THE UNIVERSE

AND

MANNED SPACE FLIGHT

by

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Message from Infinity: A Space-Age Correlation of Science and Religion

Molecular Nature of Aerodynamics

The Race for Unlimited Energy

Pathway to Excellence

Upper Atmosphere and Space Programs in Canada (co-author)

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Preface

The more the human consciousness understands the metaphysical (mathematical) science of the universe, the more it can envisage the conquest of space. If virtually unlimited space travel is to be achieved, then Newton's (absolute) science must be abandoned in favour of Einstein's (relative) science, because only the latter makes deep-space flight possible for humanity. Using the relativistic metaphysical science of the microcosm, man can emerge from today's macro-world of human experience into the relativistic macrocosm of space.

The metaphysical (mathematical) science of relativity reveals a fundamental property of the universe. This property arises from the basic premise of relativity that throughout space all objects and their motions are linked with one encompassing, immutable, universal body of natural law. This is manifested by the universal invariance of the speed of light in space; experiments have verified that the speed of light is the same in all directions, independent of the motion of the source or the motion of the receiver. The universe is, therefore, orderly and harmonious.

Today's accelerating progress in planetary investigations and in orbital missions points to new ventures in the solar system. But the metaphysical science of relativity promises much more. According to the Special Theory of Relativity, the relativistic energy of the microcosm and the relativistic time of the macrocosm open the way to deep space missions.

The conquest of space points to new vistas for humanity — to a greater sense of freedom, to new and better opportunities, to improved well-being for all mankind. Even the present state-of-the-art clearly suggests the truth of this expectation.

The author wishes to acknowledge the loving kindness expressed in so many ways by Alberta Patterson throughout the writing of this review. Only a few can appreciate the extent of the personal sacrifice involved.

Glossary

Construct. A concept constituted by a process of mental synthesis that orders and systematically unites precepts the benefits of which are attested by human experience.

Electromagnetic radiation. Energy originated by the motion of electric charges, which radiates throughout space in wave form but which interacts with matter in a corpuscular form.

Human consciousness. A developing awareness of the totality of inputs from metaphysical sources and from human experience by an individual or group, resulting in progressive states and stages of being.

Macrocosm. The outward world, extending beyond the Milky Way galaxy into the vast reaches of space; a construct of the human consciousness the constituent objects of which have characteristic dimensions much larger than the wavelength of visible light and relative speeds of any magnitude up to almost the speed of light; a domain in which only relativistic concepts are valid; a realm beyond the scope of physical-sense-limited human experience; a domain that can be interpreted only by metaphysical science.

Metaphysical science. The developing science that links ideas and their relationships among themselves with all-encompassing natural law (perceived and established in human experience) to form an orderly, harmonious construct in human consciousness that leads to progressively better states and stage of human experience; a term that often implies mathematical science.

Microcosm. The inward world of the infinitesimal; a construct of the human consciousness the constituents of which have characteristic dimensions smaller than the wavelength of visible light and relative speeds of any magnitude up to almost the speed of light; a realm that lies outside the range of the physical senses a domain of dual-natured entities that have no counterpart in human experience; a realm that can be interpreted only by metaphysical science.

Natural law. A body of law fundamental to nature. Natural law and its associated elements can be interpreted in their entirety by a single, all-encompassing principle and its related ideas.

Rest-state macro-world. A domain between the microcosm and the macrocosm the constituents of which have characteristic dimensions much larger than the wavelength of visible light and relative speeds that are negligibly small compared with the speed of light; a construct of the rest-state human consciousness that depends on the physical senses for its interpretation; a realm that embraces the beliefs of absolute position and absolute time, and the misconception of matter and energy as separate and distinct entities.

Speed of light. The speed of propagation of electromagnetic radiation, having the same value for all forms of this radiation; a universal invariant that remains the same throughout space regardless of the motion of the source or the motion of the receiver; a basic constant to which the relative speeds of the constituents of the universe at large can be referred.

PART I

MAN'S PERCEPTION AND THE ROLE OF METAPHYSICAL (MATHEMATICAL) SCIENCE

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I.1 Perspective: Myth and Fact

The windows of the classroom were open wide; the chinook winds had come and gone; warm breezes, accompanied by the sounds of an awakened river flowing over nearby rapids and by the calls of newly arrived birds looking for nesting sites, stole through the open windows of the classroom; the green of new growth was beginning to emerge in the valley and on the hills beyond the river; the promise of summertime shone through the sounds and sights of springtime.

On the outer edge of the wide "flats", nestling at the base of the undulating hills, a railway line could be seen; the tracks contoured the wide sweep of the river, converging and vanishing on the horizon.

The teacher had asked the pupils to look out the windows and sketch the scene; she was moving quietly around the room studying each drawing in turn. Then one sketch held her attention for some time — the tracks were drawn parallel all the way to the horizon! Puzzled, the teacher said to the pupil, "But I see the railway tracks converging to a point on the horizon!"

To which the pupil replied, "I have drawn what I know, not what I see. I have traveled to towns up the river and the tracks remained parallel because the size of the train never changed."

The teacher remained thoughtful for a moment and then said, "I accept your drawing and, although I am not sure you will ever become an artist, I am sure that this line of thought should be encouraged."

The picture of a train growing steadily smaller and disappearing at the horizon on converging tracks — based on the testimony of the physical sense of sight — is the myth. The picture of a train of unchanging dimensions proceeding on parallel rails to great distances from an observer — a perception unsupported by the physical sense of sight — is the fact; it is a construct of the human consciousness based on metaphysical inputs and confirmed by human experience.

I.2 The Solar System: Myth and Fact

As the human consciousness reaches beyond the Earth's horizon to the solar system, it finds again that the evidence of the physical senses is misleading. Modern astronomy is the result of the triumph of metaphysical science over the testimony of the physical senses.

One of the most tenacious beliefs accepted by the human consciousness in early history was the assumption, supported by the physical senses, that the Earth was immobile at the center of the cosmos. Back in the second century A.D., Claudius Ptolemy, a celebrated Greco-Egyptian mathematician, collated and expounded the astronomical knowledge accepted by the Greeks at that time. The Ptolemaic geocentric system, which evolved from this work, pictured the Earth as stationary at the centre of the universe around which the sun, moon, and stars rotated in circular orbits at uniform rates. Because the observed motions of the planets were not circular, Ptolemy assumed that each planet revolved in small circles, called epicycles, the

centres of which rotated around the earth in large circles. The Ptolemaic concept was to adopt "self-evident principles" — beliefs based on the physical sense of sight.

The emphasis in the Ptolemaic theory was on description, not on explanation. The mathematical description of planetary motions in terms of epicycles and cycles was merely a device to describe the evidence of the physical senses. The Ptolemaic geocentric system persisted because, by postulating enough epicyces and cycles, any motion of any heavenly body could be made to correspond with this evidence.

But, inexorably, through study and invention resulting in improved methods of observation, the Ptolemaic description of the solar system became more and more complex; what seemed so obvious to the physical sense of sight was becoming untenable; for example, the precession of the vernal and autumnal equinoxes required the addition of more epicycles and the introduction of eccentricity. Growing dissatisfaction with the geocentric theory encouraged astronomers to review the known facts about the solar system.

As early as the third century B.C. dissenters to the Greek belief in an Earth-centered universe had suggested that the Earth was rotating as it orbited the sun; for example, Aristarchus of Samos wrote a book on the subject. But this was ignored for some 1800 years. Then Nicholas Copernicus (1473-1543), a Polish astronomer, revived this concept of a heliocentric solar system and proved that it provided a simpler description of known planetary motions. He showed that a more metaphysical concept could provide the human consciousness with a better construct of the nature of the solar system. Copernicus knew that his theory would unleash a scientific and theological controversy and, to avoid drastic consequences characteristic of the times, publication of his studies was withheld until 1543, the year of his death.

Nevertheless, Copernicus still retained Ptolemy's mathematical description of planetary orbits as circles corrected by epicycles to explain deviations from uniform motion. The correct description of planetary motions emerged from the observations of Tycho Brahe (1546-1601), a Danish astronomer, from their geometrical interpretation by Johannes Kepler (1571-1630), a German astronomer, and from their confirmation using the first astronomical telescope by Galileo (1564-1642), the great Italian astronomer.

In the late sixteenth century, Tycho Brahe made significant improvements in astronomical instruments and developed an effective technique for fixing the positions of planets and stars. Despite the high caliber of his observations, in which proof of the Copernican system was inherent, he never completely accepted the heliocentric description of the solar system.

It remained for Kepler, early in the seventeenth century, to develop by geometric methods three basic rules of planetary motion that explained Tycho Brahe's observations. These rules showed that the planets moved around the sun in elliptical orbits so that the distances of the planets from the sun varied with position in the orbit — a confirmation of the

Copernician heliocentric system, now clarified with respect to the true motions of the planets relative to the sun.

Concurrently, Galileo laid the foundations of modern experimental science, initiated by his construction of the first complete astronomical telescope in 1609. He explored the heavens extensively, making a number of discoveries, and concluded that his observations supported the Copernican concept of the solar system as against the Ptolemaic.

But the human consciousness was not satisfied with a description of the solar system; the question was not only how but also why. Effect led naturally back to cause.

A mathematical explanation of the workings of the solar system was achieved by the English mathematician and physicist Isaac Newton (1642-1727), one of the greatest scientists who ever lived. One evening Newton observed an apple falling to the ground; he wondered why the moon in the sky did not fall also. A subsequent train of thought led to the theory of universal gravitation according to which the elliptical orbits found by Brahe and interpreted by Kepler could be explained if it is assumed that a force of attraction exists between a planet and the sun that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. The results of his investigations were published in his famous work, Principia, in 1687; in it Newton showed that the concept of universal gravitation could explain the motions of falling bodies on the Earth and the motions of planets, comets, and other heavenly bodies in the solar system. The human consciousness had passed one of the most significant milestones in its progress away from total dependence on the testimony of the physical senses toward more reliance on metaphysical concepts. It was simply a fact that metaphysical science could provide truer interpretations of physical phenomena.

Despite many subsequent developments in astronomy (which will be discussed later), Newton's theory, based on the concept of universal gravitation, has been and can continue to be usefully applied to the exploration of the solar system. It was sufficiently accurate to calculate the trajectories used by the astronauts who landed on the moon, and it is being used to determine required solar orbits for the various missions of exploratory space probes. Nevertheless, as we shall see, when motion in the universe beyond the solar system is considered, a more general theory is required.

The picture of the sun and planetary system revolving about a stationary Earth — based on the testimony of the physical senses — is the myth. The picture of the Earth an all other planets of our solar system orbiting the sun — a perception unsupported by the physical senses — is the fact; it is a construct of the human consciousness based on inputs from metaphysical science and confirmed by human experience. It is only as the human consciousness seeks all-encompassing, governing natural law that observed phenomena can be understood. The revelation of this natural law is the function of metaphysical science.

I.3 Enhancement of Man's Perception of the Solar System by Metaphysical Science

Astronomy has already demonstrated that, as the concepts of metaphysical science supersede the beliefs based on the testimony of the physical senses, man's powers of perception are increased. The following examples show how Newton's concept of universal gravitation and the related mechanics of motion led to the metaphysical discovery of new phenomena in the solar system.

In 1859 James Clerk Maxwell (1831-79), a Scottish mathematician and scientist of great stature, showed that the rings of planet Saturn, which appeared in the telescopes of that time to be made up of one piece of material, acually were composed of innumerable, light-reflecting fragments. The rings could not be solid, because gravitational forces, having different strengths in different places, would fracture them. Maxwell's mathematical prediction was verified when spectroscopic measurements of the period of revolution of the rings gave different results in different places, showing that the rings are not one solid piece. That each of the rings is a carousel of countless trillions of fragments, ranging from small particles to formidable rocks, was observed directly, with the help of Voyager 1, the NASA exploratory spacecraft, in November 1980.

The discovery of the planet Neptune is another example of the enhancement of man's perception by metaphysical science. It had been noticed that planet Uranus did not accurately pursue its predicted orbit. Before 1822 it moved too fast and after 1822 it moved too slowly. About 1845 John Adams (1819-92), and English mathematician, and Urbain Leverrier (1811-77), a French astronomer, concluded independently that an unknown planet in an orbit beyond that of Uranus must be exercising a gravitational pull, thereby perturbing the motion of Uranus. Subsequently (1846), guided by these calculations, the planet Neptune was observed in the predicted position in the sky by the German astronomer Johann Galle (1812-1910).

The existence of Pluto, the last of the sun's family of planets, was predicted mathematically in the same way. Percival Lowell (1855-1916), an American astronomer, observed perturbations of the orbits of both Uranus and Neptune in 1905, but did not publish a prediction of a planet beyond Neptune until 1914. He had attempted unsuccessfully during those years to find Pluto. Then in 1930, some years after Lowell's death, Clyde Tombaugh, an American astronomer, found the elusive planet.

Each of the above examples shows how the human consciousness developed a construct based on metaphysical inputs and how this construct was confirmed in human experience. Each presented a metaphysical picture that led to an improved understanding of the solar system.

In the above examples, the role of metaphysical science was to link effect with cause — to relate perturbations of an elliptical orbit to the presence of another planet. It was natural that this procedure should be applied to the eccentric behaviour of planet Mercury which exhibits a very slow rotation of its elliptical orbit around the sun. Leverrier applied Newtonian solar mechanics to this problem and concluded that this

perturbation could be due partly to the presence of "planet Vulcan." But Vulcan, a vaguely defined body, has never been observed.

