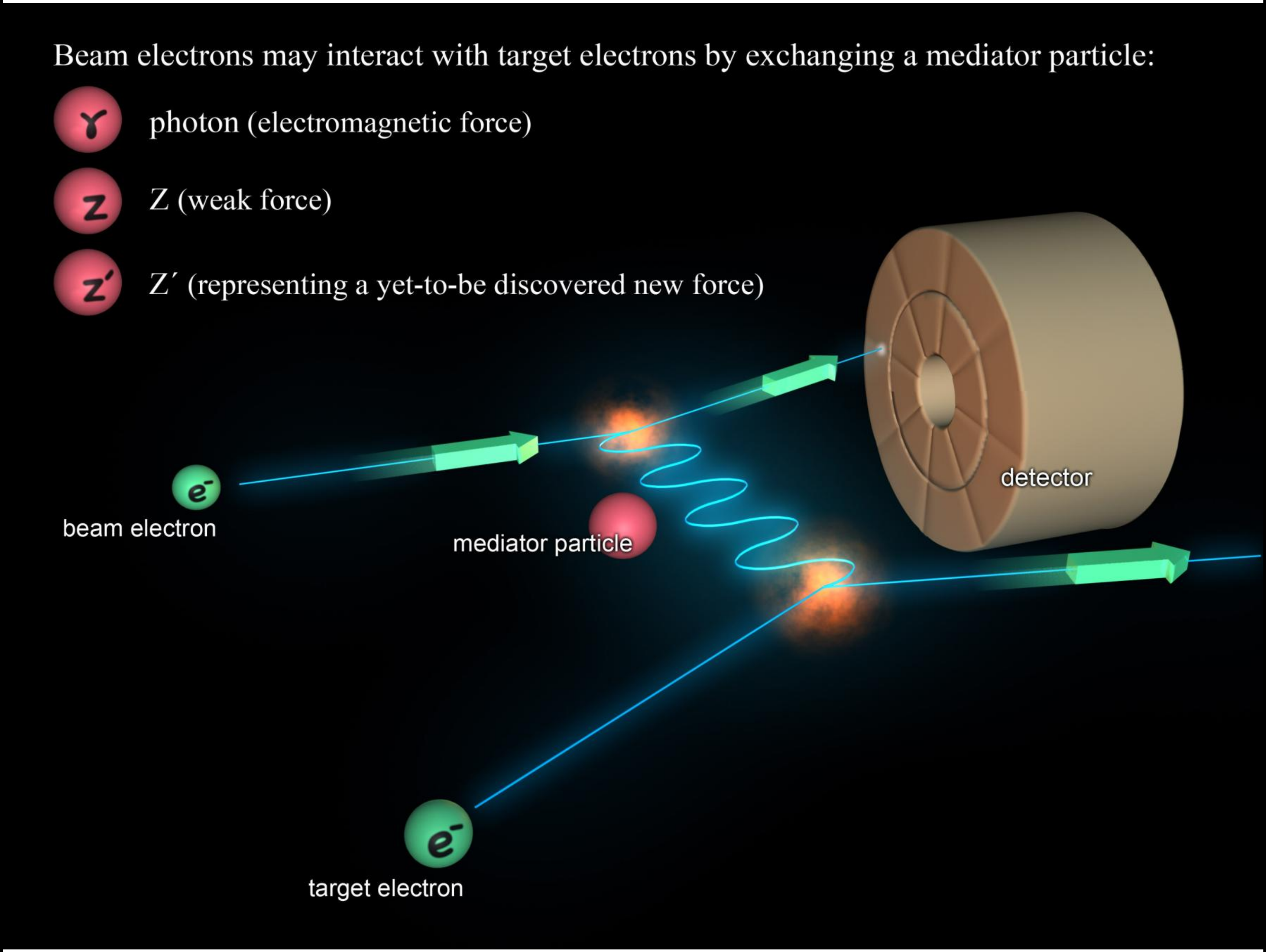
Unique Physics of Light And Astronomy



Shailesh Kadakia BE (Hon.), MSE (USA)

