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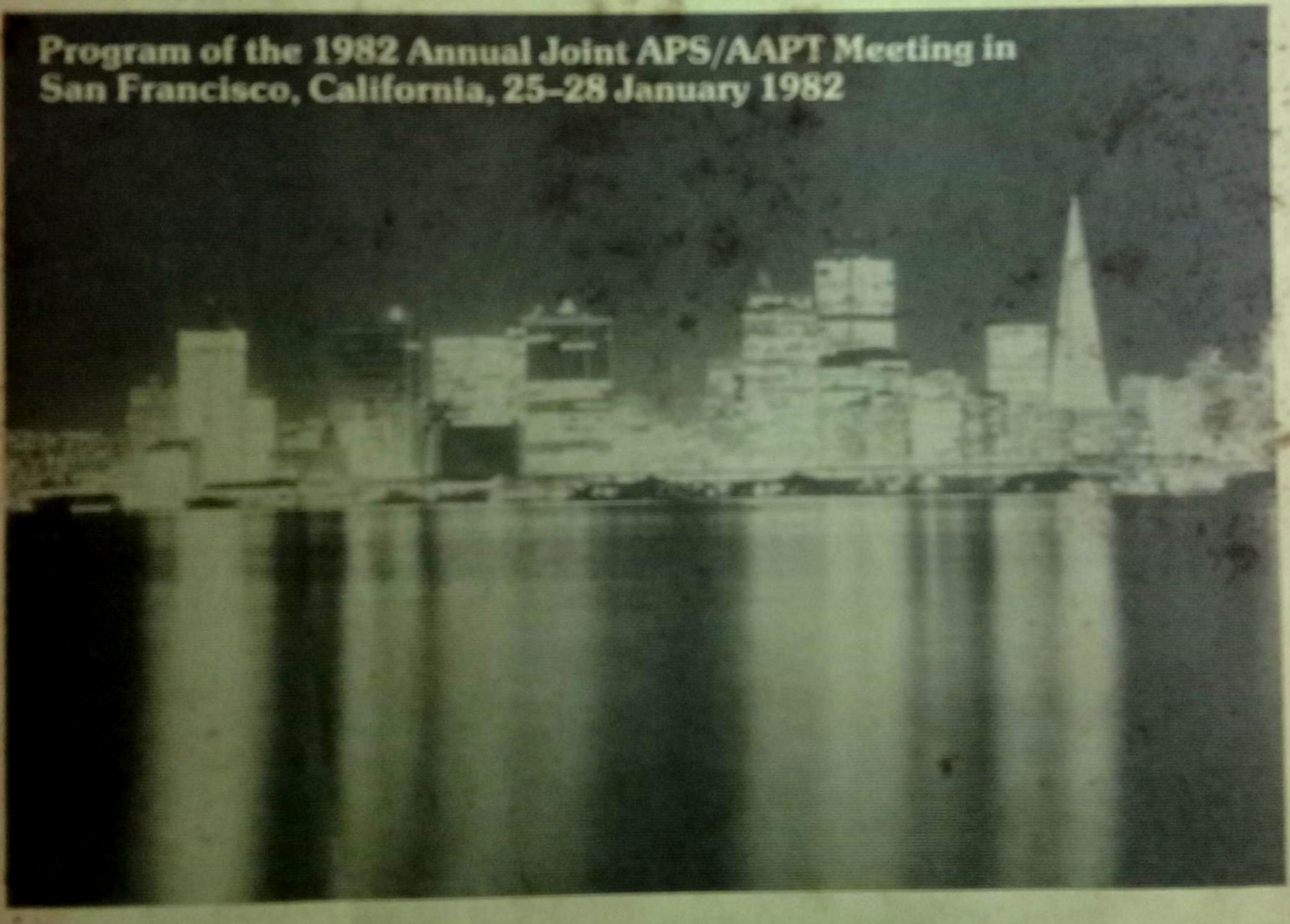

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tation, and central region "pionization." The model is consistent with the energy independent features of angular distributions and average charged particle multiplicities. $R = \langle n_s \rangle / \langle n_h \rangle$ (where n_s is the minimum-ionizing multiplicity on nuclei and n_h is the multiplicity at equal energy on hydrogen) is energy dependent and asymptotically proportional to $\bar{\nu}$, the average number of collisions in the target nucleus. We conclude that in p-p interactions target and projectile fragmentation each account for 1.5 charged particles independent of primary energy, so that the energy dependence of $\langle n_h \rangle$ resides solely in the central region contribution.

GE 14 Pair Production Processes And The New Heavy Mesons. JAY W. PHIPPEN, Weber State College, and JACK E. CHATELAIN, Utah State Univ.—The calculation of both electron-pair and muon-pair production cross-sections is made using Feynman-Dyson quantum electrodynamics. Psuedoscaler coupling is used between the nucleons and vector coupling is used between the nucleons and the pair. The nucleons are considered as Dirac particles and radiative corrections are omitted. Eight fourth-order Feynman-Dyson diagrams are used. The subsequent sixtyfour TRACES are written as a linear combination of the seven independent (topologically different) TRACES. With the mathematics and the corresponding computer programs written down, data (momenta and energy which represent the kinematics of the pair production process) are needed. Using a Monte Carlo method, random relativistically invariant data are generated and then substituted into the computer programs which calculate the pair-production cross-sections. The theoretical treatment of pair production processes (described in this paper) compares very nicely with recent experimental work.

