}{c^2}x'' - 2\frac{v^2}{\alpha c^2}T\right) \qquad (22)
\end{aligned}$$

At the end of a journey, when both clocks are again isotopic at $x = x'' = 0$, each respectively shows:

$$t_0 = 2T = 12; \quad t_0'' = 2T/\alpha = 13.9;$$

from which

$$t_0'' = t_0/\alpha. \tag{23}$$

But now it is the traveler who rejects this solution, as his clock, which before a reversal indicated a time t', satisfied by

$$t = \frac{1}{\alpha}\left(t_1' + \frac{v}{c^2}x'\right) \text{ for } x' = 0,\ t = T,$$

so that, $t' = \alpha T = 5.2$, passes the marker suddenly at time t_2'', which one obtains from the last of Eqs. (22) in which $x'' = 0$ and $t = T$, i.e,

$$t_2'' = \frac{1}{\alpha}\left(1 + \frac{v^2}{c^2}\right)T = 8.65,$$

which means that its hands were advanced, without justification, by an interval

$$t_2'' - t_1' = \frac{2v^2}{\alpha c^2} T = 3.45. \tag{24}$$

We are, then, faced with a dilemma. If solutions given by Eqs. (20) and (23) are valid, we get an absurd result: $\alpha = 1/\alpha$. If one rejects Eq. (20) because it does not satisfy a traveler, one has to reject Eq. (23) because it does not satisfy a station master.

The result of this discussion is that Lorentz transforms give two contradictory solutions, neither of which is acceptable.

We can assert that, when one addresses this problem from the viewpoint of a traveler, one supposes that the outward and return trip of all the points of the train occur simultaneously in S', whereas a station master applies simultaneity criteria in his proper system. But, in both cases the condition that, according to the clock of a traveler he reverse his course when $t = T$ and $t' = \alpha T$, is respected.

New transformations.

Following the path taken in §1.2, the two first principles motivate the following transformation formulas:

$$x = \frac{\rho}{\alpha}(x' + vt')$$
$$y = \rho y'$$
$$z = \rho z'$$
$$t = \frac{\rho}{\alpha}(t' + \frac{v}{c^2}x')$$

where $\alpha = \sqrt{(1 - v^2/c^2)}$, and ρ is an indeterminate constant. In Einstein's theory this constant has the value $\rho = 1$ by virtue of the principle that both system S and S' are equivalent. But, reasoning that served us well for examining the so-called clock paradox, which is in reality a logical absurdity, shows that *duration of a "happening" that transpires at a fixed position in an arbitrary inertial frame has to be equal to that perceived from a fixed frame*; from which it follows that to fix the value of ρ, the condition: $t_1 - t_2 = t'_1 - t'_2$ if $x'_1 = x'_2$, requires that $\rho = \alpha$. Thus, the transformations become:

$$\begin{gathered} x = x' + vt'; \\ y = \alpha y'; \\ z = \alpha z'; \\ t = t' + \frac{v}{c^2}x', \end{gathered} \tag{25}$$

where, again, $\alpha = \sqrt{(1 - v^2/c^2)}$, and from which one deduces inverse transformations to be

$$\begin{gathered} x' = \frac{1}{\alpha^2}(x - vt); \\ y' = y/\alpha; \\ z' = z/\alpha; \\ t' = \frac{1}{\alpha^2}(t - \frac{v}{c^2}x). \end{gathered} \tag{26}$$

In general, relativistic transformation relationships take the form:

$$
\begin{aligned}
x &= \alpha^{n-1}(x' + vt'); \\
y &= \alpha^{n} y'; \\
z &= \alpha^{n} z'; \\
t &= \alpha^{n-1}\left(t' + \tfrac{v}{c^2}x'\right); \\
x' &= \alpha^{-n-1}(x - vt); \\
y' &= \alpha^{-n} y; \\
z' &= \alpha^{-n} z; \\
t' &= \alpha^{-n-1}\left(t - \tfrac{v}{c^2}x\right).
\end{aligned}
\tag{27}
$$

Setting $n = 0$ gives Einstein's version, and with $n = 1$ we get a new version.