A Pragmatic View to Theoretical Astrophysics

The Greek Alphabet & English Equivalent

Greek Alphabet Lower Case	Greek Alphabet Upper Case	English Name	English Pronunciation	English Alphabet Lower Case	English Alphabet Upper Case
α	Α	alpha		a	A
β	Β	beta	BAY-ta	b	B
γ	Γ	gamma		g	G
δ	Δ	delta		d	D
ε	Ε	epsilon		e	E
ζ	Ζ	zeta	ZAY-ta	z	Z
η	Η	eta	AY-ta	h	H
θ	Θ	theta	THAY-ta	q	Q
ι	Ι	iota		i	I
κ	Κ	kappa		k	K
λ	Λ	lambda		l	L
μ	Μ	mu	MEW	m	M
ν	Ν	nu		n	N
ξ	Ξ	xi		x	X
ο	Ο	omicron		o	O
π	Π	pi		p	P
ρ	Ρ	rho	ROE	r	R
σ	Σ	sigma		s	S
τ	Τ	tau	TAOW	t	T
υ	Υ	upsilon		u	U
ϕ	Φ	phi		f	F
χ	Χ	chi		c	C
ψ	Ψ	psi		y	Y
ω	Ω	omega	o-MEG-a	w	W
φ	ϑ			j	J
ϖ	ς			v	V

Useful Powers of 10: Prefix, Value and Abbreviation

Power	Prefix	Value	Abbr.
10^0	unit	1	u
10^{-3}	milli	1/1000 u	m
10^{-6}	micro	1/1000 m	μ
10^{-9}	nano	1/1000 μ	n
10^{-12}	pico	1/1000 n	p
10^{-15}	femto	1/1000 p	f
10^{-18}	atto	1/1000 f	a
10^{-21}	zepto	1/1000 a	z
10^{-24}	yocto	1/1000 z	y

Power	Prefix	Value	Abbr.	Name
10^0	unit	1	u	
10^3	kilo	1000	k	thousand
10^6	Mega	1000 k	M	million
10^9	giga	1000 M	G	billion
10^{12}	tera	1000 G	T	trillion
10^{15}	peta	1000 T	p	quadrillion
10^{18}	exa	1000 p	E	quintillion
10^{21}	Zeta	1000 E	Z	sextillion
10^{24}	Yotta	1000 Z	Y	septillion
10^{27}		1000 Y		octillion