Supplemental Program

GE 15 Some Comparison of RFT and Classical Physics Formulas. ANATOL J. SHNEIDEROV, 2495 Sutter St., San Francisco, CA 94115.--Instead of three different forces of undefined origin and nature used in Classical Physics in explaining gravitational, electric, and magnetic phenomena, only one, well defined force and energy of Radional Field is formed of subparticles—radions ~24 orders of magnitude smaller and lighter than those of the proton. Radions, which populate "free" space with a density $\sim 5.12 \times 10^{57}$ radions/cm^3, move randomly in it along their mean free paths, 3.684×10^{15} cm, with a r.m.s. speed, $\sigma = \underline{c}$ and produce in RF a total radional pressure, 1.13×10^{31} dyn/cm^2, and total kinetic energy density, 1.130×10^{31} ergs/cm^3. Accepting the experimental value of elementary electric charge to be $\underline{e}_e = 4.803 \times 10^{-10}$ e.s.u., it is defined here as the capacity of an elementary particle to reflect perfectly and completely the fluxes of radions falling on, and normally to the great circle area of the particle. In RFT this radional screening capacity of an electron is, $\underline{e}_e = \pi a_e^2 \times J_c^{\frac{1}{2}} = 4.803 \times 10^{-10}$ e.s.u. for $\underline{a}_e = 2.134 \times 10^{-13}$ cm, as against the classical value of electron radius (1974), 2.82×10^{-13} cm. RFT formulas for gravitational, electrostatic, and magnetic interactions of RF with material bodies in it, and a formula for the temperature of RF are presented.

SESSION GX: POSTER SESSION: VARIOUS TOPICS
Wednesday morning, 27 January 1982
Continental Parlor 8 at 9:00 A.M.

GX 1 Direct Illumination Target Designs for a Pulse Shaped CO_2 Laser.* M. H. FRESE and M. L. ALME, Mission Research Corporation.--Single shell hot spot ignition targets driven by hot electrons from direct CO_2 laser irradiation were designed using an efficient 1-D radiation hydrodynamics code. The targets have LiH ablators to minimize radiation reduction of ablation pressure and are pusherless to convert more ablation pressure work to final internal energy of fuel. Two kinds of laser pulse shaping techniques were used: one creates the ablation pressure used by Kidder to control shock heating, and the other controls hot electron deposition in the fuel. Petawatt peak laser power is required for all fuel masses from 10 μg to 2.5 mg. A 100 μg target simulation reaches ignition and burn conditions with 1 MJ of laser energy.

*Supported by Los Alamos National Laboratory under subcontract 4-X11-0380U-1.

GX 2 An Exploding Shell Fusion Target Design.* M. L. ALME and M. H. FRESE, Mission Research Corporation.--Multi-shell inertial fusion targets in which the directly irradiated outer shell is exploded have been studied. The hot electrons produced by the CO_2 laser light are confined to the exploding shell by vacuum insulation. The original target concept of Kindel and Stroscio[1] has also been modified by the addition of a "pick-up" shell between the exploding shell and the inner pusher enclosing the fuel. Calculational results for targets with milligram fuel masses will be presented.

*Supported by Los Alamos National Laboratory under subcontract 4-X11-0380U-1.

[1] J. M. Kindel and M. A. Stroscio, Los Alamos National Laboratory Report LA-7167-MS, March 1978.

GX 3 Thick Target Studies of Heavy-ion Production of Secondary π⁻ Beams. D. MURPHY, J.O. RASMUSSEN, K. FRANKEL, H. BOWMAN, and J. SULLIVAN, LBL.*—Enhanced π⁻ production cross sections at 0° at beam velocity in relativistic heavy ion collisions have been observed by Benenson et al.[1] In hopes of using relativistic heavy ion collisions as a practical source of secondary π⁻ beams, we have measured pion yields in the reaction 670 MeV/A ^{20}Ne on 0.6, 2.5, 5.1, and 7.6 cm Be → π⁻. We find the angular width of the forward pion peak is not significantly degraded even with such thick targets. We note that an optimal beam for thick target π⁻ production would be ^{28}Si, where q^2/m matches pions, and this would obtain velocity matching for π⁻ and ^{28}Si. Heavy ions may offer a useful technique of π⁻ or μ⁻ beam production. These secondary beams have been of much interest for medical applications (π⁻) or for chemical analysis or fusion (μ⁻).

*Supported by Office of Energy Research, Div. of Nuclear Physics of U.S. Department of Energy.

[1] W. Benenson, G. Bertsch, G.M. Crawley, E. Kashy, J.A. Nolen, Jr., H.R. Bowman, J.G. Ingersoll, J.O. Rasmussen, J. Sullivan, M. Koike, M. Sasao, J. Peter, and T.E. Ward, Phys. Rev. Lett. 43, 683 (1979), 44, 54(E)(1980).

GX 4 The Momentum Distribution of the Neutron in ^{2}H and ^{3}He.* G.F. KREBS† A.D. MAY, and J.M. DANIELS. University of Toronto. - The momentum distribution of the neutron in ^{2}H and ^{3}He was determined by the quasi-elastic scattering of 667 MeV protons. The scattered proton and neutron were observed, and each event was analysed kinematically to find the momentum of the neutron before collision. The momentum distribution in ^{2}H fitted the Hulthén-Yamaguchi wavefunction well, and is in good agreement with the measurements of Felder[1]. The distribution in ^{3}He fits the Irving-Gunn[2] wavefunction best of all wavefunctions so far proposed for the three nucleon system, but there is a significant dip at momenta around 100 MeV/c.

*Submitted by J.M. DANIELS.

†Lawrence Berkeley Laboratory.

[1] R.D. Felder. Nucl. Phys. A264, 397 (1976).

[2] R. Frascaria. Nucl. Phys. A178, 307 (1971).

GX 5 Comparison of the Theoretical and Experimental Lifetimes of the Metastable State, | 1s 2s 2p J=5/2>* C.P. BHALLA and T.W. TUNNELL, Kansas State University-- We have calculated the x-ray and the Auger rates for the decay of the metastable state | 1s 2s 2p J=5/2> for

Z=3 to Z=26. The calculations were performed using the relativistic wave functions and included the effects of retardation. The X-ray transition energies were calculated with the Dirac-Hartree-Fock model and agree with the observed energies. The difference in the X-ray rates when calculated with the Dirac-Hartree-Fock and Dirac-Slater models is less than 1%. The resultant lifetimes are 10% longer than the earlier calculations[1] and are in excellent agreement with the available data.

[1] K.T. Cheng, C.P. Lin, and W.R. Johnson, Phys. Lett. 48A, 437 (1974).

*This work was supported by Division of Chemical Sciences, U.S. Department of Energy.

