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THE LIGHT AND ELECTROMAGNETIC WAVES, AS AN EXAMPLE IN UNDERSTANDING THE TRAVEL OF MASSIVE BODIES AT THE SPEED OF LIGHT ORVERY HIGH AND CLOSE TO HER

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SUMMARY

The intention of this article is to discuss, through a comparison, the behavior of massive bodies at the speed of light and the behavior of atoms and electromagnetic waves at the speed of light, according to Albert Einstein's Special Theory of Relativity. This will provide an outline of the concepts.This article discusses human perceptions in adulthood regarding Quantum Mechanics and the Special Theory of Relativity according to Piaget's theory. It includes a brief overview of electromagnetic waves, the Special Theory of Relativity, and the Theory of Light. The discussion extends to Quantum Field Theory and Quantum Mechanics, exploring the future possibilities of the Special Theory of Relativity as discussed by David Bohm and Bertrand Russell in the mid-20th century. Aspects such as the Twin Paradox, the Ten-Platform Reference in the Theory of Relativity, and High-Speed Light Travel are also addressed.

INTRODUCTION

Knowing that it is being discussedThe Special Theory of Relativity, as taught in university and high school physics, is limited to the teaching of basic physics.As proposed by David Bohm in "The Special Theory of Relativity" in Topic A-2[2]:

We will begin with Piaget's fascinating studies on the development of intelligence in babies and toddlers. Based on long and meticulous observations of children of all ages, from birth to ten years or more, he was able to follow the development of our customary ideas about space, time, permanent objects, permanent substance with its total conserved quantity, etc., and thus trace the process by which such notions are constructed until they seem natural and inevitable.[2].

Piaget offers strongevidence suggesting that the babybegins by experiencing an almost undifferentiated totality. In other words, he has not yet learned to distinguish between the various aspects.of the “external” or “internal” world. On the contrary, only one world is experienced, in a continuous state of flux ofsensations,perceptions,feelings,etc.,withnothingthatcanbepermanently recognized. However, the baby is endowed with certain innate reflexes,linked to feeding, movement, etc. These reflexes can develop to selectively accommodate different aspects of the environment; and thus the environment begins toto beEffectively differentiated, it even assumes certain "recognizable" characteristics. But at this stage, recognition is largely functional (for example, some objects are "for eating," others "for drinking," others "for pulling," etc.), and there seems to be little or no development of the adult's ability to recognize an object by its shape, form, structure, or other characteristics.perceived characteristics[2].

Initially, these reflexes and functions largely serve to satisfy primary needs, indicated by sensations such as hunger, etc. In the next phase,however, the so-called "circular reflex" develops, which is crucial for the development of intelligence. In this reflex, there is an impulse from within to...for a (for example, that leads to hand movement) followed, not primarily by the satisfaction of the need, but by some sensory impulse from outside to inside (for example, in the eyes, ears, etc.). One could say that this is alreadya beginning of real perception, since the most elementary way to come into contact with something that is not just the immediate satisfaction of a bodily need is to incorporate it into a process in whicha certain impulse to action is accompanied by a certain sensation[2].

As discussed in the Twin Paradox Welken Charlois Gonçalves. Time and the Solar System, a human brain condition and perception biologically limited by Darwinian evolution. DARWIAN PROCESSAND BRAIN PERCEPTION OF REALITY[3].

Wecannotanswer,aswehavenoresearchorexperience,butweknow that adopting the inertial reference of B, the Earth, we will have that A will return younger than B, as he is in a non-inertial reference and outside the timeof the solar system, Therefore, it is obvious and consequential that hewillbeyounger,however,whatwouldbethebiologicalevolutionofA
outside the solar system. We must consider that the human, both twin A and B, are biologically dependent on the Earth and the Sun, and these factors are what determines the

time and reality of perception of the physical laws of the universe. Consequently, would twin A be eternal, outside planet Earth? It is easier to believe that Twin A would die easily in space, as he is outside his biological reality, limited to living only on Earth. It reminds us of whathuman life is in the universe, the condemnation of Earth, and we would consider the following thought by Aldous Huxley, “Would Earth be a hell fromanotherPlanet?”.However,geneticengineeringcouldeasilysolvetravel beyond Earth, and thinking that humans could travel through space is completely delusional. Or, the future will be robotic in the intergalactic relations of exploring other planets, but the objective of the scientific community is to inhabit and populate other satellites[3].

The ideas of Special Relativity in Cosmology can be complemented by the Philosophy of BertrandRussell,suchasthebookABCofRelativity[4].Theintentionofthearticleistherelevance of light-speed travel in whichObjects with mass cannot travel at the exact speed of light (c)because it requires infinite energy. While theoretical models like theoretical **Alcubierre warp drives_**or **light-powered sails**exists, our fastest real-world spacecraft, the **Parker Solar Probe**, maxes out at about 0.05% of(w).
Thephysicsandvisualexamplesofapproachingthespeedoflightfollowdistinctrules:

VisualEffects(SpecialRelativity)

Accordingtothescientificconsensusdiscussioned,travelingatextremespeedscausesunique optical illusions:

- **Aberration of Light:**The starsin front of the spaceship appear to gather in a tight circle directlyahead, and the sky seems to contract.
- **DopplerShift:**Lightfromobjectsyouapproachbecomes**blue-shifted**(higherenergy/frequency), eventually shifting into ultraviolet and X-rays. Light from behind becomes**red-shifted**.
- **Terrell-Penrose Rotation:**Acube-shaped spacecraft traveling perpendicular to your line of sight at these speeds wouldn't just look flat; it would appear visually rotated and distorted.

TimeDilationandTravelTime

- **FortheTraveler:**Becauseashipcannothittheexactspeedoflight,travelingat**99.999%of**
- **(c)**means time slows down drastically for the crew. For example, a trip across the MilkyWay could feel like just a few weeks or months to you, while millions of years

pass on Earth.

- **For the Universe:**If an object with mass were somehow able to hit the speed of light (c), from an outside observer's perspective, time would cease to exist for that traveler.