Were the peculiarities in Mercury's orbit caused by an unknown planet, or was it possible that Newtonian solar mechanics did not apply to a problem in which the sun's gravitational field is extremely intense and the speed of the planetary motion being investigated is enormous? In fact, it has since been found that the radically different relativistic mechanics developed by Albert Einstein (1879-1955), one of the greatest physicists of all time, was required to explain the aberration of the perihelion of Mercury.

Thus, in this case, the interplay between effect and cause did not predict a new planet as in our previous examples; instead it indicated that there were limits to the applicability of Newtonian solar mechanics and that new developments in metaphysical science were required. In this way, the continual interplay between effect and cause produces improvement in metaphysical science through modifications, new developments, and even radical changes.

I.4 The Three Basic Levels of Metaphysical Science

Metaphysical science links ideas and their relationships among themselves with all-encompassing natural law (perceived and established in human experience) to form an orderly, harmonious construct in human consciousness. Inputs from metaphysical science to the human consciousness produce constructs that improve man's concept of himself and the universe. Besides generating a better undertanding of man's total environment (body, Earth, heavens), these constructs are often manifested in human experience through beneficial discoveries, innovations, and useful inventions. Metaphysical science in developing forms, therefore, initiates successive, progressive states and stages in human consciousness.

Metaphysical science encompasses mathematics, the science of numbers and their relationships pertaining to quantity, form, measurement, and arrangement. Mathematical science is a purely metaphysical discipline because it can exist in the absence of material objects; for example, we can speak of numbers of objectives, projects, accomplishments, and so on. It makes possible the prediction and discovery of phenomena in human experience simply by the solution of equations. In this book the term metaphysical science will often imply mathematical science.

We are concerned with three basic levels of metaphysical science, two of which have been encountered already:

(a) A primitive form of metaphyical science that describes in mathematical terms the testimony of the physical senses, the basic constituents of which are objects of human experience (sun, planets, stars). Example: Ptolemy's use of epicycles to describe the geocentric solar system.

(b) An intermediate form of metaphysical science that links constituent ideas and their relationships to established natural law, and, in so doing,

questions the evidence of the physical senses; a discipline in which the basic constituent ideas are also objects of human experience. Example: Newton's mathematical theory of the heliocentric solar system based on the concept of universal gravitation.

(c) An advanced form of metaphysical science that, through the logical interrelationship between constituent ideas and established natural law, can generate new constructs in human consciousness and corresponding beneficial effects in human experience; a discipline in which the constituent ideas are metaphysically conceived and which, within itself, has no recourse to objects of human experience. Examples: see Sections II.3, II.4.

The human consciousness must ultimately deal with the fact that the testimony of the physical senses and the affirmations from metahysical science are incompatible — as we already have seen in Sections I.1 and I.2. Sooner or later mankind must recognize that the inputs to human experience that are most beneficial are metaphysical, not physical. If, therefore, the human consciousness is to experience progressive states and stages, it must learn to abandon the testimony of the physical senses and welcome the affirmations from metaphysical science that produce beneficial constructs, manifested in human experience by innovations, inventions, and other developments that improve man's life-styles and broaden his horizons.

Subsequent sections will provide detailed discussions which will clarify the concepts outlined in this section.

PART II

ELECTROMAGNETIC RADIATION — ELUCIDATOR OF THE UNIVERSE

II.1 The Promise of Electromagnetic Radiation

II.2 General Characteristics of Electromagnetic Radiation

II.3 Duality of Electromagnic Radiation — Waves

II.4 Duality of Electromagnetic Radiation — Photons

II.1 The Promise of Electromagnetic Radiation

The early history of astronomy showed clearly that man's major medium of contact with the surrounding universe was visible light. As we shall see, visible light is but one component of a form of energy produced by the myriads of objects in space and propagated throughout the universe, called electromagnetic radiation. Today, electromagnetic radiation in general provides the major physical medium of communication of the human consciousness with the universe. Metaphysical science not only furnishes a correct understanding of astronomy, but it also provides a correct interpretation of the light signal received from objects in space, which supersedes the primitive interpretation assigned by physical sense.

Unlike the metaphysical science of the solar system (Newton's gravitational theory) in which the basic constituents are objects of human experience (sun, planets, moons), the metaphysical science of electromagnetic radiation is based on constituents that can be discerned metaphysically only. Not only do these consituents of electromagnetic radiation exist outside the range of the physical senses, but they are also characterized by a dual nature that cannot be explained in terms of human experience. Thus an investigation of electromagnetic radiation elevates the human consciousness to the utilization of an advanced level of metaphysical science (see Section I.4), the efficacy of which is clearly demonstrated in human experience by discoveries, inventions, and innovations that facilitate new, improved observations and interpretations of the universe.

II.2 General Characteristics of Electromagnetic Radiation

In this section we describe some characteristics of electromagnetic radiation and their implications needed for later discussion.

Electromagnetic radiation is energy originated by the motion of electric charges; it is radiated through space and other media in the form of a wave, but, in its interaction with matter, it exhibits properties similar to those of particles. This duality will be discussed in succeeding sections.

Most of the minute elementary subdivisions of nature carry a charge, a property that gives rise to all electrical phenomena. The electron, an entity found in the atom or in an electric current, carries unit charge of negative electricity; the proton, an entity in the nucleus of an atom, carries unit charge of positive electricity. An electric charge in motion gives rise to a magnetic field; if the motion varies with time, then associated variations in the magnetic field produce an electric field at right angles to the magnetic field. These electric and magnetic fields interact and vibrate tranversely to the direction of propagation of the energy.

Analogous to water waves, electromagnetic waves have "crests" and "troughs" and can be characterized by a wavelength, the distance from crest to adjacent crest, and a frequency, the number of complete oscillations per second.

The various types of electromagnetic radiation are differentiated by their wavelengths or frequencies, but in all other respects they are the same. For example, the speed of propagation of all types of electromagnetic radiation, defined as wavelength × frequency ($c = \lambda\nu$), is the same (299,792.8 km per sec, or approximately 300,000 km per sec in a vacuum). The various kinds of electromagnetic radiation are listed in Table 1 in the order of increasing wavelengths (corresponding to decreasing frequencies).

Of all the electromagnetic radiation available, the human eye selects only that in the narrow band of visible light indicated in Table 1. Gamma rays, a very energetic type of natural radioactivity, X rays, a highly penetrating form of electromagnetic radiation, and ultraviolet radiation, just outside the range of visibility — all have smaller wavelengths and higher frequencies than those of visible light. Infrared radiation generated by heat, microwaves constrained to travel essentially in straight lines, and radio waves so important to communication — all have larger wavelengths and lower frequencies than those of visible light.

The limits of sensitivity of man's physical sight to electromagnetic radiation are made strikingly clear by Table 1. The human eye is sensitive only to a very narrow band of electromagnetic radiation that lies in the range of wavelengths between 0.00004 cm and 0.000075 cm. Therefore most forms of electromagnetic radiation — most of the "lights" in the universe — are invisible to man's eye. The universe would appear greatly different if man's eyes were sensitive to X rays.

If, in its primitive form, the human consciousness can discern an object only through the physical senses, how proficient is this discernment? In this primitive state of human consciousness, every object is the sum of its qualities as perceived by the physical senses, that is by such qualities as its color, taste, smell, sound, shape, size, motion. But since these qualities exist only in the sense-dependent human consciousness, then the star-studded canopy of heaven — in fact, the hole environment of the human consciousness (body, Earth, heavens) — can only exist as a construct of that consciousness, a structure of conventional concepts shaped by the physical senses which only an input from metaphysical science can change.

TABLE 1

Radiation	Wavelength (angstroms)
Gamma rays	0.005 - 1.40
X-rays	0.1 - 100
Ultraviolet radiation	40 - 4000
Visible light	4000 - 8000
Infrared radiation	8000 - 10^7
Microwaves	10^7 - 300 × 10^7
Radio (Hertzian) waves	greater than 1000 × 10^7
(Note: 1 angstrom = 10^{-8} cm)	

II.3 Duality of Electromagnetic Radiation — Waves

It was natural that the study of light should begin very early in history. A controversy, originating in the time of Newton, concerned the fundamental nature of light. The question was: Did light involve a continuous propagation of energy, or did it entail a discontinuous propagation of descrete packets of energy? This controversy continued until it was established that, in fact, light has a dual nature. In this section we consider the evidence that light is wave motion.

When a beam of light passes through a round aperture, a sharply defined disk of light will appear on a screen; but if the aperture is a pinhole, then the edges of the disk are no longer sharp, and alternate, concentric light and dark bands appear. This is the phenomenon of diffraction. It can be compared with ripples on the surface of water that bend and diverge as they pass through a narrow aperture.

If light passes through two pinholes located closely adjacent, the resulting pattern is a series of parallel stripes. This is the phenomenon of interference. It can be compared with two interacting systems of ripples on water emerging from two adjacent apertures, which reinforce each other where crest meets crest (light stripes) but cancel each other where crest meets trough (dark stripes).

According to physical sense, such wave patterns could not appear if light had a purely corpuscular structure. We conclude from this evidence that light must consist of waves.

This conclusion was supported by the outstanding research of James Clerk Maxwell. Aided by the high-calibre observations recorded by Michael Faraday (1791-1867), an English scientist, Maxwell undertook a study of electromagntic radiation in general and developed a theory (published in 1865) that has its roots in Coulomb's law of force between charged particles and that describes electromagnetic radiation as the propagation of energy by continuous wave motion. Maxwell found mathematical expression for the concept that electromagnetic radiation is simply a propagation in wave form of changing electric and magnetic fields through space. He provided a unified understanding of all the electromagnetic radiation reaching Earth. Just as perceptions gained through Newton's mathematical theory of universal gravitation cleared the way for the discovery of distant planets and for the successful launching of exploratory spacecraft, so new concepts introduced by Maxwell's wave theory of electromagnetic radiation opened the way for a significant discovery and for many useful practical applications.

One immediate result of Maxwell's theory was a calculation showing that electromagnetic waves and visible light travel at the same speed. This result led him to identify light as an electromagnetic phenomenon.

Making use of Maxwell's prediction that an electromagnetic wave will be generated by an accelerating electric charge, the German physicist Heinrich Hertz (1857-94) designed a laboratory apparatus in 1888 in which electric charges oscillated in an electric circuit, and with this device he showed experimentally the existence of a form of electromagnetic radiation called radio waves. In 1901 Guglielmo Marconi (1874-1937), an Italian

physicist, demonstrated the practicality of long-distance communication by radio waves. Commercial radio and television communication took only a lifetime to radically change the life-styles of the human consciousness.

The detection of radio waves from space was a subsequent development. More recently, large X-ray and gamma-ray instruments, designed to make use of the special properties of these electromagnetic waves, have been placed in Earth orbits to study hitherto unknown high-energy sources of radiation in the universe. None of the measurements made by such instruments can be properly interpreted without the corresponding, underlying input from metaphysical science — the wave theory of electromagnetic radiation.

II.4 Duality of Electromagnetic Radiation - Photons

But further research uncovered a phenomenon that could be explained only if light is composed of individual packets of energy. In 1900, while inestigating radiation from heated bodies, Max Planck (1858-1947), German physicist, found that, in order to resolve certain problems, it was necessary to assume that the radiant energy was emitted, not as a continuous stream, but as a discontinuous flux of minute, discrete packets of energy, which he called quanta. Subsequent to Planck's experiment, Albert Einstein postulated that all forms of electromagnetic radiation were propagated through space as separate and distinct quanta of energy. He applied this concept to explain the photoelectric effect — the ejection of electrons from a metal plate when light quanta, called photons, impnge on it. It was found that the action of these photons of light on the electrons in the metal plate could be compared with the collision of two billiard balls.

According to physical sense, such collision phenomena could not be observed if light had a purely wave structure. We conclude, from this evidence, that light must consist of photons.

Is light waves or photons? It must be both, waves predominating in some situations and photons in others. In his work on heat radiation, Planck discovered the basic law that each quantum carries an amount of energy proportional to the frequency of the radiation, that is, $E = h\nu$, where h is a universal constant. Thus the energy of each quantum, which implies that radiation has a corpusclar nature, is identified with the frequency of radiation, which implies that radiation has a wave nature.

The dual nature of light cannot be explained in terms of limited, physical-sense-based human experience. According to the physical senses, a wave is a wave, a photon is a photon, and a duality of the two is inconceivable. We must conclude, therefore, that such duality is a concept introduced by metaphysical science to explain the phenomena of light observed in human experience. Thus the dual nature of light is not evident to physical sense, but it is apparent to metaphysical sense.

But this input from metaphysical science to the human consciousness does more than explain observed light phenomena; it leads to inventions that are essential to human progress. The laser, based on the wave nature of light and designed to produce coherent light (waves of the same wavelength, all in phase), is now used extensively; for example, the development of

lasers for use in communication, analogous to radio communication, is well advanced. The solar cell, based on the quantum nature of light (photoelectric effect), can provide electric power for spacecraft and other applications. Clearly, metaphysical science applied to light phenomena leads human consciousness away from total dependence on the physical senses, to metaphysical concepts conducive to improved life-styles and wider horizons.

PART III

THE THREE BASIC REALMS OF THE UNIVERSE

III.1 Definition of the Realms of the Universe in Terms of the Properties of Light

III.2 The Microcosm — a Metaphysical Realm

III.3 The Macro-world — the Realm of Human Experience

III.4 Macro-World Beliefs and the Macrocosm — No Absolute Position in Space — Universal Invariance of the Speed of Light in Space

III.5 Macro-World Beliefs and the Macrocosm — No Absolue Time in Space

III.1 Definition of the Realms of the Universe in Terms of the Properties of Light

Of man's physical senses, the sense of sight is his only contact with the universe at large. The properties of electromagnetic radiation, the medium of sight, are highly significant, therefore, in studies of the universe. In particular, it is evident that all characteristic dimensions and relative speeds of the constituents of the universe should be referred, respectively, to the wavelength and the speed of visible light. We now define three realms, perceived by the human consciousness, in accordance with these properties of electromagnetic radiation.