GX 6 Computer Simulation of Electron Trajectories Through Double Einzel Lens System. A TOTEN, F. BREYER, F.D. McDANIEL, R.P. BHALLA, J.D. GRESSETT, North Texas State U.* G.D. ALTON, Oak Ridge National Laboratory†--The electron optical lens system studied consists of two Einzel lenses with an intermediately located retardation grid system described earlier[1]. The Herrmannsfeldt computer code[2] was used to perform numerical calculations of electrostatic field distributions and electron trajectories for the double Einzel lens system. The exact electrode shapes, positions and boundary conditions of the problem are input to the code which then determines the finite difference equations for the system. The code then searches for a self-consistent solution to the finite difference form of Poisson's equation ($\nabla^2\phi=-\rho/\varepsilon_o$). The computed trajectories are used to determine lens operating parameters for a range of experimental conditions.

*Supported in part by the Robert A. Welch Foundation and the NTSU Organized Research Fund.

†Research sponsored by the U.S. Department of Energy.

1. A. Toten, F. Breyer, A. Hamdi, R.P. Bhalla, F.D. McDaniel, IEEE Trans. in Nucl. Sci., NS28, 1567(1981).

2. W.B. Herrmannsfeldt, SLAC Report 166, Stanford Linear Accelerator Center, Stanford, CA (1973).

GX 7 Auger Electron Production for H and He Ions Incident Gas Targets of N_2, O_2, Ne and Ar. J.D. GRESSETT, R.P. BHALLA, A. TOTEN, F.D. McDANIEL, North Texas State University.*--High resolution KLL Auger electron spectra for N_2, O_2, and Ne and LMM Auger electron spectra for Ar have been measured for thin gas targets under H^+ and He^{++} ion impact. Spectra were obtained using a constant energy mode π/4 electrostatic parallel plate electron analyzer employing pre-retardation. This analyzer is discussed elsewhere at this conference.

*Supported in part by the Robert A. Welch Foundation and the NTSU Organized Research Fund.

GX 8 Carbon KLL Auger Electron Yields for a Number of Hydi carbons for H and He Ion Impact. R.P. BHALLA, J. D. GRESSETT, A. TOTEN, F. D. McDANIEL, North Texas State University.*--Carbon KLL Auger electron yields are presented for a range of energies for H and He ions incident on a number of hydrocarbon compounds. The spectra were obtained using a high resolution electrostatic parallel plate analyzer described elsewhere at this conference. The dependence of the Auger electron yields on the effective charge on the carbon atom in each molecular system are presented.

*Supported in part by the Robert A. Welch Foundation and the NTSU Organized Research Fund.

GX 9 L-Subshell Ionization Cross Sections of even Elements with $56 \leq Z \leq 72$ for Proton Energies from 0.4 to 2.0 MeV. L. A. RAYBURN, The University of Texas at Arlington.--L-subshell production cross sections of Ba, La, Ce, Pr, Nd, Sm, Dy, Ho, Er, Yb and Hf for incident proton energies from 0.4 to 2.0 MeV were measured using standard techniques. An ORTEC Si(Li) X-Ray Detector with an energy resolution of 165 eV FWHM at 5.9 keV was used to detect the x-rays. Calibrated radioactive sources were used to determine the detector efficiency. Particle detectors mounted at 45° and 90° to the beam direction were used to monitor the incident proton beam. Subshell fluorescence yields and Coster-Kronig transition probabilities taken from Bambynek[1] were used in the calculation of the ionization cross sections. These measurements will be compared to the predictions of the Plane Wave Born Approximation (PWBA) and the Binary Encounter Approximation (BEA).

[1] Walter Bambynek, et. al., Rev. Mod. Phys. 44, 716 (1972).

GX 10 Superconducting Telluride Compounds Containing Mixed (Nb, Re)$_6$ Clusters. N. H. ZEROUNI, K. RAMAN AND C. G. GRENIER, Louisiana State University, Baton Rouge 70803.--We have successfully synthesized the pseudo - ternary compounds Sn (Nb_3 Re_3) Te_8 and Sn (Nb_2 Re_4) Te_8. They are superconducting at $T_c \simeq$ 1.7K and 1.6K, respectively. Their crystallographic structure is being studied to determine if they are Chevrel phase compounds. Their critical fields are about 200 gauss and they appear to be type II with very little hysteresis.

GX 11 Unified Theory of Biology and Physics. STANFORD GOLDMAN, Univ. of California, San Diego. --A surprising degree of analogy is found between the basic mechanisms of physics and biology. The genetic and somatic representation domains in biology are, respectively, highly analogous to the domain of conserved observables and the generalized configuration domain in physics. The existence of eigenstates, the relation between symmetries and conservation laws, the existence of bosons and fermions, and the existence of particles and antiparticles are shown to have detailed analogues in biology. There is reason to believe that alternation of generation, and the assimilation of negative entropy from the environment have analogues in physics which may be fundamental. Genes of biology are found to be remarkably analogous to conserved observables in physics.

GX 12 Infinite Chain Calculation for Syndiotactic Poly(Methyl Methacrylate). Irving Lipschitz and John Michael Gray, University of Lowell. The vibrational spectrum of syndiotactic poly(methyl methacrylate) has been calculated for an infinite linear zigzag backbone. The ester side chain was either entirely in the syn-syn conformation or the syn-anti conformation. The calculation was based on a modified Urey-Bradley force field with 54 force constants. No structureless masses were used for the methyl or the methylene groups. Instead, all 30 atoms in the repeat unit were used. Previous calculations based on a simplified model of PMMA have suggested the importance of the side chain conformation in the ester stretching region (1050-1300cm^{-1}) of the PMMA spectrum. Our calculation shows that much of the complexity in this region can be explained by the presence of the two side chain conformations.

GX 13 Beyond the Speed of Light. S.A. KAMAL, Indiana U., Bloomington—In contrast to the conventional theories of tachyons (faster than light particles) this paper attempts to describe a theory based on the symmetry principles of nature. A theory having symmetrical distribution of invariant speeds must leave the speed (2n-1)c, (n is an integer) invariant. The mass as a function of velocity is now a periodic function $m(v) = m(v+2c)$ for any value of v. This generalised definition of mass satisfies the world line equation

$$[p - (2n - 1)mc]\,[p - (2n + 1)mc] = -m_o{}^2c^2$$

The theory presented here is Lorentz covariant, does not involve imaginary quantities, satisfies the symmetry principles of nature, explains the kinametics of the particles and preserves the definition of momentum and energy.