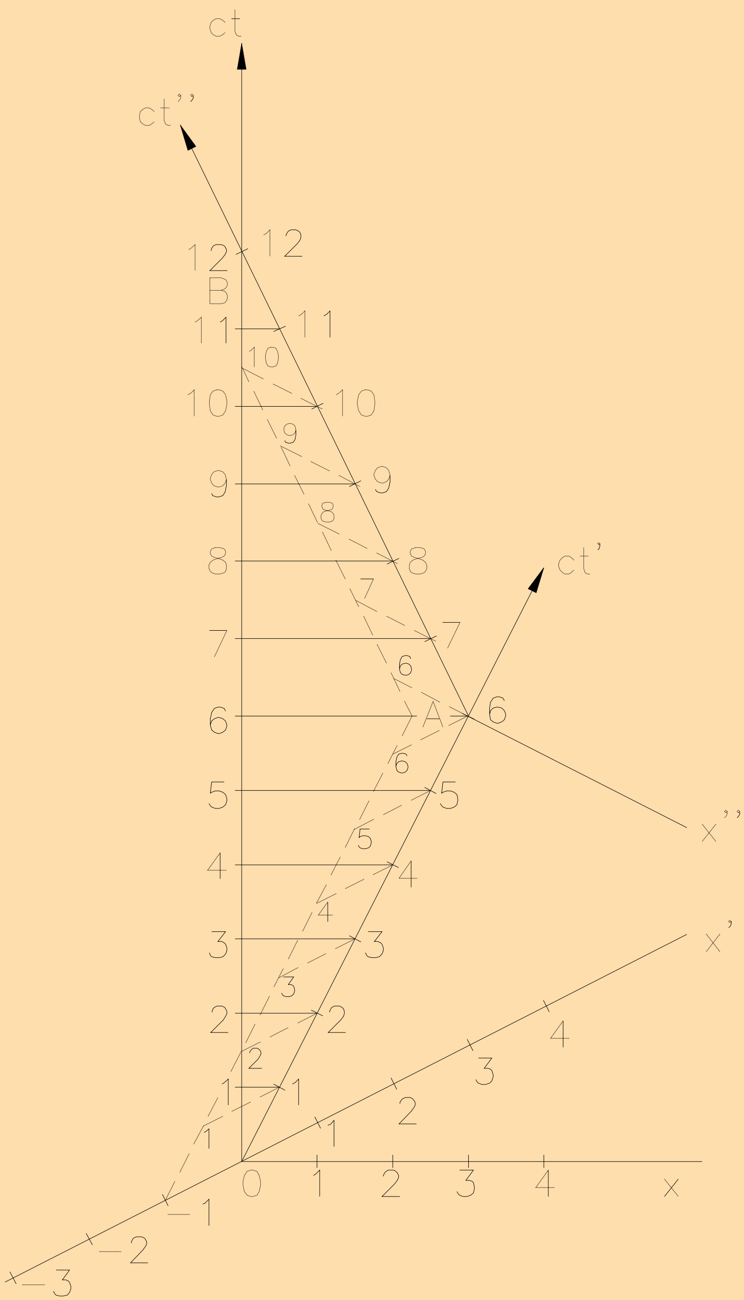
From these equations, Eqs. (27) one deduces that:

$$\left(\tfrac{\partial x}{\partial t}\right)_{x'} = v; \qquad \left(\frac{\partial x'}{\partial t'}\right)_{x} = -v,$$

which means that, except for the sign, the relative velocity is identical for both systems.

Resolution of the clock paradox

The Fig. below depicts the situation for the ‘clock paradox according to the new formulas supposing that velocity reversal is synchronized in S.



ct
ct''
ct'
x''
x'
x
A
B

tems have precisely the same positions as they have according to Lorentz transforms, but with a change in scale.

The difference between our new version and that using Lorentz's transforms rests on the fact that now all is explained by the operation of setting clocks, such that all observers have to impose an invariant clock rate in each inertial system on all clocks.

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1. Non-locality is non-existent. In particular as there are counterexamples, both models (see offprint) and experiments.

2. Asymmetric aging is not established fact.

3. Propertime may well be universal and have an intrinsic “arrow.”

4. The “Direct Interaction paradigm does not mislead one to make meaningless calculations; e.g., the energy density of ‘background’ radiation.

Clauser-Aspect type EPR-B experiments.

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The source is assumed to emit a double signal for which individual signal components are anticorrelated and, because of the fixed orientation of the excitation source, confined to the vertical and horizontal polarization modes; i.e.

$$\begin{aligned} S_1 &= (cos(n\tfrac{\pi}{2}), sin(n\tfrac{\pi}{2})) \\ S_2 &= (sin(n\tfrac{\pi}{2}), -cos(n\tfrac{\pi}{2})) \end{aligned} \quad , \tag{28}$$

where n takes on the values 0 and 1 with an even, random distribution.

Clauser-Aspect type EPR-B experiments.