The first realm to be defined is the inward world of the infinitesimal, a construct of the human consciousness containing constituents having characteristic dimensions smaller than the wavelength of visible light ($d/\lambda < 1$). This is the microcosm. Its constituents are not encompassed within the range of visibility provided by electromagnetic radiation; they exist, therefore, outside the range of the physical senses, but are known, however, by their effects in human experience.

The second realm to be defined is the macro-world of human experience, the constituents of which are objects having characeristic dimensions larger than the wavelength of visible light ($d/\lambda > 1$) and relative speeds much less than the speed of light ($v/c <<$). In this macro-world, a construct of the primitive human consciousness, objects are apparent to the physical senses and motion is slow compared with that of constituents in the universe at large.

The third realm to be defined is the outward world extending beyond our own galaxy to the vast reaches of space, a construct of the human consciousness in which all objects have characteristic dimensions larger than the wavelength of visible light ($d/\lambda > 1$) and relative speeds of any value up to almost the speed of light ($0 < v/c < 1$). This is the macrocosm. All objects in this realm are within the range of visibility provided by electromagnetic radiation; they are apparent, therefore, to the physical senses.

We will now consider the metaphysical science of these three realms in detail in subsequent sections.

III.2 The Microcosm - a Metaphysical Realm

The unique characteristic distinguishing the microcosm from the macro-world and the macrocosm arises fom the fact that the basic constituents of the microcosm have characteristic dimensions that are smaller than the wavelength of visible light. Unlike the macro-world and the macrocosm, therefore, the microcosm exists outside the range of visibility provided by electromagnetic radiation, as a purely metaphysical concept. As we saw in our study of electromagnetic radiation, the nature of the microcosm can be understood only by applying the methods of advanced metaphysical science (see Section I.4) and by observing the manifest benefits of this metaphysical science of the microcosm in human experience.

The electron is an example of a constituent of the microcosm existing outside the range of visibility provided by electromagnetic radiation. An electron is smaller than the wavelength of visible light, hence no ordinary microscope can reveal its existence. It would appear, nevertheless, that electromagnetic radiation of much shorter wavelength, such as the gamma rays of radium, could be used to "illuminate" an electron. This possibility turns out to be impractical, however, because the photons of gamma rays would interact with the electron — an interaction similar to that in the photoelectric effect (see Section II.4).

Furthermore, the metaphysical science of the microcosm shows that duality exists elsewhere in nature as well as in electromagnetic radiation. The electron and other subatomic entities also exhibit this property.

When a discharge of electricity passes between two electrodes in a gas at low pressure, luminous phenomena are observed. Early experimenters found that the electrode connected to the negative side of the electrical source (the cathode) emits what are called cathode rays. In 1897 Joseph Thomson (1856-1940), an English physicist, proved that cathode rays consisted of particles of one kind, all carrying the same negative electric charge, independent of the cathode material or the nature of the gas. He had discovered the electron. Thomson measured the ratio of charge to mass for the electron. In 1909 Robert Millikan (1868-1953), an American physicist, measured the charge on the electron. These results permitted a calculation of the mass of the electron. Thus the electron came to be regarded as an elementary particle, carrying a unit charge of negative electricity.

Then in 1924 Louis de Broglie, a French physicist, suggested that interactions between electrons and matter might better be explained if the electron were considered as having wavelike properties. In 1927 C. J. Davisson and L. H. Germer projected a beam of high speed electrons through a thin crystal — analogous to a beam of light passing through a pinhole — and obtained on film patterns that showed that electrons exhibit the wave property of diffraction. This evidence indicated that an electron should be regarded also as a system of waves.

The human consciousness cannot conceive through the medium of the physical senses an entity that is both a discrete particle and an undulating charge of electricity. But such a description of an electron can be firmly ensconced in metaphysical (mathematical) science as a concept that leads to many practical applications.

Inventions resulting from the metaphysical science of the electron include the transistor and the electron microscope. The transistor is an application of the particle nature of electrons; it is an electronic device that is used for current and voltage amplification and many other functions. It finds practical use in radios, computers, and in automatic control devices used in spacecraft. The wavelike properties of electrons are utilized in the electron microscope and other instruments. The electron microscope is capable of greater magnification and greater depth of focus than a correspondng optical microscope, and hence it reveals more details of structure. These applications of the dual nature of the electron are contributing substantially to human progress. Even though the metaphysical

realm of the microcosm forms no part of man's sense-based macro-world, nevertheless, concepts derived from the metaphysical science of the microcosm can be manifested in human experience, with many benefits.

We conclude, therefore, that a considerable part of the phenomena in the universe around man exists outside the range of the physical senses. The physical-sense-based macro-world of human experience does not include the microcosm, the realm of the electron and other subatomic entities. Furthermore, duality in the microcosm is a metaphysical concept that has no counterpart in human experience.

Although the microcosm and the macrocosm are basically dissimilar with respect to the wavelength of visible light, nevertheless, a definite similarity exists with respect to the speed of light — the constituents of the microcosm and the objects of the macrocosm can have any relative speeds short of the speed of light. The properties of motion of the consituents of the microcosm, as they relate to the speed of light, are, therefore, the same as those of the objects of the macrocosm. These properties will be made clear when the metaphysical science of the macrocosm is considered in later chapters.

III.3 The Macro-World — the Realm of Human Experience

In order to achieve an understanding of the macro-world, let us visualize a hypothetical universe in which objects are visible and the magnitudes of their relative velocities (that is, their relative speeds) are much less than the speed of light — the ratio of object relative speed to light speed is negligibly small ($v/c \ll 1$). Among the many moving objects in this hypothetical universe there exists a group of objects, each of which is at rest relative to every other object in this array. Let us associate an observer with each such object. These "rest-state" observers see themselves as relatively stationary with respect to all other moving objects; that is, relevant to the constituents of the hypothetical universe at large, they are relatively stationary observers.

To these relatively stationary observers, the relative speeds of moving objects are so small compared with the speed of a hypothetical universe, the signal appears to be transmitted virtually instanteously. Hence these relatively stationary observers, regardless of their locations in the hypothetical universe in relation to a given moving object, will observe the same position and time of the object — and hence the same motion — at the same instant of observation.

We conclude, therefore, that, in this hypothetical universe ($v/c \ll 1$), frames of reference for the specification of position, time, and motion, fixed relative to the rest-state observers, can be uniquely defined. A uniquely defined, fixed reference system implies that position (or displacement) is absolute, time (or time interval) is absolute, and motion is absolute. Thus in such a fixed frame of reference these quantitites are objective — they are the same at the same instant of observation for all relatively stationary observers regardless of their locations in the hypothetical universe in relation to the observed moving object.

The macro-world of human experience is patterned by this hypothetical universe because in the macro-world the ratio of the object relative speed to signal speed is also negligibly small ($v/c \ll 1$). On planet Earth and even throughout the solar system, the motions of various objects involve relative speeds well below the speed of light. Thus the concepts of absolute position, absolute time, absolute motion, and fixed frames of reference — all features of the hypothetical universe described above — also characterize the sense-dependent macro-world of human experience. In this realm, therefore, position, time, and motion — as perceived by all relatively stationary observers — are objective.

This macro-world is a manifestation of the Earth-bound rest state of the human consciousness; it is an objective construct adopted by the primitive human consciousness, based on sense-dependent human experience and patterned by the hypothetical universe.

According to the fundamental definition of metaphysical science, given in Section I.4, the metaphysical science of the rest-state macro-world of human consciousness must link all objects in this realm and their motions among themselves with the law of gravitation, a natural law that is immutably and universally the same for all objects in the macro-world, regardless of their motions. This definition of metaphysical science provides the means for determining the properties of a purely mechanical world — a rest-state construct of the human consciousness; it is the basis of Newton's metaphysical (mathematical) science of the heliocentric solar system (see Section I.2.)

III.4 Macro-World Beliefs and the Macrocosm — No Absolute Position in Space — Universal Invariance of the Speed of Light in Space

When the primitive, rest-state human consciousness peers into the macrocosm and tries to interpret this realm in terms of its rest-state beliefs ($v/c \ll 1$), can it discern the inherent characteristics of the macrocosm? In other words, does the sense-based, absolute Newtonian objectivity of the rest-state macro-world extend into the macrocosm ($0 < v/c < 1$)? To answer these qeustions, let us determine whether the rest-state beliefs of absolute position and absolute time are valid in the macrocosm.

We have seen (Section III.2) that the rest-state macro-world of human consciousness is patterned by the hypothetical universe in which the positions of objects can be specified in terms of a uniquely defined, fixed frame of reference. Such a fixed frame of reference can be envisaged for the solar system and even for celestial systems beyond the solar system in which relative speeds are also very much less than the speed of light ($v/c \ll 1$). But does such a fixed frame of reference exist in the macrocosm, where the objects can have relative speeds comparable with the speed of light ($0 < v/c < 1$, see Section III.1)? In other words, is there a fixed frame of reference that can be uniquely defined for all space? Is space itself a fixed frame of reference? Early studies of the mechanism of propagation of electromagnetic radiation appeared to suggest that a fixed frame of reference did exist in space.

Man's physical perception of the macrocosm is through the electromagnetic radiation that he receives from objects in this realm. If sound is vibrations propagated in the atmosphere, can it be said, by analogy with such evidence of the physical senses, that electromagnetic radiation is wave motion propagated through a medium that permeates all space and matter. For some two centuries following Newton's researches, scientists regarded this medium, which they called ether, as a reality. The ether was considered to be invisible, odorless, and of such a structure that it did not interfere with the movements of bodies through space, nor could it be pushed away by bodies moving through it. It was everywhere and immovable. The introduction of the ether concept completed a mechanical model of the universe based on Newtonian physics, that is, based on the Earth-bound, rest-state evidence of the physical senses. In terms of the ether, a fixed frame of reference in space, Newtonian physics could define motion as absolute.

But this hypothetical picture of a fixed frame of reference in space — an extrapolation from Earth-bound, rest-state human experience into the macrocosm — could not survive. There were many problems, not the least of which was the fact that the existence of the ether had never been demonstrated experimentally. A series of experiments involving measurements of the speed of light were made, with a view to proving or disproving the existence of ether.

The speed of light through air was determined in 1849 by Armand Fizeau (1819-96), a French physicist, who used a toothed wheel to interrupt the light, and in 1850 by Jean Foucault (1819-68), a contemporary French physicist, who used a rotating mirror. More recently, modern electronic methods have been used to obtain highly accurate measurements in various media. It is now accepted that the speed of lght in a vacuum is 299,792.8 km per sec (already quoted in Section II.2), its value being less in other media.

The speed of the Earth in its orbit around the sun is about 32 km per sec and, because the ether is assumed to be fixed in space and unaffected by the motion of the Earth through it, we can say that this is the speed of the Earth relative to the ether at its surface (neglecting the very small effect of Earth's rotation). Now if a beam of light is projected forward against the ether stream, it should travel at about 299,761 km per sec, whereas a beam of light projected backward with the ether stream should travel at about 299,825 km per sec. These values illustrate the order of magnitude of the velocities that must be detectable experimentally.

In the period 1881-87, Albert Michelson (1852-1931) in association with Edward Morley (1838-1923), both American physicists, succeeded in achieving and confirming measurements of the speed of light, using an instrument called an interferometer, sufficiently accurate to show such small differences. The interferometer consisted of mirrors arranged so that a beam of light could be split in two, each component being then projected in a different direction.

To a scientific world already convinced that ether really existed, the results of the Michelson-Morley experiments came as a distinct shock: regardless of the direction of the beam, the experiment showed that the

speed of light remained the same; that is, the speed of light was not affected by the motion of the Earth. The alternatives were: either the Earth was stationary, contrary to the already accepted Copernican concept that the solar system is heliocentric, or the ether did not exist.

The belief that wave motion required a material medium to sustain it, supported by the physical senses, was so strong that for many years no consensus emerged among scientists; but repeated and new experiments left matters unchanged. Not only was the universal invariance of the speed of light confirmed by further Michelson-Morley experiments, which verified that light is propagated in all directions in space at the same speed regardless of the motion of the source or the motion of the receiver, but it was confirmed also by other studies, such as observations of binary stars, of which there are many in the Milky Way galaxy. The Sirius system in which Sirius A (primary) and Serius B (secondary) revolve around a common centre of gravity is a good example. Careful observations of such binary systems from Earth, a moving reference system, have shown that the light from the approaching component has the same speed as the light from the receding component.

Finally, it was realized that the heliocentric description of the solar system could not be abandoned, because so much reliable scientific support for this concept had come from so many directions. The only conclusion was that the ether did not exist.

It was concluded, therefore, that space is not a fixed frame of reference; that, with respect to positions in space, nature has provided no absolute standard of comparison. Thus there are no absolute positions, no absolute displacements, no absolute boundaries, no absolute directions in the macrocosm.

What seems to be common sense to the Earth-bound, rest-state human consciousness does not apply to the macrocosm. With respect to position in space, no reliance can be placed on beliefs based on the rest-state testimony of the physical senses. Rest-state beliefs pertaining to position cannot be extrapolated into space.

III.5 Macro-Work Beliefs and the Macrocosm — No Absolute Time in Space

Another important aspect of the hypothetical universe (see Section III.3) is that in this realm time can be uniquely defined, independent of all relatively stationary observers, because all such observers see the same event at the same time, irrespective of their positions relative to the location of the event. When the relative speed ratio is negligibly small ($v/c \ll 1$), therefore, observer time and event time are essentially the same and time is objective.

