Although there is apparently an overwhelming amount of evidence for the postulate of the invariance of the velocity of light, it is suggested that this evidence is equivocal, and a ballistic theory of light is shown to be capable of explaining many results of modern physics.

Modern physics and a ballistic theory of light

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THE VELOCITY of light *in vacuo*, c, equal to the ratio of electrostatic to electromagnetic units, can apparently be measured, in principle, in three ways:

- by setting up standing waves in a resonator
- by sending a signal out and timing its return after reflection by a mirror
- by timing a signal over a given path one way.

Actually, the last method cannot be used with a fixed source, but it can with a moving source.

The resonator method cannot be used for a moving-source measurement. We might imagine a length of waveguide with a fixed short circuit and a movable plunger. It takes a finite time for a microwave cavity to settle down to its resonance frequency, and, if a response is to be observed, the plunger must move at a speed so low that the resonance frequency of the cavity does not change by more than the width of the response curve in the time during which the transient response is dying away. This speed is too low to permit the observation of effects due to any dependence the velocity of light may have on the speed of the plunger.

The second method can be used with either a fixed or a moving source. By virtue of the principle of relativity, we may take the source as our standard of rest and regard the mirror as moving away from the source with velocity v. A flash of light sent from the source at time $t = t_0$ (taking the zero of time to be the instant at which the mirror passes the source) will be reflected from the mirror and will return at time t_1. A second flash sent at time t_2 will return at time t_3. The measurable quantities are the time intervals t_0, t_1, t_2 and t_3. According to Einstein's theory, the returning light will travel at velocity c with respect to the source. According to the theory to be discussed below, the velocity of the returning light will be $c - 2v$.

It might be thought that the velocity of the returning light could be deduced from the values of t_0, t_1, t_2 and t_3, but in fact it is found that, whatever may be the velocity of the returning light, the relation $t_3t_0 = t_1t_2$ holds. In order to distinguish between different theories, additional information is required which cannot be obtained by the observer situated at the source without the assistance of a distant agent. The agent could, for example, be travelling with the mirror and could cast out a marker of its position when one of the flashes reached it. Then the total distance travelled by the light could be measured and its velocity deduced.

The one-way method could be used if flashes of light from a moving and a fixed source were sent over the same path and their 'times of flight' compared. Again a distant agent is necessary; for example, if the moving source passes close to the fixed source, and the flashes are emitted simultaneously, the agent could be a pair of contacts carried by the sources which touch as they pass and so trigger off the flashes, thus ensuring simultaneity.

Many experiments on the velocity of light from moving sources have failed to make use of the distant agent, and so, although giving results in agreement with the invariance postulate, have failed to distinguish between the theory based on this postulate and possible alternative theories. Other experiments have been vitiated by allowing the light to interact with the observer's apparatus in such a way that only its velocity after such interaction is measured. No information is obtained about its velocity on the way from the source to the observer.

There is one experiment[1] which does not suffer from these defects; it uses the one-way method, comparing the velocity of light from a moving source with that of light from a fixed source. Although the authors claim that their result confirms the invariance postulate, I have worked out the result from the published measurements and found it to be in agreement with the ballistic theory to be discussed below.

Ballistic theory

The bases of the orthodox theory, namely the principle of relativity and the postulate of the invariance of the velocity of light, are mutually inconsistent; but, since there is no direct evidence to support the invariance postulate, there is no difficulty in discarding it. It was the adoption of this postulate that led 20th-century physics away from Newtonian ideas.

Since we are rejecting the postulate of invariance, let us go back to Newtonian ideas and attempt to explain experimental results with their aid. Thus we retain the principle of relativity; we use the Newtonian laws for the composition of velocities, and for transforming from one co-ordinate system to another in uniform motion with respect to it. In other words, we use the Galilean transformations instead of the Lorentz. It follows that the velocity of light from a source in motion with respect to the observer is the vector sum of the velocity c and the velocity of the source; this concept replaces Einstein's invariance postulate.

The above ideas are in keeping with a ballistic theory of light. The orthodox theory of relativity requires the existence of an ether, and it is essentially a wave theory. However, all attempts to detect the ether have failed, and there is no apparent difficulty in assuming that there is no ether; this necessarily throws us back on a ballistic theory of light, and makes Newtonian ideas seem very plausible. The wave theory may then be regarded as a method for calculating the statistical distribution of light particles (photons).