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The transition matrix for a polarizer is given by,

$$P(\theta) = \left[\begin{array}{cc} \cos^2(\theta) & \cos(\theta)\sin(\theta) \\ \sin(\theta)\cos(\theta) & \sin^2(\theta) \end{array} \right], \tag{29}$$

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$$P(r_1, r_2, ..r_N) = \frac{< \prod_{n=1}^{N} E^*(r_n,t) \prod_{n=N}^{1} E(r_n,t) >}{\prod_{n=1}^{N} < E_n^* E_n >}. \tag{31}$$

It is shown in Coherence theory that the numerator of Eq. (31) reduces to the trace of $\mathbf{J}$, the system coherence or "polarization" tensor. It is easy to show that for this model the denominator consists of constants equal to 1.

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The final result of the above is:

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Eq. (31) was implemented as follows: The crystal is assumed to emit a double signal for which individual signal components are anticorrelated and confined to the vertical and horizontal polarization modes; i.e.

$$\begin{aligned} A_1 &= \left(cos(n\tfrac{\pi}{2}), sin(n\tfrac{\pi}{2})\right) \\ A_2 &= \left(sin(n\tfrac{\pi}{2}), -cos(n\tfrac{\pi}{2}\right) \\ A_3 &= \left(sin(m\tfrac{\pi}{2}), -cos(m\tfrac{\pi}{2})\right) \\ A_4 &= \left(cos(m\tfrac{\pi}{2}), sin(m\tfrac{\pi}{2})\right) \end{aligned} \qquad (33)$$

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The polarizing beam splitter (PBS) is modeled using the transition matrix for a polarizer, $P(\theta)$, Eq. (31) where $\theta = \pi/2$ accounts for a reflection and $\theta = 0$ a transmission. Thus the final field impinging on each of the four detectors is:

$$\begin{aligned} E_1 = &\quad P(\theta_1)A_1 \\ E_2 = &\quad P(\theta_2)(P(0)B_2 - P(\pi/2)A_3) \\ E_3 = &\quad P(\theta_3)(P(0)B_3 - P(\pi/2)A_2) \\ E_4 = &\quad P(\theta_4)B_4 \end{aligned} \tag{34}$$

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The principle results reported by Pan et al.: Of the 16 possible regimes setting: $\theta_i = \{0, \pi/2\}$ only $\{0, \pi/2, \pi/2, 0\}$ and $\{\pi/2, 0, 0, \pi/2\}$yield a four-fold coincidence count, C; the regime $\{\pi/4, \pi/4, \pi/4, \pi/4\}$ occurs with an intensity $C/4$ and the regime $\{\pi/4, \pi/4, \pi/4, -\pi/4\}$with zero intensity. Further, both of the later regimes yield an intensity of $C/8$ when the time between pair creation is so large that that there is no “cross-talk” between channels 2 and 3. Our model mimics everything.

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Results of a *classical* calculation of four-fold coincidences. The upper curve, without PBS's, on the left is "prepurified;" the fact that the visibility of the other curve with PBS's is higher is said to exhibit "entanglement purification." Irrespective of terminology, the phenomenon is *nonquantum:* Malus' Law or geometry.

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Franson-type experiments

These experiments exploit time-delays between pulses to define the orthogonal states played by the two states of polarization in the setups described above.See Fig. below.

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To model them, a simple tactic is to assign the signals in the long and short paths to orthogonal dimensions of a vector space; the resulting calculations are transparent and devoid of irrelevant, gratuitous complexity. For example:

$$\begin{aligned} E_r &= (\exp(-i(kx-\omega t)+\phi), \exp(-i(kx-\omega t))/\sqrt{2} \\ E_l &= (\exp(-i(kx-\omega t)+\varphi), \exp(-i(kx-\omega t))/\sqrt{2} \end{aligned} \quad , \tag{35}$$

where ϕ and φ are the extra phase shifts introduced in the long paths. Then, using Eq. (31), with the convention that the tensor product in be replaced by a vector inner product; i.e.,

$$P(\phi, \varphi) = \frac{(E_r^* \cdot E_l^*)(E_l \cdot E_r)}{(E_r^* \cdot E_r)(E_l^* \cdot E_l)}, \tag{36}$$

(to algebraically enforce the orthogonality in calculations that time-delay enforces in the experiment) quickly gives the observed correlation as a function of the phase shifts:

$$P(\phi, \varphi) \propto 1 + \cos(\phi - \varphi), \tag{37}$$

which exhibits the oscillation with 100% visibility characteristic of idealized versions of these experiments.