GX 14 DIRECT CONVERTIBILITY OF G INTO E.M.FORCE FROM MERGER OF SPACE/TIME—S.M. Ayub, A-2, Bliss Apartments, 4/1 Mc Neil Road, Karachi/Pakistan—Sometime ago the theoretical/practical conv-ersion of G into E.M.Force was given on covariance of Relative Tensor Equations and identical values of Z_1**. A.Einstein's Relativity Tensor Equation is $R_{\mu\omega} - \frac{1}{2} g_{\mu\gamma} = -KT_{\mu\gamma}$ the terms having standard meanings. In General Relativity, with the fusion of SPACE/TIME at the fringe of the Universe, the Tensor of the Gravitational potential $-\frac{1}{2}g_{\mu\gamma}$ becomes expressible in terms of Energy $-2KT_{\mu\gamma}$ Therefore, G convertibility into Energy gets confirmed. Of the other three Forces, Nuclear, N.Weak and E.M., the first two are out of question and, therefore, direct convertibility confines itself to E.M. The phenomenon is independent of parametric considerations and is confirmable experimentally, as mentioned earlier, in any suitably equipped centrifuge, with cover to cut off Earth's magnetic field. This is not possible for any two other Forces, out of 4 basic Forces.

**Reference,-A.P.S. Bulletin, April 1980, A1-15; 'A Possible Unitary Equation'.

GX 15 THE 'BIG BANG' CYCLE FROM EXPANSION/CONTRACTION OF THE UNIVERSE —S.M. Ayub, A-2, Bliss Apartments, 4/1 Mc Neil Road, Karachi/Pakistan—The cycle is calculated from He^4_2 / H^1_1 ratios and other methods. The concept of fusion of Space-Time continuum can also yield this result. When the absolute expansion of the Universe from now onwards equals 'C^2', or its fused Space-Time continuum 'C^4', the contraction forces equalise it, leading to the collapse of the Universe, and the end of the 'Big Bang' cycle. The expansion is slowing down with time and is 4.33×10^{18} cm. per year presently in absolute terms. 'C^2' in a light year is 3.1×10^{28}. If the average expansion is the same, it will be another 7.2×10^9 years to reduce the interaction to zero, leading to the end of the 'Big Bang' cycle. If the Universe is already 7.5 billion years old, as believed, its cycle will be 14.7 billion years, which is close to accepted figures.

GX 16 ROLE OF TIME IN FUSED SPACE-TIME OF RELATIVITY—S.M. Ayub, A-2, Bliss Apartments, 4/1, Mc Neil Road, Karachi/Pakistan—With three dimensions of Space in the Space-Time continuum, the normal Absolute Time 'C' is given by the fourth root of the expression. As $S \equiv T$ and both are synonymously equivalent, when S is Absolute and uni-dimensional, T must have three dimensions, T_1, T_2, T_3. The interpretation of T_1 is 'C' in normal conditions, of T_2 Earth-related 'second', of T_3 is the time-length of existence of the Universe since its birth after the 'Big Bang'. These are the only standard representations plausible. Normally S is 3-dimensional and the T component in the expression is 'C'. This will identify the role of Time in the new concepts.

GX 17 NEW HORIZONS IN RELATIVITY — S.M. Ayub, A-2, Bliss Apartments, 4/1, Mc Neil Road, Karachi, Pakistan—Space and Time fuse completely at the edge of the Universe and we can draw conclusions of universal applicability. Starting from A.Einstein's Tensor Equations, we can prove that both space/time are represented by $1 \pm \sigma K/2\gamma_3 (S^3/t^3)$ where K = cosmological constant; σ = density = M/L^3 in terms of continuum equivalence. Substituting for either space or time (absolute space is S, Space is S^3), we come to the conclusion that space/time are reversible. A.Einstein drew the Law of Conservation of mass/energy, from the field Tensor $(g^{ik}\delta U^s_{ik})_\mu$, with relativity notations. Energy is $M.L^{-1}.T^3$ and as $S \equiv T \equiv L$, T or S can have values between 0 and ∞ but normally 'C' . Substituting, we get $E = MC^2$, under normal parametric conditions, a direct derivation of Mass/Energy equivalence from the new concept of Space/Time equivalence.

GX 18 The Van Der Waals Energy Of A Neutral Adatom In Interaction With A Finite Slab Geometry. S.J.Silverman, Seton Hall University. The Van Der Waals (V.D.W.) energy of a neutral adatom and a finite semi-conductor slab geometry is investigated to dipole-dipole terms in a perturbative treatment. The energy is obtained in a form which emphasizes finite thickness effects of the slab plasma. The results include a plasma contribution to V.D.W. energy as well as finite thickness corrections.

SESSION GF: THEORETICAL PHYSICS; PLASMA PHYSICS

Wednesday morning, 27 January 1982
Continental Parlor 9 at 9:00 A.M.
R. E. Mickens, presiding

GF 1 A new thermostatic fluctuation theory using path integrals. G. RUPPEINER, Amherst College. — As is well known, the usefulness of the conventional thermostatic fluctuation theory is restricted because it breaks down at system dimensions less than the order of the correlation length. This breakdown occurs because the conventional theory fails to take into account correlations which become all important at small volumes. A thermostatic fluctuation theory which attempts to take into account correlations has been developed. The basic idea in this theory is to consider successive fluctuations in a sequence of systems of decreasing size. The mathematical structure employed is the path integral formalism developed recently primarily for use in irreversible thermodynamics. An important feature of this new theory is that it predicts the correlation length in terms of thermostatic quantities. That the correlation length can be deduced purely from thermostatics has been suggested before by the author, but for quite different reasons. The new theory of fluctuations provides a means of understanding this hypothesis and also has possibilities of working at lengths less than that of the correlation length.