Important Physical Constants

Identity	Symbol	Value	unit		Equivalent	unit
Quantum Planck's constant	h	$6.626070\ 04(81)\times10^{-34}$	J•s	=	$4.135667\ 662\times10^{-15}$	eV•s
Dirac's constant	$\hbar=h/(2\pi)$	1.0546×10^{-34}	J•s			
Space constant speed of light	c	$2.997924\ 58\times10^{8}$	m/s	=	186282.9	miles/s
Charge Coulomb constant	$k_e=1/(4\pi\varepsilon_0)$	$8.987551\ 79\times10^{9}$	N m^2/C^2			
Permeability of free space	μ_0	$4\pi\times10^{-7}$	T m/A			
Permittivity of free space	$\varepsilon_0=1/(\mu_0c^2)$	$8.854187\ 82\times10^{-12}$	C^2/N m^2			
Universal constant	G	$6.6742\ (10)\times10^{-11}$	N m^2/kg^2			
Gas constant	R	8.314472 (15)	J/(mol•K)			
Rydberg constant	R_H	$1.097373\ 16\times10^{7}$	m^{-1}			
Avogadro's number	N_A	$6.022141\ 5(10)\times10^{23}$	particles/mol			
Boltzmann's constant	$k_B = R/N_A$	$1.380650\ 5(24)\ \times10^{-23}$	J/K			
Hubble Constant	H	73 ± 1.75	km/s/Mpc			
Atomic mass unit	u	$1.660538\ 86(28)\times10^{-27}$	kg	=	931.494 043(80)	MeV/c^2
Electron volt	eV	$1.602176\ 53(14)\times10^{-19}$	J			
Electron elementary charge	e	$1.602176\ 53(14)\times10^{-19}$	C			
Electron mass	m_e	$9.109382\ 6(16)\times10^{-31}$	kg	=	.510998 918(44)	MeV/c^2
		$5.485799\ 0945(24)\times10^{-4}$	u			
Proton mass	m_p	$1.672621\ 71(29)\times10^{-27}$	kg	=	938.272 029(80)	MeV/c^2
		1.007276 46688(13)	u			
Neutron mass	m_n	$1.674927\ 28(29)\times10^{-27}$	kg	=	939.565 360(81)	MeV/c^2
		1.008664 91560(55)	u			
Bohr radius	$r_0 = \hbar^2/(m_e\ k_e e^2)$	$5.291772\ 108(18)\times10^{-11}$	m			
Bohr magneton	$\mu_B = e\hbar/(2m_e)$	$9.274009\ 49(80)\times10^{-24}$	J/T			
Nuclear magneton	$\mu_n = e\hbar/(2m_p)$	$5.050783\ 43(43)\times10^{-27}$	J/T			
Fine structure constant	$\alpha = k_e e^2/\hbar c$	$[137.035999\ 139\ (31)]^{-1}$	none			
Compton wavelength	$\lambda_c = h/m_e c$	$2.426310\ 238(16)\times10^{-12}$	m	=	0.00243	nm
Number of seconds in a	t_y	31556925.98	s	=	3.1557×10^{7} s	
Sidereal year		365d 6h 9m 9s				
Light year	l_y	63421.077	AU	=	$5.878499\ 81\times10^{12}$	miles
Parsec	pc	3.2616	ly	=	19.174×10^{12}	miles
Earth's magnetic field	B_E	0.5	Gauss	=	5×10^{-5}	Tesla

Useful Astronomical Quantities

Identity	**Symbol**	**Value**	**unit**	**Equivalent**	**unit**
<u>Sun</u>					
Age		4.57×10^{9}	years		
Solar mass	$M_{\odot}$	1.9885×10^{30}	kg		
Solar radius	$R_{\odot}$	6957×10^{2}	km		
Solar irradiance	$S_{\odot}$	1361	W m^{-2}		
Solar luminosity	$L_{\odot}$	3.83×10^{26}	W		
Orbit distance		8000	parsec		
Rotation period (axis)	$T_{\odot}$	609.12	hours		
Surface temperature		5772	K		
Average density	$\rho_{\odot}$	1408	kg/m^{3}		
Apparent magnitude		-26.74 (bright)	ratio intensity Wm^{-2}		Vega 0
Brightness compared to Vega		6.31×10^{10}			Vega 1
<u>Moon</u>					
Age		4.45×10^{9}	years		
Mass of the Moon		7.346×10^{22}	kg		
Radius of the Moon		1737	km		
Moon's orbit distance		378×10^{3}	km		
Rotation period (axis)		655.728	hours		
Surface temperature (Black body)		270.4	K		
Average density		3344	kg/m^{3}		
Apparent magnitude		--13.0(dim)	ratio intensity Wm^{-2}		Vega 0
Brightness compared to Vega		1.58×10^{5}			Vega 1
<u>HST</u> limits					
Apparent magnitude		32(faintest star)	ratio intensity Wm^{-2}		Vega 0
Brightness compared to Vega		1.58×10^{-13}			Vega 1
<u>Earth</u>					
Age		4.543×10^{9}	years		
Mass of the Earth		5.9724×10^{24}	kg		
Radius of the Earth		6371	km		
Earth's orbit distance		149.6×10^{6}	km		
Rotation period (axis)		23.9345	hours		
Surface temperature (Black body)		254	K		
Average density		5514	kg/m^{3}		
<u>Universe</u>					
Age of Universe		14×10^{9}	years		
Size of Universe		14×10^{9}	parsec		
Average temperature		2.7255	K		
Average density of Universe	Λ	4.5×10^{-18}	kg/m^{3}		
<u>Black holes</u> (Typical)					
Density		6.0×10^{18}	kg/m^{3}		
<u>Neutron star</u>					
Density		1.0×10^{17}	kg/m^{3}		