The Hazards

Because mass dictates energy, even a single stray hydrogen atom striking a spaceship traveling at a significant fraction of the speed of light packs the explosive energy of a nuclear weapon. This makes theoretical features like deflector shields mandatory.

The intention is to discuss the distinction between a massive body at high speeds, that is, at the speed of light, and the behavior of waves, such as light, whether as an electromagnetic wave or as a dual wave-particle behavior.

Knowingtheneed toraiseawareness ofconceptions atayounger ageyoung person, itwould be extremely necessaryThe revolution in textbooks and teaching laboratories in concepts of Quantum Mechanics and Cosmology, such as the Theory of Relativity. A clear example is the Paradox.The twins in the Special Theory of Relativity and the travel of massive bodies at high speeds, exceeding the speed of light. For a better understanding of inertial frames of reference and moving frames of reference, these two examples are cited.One of 10 Platforms:

Here'sasimpleexampleof**SpecialRelativity**with**10platforms**and**10 observers**.

Imagine 10 long railway platforms lined up parallel to each other. Each platform has an observer standing in the middle:

Platform	Observer	SpeedrelativetoObserver1
1	O_1	0 km/s
2	O_2	0.1c
3	O_3	0.2c
4	O_4	0.3c

5	O_5	0.4c
6	O_6	0.5c
7	O_7	0.6c
8	O_8	0.7c
9	O_9	0.8c
10	O_{10}	0.9c

where**w**That'sthespeedof light.

Event

Aflashoflightisemittedfromthecenterof Platform1whenallobserverspasseachother atthesame location.

WhatObserverO_1sees

ObserverO_1isatrestwithPlatform1.

- Thelightexpandsasaperfectsphere.
- ClocksonPlatform1aresynchronized.
- Theflashoccursattimet=0.

WhatObserverO_{10}sees

ObserverO_{10}movesat0.9crelativetoO_1. According to O_{10}:

- Hisownclockruns normally.
- Platform1ismovingbackwardat0.9c.
- Distancesalongthedirectionofmotionareshortened(length contraction).
- EventsthataresimultaneousforO_1 aregenerallynotsimultaneousforO_{10} (relativityof simultaneity).

TimeDilationExample

Forspeedv=0.9c,

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

$$\gamma = \frac{1}{\sqrt{1 - 0.9^2}} \approx 2.29$$

IfO_1 measures10secondsbetweentwoeventsonO_{10}'splatform,O_1 findsO_{10}'smovingclock advances only

$$\frac{10}{2.29} \approx 4.37 \text{ s}$$

duringthatinterval.

LengthContractionExample

Supposeeveryplatformis1000mlonginitsownrest frame.

O_1seesPlatform10movingat0.9candmeasuresitslengthas

$$L = \frac{1000}{2.29} \approx 436 \text{ m}$$

Relativityof Simultaneity

SupposelightningstrikesbothendsofPlatform1simultaneouslyaccordingtoO_1.

- O_1saysthestrikesoccuratthesame time.
- O_2throughO_{10}generallydisagree.
- Eachmovingobservercalculatesadifferenttimedifferencebetweenthetwostrikes.

MainLesson

Thereis**nosingleuniversaltime**sharedbyall10observers.Eachobserverhas:

1. Theirownmeasurementof time.
2. Theirownmeasurementof lengths.
3. Theirowndefinitionofwhichdistanteventshappen simultaneously.

Yetallobserversmeasurethesamespeedoflight,c,whichisthecentralpostulateofthe special theory of relativity developed byAlbert Einstein in 1905.

Framework

11.5.2•AnExampleofaPlaneWaveSolution(Reproductionof the Book [1])

Becausethewaveequationislinear,electromagneticwavessatisfytheSuperpositionPrinciple:Any linear combination of solutions is also a solution. complete it

TABLE 11.3 The electromagnetic spectrum

Frequency (Hz)	Description	Wavelength
10^2	super low frequency (SLF) radio waves submarine communication	3000 km
10^3	ultra low frequency (ULF) radio waves	300 km
10^4	very low frequency (VLF) radio waves	30 km
10^5	low frequency (LF) radio waves marine radio	3 km
10^6	medium frequency (MF) radio waves AM radio is 0.53×10^6 to 1.60×10^6 Hz.	300 m
10^7	high frequency (HF) short-wave radio	30 m
10^8	(VHF) aircraft radio and navigation FM radio is 0.87×10^8 to 1.08×10^8 Hz. TV channels 2–13	3 m
10^9	(UHF) cellular telephones, radar, microwave ovens, TV channels 14–83	30 cm
10^{10}	(SHF) microwaves, radar, mobile radio	3 cm
10^{11}	extremely high frequency (EHF) Cosmic microwave background maximum is at 3×10^{11} Hz.	3 mm
10^{12}	far infrared	0.3 mm
10^{13}	far infrared	30 μm
10^{14}	near infrared Visible light is 3.9×10^{14} to 7.6×10^{14} Hz.	3 μm
10^{15}	near ultraviolet	0.3 μm
10^{16}	vacuum ultraviolet	30 nm
10^{17}	soft X rays	3 nm
10^{18}	soft X rays	0.3 nm
10^{19}	hard X rays	30pm
10^{20}	gamma rays	3 pm
10^{21}	gamma rays	0.3 pm
10^{22}	cosmic gamma rays	30 fm

Set of solutions--complete in the sense that any solution can be written as a superposition of these solutions-is the set of plane waves. A plane wave is a solution of the wave equation with definite values of wavelength{lambda}and frequency v, related byw={lambda}v.

The wave fronts of a plane wave are infinite planes, perpendicular to the direction of propagation. In Sec. 11.5.3 following we'll derive the general plane wave solution from the field equations. But before we go through the derivation it will be useful to examine a specific example of a plane wave, to understand its basic form. The reader will have to be patient to see where this form comes from; that will bederived in the next section. For now let's focus on understanding the geometrical characteristics of one specific example of an electromagnetic plane wave.