GF 2 A Uniformly Valid Solution of $\varepsilon xydy/dx = x-y-y^2$. R. E. MICKENS, JILA, Univ. of CO & NBS.—The above non-linear differential equation is an Abel equation of the second kind and occurs in the investigation of stellar structure.[1] This equation does not have an exact solution which can be written in closed form in terms of elementary functions. However, for $0 < \varepsilon \ll 1$, we obtain a problem in singular perturbation theory for which a number of calculational techniques are available to obtain approximate solutions. We show, using singular perturbation theory and an iteration procedure, that a uniformly valid approximate solution can be obtained for $0 < x < \infty$. We also discuss the case $\varepsilon \gg 1$.

1. J. Jeans, Astronomy and Cosmogony (Dover, New York, 1961).

GF 3 Evaluation of Certain Oscillatory Integrals Associated with Intensity Distributions Near Caustics. NANCY A. POPE, Lawrence Berkeley Laboratory, and S.R. DEANS, University of South Florida.—Certain rapidly oscillating integrals emerge in the study of intensity patterns near caustics.[1] Typical examples are illustrated below. Apparently, there is no standard method for evaluating these integrals. An integration technique will be discussed and examples presented.

BEYOND THE SPEED OF LIGHT

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The idea of faster-than-light particles was of interest to physicists even in pre-relativistic period[1-5]. When theory of relativity was presented[6], it was thought that light speed in vacuum was the above limit of any speed. Tolman[7] believed that the existance of superluminal particles allowed information transmission into the past. However the problem was taken up again by Wigner[8], Stukelberg[9,10], Feynman and Gell-Mann[11-15], Wightman and Schweber[16], Arzalies[17], Schmidt[18,19], Tanaka[20], Brans and Dicke[21]. Sudershan and coworkers[22-24] re-examined the nature of the axioms of the relativistic quantum field theory and presented a theory for faster-than-light particles. After publication of their paper[22] a number of people started studying the subject. Among them are Jones and Franklin[25], Feinberg and Pais[26], Blockhintsev[27], Kirzlnits and Polyachenko[28], Boulware[29], Csonka[30], Grodsky and Newton[31]. In 1967 Feinberg[32] named the faster-than-light particles as 'tachyons' from ταχυς(tachys) which means swift. Bilanuik and Sudershan[22] used the name 'meta-particle' for faster-than-light-particle. The relativity theory of faster-than-light particles was called 'meta-relativity'[22]. The term 'extended relativity' is used by Recami et al.[33-35].

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Feinberg's theory[32] is not Lorentz covariant nor is Tanaka's[20]. Arons and Sudershan[36], Broido and Taylor[37] and Phillips[38] dealt with the Lorentz invariance of these particles. Newton[39], Aharonov[40] and Rolnik[41] discussed causality problems. Bilanuik and Sudershan[22,42] also discussed space-like signals and causality problems. Tachyon interactions are discussed by Sudershan and Dhar[43,44]. Bludman and Ruderman[45] considered the possibility of speed of sound exceeding the speed of light in ultradense matter. In 1969 Peris[46], Glueck[47,48], Fox et al.[49], Berzi and Gorini[50], Brown et al.[51], Parker[52], Camenzind[53] and Gleason et al.[54] discussed tachyon theory. In 1970 Newton[55], Peris[56], Strand[57], Ben-Abraham[58], Pirani[59], Ecker[60], Benford[61], Cawley[62], Baldo et al.[63], Gondrand[64] and Csonka[65] presented their views about tachyons. During the years 1971-82 Schulman[66,67], Gupta[68], Wimmel[69-71], Schroer[72], Kamoi[73], Danburg[74], Lapendes and Jacobs[75], Jones[76], Van der Spuy[77-79] and Ayub[80,81] dealt with this concept. Some of the views are against the existance of tachyons.

The first experimental quest for tachyons was performed[82] in 1963. Kolm[83] searched for magnetic monopoles. Davis, Kreisler and Alvager[84,85] searched for faster-than-light particles. Baltay, Feinberg, Yeh and Linsker[86,87] searched for uncharged faster-than-light particles. However no experimental evidence for tachyons is available uptil now[88,89].

Recently Recami and coworkers[33,35,90-94] did a lot of work on superluminal frames. For more references the reader is referred to ref.[33,35,95]

In Feinberg's theory[32] proper mass m_o is replaced by $i\mu_o$ (where μ_o is real). As the velocity approaches infinity, energy approaches zero and momentum takes a values $\mu_o c$ so that infinite speed particle carries momentum but no energy[77]. Recami and Mignani[33] gave the generalized Lorentz transformations as

(1a) $$x' = \pm (x - Vt)\, K^{-\frac{1}{2}}$$

(1b) $$y' = \pm y\, (1 - V^2/c^2)^{\frac{1}{2}}\, K^{-\frac{1}{2}}$$

(1c) $$z' = \pm z\, (1 - V^2/c^2)^{\frac{1}{2}}\, K^{-\frac{1}{2}}$$

(1d) $$t' = \pm (t - Vx/c^2)\, K^{-\frac{1}{2}}$$

where $K = |1 - V^2/c^2|$. The range of V (the frame velocity of S' with respect to S) is now from $-\infty$ to ∞. The double sign is required by the invertibility of Lorentz transformations. In the classical theory of tachyons we note that

(i) At least two of the coordinates in (1) are imaginary as V exceeds c.

(ii) At least two components of the velocity are imaginary as V exceeds c.

(iii) At infinite velocity energy is zero but momentum is $\mu_0 c$. This shows an asymmetry in energy and momentum values for the ranges 0 to c and c to infinity.

(iv) Feinberg's[32] and Tanaka's[20] theories for tachyons are not Lorentz covariant.

(v) In Feinberg's theory[32] the concept of imaginary proper mass for tachyons is not very attractive.

(vi) The correct time ordering of the events cannot be retained for superluminal frames.

Also the fact that no experimental evidence for tachyons is available uptil now[88,89], suggests that there might be a modification needed in the existing superluminal theories so that a better physical picture is obtained.