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19th-century experimental results revealed an apparent incompatibility between Newtonian mechanics and Maxwell's electromagnetic theory. The orthodox theory of relativity was an attempt to resolve the difficulty by modifying Newtonian mechanics. Now we propose to restore Newtonian mechanics; how, then, do we deal with Maxwell's equations?

First, it must be realised that Maxwell's equations, being based on 19th-century experimental results, hold good only in the conditions of those experiments—i.e. in the limiting case of small velocities of any one part of a system with respect to the others. The same is true of the Lorentz force formula

$$\boldsymbol{F} = q(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}) \quad . \quad . \quad (1)$$

for the force $\boldsymbol{F}$ on a particle of charge q moving with velocity $\boldsymbol{v}$ in an electric field $\boldsymbol{E}$ and a magnetic field whose induction is $\boldsymbol{B}$. The *apparent* incompatibility of Maxwell's equations with Newtonian mechanics arises from the extrapolation of Maxwell's equations and the Lorentz force formula to high relative velocities; this step is quite unjustified.

A number of experimental results can be explained by the ballistic theory if the Lorentz force formula is replaced by

$$\boldsymbol{F} = q\sqrt{(1 - v^2/c^2)}[\boldsymbol{E}\{1 - (\boldsymbol{v}.\boldsymbol{e}/c)^2\} + \boldsymbol{v} \times \boldsymbol{B}\{1 - (\boldsymbol{v}.\boldsymbol{b}/c)^2\}] \quad . \quad (2)$$

where $\boldsymbol{e}$ and $\boldsymbol{b}$ are unit vectors parallel to $\boldsymbol{E}$ and $\boldsymbol{B}$, respectively. The explanation of some of these results will be outlined below; the experiments mentioned are of such fundamental importance that their satisfactory explanation is an essential requirement for any theory.

One of the most important results of the orthodox theory of relativity is that, if a body is moving at velocity v with respect to the observer, its mass m is

$$m = m_0/\sqrt{(1 - v^2/c^2)} \quad . \quad . \quad (3)$$

where m_0 is its rest mass, i.e. its mass as measured by an observer with respect to whom it is at rest. The kinetic energy is, according to this theory,

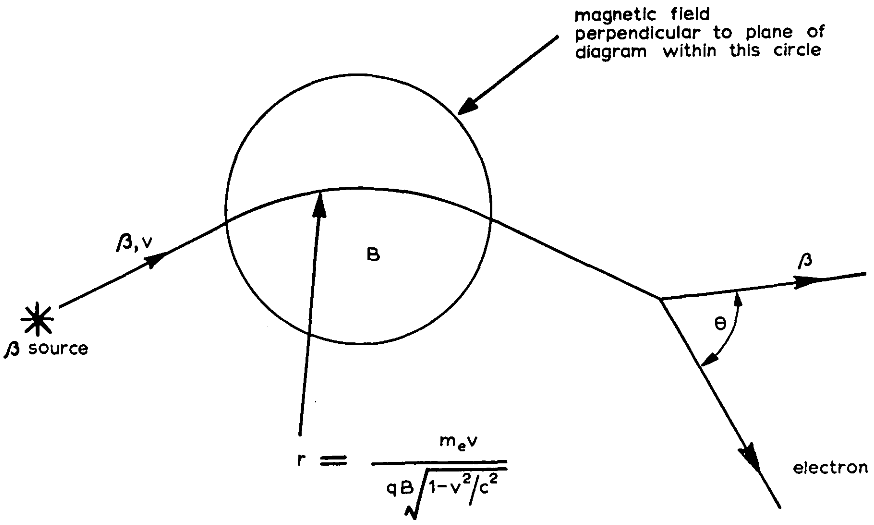
$$T = (m - m_0)c^2 = m_0c^2\left\{\frac{1}{\sqrt{(1 - v^2/c^2)}} - 1\right\} \quad (4)$$

Eqn. 4 expresses the famous mass–energy equivalence; a mass m is equivalent to energy mc^2, and the two are interchangeable.

According to the ballistic theory, mass and energy are separately conserved. It is claimed that there is much experimental evidence to support the orthodox view, and this appears at first sight as a serious obstacle to the ballistic theory. However, no experiment has ever been performed that tests eqn. 4. Innumerable experiments have been performed in which the tracks of charged particles, moving under the influence of electric and magnetic fields, have been recorded in cloud chambers and bubble chambers or on photographic plates. It is these tracks that must be explained by any viable theory, not eqns. 3 and 4.