The coincidence of the rest-state macro-world with the hypothetical universe implies that time can be uniquely defined in human experience also. Thus the primitive, Earth-bound, rest-state human consciousness, in league with the physical senses and aware only of a world in which the relative speed ratio is infinitesimal ($v/c \ll 1$), believes that there is a steady, inexorable, universal flow of time from the remote past to the distant

future — a flow of time that is independent of and uniquely the same for all relatively stationary observers.

Based on this belief, time for all Earth's residents has been made objective by referring all events to a clock that correlates with the motion of planet Earth. An hour corresponds to an arc of 15° in the daily rotation of planet Earth about its axis; a day is the time taken by Earth to complete this rotation; a year is the time taken by Earth to orbit the sun.

But is time objective in the macrocosm? No relatively stationary observer sees an event in the macrocosm at the instant it occurs because the relative speed ratio is finite ($0 < v/c < 1$, see Section III.1), which means that it takes time for a signal, radiated from an event, to reach an observer. Each observer has his own particular time. Time in the macrocosm, therefore, is not objective — it is subjective.

Thus there is no "now" in the macrocosm. To illustrate this, let us consider Arcturus, an orange, first-magnitude star in the constellation of Bootes, with a diameter ten times that of the sun. This star is about thirty-six light-years* away from the Earth. Thus, if we try to communicate with Arcturus by radio, it will take thirty-six years to reach the star and another thirty-six for a reply. When we observe Arcturus, our eyes are receiving a light signal that left the star thirty-six years before. Thus, as we look out into space at a time we would call "now," we see many objects in different states and stages, each corresponding in general to a different time in the past.

Again we see that what seems to be common sense to the Earth-bound, rest-state human consciousness does not apply to the macrocosm. With respect to time in space, no reliance can be placed on beliefs based on the rest-state evidence of the physical senses. Rest-state beliefs pertaining to time cannot be extrapolated into space.

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* A light-year is the distance that light travels in one year — about 10 trillion kilometers.

PART IV

METAPHYSICAL SCIENCE (RELATIVITY) OF THE MACROCOSM

IV.1 Special Relativity of Position and Time

IV.2 Special Relativity of Mass and Energy

IV.3 Experimental Verification of the Special Theory of Relativity — Antiparticles.

IV.1 Special Relativity of Position and Time

We have learned From Sections III.4 and III.5 that the basic characteristics of the macrocosm cannot be objectively perceived by extrapolating the rest-state beliefs of the physical-sense-dependent macro-world into the macrocosm. As will now be shown, the true characteristics of the macrocosm can be objectively discerned only through metaphysical science. The nature of the metaphysical science of the macrocosm was made clear by Albert Einstein's famous theory of relativity.

Albert Einstein's basic premise, which underlies the metaphysical science of the macrocosm, is based on the cardinal definition of metaphysical science given in Section I.4, applied to the macrocosm. This basic premise states that the metaphysical science of the macrocosm links all objects in this realm, and their motions among themselves, with natural law that is immutably and universally the same for all objects, regardless of their state of motion. Einstein succeeded in defining the link between immutable, universal natural law and the characteristic objects and their motions in the macrocosm, which ensures order and harmony everywhere in space, through his theory of relativity, the basis of the relativistic metaphysical science of the macrocosm.

If relativistic metaphysical science is to promote the growth of the rest-state human consciousness out of itself by engendering new, progressive constructs of the universe, then a basic objective must be to relate distance and time in the macrocosm ($0 < v/c < 1$) to these quantities in the rest-state macro-world of human experience ($v/c \ll 1$). In pursuit of this objective, Einstein's early research resulted in the Special Theory of Relativity (Ref. 2), which relates not only distance and time but also mass and energy in the macrocosm with these quantities in the rest-state macro-world. This theory is "special" because it pertains to motion in free space: that is, space free from gravitational effects and characterized, therefore, by uniform motion. This restriction is acceptable in many contexts because, in so much of the universe, the effects of gravitational fields are not significant compared with the effects of motion at relative speeds comparable with the speed of light.

The great significance of the Special Theory of Relativity lies in the fact that Einstein was able to develop a mathematical transformation that relates intervals of distance and time, observed with respect to uniformly moving objects in the macrocosm, to the conditions of the rest-state macro-world, keeping the speed of light universally constant, so that the universality of natural law is preserved. This transformation is called the Lorentz transformation after Hendrik Lorentz (1853-1928), a Dutch physicist, who used it originally in connection with a now outdated theory of his own.

The Lorentz transformation allows for the following characteristics of a relativistic macrocosm (Appendices I, II):

(a) An interval of distance, or a displacement, is a relative concept; that is, as seen by a relatively stationary observer, it depends on the relative speed (v/c, Section III.1). The belief in a universal, absolute interval of distance is abandoned.

(b) An interval of time is relative concept; that is, as seen by a relatively stationary observer, it depends on the relative speed ratio (v/c, Section III.1). The belief in a universal, absolute interval of time is abandoned.

The Special Theory of Relativity, an input from the metaphysical science of the macrocosm, made a startling impact on the human consciousness. According to the Lorentz transformation:

(a) A measuring rod, moving uniformly in the direction of its length in the macrocosm, has a different length compared with that of an equivalent rod at rest in the macro-world; specifically, the higher the relative speed ratio (v/c, the ratio of the speed of an object in the macrocosm viewed by a relatively stationary observer referred to the speed of light), the greater the contraction of the rod.

(b) A clock in uniform motion in the macrocosm runs at a different rhythm compared with that of an equivalent clock at rest in the macro-world; specifically, the higher the relative speed ratio (v/c), the slower the clock runs.

In stating these results, we have made use of the fact that, because, in general, all relative speeds in the rest-state macro-world ($v/c \ll 1$) are so small compared with those in the macrocosm ($0 < v/c < 1$), each observer in the rest-state macro-world an be identified as a relatively stationary observer.

Thus a relatively stationary observer perceives that, in the macrocosm, a moving rod is shorter than his equivalent stationary rod, and a moving clock runs slower than his equivalent stationary clock. On the other hand, an observer in motion with the moving rod and the moving clock would notice that length and rhythm are the same, irrespective of the relative speed of motion.

According to the Lorentz transformation, if the relative speed of an object in the macroscosm should attain the speed of light ($v/c \to 1$), then, as seen by a relatively stationary observer, its dimension in the direction of motion would be reduced to zero. Furthermore, if a clock in the macrocosm should attain the speed of light ($v/c \to 1$), then, as observed by a relatively stationary observer, it would stop completely. It is apparent, therefore, that the maximum relative speed possible in a relativistic macrocosm is the speed of light.

The Special Theory of Relativity describes a universe beyond the world conceived by the lethargic, Earth-bound, rest-state human consciousness. It shows that the limited perceptions of the rest-state human consciousness can be extrapolated into the macrocosm. The rest-state human consciousness, based on testimony of the physical senses pertaining only to motion at speeds much less than the speed of light, tries to persuade mankind that the dimensions of an object and the rhythm of a clock are invariant whether or not they are in motion relative to an observer; it recognizes only rest-state self-evident beliefs such as that which fixed the

Earth at the centre of the universe (see Section I.2). Thus the rest-state human consciousness, constrained by beliefs in absolute distance and absolute time, could only misinterpret the macrocosm until Einstein's concepts — inputs from relativistic metaphysical science — removed the rest-state constraints and introduced a new construct of the universe.

We conclude that the construct of the universe by the rest-state human consciousness, which is based on phenomena limited to characteristic relative speeds much less than the speed of light and which accords with beliefs of absolute distance and absolute time, must be replaced by a construct predicated upon inputs from relativistic metaphysical science, which is based on phenomena restricted to characteristic relative speeds less than, but often comparable with, the speed of light and which accords with concepts of relative distance and relative time.

IV.2 Special Relativity of Mass and Energy

The relativity of mass and energy — that is, the dependence of the mass and energy of an object on the relative speed ratio (v/c) as seen by a relatively stationary observer — is the most significant concept to emerge from the Special Theory of Relativity (Ref. 2). The impact of this input to the human consciousness from relativistic metaphysical science was both significant and immediate. It destroyed the belief of the rest-state human consciousness that, everywhere in the universe, the mass and energy of an object are separate and distinct entities; it showed that the mass and energy of an object are the same at the same magnitude of the relative speed ratio (v/c); it proved that mass and energy are indistinguishable.

Previous to the development of the Special Theory of Relativity, sense-incarcerated human consciousness, which knew only a slowly moving world, supported the belief that the universe contained two separate and distinct entities: mass and energy. Mass was regarded as the quantity of matter in an object cognized by the physical senses; energy was apparent to the physical senses as a measurement of the ability or capacity of an object to do work or to produce change. To the Earthbound, rest-state human consciousness, mass continues to be inert and tangible, energy continues to be active and invisible. These concepts of the rest-state human consciousness are identifiable within, and governed by, classical Newtonian mechanics, which is based on beliefs of absolute position, absolute time, and on separate and distinct entities for mass and energy. But from the Lorentz transformation (see Section IV.1) the portentous conclusion can be drawn that mass and energy are the same thing (Appendices III, IV).

With regard to the relativity of mass and energy, the Lorentz transformation states:

(a) An object in uniform motion in the macrocosm has a different mass compared with that of an equivalent object at rest in the macro-world; specifically, the higher the relative speed ratio (v/c), the greater the mass of the object.

(b) An object in uniform motion in the macrocosm has a different energy compared with that of an equivalent object at rest in the macro-world;

specifically, the higher the relative speed ratio (v/c), the greater the energy of the object.

The Lorentz transformation shows that the energy of a uniformly moving object,* compared with that of an equivalent object at rest, tends to become infinitely large as the relative speed of the object approaches the speed of light ($v/c \rightarrow 1$). It must be concluded, therefore, that however great the input of energy may be, it can never be sufficient to accelerate the object to speeds equal to or greater than the speed of light.

Because the mass and energy of an object increase in the same way with the relative speed ratio, it must be concluded that the increased mass of a moving object comes from its increased energy. In fact, mass and energy must be identical. We can say, therefore, that mass is not an inherent property of an object; that it must be perceived as a form of energy. This equivalence of mass and energy, demonstrated by the Special Theory of Relativity, is expressed by the relation $m = E/c^2$, which states that, at a given relative speed ratio, the mass (m) of an object is equal to the corresponding energy (E) divided by the square of the speed of light, a universal constant.

The importance of Einstein's Special Theory of Relativity to the human consciousness is phenomenal. This input from relativistic metaphysical science shows that what appears to the rest-state human consciousness as the mass of an object at rest is really concentrated, congealed, frozen energy (rest-energy); conventional mass is rest-energy ($E_0 = m_0c^2$). In 1905 Einstein wrote: "... we are led to the more general conclusion that the mass of a body is a measure of its energy content ...." With this significant concept held firmly in view, man can see beyond the confines of the physical senses; he can be much more aware of the kind of universe that surrounds him, so radically different from any concept that might be obtained through extrapolation from the beliefs of the rest-state human consciousness.

The persistence of a rest-state belief in matter and energy as separate and distinct entities was the result of limited human experience. For example, chemists believed at one time that experiments had demonstrated the indestructibility of matter. When hydrogen gas was burned in oxygen gas, water was produced along with light and heat. Measurements appeared to show that the total mass of gas before the reaction and the mass of water after the reaction were the same, and that light and heat had no mass — that mass and energy were separate entities. Nevertheless, Einstein's famous energy equation ($E_0 = m_0c^2$) does explain correctly the combustion of hydrogen, because in that process, characteristic of Earth-bound human experience, the energy of motion of the light and heat is so small compared with the rest-energies of the chemical substances that it could not be detected using available techniques.

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* $E = E_0/\sqrt{1 - (v/c)^2}$ where E_0 is the rest-energy, v is the relative speed of the object, c is the speed of light.

It is not surprising that when the process of combustion, as elucidated by the rest-state human consciousness on the basis of separate entities for mass and energy, is applied to explain the output of light and heat from the sun, it is found that the sun's output would be sustained for no longer than about a thousand years. On the other hand, Einstein's energy equation, which expresses the equivalence of mass and energy, explains why the sun and stars can go on radiating light and heat for billions of years. The beliefs of the rest-state human consciousness cannot be extrapolated to explain the surrounding universe but relativistic metaphysical science can provide new, beneficial constructs of the universe.

The Lorentz transformation implies that, as phenomena involving relative speeds close to the speed of light become part of man's experience, corresponding inputs from relativistic metaphysical science will lead the human consciousness out of a purely physical, rest-state belief of substance into a more metaphysical perception. We conclude that the construct of the universe by the rest-state human consciousness, which is based on phenomena limited to characteristic relative speeds much less than the speed of light and which accords with the belief of matter-substance, must be replaced by a construct predicated upon inputs from relativistic metaphysical science, which is based on phenomena restricted to characteristic relative speeds less than but often comparable with the speed of light and which accords with the concept of energy-substance.

IV.3 Experimental Verification of the Special Theory of Relativity — Antiparticles

Experimental verification of the Special Theory of Relativity is practical only when energy of motion becomes appreciable compared with rest-energy. Motions within present-day human experience do not meet this requirement; for example, it is noteworthy that an Apollo spacecraft, projected on a moon mission, possesses an energy of motion which, compared with its rest-energy, is much too small to enter calculations of launch energy. The energy of motion of an object becomes comparable with its rest-energy only when the object moves at a relative speed close to the speed of light — as the Lorentz transformation implies. The macrocosmic input from relativistic metaphysical science, which will lift the human consciousness out of the rest state, must await man's greater achievements in space.