Theelectricfieldforaplanewavetravelinginthezdirection,polarizedinthexdirection,is

$$\mathbf{E}(\mathbf{x}, t) = E_0 e^{i(kz-\omega t)}\,\hat{\mathbf{i}}. \qquad (11.80)$$

AND_0is the amplitude, i is the polarization direction, the wavelength is{\lambda}= 2{\pi}/ k, and the frequency is v ={\omega}/ 2{\pi}. The parameter k is called the wave number. The relation between w and k, called the dispersion relation, is

$$\omega = ck, \qquad (11.81)$$

which is equivalent{\lambda}v= c. Equation (11.80) shows that the wave propagates with velocity w/ k, which is called the phase velocity. Then by (1 1.81) the phase velocity of the plane wave is c. We've written the field at x and t as a complex number, but of course physically E must be real. When we write (1 1.80), using the complex exponential function, we mean that the physical field is the real part of the right-hand side of the equation.

The use of complex numbers, although it will take some getting used to, is tremendously convenient. 18 This will be explained more in the following subsection.

There are several ways to see that (11.80) satisfies the wave equation. The simplest is just by direct substitution. ∇^2 acting on the exponential e^{ikz} becomes $-k^2$, and $\partial^2/\partial t^2$ acting on $e^{-i\omega t}$ becomes $-\omega^2$; so the wave equation is satisfied if $k = \omega/c$. Or, by a more roundabout argument, note that $\mathbf{E}(\mathbf{x}, t)$ can be written as

$$\mathbf{E}(\mathbf{x}, t) = F(z - ct)\,\hat{\mathbf{i}},$$

where $F(\zeta) = \exp(ik\zeta)$; the right-hand side has the familiar form of a one-dimensional wave, propagating in the z direction with speed c. The physical field $\mathbf{E}$ is $E_0 \cos(kz - \omega t)\,\hat{\mathbf{i}}$, the *real part* of (11.80). It oscillates in the $\pm\hat{\mathbf{i}}$ direction (the polarization direction) as the wave propagates in the $\hat{\mathbf{k}}$ direction.

Now, it is not enough that E(x, t) satisfies the wave equation. The wave equation is necessary but not sufficient. E(x, t) and B(x, t) must together satisfy the four Maxwell equations. Therefore there must be a magnetic field as well, coupled with the electric field in ways specifiedbyMaxwell'sequations.Themagneticfield,whichmustbepresentwiththeelectricfield(11 .80),is

$$\mathbf{B}(\mathbf{x}, t) = B_0 e^{i(kz-\omega t)}\,\hat{\mathbf{j}}, \qquad (11.82)$$

where

$$B_0 = E_0/c. \qquad (11.83)$$

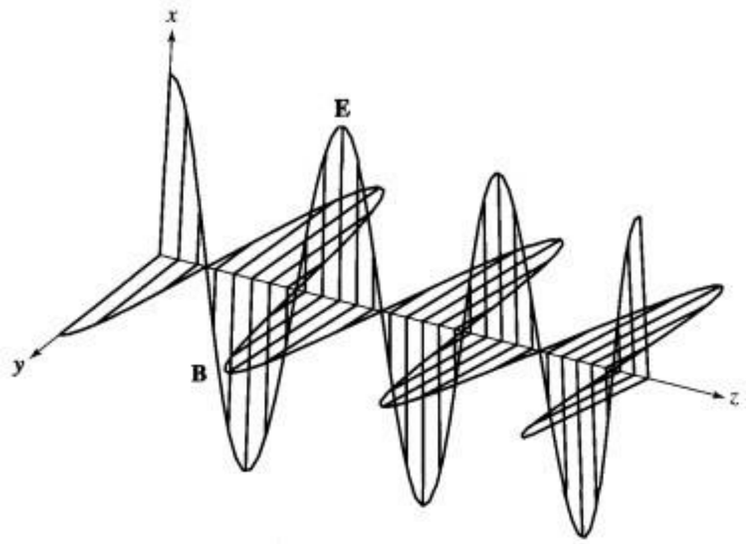


FIGURE 11.9 Electric and magnetic fields in an electromagnetic wave. The direction ofpropagation is k.The wave fronts are planes parallel to the xy plane.The figure is a snapshot of the fields alol!g one line perpendicular to the xy plane. E oscillates in the ±i direction, and B in the ±j direction. Nodes of E and B coincide, as of the field maximum. E x B points in the direction of propagation.

Again, we will derive this result in complete generality in the next section, but fi!, st let'ssee what it means. Note that E and B oscillate in orthogonal directions (i and j, respectively) and the wave in both cases travels in the third orthogonal direction (k). That is, E, B, and k form an orthogonal triad of vectors. Figure 11.9 illustrates the geometrical form of the plane-wave solution (11.80) and (11.82)

12. ElectromagnetismandRelativity(ReproductionoftheBook [1])

"Everythingshouldbemadeassimpleaspossible,butnotsimpler."AlbertEinstein

Einstein's theory of special relativity, published in 1905, 1 is the theory of coordinate transformations between inertial frames. It is based on two postulates:

1. Postulateofrelativity.Thelawsofphysicsarethesameinallinertial frames.
2. Postulateoftheabsolutespeedoflight.Thespeedoflightinvacuumis

An inertial frame means a coordinate system with respect to which Newton's first law of motion-the law of inertia-is true.An inertial frame moves with constant velocity with respect to any other inertial frame. A noninertial frame is one that accelerates with respect to inertial frames. A reference frame has both a spatial coordinate system that locates positions by the distances x, y, z along Cartesian axes from an origin, and a time coordinate that locates events in time.

Einstein was led to these postulates, especially the second, by the study of Maxwell's theory of the electromagnetic field. Maxwell's equations imply that light is an electromagnetic wave, with wave speed $c = 1/\sqrt{\mu_0\epsilon_0}$ in vacuum. But this result raises an obvious question: *With respect to what frame of reference* is the speed equal to $1/\sqrt{\mu_0\epsilon_0}$? In classical physics, if an object P moves with speed u in one inertial frame, then its speed in another frame is different. For example, if the second frame moves with speed v relative to the first frame, in the same direction as the velocity of P, then the speed of P in the second frame is $u - v$. However, there is no possibility within Maxwell's equations for the speed of an electromagnetic wave in vacuum to be anything but $1/\sqrt{\mu_0\epsilon_0}$. To what frame of reference does that speed correspond? The answer is that the speed of light is $1/\sqrt{\mu_0\epsilon_0}$ in *every* inertial frame, and the classical formula for combining velocities is wrong.