In this paper an attempt is made to present a theory which is based on the symmetry principles of nature. The theory presented here is Lorentz covariant, does not involve imaginary quantities, explains the kinametics of the particles and preserves the definition of momentum and energy. The invariant quantity c in the Lorentz transformations comes out to be equal to the speed of light in vacuum as a consequence of Maxwell's equations. This does not exclude the possibility of other types of radiations travelling at other speeds which are also invariant in all frames of reference[96,97]. If we look at the properties of particles which travel with speeds less than the speed of light (bradyons) and the particles which travel with speeds greater than the speed of light (tachyons), we think why nature has preferred the speed $u = c$ to be invariant in all frames of reference and why this becomes a demarkation line on each side of which there exist particles with remarkably different properties. For massive particles the range 0 to c is allowed as well as the range c to infinity but $u = c$ is not permitted. Extending this concept to negative values we note that $u = +c$ and $u = -c$ are invariant in all frames (by $u = -c$, we mean the particles corresponding to the lightlike worldline described by $x - ct = 0$). Are there only two values $u = +c$ and $u = -c$ which are invariant under all transformations? If so, then why preference is given only to these values. There must be analogues to these speeds in the space-time continuum which fit symmetrically in such a way that there is no preference to any such speed. A theory having symmetrical distribution of invariant speeds must leave the speed $(2n - 1)c$, (n is an integer) invariant. The invariant speeds are now

$$\ldots\ldots, -7c, -5c, -3c, -c, c, 3c, 5c, 7c, \ldots\ldots$$

The mass is now a periodic function of velocity

$$m(u) = m_o(1 - u^2/c^2)^{-\frac{1}{2}}, \quad -c < u < c \tag{2a}$$

$$= m(u - 2c), \quad u > c \tag{2b}$$

$$= m(u + 2c), \quad u < -c \tag{2c}$$

This can be expressed as a Fourier series[97]

$$m(u) = \pi m_o \left[\tfrac{1}{2} + \sum_{j=1} J_o(j\pi)\cos(j\pi u/c)\right] \tag{3}$$

where $J_o(j\pi)$ is the Bessel function of order zero. The momentum and energy are given by

$$p(u) = u\, m(u); \qquad E(u) = c^2\, m(u) \tag{4}$$

Figures 1 and 2 show E/m_oc^2 and p/m_oc as functions of u/c for values of u/c between -3 and -3.

If $c < u < 3c$, u can be written as $v + 2c$, where $-c < v < c$ and so $m(u) = m(v)$. If $3c$ is also an invariant speed we must have

$$(p - 3mc)(p - mc) = -m_o^2c^2 \tag{5}$$

The above relation can be verified by substituting $m = m_o(1 - v^2/c^2)^{-\frac{1}{2}}$ and $p = mu = m_o(1 - v^2/c^2)^{-\frac{1}{2}}(v + 2c)$. In general if $(2n - 1)c < u < (2n + 1)c$, we can write $p = mu = m_o(1 - v^2/c^2)^{-\frac{1}{2}}(v + 2nc)$; $m = m_o(1 - v^2/c^2)^{-\frac{1}{2}}$ where $u = v + 2nc$ (n is an integer). Therefore

$$(6) \qquad \left[p - (2n + 1)mc\right]\left[p - (2n - 1)mc\right] = - m_o^2c^2$$

Using $m = E/c^2$ and solving the above equation for E we get

$$(7) \qquad E = (4n^2 - 1)^{-1}\left[2ncp - \left\{c^2p^2 + m_o^2c^4(1 - 4n^2)\right\}^{\frac{1}{2}}\right]$$

The correct sign is chosen by the requirement that $E = m_oc^2$ when $u = 2nc$. For $n = 0$, eqs. (6) and (7) reduce to

$$(8a,b) \qquad (p + mc)(P - mc) = - m_o^2c^2; \qquad E = (c^2p^2 + m_o^2c^4)^{\frac{1}{2}}$$

If E(u) and p(u) are the energy and momentum of a particle in the Laboratory frame of reference and E(u') and p(u') are the values in a frame moving with velocity βc in the direction of p(u) ($|\beta| < 1$), the energy and momentum are related by

$$(9a) \qquad cp(u') - 2n'E(u') = (1 - \beta^2)^{-\frac{1}{2}}\left[\left\{cp(u) - 2nE(u)\right\} - \beta E(u)\right]$$

$$(9b) \qquad E(u') = (1 - \beta^2)^{-\frac{1}{2}}\left[E(u) - \beta\left\{cp(u) - 2nE(u)\right\}\right]$$

where $u' = 2n'c + v'$ (n' is an integer), $u = 2nc + v$, $-c < v' < c$, $-c < v < c$, $v' = (1 - \beta v/c)^{-1}(v - \beta c)$. The integers n, n' are defined by the conditions

$$(10a,b) \qquad \left|\left[cp(u)/E(u)\right] - 2n\right| < 1; \qquad \left|\left[cp(u')/E(u')\right] - 2n'\right| < 1$$

Using eq. (7) it can be easily verified that

$$(11)\quad \left[E(u')\right]^2 - \left[cp(u') - 2n'E(u')\right]^2 = m_o{}^2c^4 = \left[E(u)\right]^2 - \left[cp(u) - 2nE(u)\right]^2$$

Therefore $(E(u), 0, 0, cp(u) - 2nE(u))$ are the components of a four-vector (p^0, p^1, p^2, p^3).