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Shailesh (Sky) Kadakia

A text book with more than 200 Colorful illustrations,

40 Tables of useful data and 600 Problems/Questions

MWP PRESS

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Shailesh R. Kadakia, B.E. (India), M.S. (US)
2530 Bear Valley Pkwy, Unit 210
Escondido, CA 92027
Website: http://www.skylativity.com

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Dedication

To my best friend & Wife

Carole Kadakia

Thank you for your love and inspiration

Shailesh Kadakia

Preface

After contemplating the success of the previous reference book, *True Physics of Light Beyond Relativity* (1^{st} and 2^{nd} edition), the author decided to produce an expanded version of the book covering its topics in greater detail, as well as other pertinent issues of Astronomy. This book entitled *Unique Physics of Light and Astronomy* has been created with the objective to introduce revolutionary concepts about the origin of radiation, gravity and its application to Astronomy. This new book is designed as a text book for university students of junior level physics. The book provides enough information which makes it suitable for physics experts and professors who wish to advance their knowledge in the field of physics. Every chapter begins with an outline for each topical section. The outline for each section is followed by carefully articulated explanations of each unique concept introduced. The explanations are supplemented with appropriate examples and diagrams.

Each chapter is summarized with subsections containing definitions, concepts and principles, problem solving analysis models, and applications. The summary exercise section is developed to test the understanding of students about the contents of each chapter. This section has a variety of interesting questions that will enable educators to examine and evaluate the student's ability to grasp concepts therein and to determine their skill level within the field. Some questions require a description as an answer, such as a brief essay, while other questions are more objective, for which correct answers would be selected by students from a bank of multiple choices. Additionally, problem questions are posed to evaluate the student's problem solving capability. Problems are designed in two varieties. Some problems may be solved by a simple substitution of parameters within a formula. Answers to these problems are arrived by plugging in correct values. Other problems require exercising strong analytical skills on the student's part. Problems for extra credit are included in a section called Problems for Exploration. These are challenging assignments and are reserved for students who should like to master the course material.

Light is one of the most perceptible, abundant, and essential sources of energy, and yet it is the most misinterpreted entity regarding its origin. According to Big bang theory, and interestingly in Bible, light was created first. There is an eternal truth and agreement on this fact abided by experts from scientific community, as well as those within the conservative religious arena. The most amazing fact about light is that it has no material mass and yet has seemed to revealed visible characteristics of mass through several physical phenomena. The most popular examples are interference effects of light that creates multiple images of a point source (bands of bright and dark fringes) during passage of light through narrow slits, and the diffraction of light reflected by selectively etched mirrored surfaces. Other phenomena in this category are the photoelectron emissions and scattering of x-rays in the Compton's effect. Misunderstanding this strange behavior of light energy waves has led many physicists, including the profound physicist Albert Einstein, to formulate a principle that light behaves both as a wave and as a particle. The author of this text book takes an entirely new approach. While physicists of prior centuries ignored the investigation of the origin of radiations, leaving gaps in their theories, we focus on the processes that create radiations from their infancy, so to speak.

This book intuitively penetrates the basis for the creation of radiation energy in general and the behavior of light in particular. From our fresh, unbiased perspective we have posited that whenever electrons orbiting the nuclei of atoms in some substances make a transition from a high energy state to a lower energy state (ground state), the energy difference (quantum value) is manifested in the form of electron vibrations. During these vibrations the electrons dissipate energy through the electrostatic charge (ESC) field that exists around protons within the nuclei and the electrons in their orbit. The transfer of energy from the electrons to the ESC field causes reverberation of the field that emits radiation in various bands of frequencies. The frequency of emitted radiations depend on the energy transfer from the vibrating electrons to the reverberating ESC field that is in accord with the energy differential released by an electron within a specific orbital transition event. We deduced that the electron energy is dissipated in an ESC field at a rate which corresponds to the constant speed of c km/s within a vacuum. Also, we drew a unique conclusion by analyzing the research data of the brilliant physicists of the past and present generations to support the theory that all radiations are waves of quantized amounts of energy. We have arrived at this premise after consulting many experts both in industry and in academia.