The archetype of such experiments is that of Champion[2] (Fig. 1). β particles (electrons) from a radioactive source passed through a magnetic field B and then collided with electrons in ordinary matter. From the curvature of the paths of the β particles in the magnetic field, their velocity was calculated. On using eqns. 1 and 3, the relation between radius and velocity is found to be

$$r = \frac{mv}{qB} = \frac{m_0v}{qB\sqrt{(1 - v^2/c^2)}} \quad . \quad (5)$$



1 Champion's experiment on the collision of fast β particles with an electron. The particles' velocities are calculated from the curvature of their paths in the magnetic field $\boldsymbol{B}$

The same result is obtained on the ballistic theory, using eqn. 2. Thus there is no disagreement between the two theories about the velocity to be deduced from the observed curvature.

After a β particle collides with a stationary electron, the two particles move in directions differing by an angle θ (Fig. 1). If the particles could be regarded as identical spheres, the angle between their paths after collision would be given as 90° by Newtonian mechanics, assuming them to be hard spheres like billiard balls. Using eqn. 4, Champion calculated θ as a function of the velocity v of the β particles and obtained values of θ less than 90° by an amount depending on v. This relation between θ and v was confirmed experimentally by observing the tracks of the particles in a cloud chamber.

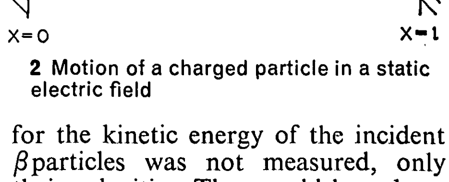
However, electrons are not billiard balls, and they do not collide in the way that billiard balls do. Their interaction is essentially electrostatic, and the force on either one of them is due to the effect on its charge of the potential field of the other. According to the orthodox theory, the energy of a particle of charge q which is accelerated through a potential difference V is

$$T = qV \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

From eqns. 4 and 6,

$$qV = m_0c^2\left\{\frac{1}{\sqrt{(1 - v^2/c^2)}} - 1\right\} \quad (7)$$

It is eqn. 7 that is actually verified by Champion's experiment, not eqn. 4,



2 Motion of a charged particle in a static electric field

for the kinetic energy of the incident β particles was not measured, only their velocities. They could have been accelerated to these velocities by a potential difference, and the relation confirmed would have been that between θ and V. Only if eqn. 6 is verified can eqn. 4 be upheld, but eqn. 6 was not tested.

The ballistic theory, therefore, has to predict eqn. 7, not eqn. 4, and in fact, if we consider the acceleration of a charged particle through a potential difference V and calculate its velocity, eqn. 7 is obtained. We can also calculate the kinetic energy, as follows.

Fig. 2 illustrates a particle of mass m_0 moving between two electrodes with potentials 0 (at $x = 0$) and V_0 (at $x = l$), starting with zero velocity at $x = 0$. The electric field is V_0/l, and eqn. 2 gives the force as

$$F = (qV_0/l)(1 - v^2/c^2)^{3/2} \quad . \quad (8)$$

The velocity and voltage at any point are related by eqn. 7. From eqns. 7 and 8 we obtain a relation between F and V. The kinetic energy is the work done on the particle, i.e.

$$T = \int_0^l F dx = \int_0^{V_0} F dV \quad . \quad . \quad (9)$$

Substituting for F in terms of V, we obtain

$$T = \frac{m_0 c^2}{2}\left\{1 - \frac{1}{(1 + qV_0/m_0c^2)^2}\right\} \quad (10)$$

Using eqn. 7, with V replaced by V_0, we obtain for the kinetic energy when the particle reaches $x = l$

$$T = \tfrac{1}{2}m_0 v^2 \quad . \quad . \quad . \quad . \quad . \quad (11)$$

agreeing with the classical formula for kinetic energy.

In the limit as $V_0 \to \infty$, $v \to c$ and $T \to \frac{1}{2}m_0c^2$. Thus the velocity of light is an upper limit to the velocity to which a charged particle can be accelerated by a steady electrostatic field.

Electron–positron annihilation

When a positron encounters an electron, they both disappear and two γ rays—or γ particles as we shall prefer to call them—are formed. If m_e is the (rest) mass of an electron, the total mass of the positron and electron is $2m_e$, and according to the orthodox theory this mass is converted into energy m_ec^2 per γ particle. While the mass–energy bookkeeping is satisfactory, no insight is given into the nature of the process.