Brendel type experiments

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In the above experiment the radiation source was taken to be ideal, that is, it produced two signals of exactly the same frequency with no dispersion. In some experiments, the source used was a nonlinear crystal generating two correlated but not necessarily identical pulses, which satisfy ‘phase matching conditions’ so that if one signal in frequency is above the mean by s (spread), the other is down in frequency by the same amount. This leads to an additional phase difference at the detectors which is also proportional to those already there; i.e., $s\varphi$ and $s\phi$, so that:

$$\begin{aligned} E_r &= (\exp(-i(kx-\omega t)+\phi(1+s)), \exp(-i(kx-\omega t)) \\ E_l &= (\exp(-i(kx-\omega t)+\varphi(1-s)), \exp(-i(kx-\omega t)) \end{aligned} . \tag{38}$$

Since the value of s is different for each pulse (photon) pair, the resulting signal is an average over the relevant values of s:

$$\frac{1}{2s}\int_{-s}^{s} P(\phi, \varphi, s)ds, \tag{39}$$

where $P(\phi, \varphi, s)$ was computed as for ‘Franson’ experiments. The final result closely matches that observed by BRENDEL et al. See following fig.

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Suarez-Gisin type experiments

In experiments of this type one of the detectors is set in motion relative to the other. By doing so with appropriately chosen parameters, it is possible to arrange the situation such that each detector precedes the other in its own frame. Thus, not only is the ‘collapse’ of the wave packet “nonlocal,” it occurs such that there is also “retrocausality.” In the model proposed herein, however, this complication (paradox) can not arise in the first instance. All the properties of each pulse are determined completely at the common point at which the signals are generated. Properties measure at one detector in no way determine those at the other detector, regardless of the order in which an observer receives reports of the results from the two detectors, or regardless of what conditional probabilities he might write to describe the state of his hypothetical or real knowledge as determined by the time order of his receipt of information from the detectors.

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- Measurement stations: polarizing beams splitters feeding two each photodetectors.
- Data collection & analysis: "coincidence circuitry:" also per Malus' Law get relative intensity:

$$\kappa^* = \cos^2(\theta_r - \theta_l) - \sin^2(\theta_r - \theta_l), \tag{40}$$

- Expand with:

$$\begin{aligned} \cos(\theta_r - \theta_l) &= \cos(\theta_r)\cos(\theta_l) + \sin(\theta_r)\sin(\theta_l), \\ \sin(\theta_r - \theta_l) &= \sin(\theta_r)\cos(\theta_l) - \cos(\theta_r)\sin(\theta_l); \end{aligned} \tag{41}$$

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- Get values of individual terms from Malus' Law:

$$\begin{aligned}\cos(\theta_l) &= \sqrt{N_{hl}/N}, \\ \sin(\theta_l) &= \sqrt{N_{vl}/N}. \end{aligned}$$

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Gleason-Kochen-Specker “Experiments”

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- What goes into the extraction of a Bell Inequality?

First, recall

$$\int dx\, f(x)\delta(x-l)\delta(x-m) = 0, \tag{42}$$

whenever $l \neq m$.

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The derivation of a Bell Inequality starts from BELL's fundamental *Ansatz*:

$$P(a,b) = \int d\lambda \rho(\lambda) A(a,\lambda) B(b,\lambda), \tag{43}$$

where, per *explicit assumption:* A is not a function of b; nor B of a; and each represents the appearance of a photoelectron in its wing, and a and b are the corresponding polarizer filter settings. This is motivated on the grounds that a measurement at station A, if it respects 'locality,' so argues Bell, can not depend on remote conditions, such as the settings of a remote polarizer. By definition:

$$|A| \leq 1, \;\; |B| \leq 1, \tag{44}$$

which in this case effectively restricts the analysis to the case of just one photoelectron per time window per detector. Eq. (43) expresses the fact, that when the hidden variables are integrated out, the usual results from QM are to be recovered.

The λ above in Bell's analysis are to be the hypothetical "hidden variables", which, if they exist, should render QM deterministic. As is customary, the single symbol λ represents actually a set of such 'hidden variables' that may include many different characters, such as discrete, continuous, tensor or whatever.