But the Special Theory of Relativity is not confined to the macrocosm; it is valid also in the microcosm (see Section III.2). In the laboratory, subatomic particles can be accelerated to relative speeds close to the speed of light, and energies of motion can be generated that are substantially larger than the rest-energies of the particles; for example, the powerful linear accelerator at Stanford University can accelerate electrons to energies of motion about 40,000 times their rest-energies (masses).

Relativistic retardation of time intervals was confirmed by Herbert Ives (1882-1953), an American scientist, in 1936. He made use of the fact

that a radiating atom acts like a clock because it emits light of a definite frequency and wavelength that can be accurately measured using a spectroscope. In an experiment in which the light emitted by fast-moving hydrogen atoms was compared with that emitted by hydrogen atoms at rest, Ives found that the frequency of vibration of the fast-moving atoms was reduced according to the Special Theory of Relativity.

Time dilation also has been confirmed by observing the decay of subatomic particles which spontaneously disintegrate into other particles. These studies have demonstrated that particles in motion decay more slowly than particles at rest.

The muon is a subatomic particle well suited to tests of time dilation. The muon is an elementary particle that resembles an electron in every respect except one — its mass is 207 times the mass of the electron. But it is short-lived: it is unstable and decays, with an average lifetime of 2.2 microseconds, into an electron and other particles. Will muons moving close to the speed of light experience a noticeable increase in their life span compared with that of rest-state muons?

This question was answered by Emilio Picasso and an international team of scientists at the European Center for Nuclear Research (CERN), near Geneva. In their experiments, muons were circulated at relative speeds close to the speed of light (99.95%) under the control of a ring of electromagnets, and the demise of muons was recorded by electron detectors. These tests showed that the lifetime of a typical moving muon was extended nearly thirty-fold compared with the lifetime of a relatively stationary muon. These results, reported in 1977, confirmed almost exactly the predictions of the Special Theory of Relativity.

A direct verification of Einstein's energy equation was made in 1932 by English physicists John Cockroft and Ernest Walton, who built an electric accelerator designed to project protons (nuclei from hydrogen atoms) at a target of lithium metal. When a proton impinged on a lithium nucleus, the latter was split into two new nuclei of helium. It was found that the rest-energies of the two helium nuclei together were slightly less than the combined rest-energies of the proton and the lithium nucleus; that is, energy of motion was generated. The energies of motion of the two helium nuclei were measured and, to within a few percent, they accounted for the missing rest-energy in accordance with Einstein's energy equation, $E_o = m_o c^2$.

It is now recognized that the Special Theory of Relativity and deductions therefrom are fully established; they are now part of modern science.

The application of relativistic metaphysical science to the microcosm has greatly extended our knowledge of that realm. The existence of the "anti-electron", for example, was predicted in 1928 by Paul Dirac (1902-1984), an English physicist, from his relativistic Quantum Theory of the electron.

An antiparticle is an elementary particle that corresponds to an ordinary particle such as an electron or a proton in all respects, except

that it has the opposite electric charge and magnetic moment. Thus the antiparticle of an electron, the positron, is a positively charged particle having the same mass (rest-energy) and charge magnitude as the electron.

In 1932 the positron was discovered by Carl Anderson, an American physicist, while he was studying cosmic rays from outer space — the first known antiparticle. Some twenty-three years later, the antiproton and antineutron were discovered. It is now recognized that in theory every known elementary particle has a corresponding antiparticle.

A collision between an electron and a positron results in the conversion of their combined rest-energies (masses) into the energy of motion of two or three photons — a verification of the concept that conventional mass is rest-energy. More generally, although both particle and antiparticle are annihilated in a collision, as in the electron-positron interaction, other particles besides photons are produced — a partial conversion of mass (rest-energy) to energy of motion.

On the other hand, simultaneous creation of a particle and its antiparticle by combining the same products that result from their mutual annihilation (called pair production) makes possible the creation of antiparticles, and hence antimatter, in the laboratory. The antimatter that emerges from this reverse process is made up of atoms which are composed of antiprotons and antineutrons in a nucleus surrounded by positrons.

The direct and reverse conversions described above are in accordance with Einstein's energy equation in all respects. It appears possible, therefore, that the microcosm, a purely metaphysical realm, might provide the substantial amounts of energy needed to make man's deep-space ventures a reality.

PART V

MANNED SPACE FLIGHT

V.1 Capability for Near-Space Missions

V.2 Prospects for Deep-Space Missions

V.3 Immediate Objectives in Space

V.1 Capability for Near-Space Missions

With regard to man's inevitable venture into space, we must not overlook progress already made and the ever increasing speed with which this progress has been accomplished. In some eighty years, man has progressed from the first flight of a heavier-than-air craft to a shuttle in orbit. Such progress is exponential: each decade sees developments that are twice those of the preceding decade. Will it be so long before man begins his exploration of the space frontier?

What are man's prospects for an investigation of the near-space frontier? In this section, let us review some present and future potentialities of space propulsion, launch systems, trajectory mechanics, and space communication.

Current propulsion systems, based on rest-state, classical combustion energy, are not optimal. This is indicated by the fact that the weight of chemical fuel on board present-day spacecraft accounts for 90 to 95 per cent of the total weight of the vehicle. An improved propulsion system will require the production of much more energy per unit weight of fuel. Future development may make use of the concept that mass is rest-energy, but new technology is needed to uncover methods for converting rest-energy into energy of motion. We have seen (Section IV.2) that the energy of motion available from a particle is equal to the mass (rest-energy) of the particle multipled by the square of the speed of light (300,000 km per sec) — an enormous energy per unit weight. Will it be possible to build a spacecraft power plant that will liberate energy of motion by interacting matter with antimatter to convert substantially all the energy of mass into kinetic energy?

The amount of fuel needed for a given space exploration depends on the launching system used. On planet Earth, a spacecraft sits at the bottom of an encircling gravitational well out of which it must climb to reach free space; considerable energy is needed to accomplish this. Do other possibilities exist for the efficient and economic launching of spacecraft? Because the moon's gravitational well is shallower than that of the Earth by a factor 1/22, and because many materials needed for the construction of a spacecraft can be found on the moon, we must consider the question: Is this Earth satellite a better location for a space manufacturing and launching capability? Studies have shown, however, that the launching of spacecraft from an Earth orbit would be more efficient and economical because of easy access from Earth, provided most materials for construction can be brought to the orbital launch site from such shallow gravity wells as those of the moon or asteroids. These studies showed that moon materials, stored in a shallow Earth-moon gravitational well in space near the moon and projected as required on a trajectory controlled by the Earth-moon gravitational field, would arrive close to a stable orbit around Earth in about two weeks. An efficient and economic launch site is now seen to be in an orbit around Earth some 350,000 kilometers from Earth at its farthest point and some 150,000 kilometers at its nearest point, the period of each revolution around Earth being a little less than two weeks.

Man's entry into space probably will begin with flights within the solar system at speeds much less than the speed of light. The calculation

of initial trajectories for such space missions can be made with sufficient accuracy, therefore using Newton's law of gravitation combined with his laws of motion.

Although the calculation of a trajectory is highly complex — among other things, it depends on the initial thrust, on the depth of the gravity well, on orbital mechanics and on the influence of the gravitational fields of various bodies in the solar system — it is possible, nevertheless, to predict accurately the trajectory of a spacecraft from given initial conditions. The trajectory of a space vehicle launched from Earth is a closed orbit around the Earth, if the craft exceeds a speed of 8 km per sec but does not attain the escape speed of 11.3 km per sec. If the speed of an Earth-launched space vehicle does exceed this escape speed, then its trajectory will be an open orbit; that is, it will depart from Earth. If the craft attains a speed less than 8 km per sec, then the flight path is suborbital; that is, the trajectory is an arc that returns the vehicle to Earth.

The trajectory of a satellite moving close to the Earth can be calculated with sufficient accuracy by considering only the gravitational field of the Earth and ignoring the effects of other bodies in the solar system. But trajectories for flight from the Earth to the moon or planets are very complex because the influences of the sun, the moon, and planets other than Earth must be taken into account also. Gravitational fields throughout the solar system can be used with advantage to produce a "slingshot" effect; that is, the spacecraft can be accelerated as it swings by a planet if it has the appropriate trajectory.

For travel beyond the solar system, the effect of intervening gravitational fields should be assessed. Until a spacecraft approaches its destination, however, gravitational effects beyond the solar system may be negligible because space is mostly empty. For example, the distance from the sun to the nearest star (Alpha Centauri) is 100 million times the distance from the Earth to the moon.

The science and technology of the controlled flow of electrons or other carriers of electric charge and of the related electromagnetic radiation resulting from the motion of these electric charges provides the basis for space communication. Without modern electronics, based on miniaturized transistor circuitry, space travel would be severely limited. This development has made possible the radio contact required for tracking; that is, the continuous reporting of a spacecraft's position relative to Earth; for telemetry, that is, the transmission of information back to Earth by an on-board instrument; for control, the directing of the motion of a spacecraft to maintain a required trajectory; for commands, signals that order the execution of a function such as turning on and controlling a camera; and for the transmission of results from on-board computers that serve many functions requiring rapid calculation and quick response.

V.2 Prospects for Deep-Space Missions

Man's ventures into deep space will become possible only as a more metaphysical construct of the universe is accepted by the human

consciousness. As a first step, the (Newtonian) rest-state construct of the universe must be replaced by the relativistic construct.

The rest-state construct of the universe by the human consciousness, based on the evidence of the physical senses and structured on beliefs of absolute motion and separate and distinct matter-substance (Sections II.3, IV.2), appears to present many insurmountable obstacles to the space adventurer. These beliefs suggest that, because of energy limitations characteristic of the rest state, travel in space must always be at relative speeds much less than the speed of light ($v/c << 1$), that distances are too great and lifetimes too short, therefore, to permit deep space ventures. In effect, these rest-state beliefs would greatly restrict man's freedom of movement in space.

The replacement of the rest-state construct by a relativistic construct of the universe, based on relativistic metaphysical science and structured on concepts of relative motion and energy-substance, opens the door to the possibility of deep-space missions that will utilize to the full relativistic slowing down of time (that is, the relativistic moderation of the aging process) and the relativistic conception that mass is rest-energy (see Sections IV.1, IV.2). What the rest-state human consciousness saw as space missions that required longer than a lifetime to complete, now become space ventures that could be accomplished in a decade or so.

Relativistic metaphysical science states that the prime requirement for space travel is that the spacecraft should travel at speeds approaching the speed of light. The success of a deep-space mission depends primarily, therefore, on the availability of a source of sufficient energy. How much energy? We have seen (Section IV.2) that to accelerate a space vehicle up to the speed of light requires an infinite input of energy. Can relativistic metaphysical science provide sufficient energy for a successful deep-space mission? It is clear that research and development directed toward deep-space missions must focus primarily on the provision of very large sources of relativistic energy.

V.3 Immediate Objectives in Space

If man is to conquer the space environment, the first and foremost requirement is the abandonment of the rest-state construct of the universe in favour of the relativistic-state construct. Only by relinquishing the beliefs that characterize the macro-world — absolute position, absolute time, and matter-substance — and replacing them with the concepts that delineate the macrocosm — relative position, relative time, and energy-substance — can the benefits of space exploration be achieved.

The belief in absolute position will be the first misconception of the rest state to be abandoned. We have learned from metaphysical science that there is no fixed frame of reference in space — no absolute (preferred) position, no absolute boundaries, no absolute directions. Nevertheless, the surface of planet Earth is separated by apparently well-defined boundaries to isolate and protect the interests of peoples with different political, social, and economic requirements. But how definitive are these boundaries between nations now, when artificial Earth satellites

invariably promote international co-operation? Satellites for worldwide communications, weather forecasting, Earth resources sensing, search and rescue operations, navigation — all must look at Earth's globe as a whole; their missions are more effective and efficient if planned on an international scale. Inevitably, satellite technology points away from nationalism toward internationalism.

Boundaries between nations are conducive to confrontations, but surveillance satellites already have begun to moderate fears of major conflicts. Surveillance of terrestrial military activity from space now regularly exercises an influence for peace; orbiting monitors provide information to both sides on military production and equipment and on the deployment and employment of military forces. Surveillance satellites permit an assessment of military actions and provide a warning of impending actions. They have reduced substantially the element of surprise, so that one nation can no longer attack another with inpunity provided the target nation maintains an adequate deterrent strength.

It is essential to understand that the rivalries, hostilities, and conflicts of the rest-state human consciousness, based on the false testimony of the physical senses, cannot be projected into relativistic space. As man ventures farther into space at relative speeds ever increasing toward the speed of light, the elevation of the human consciousness to levels above that of the rest state is inevitable.

What is most needful now is a space project that will provide the people of planet Earth with an opportunity to unite peaceably in an economically feasible enterprise that will emphasize the development and utilization of more advanced metaphysical science in order to initiate and substain the growth of the human consciousness out of the rest state. Is a permanent space facility in a low Earth orbit an answer?

An important step toward the development of such a facility was initiated in January 1984 by the President of the United States in his State of the Union address — a significant decision that will initiate mankind's inevitable exploration of the space frontier. Not only will this project facilitate new scientific research and technological development in space, but it will establish man's permanent presence in orbit, evaluate the role man will play in space exploration and exploitation, encourage international co-operation, and prepare mankind in the long term for deep-space missions.

The human consciousness must also abandon the rest-state belief that there is an inexorable, universal flow of time from the remote past to the distant future because relativistic metaphysical science states that there is no such thing as time independent of the observer. Relativity, therefore, affects the Earth age of the space traveler.