To determine the elusive truth about the behavior of light, we have also passionately studied the alternate competing theory of the strange behavior of light, Quantum Electrodynamics (QED) from the fruitful mind of Richard Feynman, who incidentally favored the wave nature of light. While we were putting all the pieces together in search of the true nature of light, we struck intuitively on an idea that light photons, as particles defined by Einstein, do not have the key characteristic of a particle, pointedly, a center of gravity. Therefore, photons as light particles described by Einstein must be of a different kind. We decided to probe the issue further and realized that light photon particles are *hypothetical* and should be classified as virtual particles. Thus, in this text book we decided to view and refer to light and radiation energy waves as a conspicuous source of energy, Planck's quantum waves.

Another vital source of energy with which we deal in daily life is the force of gravity, the cause of which is not known to date. In this text book, we have attempted to analyze the root cause of the force of gravity between objects from its origin perspective. Another puzzling question about gravity is: At what speed does the force of gravity propagate? Twentieth century pioneer physicist Albert Einstein had suggested that in a vacuum, the propagation speed of gravity is the same as the speed of light waves. According to the postulates of his Special Theory of Relativity (STR), the speed of light in a vacuum is a constant **c** and does not vary in different inertial systems. Therefore, it was universally accepted that the force of gravity propagates at the same speed that the speed of light propagates, c km/s. Our views are different from Einstein when it relates to the speed at which the force of gravity propagates. We believe that the force of gravity propagates instantaneously, analogous to the transfer of a property connected with an agent in the quantum entanglement scenario. Also, we found a unique connection between the forces of gravity and forces of dark matter.

The primary purpose of this book is to develop an understanding of new concepts regarding the fundamental phenomena responsible for the generation of radiations and force of gravity. The secondary objective is to revise the principles of the special theory of relativity and the general theory of relativity (GTR) founded by Einstein without the present "gaps" so that they make complete sense. Another objective of this book is to explicate sophisticated theories in rhetorical English literature style so that the average person may comprehend the subject matter without the need of incomprehensible mathematics. The audience for which the book is written are students of a Junior class seeking to pursue a physics curriculum, as well as for experienced physicists. The author assumes that readers have a basic introductory knowledge of nuclear physics and the fundamental principles of quantum mechanics. Since our emphasis is on improving the understanding of concepts of physical phenomena rather than rigorous, mathematical proofs thereof, we have refrained from discussing analytical complexities of derivations and have, instead, chosen to state the end results for the sake of simplicity.

Another purpose of this book is to determine an ideal theory of everything, unifying all the forces of nature and their interactions amidst different types of particles. It is a well known fact that all objects in the universe are formed by composite particles. The universe is composed of vast celestial entities such as galaxies, nebulae, and stars, which are, in turn, comprised of the tiniest of fundamental particles, quarks, fermions, and perhaps "strings", as posited by the string theory. We wish to achieve our objective by presenting the concepts of the **Skylativity**® theory in pedagogical style. The techniques developed here allow us to characterize the effects of gravity on particles of "quantum" size. Previously, the force of gravity was a main obstacle in the formulating of the Grand Unified Field theory (GUT). After studying this book you will realize that we have successfully eliminated these limitations and, through some fine-tuning, founded a basis for the principles underlying a Grand Unified Field Theory of Everything.