BeforeEinstein,theoristsassumedthatlightpropagatesinaphysicalmediumcalledthe aether.Maxwell,andthefieldtheoristsofthenextgeneration,thoughtthatthefieldequations would describe the electromagnetic field in the rest frame of the aether. Then the calculated wave speedwouldbethespeedrelativetothefixedaether.Inareferenceframemovingwithrespecttothe aether, the speed of electromagnetic waves would be different than the speed relative to the aether.

Inafamousseriesofexperiments,culminatinginaverypreciseexperimentin1887,MichelsonandMorleyattemptedtoobserveavariationinthespeedoflightduetomotionof theEarth through the aether. Using a very accurate interferometer, they measured the interference between light waves that had traveled in orthogonal directions. Varying the orientation of the apparatus would change the interference if the aether theory were true, but there was no observed change in the interference. The experiment had a null result. This was surely the most importantnullresultinthehistoryofphysics!Thereisnodetectablevariationinthespeedoflighttravelingin different directions with respect to the moving Earth. This striking result is explained in special relativitybyoverthrowingabasicassumptionofclassicalphysics-thatlengthsandtimeintervalsare absolute quantities, i.e., the same for all observers.

The Lorentz transformation is the coordinate transformation between inertial frames constructed such that Postulate 2 is obeyed. We assume that the reader has some familiarity with this transformation,2 although we will review it briefly. Our main interest in this chapter is to understand how Postulate 1 is satisfied in the theory of the electromagnetic field.

COORDINATETRANSFORMATIONS(Reproduction oftheBook[1])

•TheGalileanTransformation

Thefirststatementof theprincipleof relativity wasby Galileo. Heclaimed thatanobserver, enclosed below decks in the hold of alarge ship, would notbe able to determine by any experiment whether the ship is at rest or moving with constant velocity. This passage from his writings (Ref. I) is a statement clearly equivalent to Postulate I:

"Shut yourself up with some friend in the largest room below decks of some large ship and there look for gnats, flies, and such other small winged creatures. Also get a great tub full of water and put within it certain fishes; let also a certain bottle be hung up, which drop by drop lets forth its water into another narrow-necked bottle placed underneath. Then, the ship lying still, observe how those small winged animals fly with like velocity towards all parts of the room; how the fish swim indifferentlytowardsallsides;andhowthedistillingdropsallfallintothebottleplacedunderneath.

In modem terms we say that the laws of motion are the same in all inertial frames. Consider two inertial frames, F and F' , in relative motion.

The two frames of reference are illustrated in Fig. 12.1.An event that occurs at coordinates x,y,zandtimetofF,occursatcoordinates x',y',z'andtimet'ofF'.Tobespecific,supposeframe F' moves with velocity vi, in the x direction, relative to F . For example, the origin 0' of F' is at (x', y', z') = (0, 0, 0). The coordinates of 0' in F are (x, y, z) = (vt, 0, 0) so that 0' has velocity vi inF. Conversely, theorigin 0 of Fmoves with velocity -viwith respect to F' .Weassume thattheorigins of F and F' coincide at t = 0, which defines what we mean by "time zero." The transformation from F to F' is a set of equations that report the coordinates and time of an event observed in the two frames of reference. The classical transformation from F to F' is called the Galilean transformation. If F' moves with velocity vi with respect to F, then the Galilean transformation is

$$x' = x - vt, \quad y' = y, \quad z' = z, \quad t' = t. \qquad (12.1)$$

Note that 0' has F' coordinate x' = 0, so by (12.1) it has F coordinate x = vt, as specified. ForanarbitraryvelocityvectorvofF'relativetoF,theGalileantransformationis

$$x'_{\parallel} = x_{\parallel} - vt, \quad \mathbf{x}'_{\perp} = \mathbf{x}_{\perp}, \quad t' = t, \qquad (12.2)$$

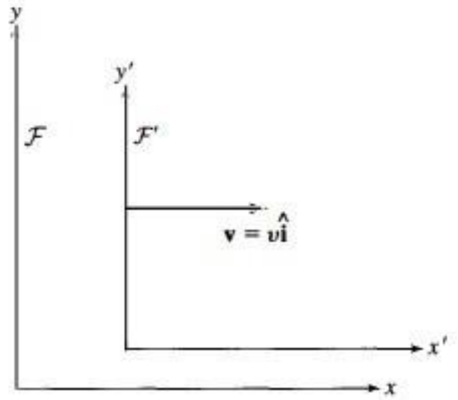


FIGURE12.1Twoinertialframesofreference.F'moveswithvelocityvirelativetoF.

say to v. We emphasize that the relative velocity v must be constant. Newton's equation of motion foramassmisthe samein ForF',providedthe forceisinvariant underthe transformation.The equation of motion in frame F is md2x/dt2 = F(x). Assume F' (x') = F(x) is the force in the coordinates of F' . What is the equation of motion with respect to F' ? We need to write the accelerationvectorinF' coordinates.Firstconsiderthevelocity.TheparticlevelocityintheframeF is u = dx/ d t. The particle velocity in F' is

$$u'_{\parallel} = \frac{dx'_{\parallel}}{dt'} = \frac{d(x_{\parallel} - vt)}{dt} = u_{\parallel} - v, \qquad (12.3)$$

$$\mathbf{u}'_{\perp} = \frac{d\mathbf{x}'_{\perp}}{dt'} = \frac{d\mathbf{x}_{\perp}}{dt} = \mathbf{u}_{\perp}; \qquad (12.4)$$

thisresultisjusttheclassicalruleforcombiningvelocities:u'=u-v^3TheGalileantransformation for the acceleration is

$$\mathbf{a}' = \frac{d\mathbf{u}'}{dt'} = \frac{d(\mathbf{u} - \mathbf{v})}{dt} = \mathbf{a}$$

because v is constant.Acceleration is a Galilean invariant. Therefore the equation of motion in the frame F' is md2x' / d t'2 = F' (x'), the same as in F as claimed.