Any periodic motion, including that of the human heart, can be used to measure time. According to the Special Theory of Relativity, therefore, to a relatively stationary observer, a human heart will slow down if it is in a moving frame of reference (though the space traveler is not aware of this), the effect becoming very great as the relative speed of the frame of reference approaches the speed of light. If an astronaut travels to the nearest star system (Alpha Centauri) and returns to Earth, the speed of the

spacecraft being a steady 95 per cent of the speed of light, then during the voyage the astronaut will age by only three years while people on Earth will age by nine years. In other words, when the space traveler returns to Earth, he is younger than those who were his contemporaries when the space voyage began. Thus relative time and relative age, concepts from relativistic metaphysical science, have replaced the rest-state beliefs of absolute time and relentless age.

The rest-state belief that there must always be a beginning and an ending will be questioned also, the concomitant quintumvirate of beliefs — birth, growth, maturity, decay, death — will begin to undergo a metamorphic change, heralded by greater longevity.

As we have seen, energy availability is a major consideration in the planning of any space mission; as man undertakes more advanced projects, the requirements for energy will rise steeply, and ultimately the classical sources of the rest state will not be adequate. The conversion of rest-energy to energy of motion, a concept in metaphysical science beyond the rest state, now becomes necessary. Thus, once again, man's space missions will inevitably produce an elevation of the human consciousness above the rest state; clear evidence will become apparent that matter is not an entity unto itself.

The barriers to international understanding erected by belief in absolute position and absolute boundaries, the obstacles to longevity generated by belief in absolute time, the limitations of energy drawn by belief in matter as a separate and distinct entity — all such beliefs, characteristic of the rest-state macro-world, must vanish from human consciousness as it ascends to the relativistic concept of the universe — to a construct that not only prepares the way for man's conquest of the space frontier, but also points to the solution of many of Earth's problems.

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THE UNIVERSE AND MANNED SPACE FLIGHT

APPENDIX I

THE LORENTZ TRANSFORMATION

In support of Part IV, let us now discuss the mathematical details of the Lorentz transformation. Let us consider two observers: (a) a relatively stationary observer (O), which we identify as an observer in the macro-world ($v/c \ll 1$), located at the origin of a relatively stationary system of rectangular coordinates (x, y, z), and (b) a relatively moving observer (O') at the origin of a system of rectangular coordiantes (x', y', z'), moving in the direction of the x-axis at a constant speed V relative to O (Fig. 1). Now according to Section III.4, electromagnetic radiation is

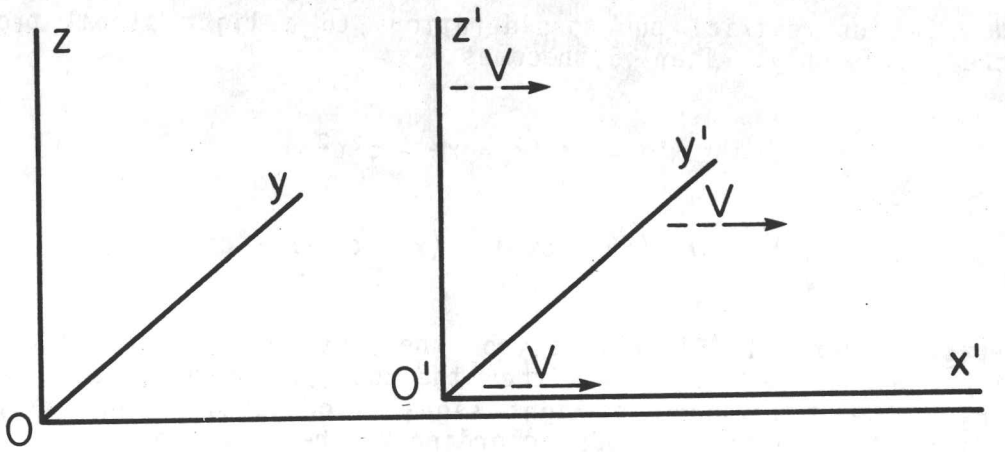

Fig. 1

propagated in all directions in empty space at the same constant speed, independent of the motion of the source or the motion of the receiver. The law of propagation of electromagnetic radiation, therefore, is given by

$$c = \frac{r}{t} \tag{1}$$

for the relatively stationary O-system of coordinates and by the corresponding relation

$$c = \frac{r'}{t'} \tag{2}$$

for the relatively moving O'-system of coordinates. Now we can write (1) in the form

$$r = (x^2 + y^2 + z^2)^{1/2} = ct$$

or

$$x^2 + y^2 + z^2 - c^2t^2 = 0 \tag{3}$$

Similarly (2) may be written

$$x'^2 + y'^2 + z^2 - c^2t'^2 = 0 \tag{4}$$

Then because the law of transmission of electromagnetic radiation is the same in both systems of coordinates, we must have

$$x'^2 + y'^2 + z'^2 - c^2t'^2 = x^2 + y^2 + z^2 - c^2t^2 \tag{5}$$

Now let us restrict our considerations to a light signal propagated along the x-axis only. Then (5) becomes

$$x'^2 - c^2t'^2 = x^2 - c^2t^2 \tag{6}$$

or

$$(x' - ct')(x' + ct') = (x - ct)(x + ct) \tag{7}$$

This separated form of (6) follows from the fact that a light signal can be transmitted along the x-axis in either the positive or negative directions. As seen by the 0-observer, a light signal propagated along the positive direction of the x-axis proceeds according to the relation

$$c = \frac{x}{t}, \quad x = ct, \quad \text{or} \quad x - ct = 0 \tag{8}$$

But, because the same light signal must be transmitted relative to the 0'-observer with the same constant speed c, then the propagation of this light signal, as seen by the 0'-observer, must be given by the analogous relation

$$x' - ct' = 0 \tag{9}$$

If, according to the law of transmission of the light signal, (9) is to be a consequence of (8), then we must have

$$x'-ct' = f\left(\frac{V}{c}\right)(x-ct) \tag{10}$$

were f(V/c) is a constant for a given constant velocity of the 0'-observer relative to the 0-observer.

Similarly, for a light signal propagated in the negative direction of the x-axis, the corresponding relation is

$$x' + ct' = g\left(\frac{V}{c}\right)(x+ct) \tag{11}$$

Multiplying (10) and (11), we arrive at (7) where

$$f\left(\frac{V}{c}\right) g\left(\frac{V}{c}\right) = 1 \tag{12}$$

We can solve (10) and (11) as simultaneous equations for x' and t' in terms of x and t as follows:

By addition

$$x' = \left(\frac{f+g}{2}\right) x - \left(\frac{f-g}{2}\right) ct = \alpha x - \beta ct \tag{13}$$

By subtraction

$$ct' = \left(\frac{f+g}{2}\right) ct - \left(\frac{f-g}{2}\right) x = \alpha ct - \beta x \tag{14}$$

We now evaluate the constants α, β.

We note first that the position of 0' (corresponding to x' = 0) relative to 0 at any time t is given by (13),

$$x = \frac{\beta c}{\alpha} t \tag{15}$$

But, for any time t, the position of 0' is also given in terms of the velocity of 0' relative to 0 by

$$x = Vt \tag{16}$$

Therefore

$$\frac{\beta}{\alpha} = \frac{V}{c} \tag{17}$$

A second relation for α and β can be derived by substituting for x' and ct' in the left-hand-side of (6) from (13) and (14). The identity required by the law of electromagnetic radiation will be obtained if

$$f\left(\frac{V}{c}\right)g\left(\frac{V}{c}\right) = \alpha^2-\beta^2 = 1 \tag{18}$$

From (17) and (18) we obtain the results

$$\alpha = \frac{1}{\sqrt{1 - \frac{V^2}{c^2}}} \tag{19}$$

$$\beta = \frac{\frac{V}{c}}{\sqrt{1 - \frac{V^2}{c^2}}} \tag{20}$$

If now we return to the more general case in which events are included which take place elsewhere than on the x-axis (but the velocity V of O' relative to O continues to be in the x-direction), then the Lorentz transformation may be written

$$\left.\begin{aligned} x' &= \frac{x - Vt}{\sqrt{1 - \frac{V^2}{c^2}}} \\ y' &= y \\ z' &= z \\ t' &= \frac{t - \frac{V}{c^2}x}{\sqrt{1 - \frac{V^2}{c^2}}} \end{aligned}\right\} \tag{21}$$

We can solve (21) for x, y, z, t and obtain the alternative forms

$$\left.\begin{aligned} x &= \frac{x' + Vt'}{\sqrt{1 - \frac{V^2}{c^2}}} \\ y &= y' \\ z &= z' \\ t &= \frac{t' + \frac{V}{c^2}x'}{\sqrt{1 - \frac{V^2}{c^2}}} \end{aligned}\right\} \qquad (22)$$

Two significant results follow immediately from the above analysis. Consider a meter rod moving with the O'-frame of reference at velocity $v = V$, aligned along the x'-axis such that one end is at $x' = 0$ and the other end is at $x' = 1$. The O'-observer sees a rod one meter in length. What does the O-observer see? According to the first of (21), at $t = 0$ the O-observer sees the near end of the rod at

$$x = 0 \cdot \sqrt{1 - \frac{v^2}{c^2}} = 0 \qquad (23)$$

and the far end at

$$x = 1 \cdot \sqrt{1 - \frac{v^2}{c^2}} \qquad (24)$$

that is the O-observer sees a rod of length $\sqrt{1 - (v^2/c^2)}$ of a meter. We conclude that, as viewed by a relatively stationary (macro-world) observer, a rigid rod is shorter when it is moving than when it is at rest, and the more the speed of the rod approaches the speed of light, the shorter it is seen to be. We note that if the meter rod is at rest in the O-frame of reference, then its length as judged by the O'-observer is again $\sqrt{1 - (v^2/c^2)}$. Clearly the length of a rigid rod is a function of the relative speed ratio only ($0 < v/c < 1$).

Now let us consider a clock moving with the O'-frame of reference at velocity $v = V$ and located at $x' = 0$. A second on the clock occurs between $t' = 0$ and $t' = 1$. Since $x' = 0$, the last equation of (22) becomes

$$t = \frac{t'}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad (25)$$

Thus while the O'-observer is aware of a time interval of 1 second between $t = 0$ and $t' = 1$, the O-observer perceives an interval of time between $t = 0$ and $t = 1/\sqrt{1 - (v^2/c^2)}$, that is $1/\sqrt{1 - (v^2/c^2)}$ sec., a somewhat longer period of time. We conclude that every clock appears to run slower as its speed relative to the O-observer increases, and it runs at its faster rate when it is at rest relative to the O-observer.

APPENDIX II

INERTIAL SYSTEMS AND THE PRINCIPLE OF RELATIVITY

In any system in which the constituent bodies do not interact with each other, such bodies will continue in their states of rest or straight-line motion; that is, the motion of such bodies is uniform (unaccelerated). This is the law of inertia. Expressed mathematically, the law of inertia states that the acceleration of each body in an inertial system is zero, that is

$$\frac{d^2x}{dt^2} = 0, \qquad \frac{d^2y}{dt^2} = 0, \qquad \frac{d^2z}{dt^2} = 0 \tag{26}$$

where x, y, z are the coordinates of a body at time t. Therefore the three corresponding components of velocity of each body — the first integrals of (26) — are constant,

$$v_x = \text{const.}, \qquad v_y = \text{const.}, \qquad v_z = \text{const.} \tag{27}$$

A fundamental characteristic of the Lorentz transformation, which, as we have seen, is based on the law of propagation of electromagnetic radiation, is that the law of inertia remains invariant through this transformation. This fact leads us to the principle of relativity as it applies to inertial systems: If relative to the coordinate system O, O' is a uniformly moving (unaccelerated) coordinate system (devoid of rotation), then all natural phenomena in the O'-system conform to the same body of law as those that pertain to the O-system. We conclude, therefore, that all the laws of nature are the same for all uniformly moving systems. This is the basic premise that underlies Albert Einstein's Special Theory of Relativity.

The fact that the law of inertia is invariant with respect to the Lorentz transformation can be demonstrated as follows: from (21) we have in differential form

$$
\left.
\begin{aligned}
dx' &= \frac{dx - Vdt}{\sqrt{1 - \frac{V^2}{c^2}}} \\
dy' &= dy \\
dz' &= dz \\
dt' &= \frac{dt - \frac{V}{c^2}\,dx}{\sqrt{1 - \frac{V^2}{c^2}}}
\end{aligned}
\right\} \qquad (28)
$$

then

$$
\frac{dx'}{dt'} = \frac{dx - Vdt}{dt - \frac{V}{c^2}\,dx} = \frac{\frac{dx}{dt} - V}{1 - \frac{V}{c^2}\,\frac{dx}{dt}} \qquad (29)
$$

or

$$
v_x' = \frac{v_x - V}{1 - \frac{V}{c} \cdot \frac{v_x}{c}} = \text{const.} \qquad (30)
$$

We have also

$$
\frac{dy'}{dt'} = \frac{dy\sqrt{1 - \frac{V^2}{c^2}}}{dt - \frac{V}{c^2}\,dx} = \frac{\frac{dy}{dt}\sqrt{1 - \frac{V^2}{c^2}}}{1 - \frac{V}{c^2}\,\frac{dx}{dt}} \qquad (31)
$$

or

$$
v_y' = \frac{v_y\sqrt{1 - \frac{V^2}{c^2}}}{1 - \frac{V}{c} \cdot \frac{v_x}{c}} = \text{const.} \qquad (32)
$$

Similarly

$$v'_z = \frac{v_z \sqrt{1 - \frac{V^2}{c^2}}}{1 - \frac{V}{c} \cdot \frac{v_x}{c}} = \text{const.} \qquad (33)$$

where we note that v_x, v_y, v_z are the components of velocity of a body with respect to the O-coordinates and v'_x, v'_y, v'_z are the components of velocity of the same body with respect to the O'-coordinates as derived by the Lorentz transformation. Further differentiation of v'_x, v'_y, v'_z shows the acceleration in the transformed state is zero; that is, if the original state is inertial, then the transformed state is also inertial.