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Extraction of inequalities proceeds by considering differences of two such correlations where (a, b), *i.e.*, the polarizer axis of measuring stations left and right, differ:

$$\begin{aligned} P(a,b) - P(a,b') = \\ \int d\lambda \rho(\lambda)[A(a,\lambda)B(b,\lambda) - A(a,\lambda)B(b',\lambda)] = 0, \end{aligned} \tag{45}$$

to which one adds ± 0 in the form:

$$\begin{aligned} A(a,\lambda)B(b,\lambda)A(a',\lambda)B(b',\lambda) - \\ A(a,\lambda)B(b',\lambda)A(a',\lambda)B(b,\lambda) = 0, \end{aligned} \tag{46}$$

to get:

$$\begin{aligned} P(a,b) - P(a,b') = \\ \int d\lambda \rho(\lambda)A(a,\lambda)B(b,\lambda)[1 \pm A(a',\lambda)B(b',\lambda)] - \\ \int d\lambda \rho(\lambda)A(a,\lambda)B(b',\lambda)[1 \pm A(a',\lambda)B(b,\lambda)], \end{aligned} \tag{47}$$

which, in turn, upon taking absolute values and in view of Eqs. (44), Bell wrote as

$$
\begin{aligned}
&|P(a,b) - P(a,b')| \leq \\
&\quad \int d\lambda \rho(\lambda)[1 \pm A(a',\lambda)B(b',\lambda)] + \\
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Then, using Eq. (43), and the normalization condition $\int d\lambda \rho(\lambda) = 1$, he got, for example:

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|P(a,b) - P(a,b')| + |P(a',b') + P(a',b)| \leq 2, \tag{49}
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Now, however, if the λ are a complete set, thereby rendering everything deterministic so that all probabilities become Dirac or Kronecker delta distributions, then the A's and B's in Eq. (47) are pair-wise, that is as individual events comprising the generation at the source of one pair, non-zero for distinct values of λ, which, by virtue of completeness, do not coincide for distinct events, *i.e.*, for different pairs. That is, for each pair of settings (a, b) and iteration of the experiment, there exists a unique value (or set of values), $\lambda_{(a,b)}$ say, for which $A(a|\lambda_{(a,b)})B(b|\lambda_{(a,b)})$ is non-zero (± 1 in the discrete case, $\pm\infty$ in the continuous case). In other words, each product $A(a|\lambda_{(a,b)})B(b|\lambda_{(a,b)})$ can be written in the form $f(x)\delta(x-\lambda_{(a,b)})$, so that all quadruple products

$$A(a|\lambda_{(a,b)})B(b|\lambda_{(a,b)})A(a|\lambda_{(a',b')})B(b|\lambda_{(a',b')}), \tag{50}$$

are of the form:

$$f(x)\delta(x-\lambda_{(a,b)})g(x)\delta(x-\lambda_{(a',b')}), \tag{51}$$

where x is a dummy variable of integration to run over all admissible values of

λ. Therefore, such terms with pair-wise different values of $\lambda_{(ab)}$ in Eq. (47), *i.e.*, when either $a \neq a'$ or $b \neq b'$, are, in accord with Eq. (42), identically zero under integration over λ. This annihilates two terms on the left of eq. (49), so that the final form of this Bell Inequality, *resulting from the above complex of hypotheses,* is actually, for example, the trivial identity[**?**]:

$$|P(a,b)| + |P(a',b')| \leq 2. \tag{52}$$

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- Is taken data compatible with a Bell inequality?

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Suppose there is a string of data available from an experiment. It will be comprised of four virtually equal length subsets, one for each setting combination; let the term-wise product series of the first subset be denoted a_1b_1, the second a_2b_2', etc. (and where another serial subscript is understood). With this notation, Eq(49) becomes:

$$|<a_1b_1>+<a_2b_2'>|+|<a_3'b_3'>-<a_4'b_4>|\leq 2. \tag{53}$$

Now, it is obvious that for a particular polarizer setting, the percentage of $+1$'s in the total of long enough samples will be equal; *i.e.*, the number for a_1 equals the number for a_2 etc.; so that one can imagine re-sorting a_2 so that it has nearly the identical serial pattern as a_1. Denote the re-sorted version as $\tilde{a}_2$.

Thus, the re-sorted second term in Eq. (**??**), for example, becomes

$$a_2 b'_2 \Rightarrow \tilde{a}_2 \tilde{b}'_2 \cong a_1 \tilde{b}'_2$$

the resorted third term becomes:

$$a'_3 b'_3 \Rightarrow \tilde{a}'_3 \tilde{b}'_3 \cong \tilde{a}'_3 \tilde{b}'_2$$

and then the fourth term:

$$a'_4 b_4 \Rightarrow \tilde{a}'_4 \tilde{b}_4 \cong \tilde{a}'_3 \tilde{b}_4 .$$

So that Eq. (53) converts to:

$$< |a_1||(b_1 + \tilde{b}'_2)| > + < |\tilde{a}'_3||(\tilde{b}'_2 - \tilde{b}_4)| > . \tag{54}$$

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- Details: quant-ph/01 08 057; (+more on arXiv;
  search: Kracklauer — all categories/all years)

- e-file with MAPLE or SCILAB routines for the above available upon request.
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