We have just seen that Newtonian mechanics satisfies Postulate 1 if the transformation between inertial frames is Galilean and the force is invariant. However, Postulate 2 is not satisfied by the Galilean transformation. The coordinate transformation (12.2) implies the classical velocity addition formula, u' = u - v. But if u is the velocity of a pulse of light in F, then the speed lu'l in F' would not be equal to the speed lui in F. Einstein's Postulate 2 implies that (12.2) is not the correct transformation between inertial coordinates. Equation (12.2) seems so obvious!

How can it be wrong? There is an implicit assumption hiding in (12.2). These equations assume that lengths and time intervals are absolute quantities-the same for all observers. 4However, on the contrary, length and time are relative. What is absolute is the speed of light.

•The Lorentz Transformation (Reproduction of the Book [1])

The relativistic transformation between inertial frames is called the Lorentztransformatio,..n. Again, suppose that an inertial frame F' is moving with constant velocity vi relative to another frame of reference F, as illustrated in Fig. 12.1.The Lorentz transformation from coordinates x, y, z and time t of F, to coordinates x ' , y' , z' and t' of F' , is

$$x' = \gamma(x - vt), \quad y' = y, \quad z' = z, \quad t' = \gamma(t - vx/c^2) \qquad (12.5)$$

where

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}. \qquad (12.6)$$

Aneventthatoccursatx,y,Z,tinframeFoccursatx',y',Z',t'givenby(12.5)inF'.

It is a simple calculation to show that (12.5) implies Einstein's Postulate 2. Suppose that a flash of light is emitted from x = 0 at time t = O. As observed in the frame F, there will be a spherical pulse of light traveling away from x = o with speed c. The radius of the expanding light pulse is ct at time t, so the coordinates of any point on the pulse are satisfied

$$x^2 + y^2 + z^2 = c^2t^2. \qquad (12.7)$$

Now consider the same point on the pulse in F' coordinates, given by (12.5). The squared distance from the origin 0' is

$$\begin{aligned} x'^2 + y'^2 + z'^2 &= \gamma^2(x - vt)^2 + y^2 + z^2 \\ &= \gamma^2(x - vt)^2 + c^2t^2 - x^2 \\ &= (\gamma^2 - 1)x^2 - 2\gamma^2 xvt + (\gamma^2 v^2 + c^2)t^2 \\ &= c^2\gamma^2(t - vx/c^2)^2. \end{aligned} \qquad (12.8)$$

Inthelaststepweused(12.6)fory.Thefinalresult,using(12.5)fort',isthat

$$x'^2 + y'^2 + z'^2 = c^2 t'^2. \qquad (12.9)$$

That is, the light pulse observed in the inertial frame F' is also a sphere traveling outward from x' = 0 with speed c. Thus Postulate 2 is satisfied if the space and time coordinates of different inertial frames are related by (12.5). We could reverse this calculation to derive (12.5). If we demand (12.9), and require that the transformation be linear and not change the perpendicular coordinates (y and z), then the transformation must be (12.5).5 For an arbitrary relative velocity v the Lorentz transformation is

$$x'_{\parallel} = \gamma \left(x_{\parallel} - vt\right), \quad \mathbf{x}'_{\perp} = \mathbf{x}_{\perp}, \quad t' = \gamma \left(t - v x_{\parallel}/c^2\right) \qquad (12.10)$$

where again II and ..1 denote vector components parallel and perpendicular to v. This form of the transformation gives x' and t' in terms of x and t.The inverse transformation, which gives x and t in te

$$x_{\parallel} = \gamma \left(x'_{\parallel} + vt'\right), \quad \mathbf{x}_{\perp} = \mathbf{x}'_{\perp}, \quad t = \gamma \left(t' + v x'_{\parallel}/c^2\right). \qquad (12.11)$$

The inverse is equivalent to exchanging (x, t) and (x', t') and replacing v by -v, because .1' moves with velocity -v with respect to .1" .
Now that we know how to satisfy Postulate 2, by the Lorentz transformation (12.10), what remains is to find theories that obey Postulate 1 for this transformation. The equations of physics must be the same whether written in coordinates of .1' or .1" . This property of the equations is called covariance. We shall analyze the covariance of electromagnetism in Sec. 12.3.

TheTheoryofLight(ReproductionoftheBook[1])

Inthelate17thcenturyadisputearoseoverthenatureoflight, between Newton whoargued for a particle theory of light, and Huygens who favored a wave theory of light.At the beginning of the19thcentury,Youngobservedinterferenceoflight,andsoshowedthatlightbehaveslikea wave.Fresnelexplainedthattheopticalphenomenaoflightpolarizationimplythatlightisa transverse wave. LaterMaxwell developedthe mathematical theoryof theelectromagnetic field, and found that solutions of the field equations describe the properties of light as an electromagnetic wave. These concepts were further developed by a group of British and Irish physicists, including Heaviside, FitzGerald, and Lodge, who called themselves the

Maxwellians. However, Maxwell'stheoryisnottheendofthehistoryofthescienceoflight.Earlyinthe20thcentury, PlanckandEinsteinshowedthatlightenergyisquantized.Thereforelightalsobehavesasif composedofparticles,whichwecallphotons.ComptondiddefinitiveexperimentsonX-ray scatteringthatverifiedthepredictionsofthephotontheory.Diracformulatedaquantumfield theoryofelectromagnetism.ThisquantumtheoryoflightdoesnotnegateMaxwell'stheoryofelectro magnetism.Indeed,Maxwell'sequationsarealsotrueinquantumelectrodynamics(QED), although their interpretation is different from the classical theory because in QED the fields have quantum uncertainty.