APPENDIX III

RELATIVISTIC CONSERVATION LAWS

What is the form of the conservation laws that are invariant through a Lorentz transformation? To answer this question, let us begin by defining the relativistic momentum and relativistic change of energy of a body. By definition, the momentum of a body in a given direction is proportional to the velocity component in that direction. In classical (macro-world) mechanics, the coefficient of proportionality has been called the mass (m) of the body. But we have seen that, according to the Lorentz transformation, intervals of distance and time are functions of the relative speed ratio v/c. It is reasonable to expect that relativistic momentum also depends on v/c, and that we should write

$$p_i = \mu(m, \frac{v}{c})\, v_i \tag{34}$$

as a definition of relativistic momentum. Clearly our discussion of relativistic momentum revolves around the explicit functional form of the relativistic mass $\mu(m, v/c)$.

It follows that the relativistic change of energy of a body must also depend on both m and v/c. By definition, the change of energy is a product of the rate of change of momentum and the distance travelled; that is, it is the product of the change of momentum and the velocity. In differential form

$$dE = \underset{\rightarrow}{dp} \cdot \underset{\rightarrow}{v} = d(\mu \underset{\rightarrow}{v}) \cdot \underset{\rightarrow}{v}$$

$$= v_x d(\mu v_x) + v_y d(\mu v_y) + v_z d(\mu v_z)$$

$$= [d(\mu v_x^2) - \mu v_x dv_x] + [d(\mu v_y^2) - \mu v_y dv_y] + [d(\mu v_z^2) - \mu v_z dv_z]$$

$$= d(\mu v^2) - \mu v dv = v\, d(\mu v) \tag{35}$$

where

$$v^2 = v_x^2 + v_y^2 + v_z^2 \tag{36}$$

or we can write

$$\frac{dE}{dt} = v \frac{d}{dt}(\mu v) \tag{37}$$

As in the case of relativistic momentum, we see that a discussion of relativistic change of energy must await the determination of an explicit expression for $\mu(m, v/c)$.

In search of a functional form for $\mu(m, v/c)$, let us apply the law of conservation of momentum to the interaction of two mass points. It is assumed that the interaction occurs only during the instant in which the separation between the two mass points is negligibly small and that the process of conservation of momentum takes place during this infinitesimal interaction time. Before and after interaction, the motion of the two mass points is uniform (unaccelerated) and, therefore, we can apply the Special Theory of Relativity to this part of the motion.

In order to keep our calculations uncomplicated, let us choose an interaction model in the O-system (macro-world) of coordinates that has the following properties:

(1) We will assume that the interaction between the two mass points is such that the total kinetic energy remains unaltered by the interaction — termed an elastic collision; that is, no kinetic energy is transformed to other forms of energy such as heat.

(2) The mass points have the same mass.

(3) They meet at the origin of the O-system of coordinates at time $t = 0$.

(4) The speeds of the colliding mass points are the same before and after collision and equal to each other.

(5) The motion takes place entirely in the x, y-plane.

The collision model we have chosen is illustrated in Fig. 2. The interaction takes place in the O-system of coordinates — the macro-world. The particles have the same mass (m) and the same speed (v) before and after collision. With regard to notation, we note that the subscripts 1, 2 refer to particle 1 and particle 2, respectively, the subscripts x, y, z denote the components of particle position or velocity in the x, y, z-directions, respectively, and the subscripts b, a indicate that the relevant quantity refers to the motion before and after the collision.

According to Fig. 2, the components of particle velocity before collision are:

$$\left.\begin{aligned} (v_{1x})_b &= -(v_{2x})_b = \xi \\ (v_{1y})_b &= -(v_{2y})_b = \eta \\ (v_{1z})_b &= (v_{2z})_b = 0 \end{aligned}\right\} \qquad (38)$$

where ξ, η are constants. The components of particle velocity after collision are:

$$\left.\begin{aligned} (v_{1x})_a &= -(v_{2x})_a = \xi \\ -(v_{1y})_a &= (v_{2y})_a = \eta \\ (v_{1z})_a &= (v_{2z})_a = 0 \end{aligned}\right\} \qquad (39)$$

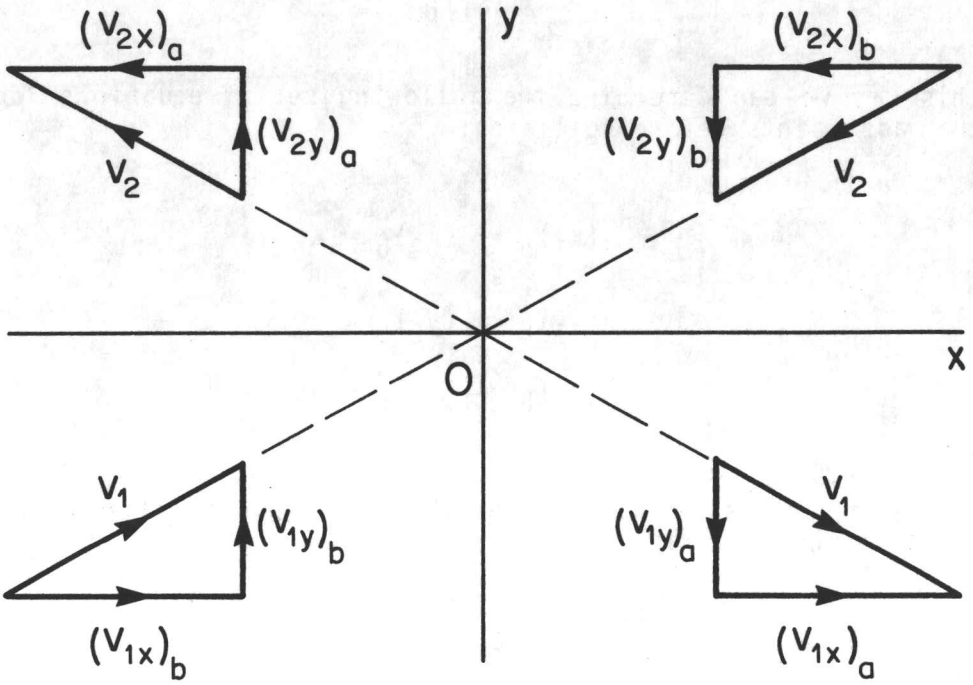

Fig. 2

The following equations for the conservation of momentum in the O-system of coordinates ($v/c \ll 1$).

$$\left.\begin{aligned} m(v_{1x})_b + m(v_{2x})_b &= m(v_{1x})_a + m(v_{2x})_a \\ m(v_{1y})_b + m(v_{2y})_b &= m(v_{1y})_a + m(v_{2y})_a \\ m(v_{1z})_b + m(v_{2z})_b &= m(v_{1z})_a + m(v_{2z})_a \end{aligned}\right\} \qquad (40)$$

are satisfied identically.

The equations of motion before collision can be readily obtained. Thus we note that since

$$(v_{1x})_b = \left(\frac{dx_1}{dt}\right)_b = \xi \qquad (41)$$

then

$$(x_1)_b = \xi t + \text{const.} \tag{42}$$

Now if $x_1 = 0$ at $t = 0$ [see (3) above], then the constant is zero and we have

$$(x_1)_b = \xi t \tag{43}$$

In this way we can determine the following set of equations for the motion of the mass points before collision:

$$\left.\begin{aligned} (x_1)_b &= -(x_2)_b = \xi t \\ (y_1)_b &= -(y_2)_b = \eta t \\ (z_1)_b &= (z_2)_b = 0 \end{aligned}\right\} \tag{44}$$

The equations of motion for the mass points after collision can be obtained in the same way:

$$\left.\begin{aligned} (x_1)_a &= -(x_2)_a = \xi t \\ -(y_1)_a &= (y_2)_a = \eta t \\ (z_1)_a &= (z_2)_a = 0 \end{aligned}\right\} \tag{45}$$

We are now in a position to obtain the equations of particle motion in the O'-system of coordinates — the macrocosm ($0 < v/c < 1$) — by applying the Lorentz transformation to (44) and (45). The O'-system moves relative to the O-system in the positive direction of the x-axis with the constant velocity V. To avoid unnecessary complications in subsequent calculations, we choose $V = \xi$.

The Lorentz transformation yields the following particle equations of motion in the O'-system of coordinates:

A. Before collision:

$$(x_1')_b = \frac{(x_1)_b - Vt}{\sqrt{1 - \frac{V^2}{c^2}}} = 0 \tag{46}$$

[see (21), (43), $V = \xi$]

$$(x_2')_b = \frac{(x_2)_b - \xi t}{\sqrt{1 - \frac{\xi^2}{c^2}}} = -\frac{2\xi t}{\sqrt{1 - \frac{\xi^2}{c^2}}} = -\frac{2\xi t'}{1 + \frac{\xi^2}{c^2}} \tag{47}$$

[see (21), (44), (22)]

$$(y_1')_b = \eta t = \eta \cdot \frac{t' + \frac{\xi}{c^2}(x_1')_b}{\sqrt{1 - \frac{\xi^2}{c^2}}} = \frac{\eta t'}{\sqrt{1 - \frac{\xi^2}{c^2}}} \tag{48}$$

[see (21), (44), (22), (46)]

$$(y_2')_b = -\eta t = -\eta \cdot \frac{t' + \frac{\xi}{c^2}(x_2')_b}{\sqrt{1 - \frac{\xi^2}{c^2}}} = -\eta t' \cdot \frac{\sqrt{1 - \frac{\xi^2}{c^2}}}{1 + \frac{\xi^2}{c^2}} \tag{49}$$

[see (21), (44), (22), (47)]

B. After collision:

$$(x_1')_a = \frac{(x_1)_a - \xi}{\sqrt{1 - \frac{\xi^2}{c^2}}} = 0 \tag{50}$$

[see (21), (45)]

$$(x_2')_a = \frac{(x_2)_a - \xi t}{\sqrt{1 - \frac{\xi^2}{c^2}}} = -\frac{2\xi t}{\sqrt{1 - \frac{\xi^2}{c^2}}} = -\frac{2\xi t'}{1 + \frac{\xi^2}{c^2}} \tag{51}$$

[see (21), (45), (22)]

$$(y_1')_a = -\eta t = -\eta \cdot \frac{t' + \frac{\xi}{c^2}(x_1')_a}{\sqrt{1 - \frac{\xi^2}{c^2}}} = -\frac{\eta t'}{\sqrt{1 - \frac{\xi^2}{c^2}}} \qquad (52)$$

[see (21), (45), (22), (50)]

$$(y_2')_a = \eta t = \eta \cdot -\frac{t' + \frac{\xi}{c^2}(x_2')_a}{\sqrt{1 - \frac{\xi^2}{c^2}}} = \eta t' \cdot \frac{\sqrt{1 - \frac{\xi^2}{c^2}}}{1 + \frac{\xi^2}{c^2}} \qquad (53)$$

[see (21), (45), (22), (51)]

The components of velocity of the mass points in the O'-system of coordinates before collision are readily obtained from (46) - (49).

[Note: $(v_{1x}')_b = \frac{d}{dt'}(x_1')_b$, etc.]

$$\left.\begin{aligned} (v_{1x}')_b &= 0 \ , \ (v_{2x}')_b = -\frac{2\xi}{1 + \frac{\xi^2}{c^2}} \\ (v_{1y}')_b &= \frac{\eta}{\sqrt{1 - \frac{\xi^2}{c^2}}} \ , \quad (v_{2y}')_b = -\eta \cdot \frac{\sqrt{1 - \frac{\xi^2}{c^2}}}{1 + \frac{\xi^2}{c^2}} \end{aligned}\right\} \qquad (54)$$

The resultant velocities in the O'-system before collision are:

$$(v_1')_b = \left[(v_{1x}')_b^2 + (v_{1y}')_b^2\right]^{1/2} = \frac{\eta}{\sqrt{1 - \frac{\xi^2}{c^2}}} \tag{55}$$

$$(v_2')_b = \left[(v_{2x}')_b^2 + (v_{2y}')_b^2\right]^{1/2} = \frac{\sqrt{4\xi^2 + (1 - \frac{\xi^2}{c^2})\eta^2}}{1 + \frac{\xi^2}{c^2}} \tag{56}$$

The components of velocity of the mass points in the 0'-system of coordinates after collision are determined from (50) - (53),

$\left[(v_{1x}')_a = \frac{d}{dt'}(x_1')_a \text{ , etc.}\right]$:

$$(v_{1x}')_a = 0 \text{ , } \quad (v_{2x}')_a = -\frac{2\xi}{1 + \frac{\xi^2}{c^2}}$$

$$(v_{1y}')_a = -\frac{\eta}{\sqrt{1 - \frac{\xi^2}{c^2}}} \text{ , } \quad (v_{2y}')_a = \eta \cdot \frac{\sqrt{1 - \frac{\xi^2}{c^2}}}{1 + \frac{\xi^2}{c^2}} \tag{57}$$

The resultant velocities in the 0'-system before collision are:

$$(v_1')_a = \left[(v_{1x}')_a^2 + (v_{1y}')_a^2\right]^{1/2} = \frac{\eta}{\sqrt{1 - \frac{\xi^2}{c^2}}} \tag{58}$$

$$(v'_2)_a = [(v'_{2x})_a^2 + (v'_{2y})_a^2]^{1/2} = \frac{\sqrt{4\xi^2 + (1 - \frac{\xi^2}{c^2})\eta^2}}{1 + \frac{\xi^2}{c^2}} \qquad (59)$$

It is helpful to examine the configuration of the collisiion in the moving O'-system of coordinates when $\xi/c << 1$, corresponding to a transformation of coordinates that lies entirely in the macro-world (a Galilean transformation). The Lorentz transformatiion reduces to ($V = \xi$),

$$\left.\begin{aligned} x' &= x - \xi t & x &= x' + \xi t' \\ y' &= y & y &= y' \\ z' &= z & z &= z' \\ t' &= t & t &= t' \end{aligned}\right\} \qquad (60)$$

and the velocity components with their resultants become:

Before collision

$$\left.\begin{aligned} (v'_{1x})_b &= 0, & (v'_{2x})_b &= -2\xi \\ (v'_{1y})_b &= \eta, & (v'_{2y})_b &= -\eta \\ (v'_1)_b &= \eta, & (v'_2)_b &= \sqrt{4\xi^2 + \eta^2} \end{aligned}\right\} \qquad (61)$$

After collision

$$\left.\begin{aligned} (v'_{1x})_a &= 0, & (v'_{2x})_a &= -2\xi \\ (v'_{1y})_a &= -\eta, & (v'_{2y})_a &= \eta \\ (v'_1)_a &= \eta, & (v'_2)_a &= \sqrt{4\xi^2 + \eta^2} \end{aligned}\right\} \qquad (62)$$

The main effect of the Lorentz transformation, as illustrated by Fig. 3 for the special case in which $\xi/c \ll 1$, is to eliminate the component of velocity of particle 1 parallel to x' and to accentuate the component of velocity of particle 2 parallel to x'.