On the ballistic theory, an electron is assumed to consist of a very large number of minute particles (x particles) of charge $-dq$, mass dm, with $dm/dq = m_e/q_e$, $-q_e$ being the charge on an electron. An electron has an internal energy equal to the energy which would be liberated if it disintegrated and all the x particles were repelled to infinity under their mutual repulsion. Imagine the x particles to be expelled one at a time. Then, after one has travelled a distance r, the force on it is, from eqn. 2,

$$F = (qdq/r^2)(1 - v^2/c^2)^{3/2}$$

Integrating Fdr from $r = 0$ to ∞, and then from $q = 0$ to q_e, we obtain for the internal energy

$$W_i = \tfrac{1}{2}m_ec^2 \quad . \quad . \quad . \quad . \quad . \quad (12)$$

The positron has the same internal energy.

There is also an energy of attraction between the positron and electron. Using eqn. 2, this works out to $W_a = \frac{1}{2}m_ec^2$ per particle. Thus the total energy of the system is

$$W = 2W_a + 2W_i = 2m_ec^2 \quad (13)$$

This is just the energy of the γ particles. Also, the total mass of the positron and electron is $2m_e$, and, where this is converted into energy according to the orthodox theory, it appears as the mass of the γ particles according to the ballistic theory. The γ particles consist of equal numbers of positive and negative x particles and so are electrically neutral. The reaction is seen to consist in a rearrangement of the x particles of which the electron and positron are composed, and the mass books and the energy books are separately balanced.

> **Pair production**
>
> A γ particle of sufficient energy ($\geqslant 2m_ec^2$) will, in the neighbourhood of a massive atomic nucleus, split into an electron and a positron. This is a reversal of the annihilation process described above. The positive and negative x particles of the γ particle are separated to make the electron and the positron; the process is a rearrangement of matter, which is conserved in the process. The heavy nucleus is required to absorb momentum so that this quantity can be conserved. According to the ballistic theory, too, the large charge on the nucleus serves to polarise the photon so as to separate the positive x particles from the negative x particles.

Photons

A photon of mass m, according to the above picture, has energy $W = mc^2$. Half of this is kinetic, and the other half can be shown to be due to the mutual attractions of the positive and negative x particles of which the photon is composed. The momentum is $p = mc$, and thus

$$p = W/c \quad . \quad . \quad . \quad . \quad (14)$$

This relation is identical with that given by the orthodox theory, and is confirmed by observations of radiation pressure.[3]

When a photon interacts with matter, it may be absorbed completely, when the total energy is observed, or it may suffer an elastic collision, when only the kinetic comes into play, possibly being partially exchanged with the body the photon collides with; in an elastic collision, the internal energy plays no part. Radiation pressure is one example of an elastic collision,[4] and the scattering of a photon (Xray) by an electron (Compton effect) is another. In Compton scattering, the photon loses energy and suffers a change of wavelength. This is explained on the ballistic theory in simple Newtonian terms.[5]

If a photon is emitted by a source approaching the observer with velocity v, its velocity is $c + v$. Its internal energy is $\frac{1}{2}mc^2$, but its kinetic energy is increased; the total energy is

$$W = \tfrac{1}{2}mc^2 + \tfrac{1}{2}m(c + v)^2$$
$$= mc^2(1 + v/c + \tfrac{1}{2}v^2/c^2) \quad (15)$$

Measurements of frequency on light are essentially measurements of energy. This is evident in the case of the photoelectric effect. For a measurement by a diffraction grating, light must diverge from the slit, and for this it must have been absorbed and re-emitted. On re-emission its energy will be the same, W, because the electrons will jump between the same energy-levels in the material of the slit as they did when absorbing energy. But the velocity will be c with respect to the slit and the apparent frequency will have changed. The apparent frequency of light from the moving source is given by $h\nu = W$. If the source were fixed, its frequency would be given by $h\nu_0 = mc^2$. Hence

$$\nu/\nu_0 = 1 + v/c + \tfrac{1}{2}v^2/c^2 \quad . \quad (16)$$

This may be compared with the orthodox Doppler formula

$$\frac{\nu}{\nu_0} = \sqrt{\frac{1 + v/c}{1 - v/c}}$$
$$= 1 + \frac{v}{c} + \frac{1}{2}\frac{v^2}{c^2} + \frac{1}{8}\frac{v^3}{c^3} + \ldots \quad . \quad . \quad . \quad . \quad . \quad (17)$$

These equations have been confirmed to the second order only.[5]

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