The content of this text book is organized as follows:

In **Chapter 1** we outline salient features of the Special and General theories of relativity as postulated by Albert Einstein in the early 20th Century. His laudable pioneering efforts, however, left several voids behind in GTR and STR postulates, inasmuch as he was first to blaze the trail and so understandably ignorant about the origination mechanisms propagating 1) radiations and 2) the force of gravity. Therefore, with natural propensity he predicted the bending of light and the novel curvature of space and time dimensions in the presence of strong gravitational fields. To validate this point, he proposed three different kinds of tests. In this chapter we will critically examine results of many tests performed to prove his prediction about the nature and behavior of light. First, we will revisit fundamental concepts of classical mechanics that will help you understand principles described within the entire text book. Then, we will discuss the outcome and conclusions of experiments to test Einstein's theories (e.g., the deflection of light from a star due to force of gravity from the sun, Michelson's Interferometer experiment, the Photoelectric effect, the Compton effect, and the short wavelength limit x-rays). After studying the material in this chapter you will be convinced that light and all kinds of radiations are waves of quantized amounts of energy.

Chapter 2 is about one thing for which Einstein did not account: the origination mechanisms for radiations and radio frequency (RF) waves. Therefore, STR, which described the characteristics of light and EM radiations was incomplete. He emphasized a particle nature as well as a wave nature of light. This chapter addresses three critical points about origin and nature of radiations. We show that all types of radiations, visible as well as invisible, originate as a result of oscillations of bound electrons orbiting the nuclei of atoms. We establish that radiations are the manifested results of the reverberation of the ESC fields of atoms and are therefore composed of only electric field vectors. We designate them as Planck waves. On the other hand, RF waves propagate due to oscillations of mobile (free) charge carriers (i.e., electrons and holes in electric circuits) and as a result RF waves are composed of electric and magnetic field vectors. The RF waves are analog in nature and obey Maxwell's classical EMF theory model.

With regards to the nature of radiations, we characterized them as quanta of energy waves that propagate at an absolute speed of c km/s in space (vacuum). We developed new concepts of absolute speed and absolute time in contrast to proponents of Einstein's defined relative speed and relative time. In Einstein's realm the speed of light is a fixed quantity independent of the speed (motion) of an observer, whereas we have proposed a Varying Speed theory of Light (VSL). A reckoning was made that there are many differences between RF waves and Planck waves. The most striking of which was the expressions found for the amount of energy carried by two entirely different types of waves. This distinction of origination and nature lead us to develop a new model for Planck wave radiations, which leaves out RF waves. We then derive an expression for energy contained in each type of wave.

As discussed earlier, the magnetic properties of light waves are not firmly established. Therefore, we investigated the profound results of an experiment performed by Michael Faraday. The intention of his experiment was to depict the sensitivity of light waves to magnetic fields. In that experiment, we show that there was a change in light polarization due to polarity of magnetic field switched. For reasons not apprehended at the time, it was concluded that light is composed of electric and magnetic field vectors. As per our explanation it follows that light and other radiations are composed of ESC field and hence forth should be referred to as Planck waves.

The main purpose of **Chapter 3** is to give readers a good overview of the fundamental concepts of **Skylativity**® theory that we have interpolated from the known realm of the greatest minds in physics. One of the greatest disadvantages of Einstein's theory was that it introduced a curvature in the space-time fabric of our dimension. Necessarily, the non-linearity of space required the use of the complex Lorentz coordinate transformation for the computation of dilated values of mass, length and time of objects within four dimensional space for velocities of high value close to that of **c**. A side effect of Einstein's theory was that physicists were forced to partition the phenomena of mobile objects into three categories; e.g., space-like, time-like, and light-like events.

In order to develop a framework of a space-time concept, we will define terms that will help you understand Einstein's theory of relativity. Then we will state the concepts of STR and GTR from Einstein as he saw them. After that we will expose the weak points of relativity. We will then introduced postulates of the special and general **Skylativity**® theories posited by us. Finally, we will assess the effects of the varying speed of light and the concepts of **Skylativity**® theory over Maxwell's field equations and over the solution of Einstein's field equations.