Consider a frame moving with velocity αc $(|\alpha|>1)$ in the direction of $p(u)$. We can write $\alpha = \beta_o + 2n''$ (n'' is an integer such that $|\alpha - 2n''|<1$). Eq. (11) should, therefore, be modified as

$$(12)\quad \left[(1 - 2n'')E' + (cp' - 2n'E')\right]\left[(1 + 2n'')E' - (cp' - 2n'E')\right] = m_o{}^2c^4$$
$$= \left[E + (cp - 2nE)\right]\left[E - (cp - 2nE)\right]$$

where E', p', E, p are used in place of $E(u')$, $p(u')$, $E(u)$, $p(u)$ respectively. Solving for E' we get

$$(13)\quad E' = (4n'^2+4n''^2+8n'n''-1)^{-1}\left[2(n'+n'')cp' - \left\{c^2p'^2 + (1-4n'^2-4n''^2-8n'n'')m_o{}^2c^4\right\}^{\frac{1}{2}}\right]$$

Correct sign for the square root is chosen using the condition $E = m_oc^2$ when $p = 0$, $n' = n'' = 0$. Eq. (13) can be rewritten as

$$(14)\quad E'^2 - \left[cp' - 2(n' + n'')E'\right]^2 = m_o{}^2c^4 = E^2 - (cp - 2nE)^2$$

Therefore eq. (9) is modified as

$$(15a)\quad cp' - 2(n' + n'')E' = (1 - \beta_o{}^2)^{-\frac{1}{2}}\left[(cp - 2nE) - \beta_oE\right]$$

$$(15b)\qquad E' = (1 - {}_o{}^2)^{-\frac{1}{2}}\left[E - \beta_o(cp - 2nE)\right]$$

Eq. (11) and (14) are written using the matrix

$$\eta = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix} \tag{16}$$

If this theory is correct we should be able to observe particles (antiparticles) with energy m_0c^2 and momentum $2m_0c$ (corresponding to $u' = 2c$). Consider a photon incident along positive x-axis having energy 1.02 MeV. Its momentum is 1.02 MeV/c. According to this theory the photon may produce an electron-positron pair (Fig. 3). The electron and positron should equally divide the energy and momentum and travel with speeds 2c making an angle 60° on opposite sides of x-axis. We now have

$E_\gamma = 1.02$ MeV, $p_\gamma = 1.02$ MeV/c, $E_{e^-} = 0.51$ MeV, $p_{e^-} = 1.02$ MeV/c, $(p_x)_{e^-} = 0.51$ MeV/c, $(p_y)_{e^-} = 0.51\sqrt{3}$ MeV/c, $E_{e^+} = 0.51$ MeV, $p_{e^+} = 1.02$ MeV/c, $(p_x)_{e^+} = 0.51$ MeV, $(p_y)_{e^+} = -0.51\sqrt{3}$ MeV/c.

Therefore

$$E_\gamma = E_{e^-} + E_{e^+}; \qquad p_\gamma = (p_x)_{e^-} + (p_x)_{e^+}; \qquad 0 = (p_y)_{e^-} + (p_y)_{e^+}$$

A determination of velocity, energy and momentum of these particles would provide a test of this theory.

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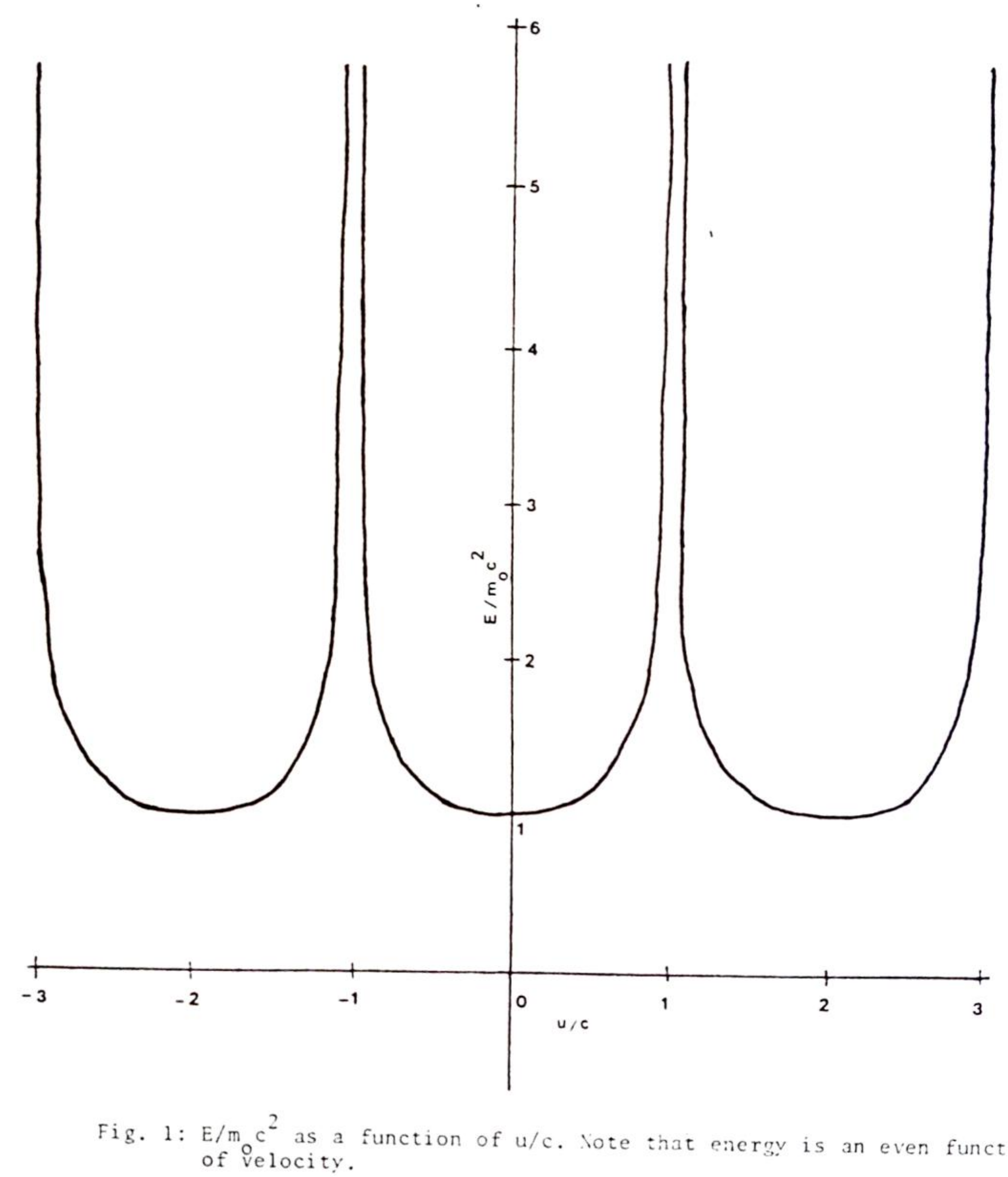

Fig. 1: E/m_oc^2 as a function of u/c. Note that energy is an even function of velocity.