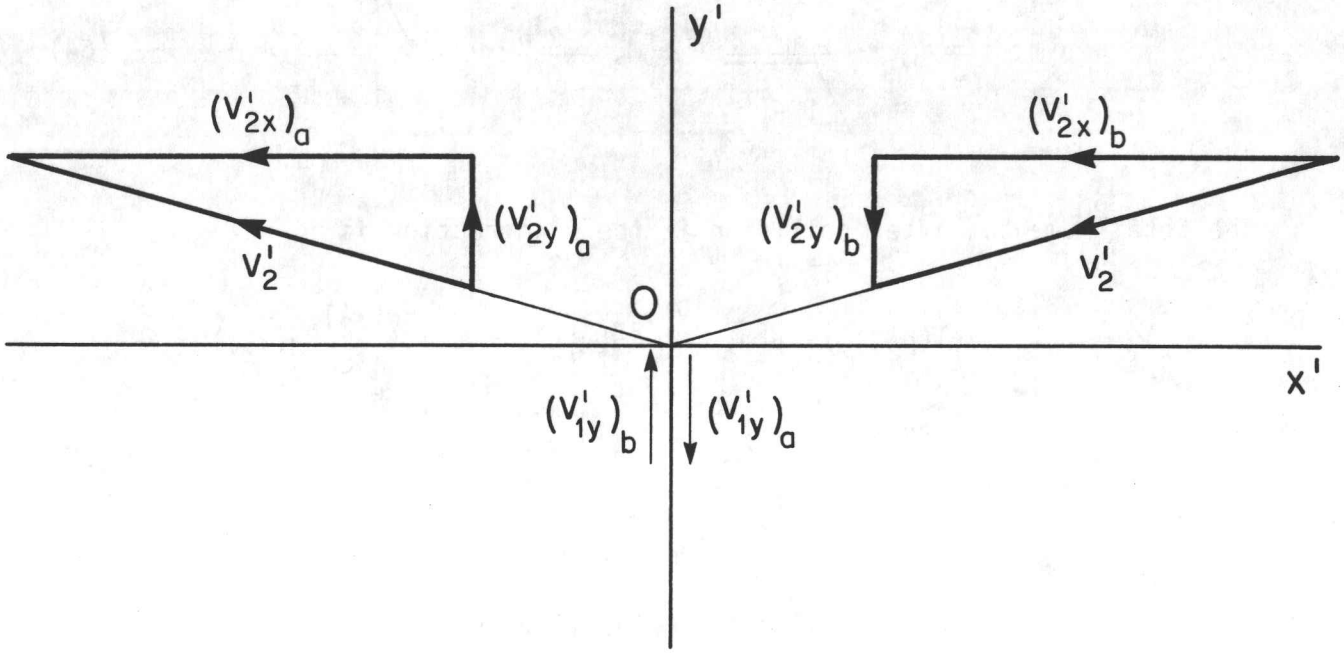

Fig. 3

We can now determine the momenta of the two colliding mass points before and after collision, and then apply the law of conservation of momentum. The resulting equation will contain the unknown function μ.

The total momentum before collision in the x'-direction is

$$(p'_x)_b = (p'_{1x})_b + (p'_{2x})_b = \mu[m, \frac{(v'_1)_b}{c}](v'_{1x})_b + \mu[m, \frac{(v'_2)_b}{c}](v'_{2x})_b$$

$$= 0 - \mu[m, \frac{(v'_2)_b}{c}] \cdot \frac{2\xi}{1 + \frac{\xi^2}{c^2}} \qquad (63)$$

The total momentum before collision in the y'-direction is

$$(p'_y)_b = (p'_{1y})_b + (p'_{2y})_b = \mu[m, \frac{(v'_1)_b}{c}](v'_{1y})_b + \mu[m, \frac{(v'_2)_b}{c}](v'_{2y})_b$$

$$= \mu[m, \frac{(v'_1)_b}{c}] \cdot \frac{\eta}{\sqrt{1 - \frac{\xi^2}{c^2}}} - \mu[m, \frac{(v'_2)_b}{c}] \cdot \eta \frac{\sqrt{1 - \frac{\xi^2}{c^2}}}{1 + \frac{\xi^2}{c^2}} \tag{64}$$

The total momentum after collision in the x'-direction is

$$(p'_x)_a = (p'_{1x})_a + (p'_{2x})_a = \mu[m, \frac{(v'_1)_a}{c}](v'_{1x})_a + \mu[m, \frac{(v'_2)_a}{c}](v'_{2x})_a$$

$$= 0 - \mu[m, \frac{(v'_2)_a}{c}] \cdot \frac{2\xi}{1 + \frac{\xi^2}{c^2}} \tag{65}$$

The total momentum after collision in the y'-direction is

$$(p'_y)_a = (p'_{1y})_a + (p'_{2y})_a = \mu[m, \frac{(v'_1)_a}{c}](v'_{1y})_a + \mu[m, \frac{(v'_2)_a}{c}](v'_{2y})_a$$

$$= - \mu[m, \frac{(v'_1)_a}{c}] \cdot \frac{\eta}{\sqrt{1 - \frac{\xi^2}{c^2}}} + \mu[m, \frac{(v'_2)_a}{c}] \cdot \eta \frac{\sqrt{1 - \frac{\xi^2}{c^2}}}{1 + \frac{\xi^2}{c^2}} \tag{66}$$

The laws of conservation of momentum require that $(p'_x)_b = (p'_x)_a$, $(p'_y)_b = (p'_y)_a$. The conservation of momentum in the x'-direction, therefore, yields an identity, but the conservation of momentum in the y'-direction yields a relation that contains μ. We have

$$(p'_y)_b = (p'_y)_a \tag{67}$$

that is

$$\mu\left[m, \frac{(v_1')_b}{c}\right] \cdot \frac{\eta}{\sqrt{1 - \frac{\xi^2}{c^2}}} - \mu\left[m, \frac{(v_2')_b}{c}\right] \cdot \eta \frac{\sqrt{1 - \frac{\xi^2}{c^2}}}{1 + \frac{\xi^2}{c^2}}$$

$$= -\mu\left[m, \frac{(v_1')_a}{c}\right] \cdot \frac{\eta}{\sqrt{1 - \frac{\xi^2}{c^2}}} + \mu\left[m, \frac{(v_2')_a}{c}\right] \cdot \eta \frac{\sqrt{1 - \frac{\xi^2}{c^2}}}{1 + \frac{\xi^2}{c^2}} \qquad (68)$$

But according to (55) and (58), (56) and (59), $(v_1')_b = (v_1')_a$ and $(v_2')_b = (v_2')_a$, respectively. Therefore (68) becomes

$$\left.\begin{aligned} &\mu\left[m, \frac{(v_1')_b}{c}\right] - \frac{1 - \frac{\xi^2}{c^2}}{1 + \frac{\xi^2}{c^2}} \mu\left[m, \frac{(v_2')_b}{c}\right] = 0 \\ &\text{where} \\ &\frac{(v_1')_b}{c} = \frac{\frac{\eta}{c}}{\sqrt{1 - \frac{\xi^2}{c^2}}}, \qquad \frac{(v_2')_b}{c} = \frac{\sqrt{4\frac{\xi^2}{c^2} + \frac{\eta^2}{c^2}\left(1 - \frac{\xi^2}{c^2}\right)}}{1 + \frac{\xi^2}{c^2}} \end{aligned}\right\} \qquad (69)$$

The relativistic conservation laws have led, therefore, to (69), from which an explicit functional form for μ can be determined.

APPENDIX IV

RELATIVISTIC MASS AND ENERGY

We have seen that a fundamental objective in any application of the Special Theory of Relativity is to relate the derived concepts with those of human experience in order to promote the growth of the human consciousness out of the rest state toward a better understanding of the relativistic universe. In determining the functional form of μ, therefore, we should relate this relativistic mass to its form in the rest state.

Let us specify that, characteristic of the rest state, $(v_1')_b/c \ll 1$, that is $\eta/c \ll 1$. Then $\mu[m, \frac{(v_1')_b}{c}] \to m$, the "rest-state" mass. Hence the functional form of the relativistic mass can be obtained from

$$\mu[m, \frac{v}{c}] = m[\frac{1 + \frac{\xi^2}{c^2}}{1 - \frac{\xi^2}{c^2}}] \tag{70}$$

The quantity $(v_2')_b/c$ has been replaced by the argument v/c, where according to (69)

$$\frac{v}{c} = \frac{2\frac{\xi}{c^2}}{1 + \frac{\xi}{c^2}} \qquad (0 < \frac{v}{c} < 1) \tag{71}$$

We note that, solving (71) for ξ/c, we have

$$\frac{\xi}{c} = \frac{c}{v}\left[1 \pm \sqrt{1 - \frac{v^2}{c^2}}\right] \tag{72}$$

and hence

$$\frac{1 + \frac{\xi^2}{c^2}}{1 - \frac{\xi^2}{c^2}} = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{73}$$

The explicit functional expression for the relativistic mass is, therefore,

$$\mu\left[m, \frac{v}{c}\right] = \frac{m}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{74}$$

and the relativistic momentum of a mass point takes the form

$$\underset{\rightarrow}{p} = \mu\left[m, \frac{v}{c}\right] \underset{\rightarrow}{v} = \frac{m\underset{\rightarrow}{v}}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{75}$$

The relativistic mass of a particle may be regarded otherwise as the ratio of momentum to velocity.

The relativistic energy of a mass point can be derived from (37) using (74),

$$\frac{dE}{dt} = v \frac{d}{dt}(\mu v) = v \frac{d}{dt}\left[\frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}\right] = \frac{mv}{\left(1 - \frac{v^2}{c^2}\right)^{3/2}} \frac{dv}{dt} \tag{76}$$

But since

$$\frac{d}{dt}\left[\frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}\right] = \frac{mv}{\left(1 - \frac{v^2}{c^2}\right)^{3/2}} \frac{dv}{dt} \tag{77}$$

we can write

$$\frac{dE}{dt} = v \frac{d}{dt}\left[\frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}\right] = \frac{d}{dt}\left[\frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}\right] \tag{78}$$

Upon integration we have

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} + \text{constant} \tag{79}$$

Let us examine the first term on the right-hand-side (RHS) of (79). It can be expanded as follows:

$$\frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} = mc^2\left[1 + \frac{1}{2}\frac{v^2}{c^2} + \frac{1\cdot 3}{2\cdot 4}\frac{v^4}{c^4} + \frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6}\frac{v^6}{c^6} + \ldots\right]$$

$$= mc^2 + \frac{1}{2}mv^2\left[1 + \frac{3}{4}\frac{v^2}{c^2} + \frac{3\cdot 5}{4\cdot 6}\frac{v^4}{c^4} + \ldots\right] \qquad (80)$$

We note that this term consists of two parts: (1) the quantity mc^2 which relates to the rest mass (m), and does not vanish when v = 0, called the "rest energy" (E_0) of the mass point; (2) a term which relates to the rest mass (m) and particle velocity (v), called the relativistic kinetic energy

$$(\text{Rel.})\text{K.E.} = mc^2\left[\left(1 - \frac{v^2}{c^2}\right)^{-1/2} - 1\right] = E - mc^2 \qquad (81)$$

of the mass point. This first term on the RHS of (79) is called the total relativistic energy (E) of the mass point [the constant in (79) is dropped].

Examining the relation for total relativistic energy,

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} = \mu c^2 \qquad (82)$$

and that for the rest energy,

$$E_0 = mc^2 \qquad (83)$$

we see that there is, therefore, a close equality between the mass and energy of a mass point in the relativistic state which has no parallel in the rest state. This is the most important result to emerge from the Special Theory of Relativity.

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1. Levels of Metaphysical (Mathematical) Science 2. Microcosm 3. Macro-world
4. Macrocosm 5. Special Theory of Relativity 6. Near-Space and Deep-Space Travel

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