In **Chapter 4**, we explore the limitations of Einstein's GTR and STR principles by describing simple experimentation. In Sections 4.1, 4.2, and 4.3, we demonstrate that the operation of a light bulb invented by Edison conflicts with the postulates of STR. A key component of STR was that it insisted on an invariance of velocity of light within different inertial systems. This requirement resulted in complicated relationships involving such effects as the amplification of mass, the contraction of length, and the dilation of observed time for characterizing the motion of objects within different reference systems. Einstein handled this complexity by applying the Lorentz transformation equations and computed an effective values of mass, length and time. You will learn in Chapter 5, that these transformations are not essential.

Einstein's mass was composed of two parts, rest mass and energy mass. It was evident to us that the effect of rest mass was separate from energy mass. Therefore, we have introduced novel concepts of complex mass and complex dimensions for mass, and length and time measurements based on the principles of quantum theory. It so happens that the time dilation effect is a very important matter in atomic clock applications. We analyze the impact of the trajectory of light waves concerning those two clocks. (One was located on the surface of the Earth and the other was transported to a spacecraft that was supposed to orbit the Earth at high speed and at high elevation.) At the end this chapter, we will also describe the effect of the Sun's gravitation on the apparent position of a star.

The focal point of **Chapter 5** is to establish the fact that the Lorentz transformation is useless for the analysis of the motion of objects within an inertial frame based on the principles of the **Skylativity**® theory. It was known for a long time that the Lorentz transformations were necessary in characterizing the motion of objects using Einstein's STR. He utilized the transformations to determine the length of rods and time delays within different inertial systems. To investigate the effect of the variable speed of light on the length and time measurements, we re-derived the Lorentz transformation equations. We analyze the values of length and time measurements for two different scenarios, the approaching systems and the receding systems. We compared the length and mass values derived from two different sets of worldlines by applying Einstein's postulates and **Skylativity**® theory axioms.

The gist of **Chapter 6** is to explain magnificent concepts of Feynman's Fascinating Theory of light, and describe the rules of Quantum Electrodynamics (QED). A problem that prevented the acceptance of Feynman's QED by physicists was regard Path Integral Formalism (PIF), which deals with the Probability amplitude (PA) of light quanta. Specifically, QED lacked the theoretical consideration for the computation of the PA of light during its propagation in space and through different mediums. We have proposed a solution that corrects the problem. We applied the QED principles to several phenomena observed in nature and explained refraction, reflection, and the transmission of light through thin glass plates using PIF concepts. We have identified real life examples that illustrate the interaction of light quanta with electrons within the atoms of substances on the basis of QED action rules. We closed the chapter by discussing topics that were not addressed by QED.

The focus of **Chapter 7** is to highlight the benefits derived from the new postulates of the Varying Speed of Light **Skylativity**® theory. Specifically, we emphasize that the unique concepts of **Skylativity**® theory are most suitable for space exploration and in the field of Astronomy. For planning missions to distant planets, such as Jupiter, Mars, and Saturn it, is crucial that we must travel at much greater velocities than of current spacecraft design. Therefore, we discuss the issues which are critical for performing space travel in our future that will involve travel at a much greater fraction of the speed of light than now possible as part of the design of space probes and spacecrafts. Additionally, we will then elucidate on the alpha, beta and gamma decay processes. Our goal here is to show that no mass is consumed and transformed into energy in these processes in order to strengthen the ideas presented by **Skylativity**® theory. Finally, we will discuss application of new postulates of **Skylativity**® theory for developing machines in bio-medical arena which are useful in diagnosis and for cure of diseases.

Chapter 8 is about assessing the effect of gravity on atomic and sub-nucleonic particles. Physicists have successfully measured and developed models to characterize the effects of all types of forces except the force of gravity. A troublesome aspect of gravity is that it is an extremely weak force. Therefore, its effect is observed only when one of an object pair is as large as a planetary body or a star. Moreover, it's effect is very minuscule for tiny objects, yet it exerts a strong effect that holds planets, as well as satellites, in orbits and holds stars in fixed positions relative to other stars. For the reasons stated, attempts to formulate a Quantum Theory of Gravity (QTG) has had limited success in past. Also, physicist have been unable to unify the force of gravity with other forces found in nature. We will attempt to solve these problems in a systematic way.