Classical electrodynamics-Maxwell's theory-is a valid description of electromagnetic phenomena, including light, in the limit of large field intensities.Alarge field intensity corresponds to large numbers of photons, so that the quantization unit (one photon) is small on the scale of the field. The classical theory is the limit of QED in the same sense that classical mechanics is the limit of quantum mechanics for large mechanical systems. The mean value of the quantum field obeysthe classical field equations, and if the field intensity is large then the effects of uncertainty are negligible. The classical theory does break down for very small systems, such as a single photon or atom. But the classical theory remains important despite this limitation, for the many phenomena that occur on scales much larger than a single atom[1].

DISCUSSION

Outside**massivebodymovingathighspeed**,thesimpleequation

$$E = mc^2$$

isonlythe**restenergy**ofthebody.Itapplieswhentheobjectisatrestrelativetotheobserver. ThefullrelativisticexpressiondevelopedfromtheworkofAlbertEinsteinis:

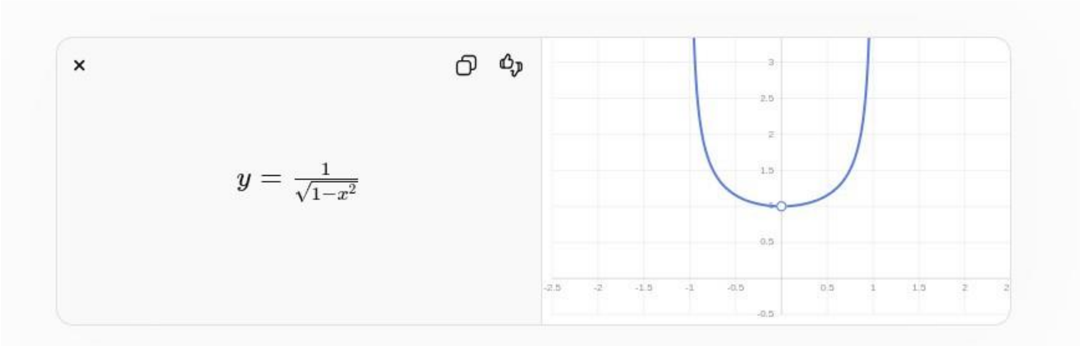
$$E = mc^2$$

where

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

Thefactorγincreasesrapidlyasthevelocityvapproachesthespeedoflightc.

AgraphoftheLorentzfactorisshown below:



Thetotalenergyandmomentumsatisfythefundamentalrelativisticrelation:

$$E^2 = (pc)^2 + (mc^2)^2,$$

where:

- E =totalenergy,
- p=relativistic momentum,
- m =restmass,
- c =speedof light.

Forabody movingat0.99°C,

$$\gamma \approx 7.09,$$

soitstotalenergyisabout7.09timesitsremainingenergy:

$$E \approx 7.09\, mc^2.$$

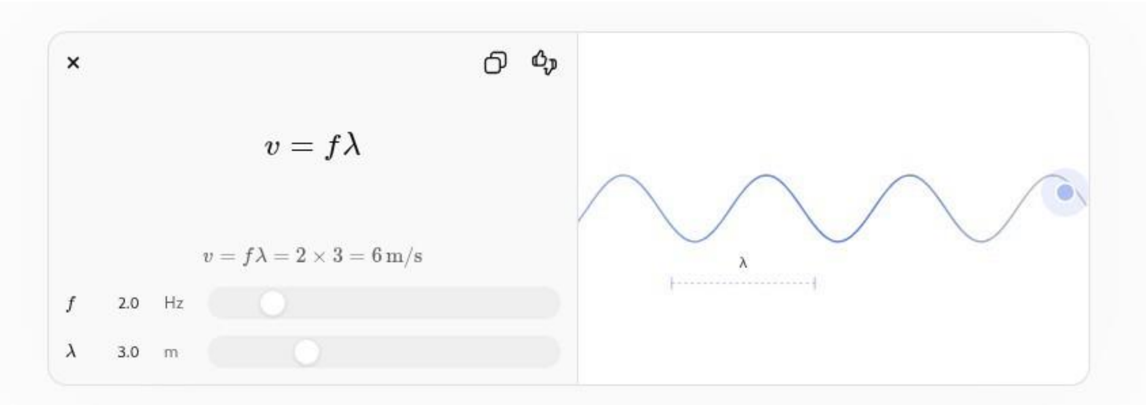
Tthekineticenergyis

$$K = (\gamma - 1)mc^2.$$

As $v \to c$,

$$\gamma \to \infty,$$

and therefore the energy required to continue accelerating the object grows without bound. This is why, according to SpecialRelativity, no objectwith nonzero restmasscan be accelerated to exactly the speed of light.



In physics, **electromagnetic waves** are waves made of oscillating**e lectric fields** and **magnetic fields** that travels through space and carries energy. Unlike sound waves, they do **do not need a material medium** and can travel through a vacuum.

1. ElectromagneticWaves

Examplesinclude:

- Radiowaves
- Microwaves
- Infraredradiation
- Visiblelight
- Ultravioletradiation
- X-rays
- Gammarays

2. Frequency(f)

Frequencyisthenumberofwavecyclespassingapointeach second.

- Unit:**Hertz(Hz)**
- 1Hz=1cyclepersecond Examples:

  - Radio station: 100 MHz = 100 million cycles per second
  - Green light: about 5.5×10^{14} Hz

3. SpeedofElectromagneticWaves

Inavacuum,**allelectromagneticwavestravelatthespeedoflight**:

$$c = 299,792,458 \text{ m/s}$$

Approximately:

$$c \approx 3.0 \times 10^8 \text{ m/s}$$

Thisistrueforradiowaves,visiblelight,X-rays,andgammarays.