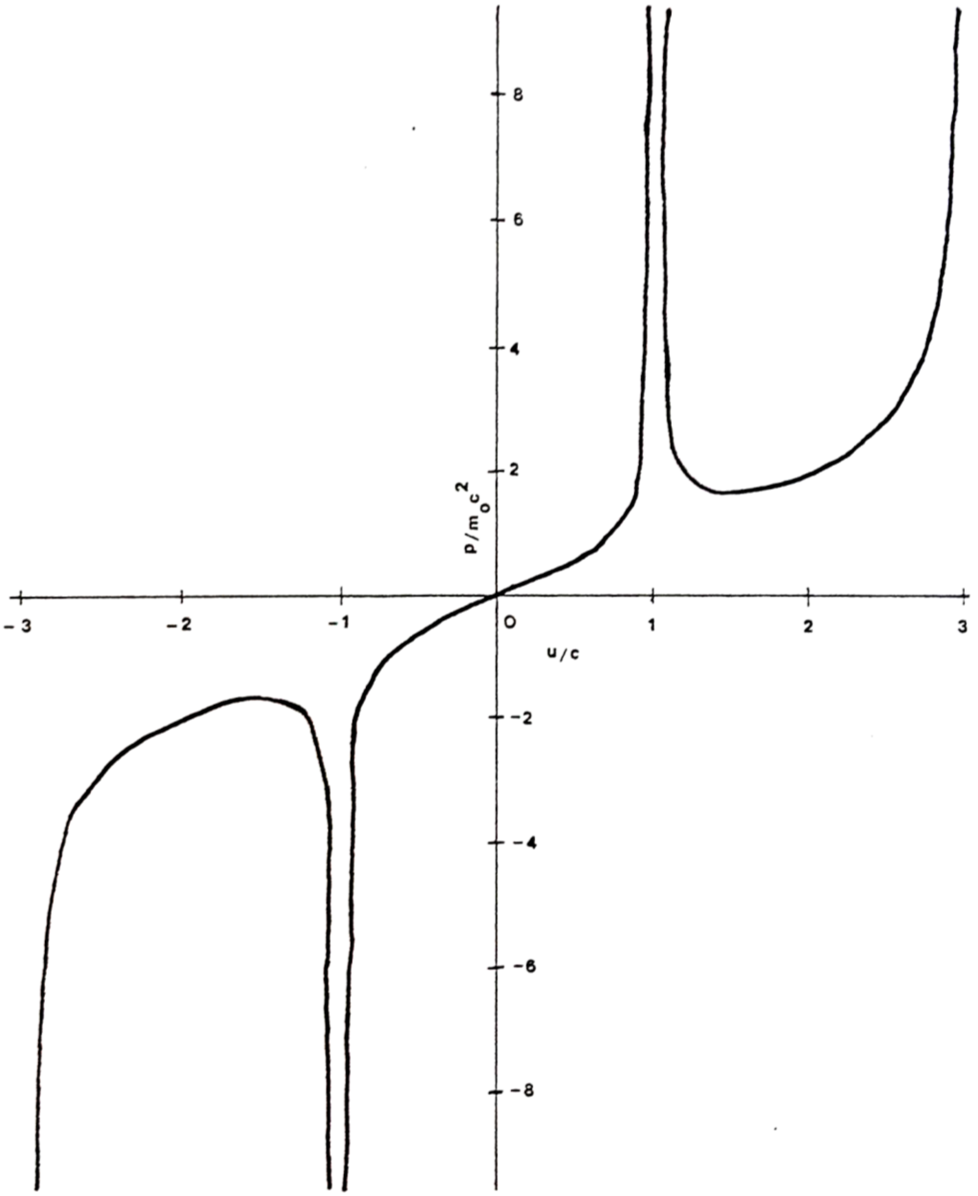

Fig. 2: p/m_oc as a function of u/c. Note that momentum is an odd function of velocity.

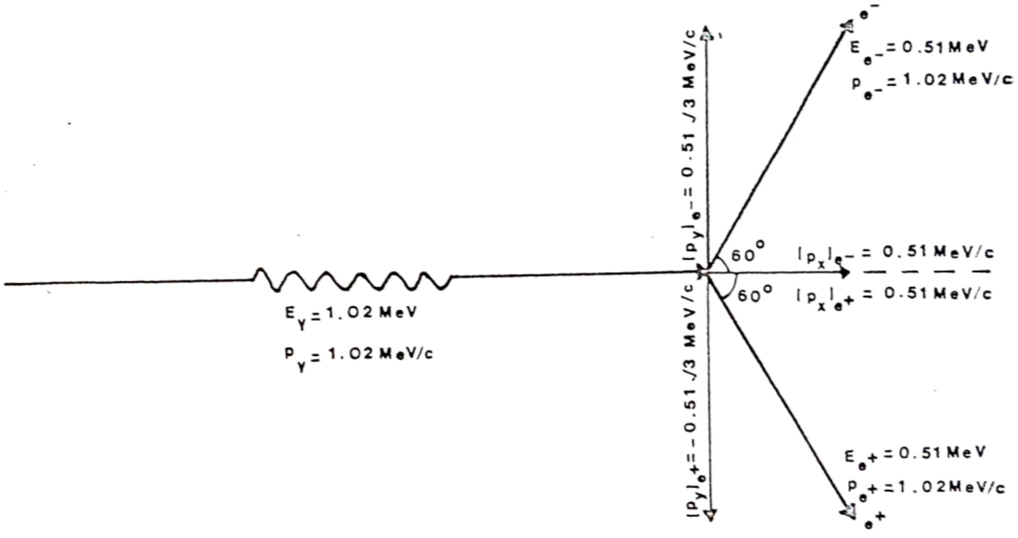

Fig. 3: A photon decaying into electron-positron pair. Both electron and positron should travel with a speed twice the speed of light.

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