4. RelationshipBetweenSpeed,Frequency,andWavelength

$$v = f\lambda$$

where:

- v = wave speed (m/s)
- f = frequency (Hz)
- λ = wavelength (m)

Forelectromagneticwavesinavacuum:

$$c = f\lambda$$

Example

Supposeawavehasfrequency:

$$f = 100 \text{ MHz} = 1.0 \times 10^8 \text{ Hz}$$

Thenitswavelengthis:

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8}{1.0 \times 10^8} = 3 \text{ m}$$

Summary

Quantity **Definition** **Unit**

Electromagnetic wave Oscillatingelectricandmagneticfieldscarrying __ energy

Quantity	Definition	Unit
Frequency(f)	Numberofcyclesper second	Hertz(Hz)
Wavelength(λ)	Distancebetweensuccessivewavepeaks	Meter(m)
Speed(c)	Speed ofEMwavesinvacuum	(3.0\times10^8)m/s

According to the theory of **Albert Einstein**, the speed of light in a vacuum is the same forall observers and is a fundamental constant of nature.

According to the theories above, it is not possible for a body to reach the speed of light, according to the Special Theory of Relativity with its Second Postulate. And in the mass-energy equivalence relationship, for a very high speed, the energy would be very large. Therefore, from the point of view of the transmutation of matter, a biological human body would not have the conditions for transmutation and remain alive, just as a carbon fiber spacecraft wouldnot.Aluminum and titanium.With so much energy, the process of matter transformation would occur, and according to physics theory, a large explosion would also happen.An example, besides the relevant transformation of matter, is the transmutation of matter in nuclear physics for the analysis of massive bodies at high speeds, as defined below:

Nuclear transmutation is the process of converting one chemical element or isotope into another by changing the number of protons or neutrons in its nucleus. Because an element's chemical identity is determined by its proton count, changing the nucleus inherently changes the element.

The fundamental principles of this process rely on subatomic manipulation, conservation laws, and the forces of nature:

1. Mechanisms of Nuclear Change

Transmutationoccursthroughthreeprimaryprocesses:

- **Radioactive Decay:**An unstable nucleus spontaneously emits particles (such as alpha or beta particles) or energy (gamma rays) to achieve a more stable state, consequently altering its proton count and transforming into a new element.
- **NuclearFission:**Aheavy,unstablenucleus(likeUranium-235)issplitintotwosmaller,morestable intermediate nuclei, accompanied by the release of neutrons and vast amounts of energy.
- **NuclearFusion:**Twolighternuclei(likeHydrogenisotopes)areforcedtogetherunderextremehe

at and pressure to form a single heavier nucleus, releasing massive amounts of energy.

2. ThePhysicsof Bombardment

Scientists artificially induce transmutation using particle accelerators to forcefully collide high-energy particles (protons, alpha particles, or ions) into target nuclei. Because of the electrostaticrepulsion(theCoulombbarrier)betweenpositivelychargedparticles andthepositively charged nucleus, immense energy is required. Neutrons are highly effective for this processbecause,havingnoelectricalcharge,theyarenotrepelledbythenucleusandcaneasilypenetra teit.

3. ConservationLaws

In any transmutation reaction, the total number of protons and neutrons, as well as total mass-energy, are strictly conserved. These reactions are written as balanced nuclear equations. For example, when Ernest Rutherford first artificially transmuted Nitrogen into Oxygen in 1919, he bombarded a Nitrogen-14 atom with an alpha particle to yield an Oxygen-17 atom and a proton:

$${}_{7}^{14}N + {}_{2}^{4}He \rightarrow {}_{8}^{17}O + {}_{1}^{1}H$$

4. Real-WorldApplications

- **SyntheticElements:**Particlebombardmentallowsscientiststocreatetransuraniumelements (elements with atomic numbers greater than 92), which are highly unstable and not found in nature.
- **EnergyProduction:**Fissionreactionsinpowerplantstransmutenuclearfuelintovarious radioactive byproducts while generating electrical power.
- **Waste Management:**Advanced nuclear research explores partitioning and transmutation technologies to convert long-lived radioactive waste into short-lived or stable elements.

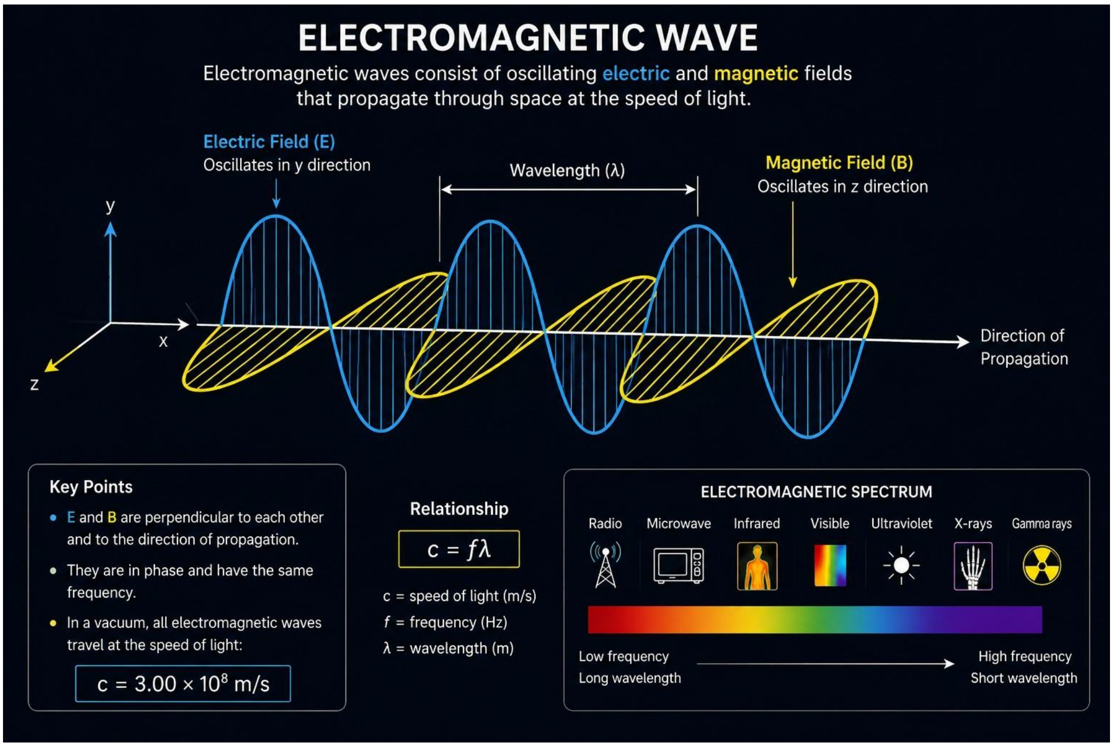
This establishes the identity that massive bodies at high speeds would need to have a wave-particle duality behavior or electromagnetic wave behavior at high speeds, or speeds very close to the speed of light. In other words, according to Quantum Mechanics analysis, using photons as an example, massive bodies in Classical Mechanics, such as a human body or a car, would need to exhibit a similar behavior.wave-particle duality or wave-electromagnetic duality, **In order to support high frequencies, high energies, and very high speeds close**

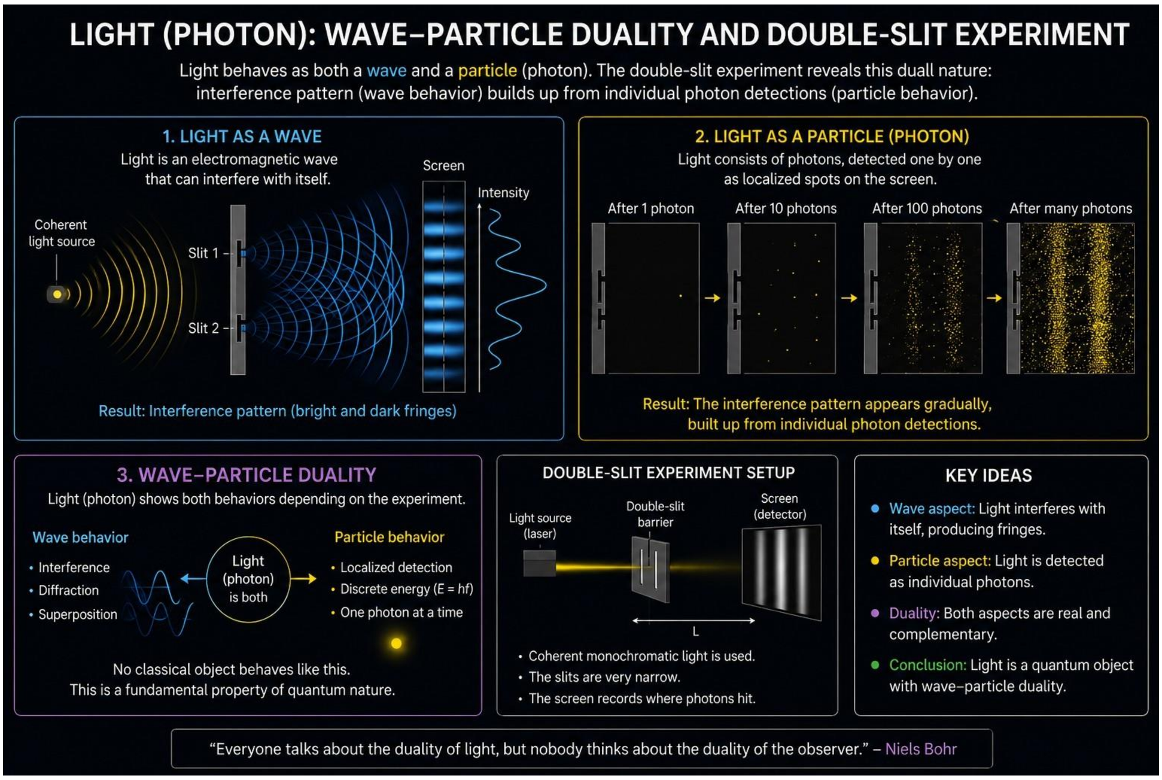
to the speed of light..As defined by Louis de Brouglie's theory, the Wave Theory of Rigid Bodies has an infinitely small wavelength in the classical world, when used in the Quantum Mechanics theory of Louis de Brouglie.A tiny amount of matter contains an unimaginable amount of energy due to the immense value of (c^2).)((9x10^16). This conversion is the basis of physical processes such as**nuclear fission**in power plants and stellar fusion in the Sun.Frequency, wavelength, and the speed of light arethecornerstonesofelectromagnetism,unitedbytheequation...(c={lambda}.f)Themass-energy relationship, defined by E = mc^2, demonstrates that matter and energy are convertible. Since the speed of light c is constant, the wavelength{lambda}and the frequency (f) are**inversely proportional**If the frequency of a light wave is high, its wavelength will be proportionally short.

De Broglie went further by analyzing how the total energy and momentum of particles interact. He deduced that the velocity of the "phase wave" associated with a moving particle differs from the velocity of the particle itself (v), being related to the speed of light (c) by the equation:

- Equação: $V_{\text{onda}} = \frac{c^2}{v}$

These concepts form the basis of modern quantum mechanics, demonstrating that objects with mass also exhibit diffraction and interference at appropriate subatomic scales.Therefore, for a human body and an automobile, sAccording to Louis de Broglie's wave-particle duality theory, all matter possesses wave-like properties. For macroscopic bodies (such as humans and automobiles), these wavelengths are infinitely smaller than the size of an atom, making quantum effects imperceptible in everyday life.An interesting example in the Theory of Light and the Theory of Special Relativity, as a philosophical discussion, would be the quantization of the electromagnetic field in Quantum Field Theory. This article outlines what high-speed velocity would be for a massivebody,differentfromanatomoraphoton, aswellasdiscussinglightandatomsinQuantum Electrodynamics.As a defined example, the real human and biological body at high energies in the mass-equilibrium relationship, such as aluminum and titanium materials, is used based on the transformation and Lorentz factor in the Theory of Special Relativity and its high-energy relationships with nuclear physics. This example serves as a basis for reflection.for the Study of Conceptions of the Special Theory of Relativity, as well as the Twin Paradox, and undoubtedlyThe best example for understanding the Special Theory of Relativity is an example, such as the 10 Platforms with a light source on the first Platform or light sources on all 10 Platforms or more Platforms, with or without the observers switching between Platforms.





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