First we will analyze the reasons why the force of gravity comes into play amidst molecules and atoms of objects formed by the composition of elementary particles. Also, we will compare the strength of the force of gravity with the electrostatic charge force. Next, we will study the features of the theory of Graviatation as proposed by Einstein. We will analyze the results of three tests that supported the postulates of Einstein's General Theory of Relativity (GTR). You will discover that Einstein's GTR was a great success in characterizing the motion of vast celestial objects. On the basis of GTR, we have formulated a theorem: Uniqueness of Gravitation.

We noticed that atomic clocks are very useful for assessing the effect of the force of Earth's gravity. Very small variations in the frequency of these clocks can be detected. Therefore, we analyzed Bohr's model of the hydrogen atom and the frequency characteristics of emitted radiation. We made an addition of a correction term in the expression for the frequency variation that accounts for the effect of Earth's force of gravity on atomic vibrations. We described the construction and the operation of a Cesium atomic clock. We discuss the fact that the tidal forces caused by Moon can have a very detrimental effect on the weather. We therefore suggested updates in pressure parameters in weather simulation program to improve the accuracy of weather prediction.

The primary objective of **Chapter 9** is to highlight the characteristics of our solar system composed of nine planets (if we count Pluto) and approximately 168 satellites. First we describe theories about the origin of stars and the birth of planetary systems around stars in general. Then we identify the most probable cause (and a promising theory) for the birth of the Sun and our solar system. As it happened, all our planets have an elliptical orbit in our solar system. We also discuss in detail Kepler's three laws of motion that culminate into a relationship between the semi-major axis of a planet's orbit and the period of the planet. Next we analyze the conditions that favored the existence of life on the Earth.

Planets orbit the Sun at different rates and rotate on their axes in different directions because of differentials in their mass and tidal forces. The composition of a planet changes in its form from a gas to a liquid and to a solid phase during various stages of its life. We will study how a planet's rotational speed varies due to shrinkage in size as its surface temperature decreases and some of its gaseous matter escapes into space. Further, you will learn the reasons for the long tails of comets and their unusually long and very high eccentric elliptical orbits around the Sun. Einstein's energy equivalence equation helped the scientific community to determine the life-span of stars and planetary systems. A physicist from Great Britain, Robert Atkinson, discovered the details of a thermonuclear fusion reaction occurring in the Sun in which hydrogen was fused into helium, a three step process. The process details were subsequently confirmed by a distinguished Harvard Professor, John Bahcall, then at Princeton, New Jersey. Supposedly, the fusion process maintains an equilibrium condition between the inward pressure of self gravity and outward pressure of the kinetic energy of gas.

To estimate how long the sun will remain in its current state, it is imperative that we study its temperature profile and its internal composition. We present details of an improved model of its temperature variation. Furthermore, we have added an interesting parameter in profiling the temperature at which the hydrogen fuses into helium. The inclusion of this parameter has significant impetus on the life-span computation of the Sun and the existence of our civilization. We end this chapter by discussing the details of the terminal phase in the life cycle of the Sun.

Chapter 10 is about the composition of matter within black holes. It has been the claim of pioneer physicist Stephen Hawking that black holes have no hair, meaning they are objects made of unknown matter. Moreover, his no hair theorem stated that black holes can be completely characterized by only three externally observable classical parameters: mass, electric charge, and angular momentum. We will show that black holes are indeed composed of quarks. Scientists had hypothesized that black holes are massive with a super gravitational field in which light is trapped. We present a new school of thought that light is not reflected from the black holes because black holes lack electrons which are known to absorb and re-emit radiation quanta from atoms of elements.

The first section explains the origin of black holes from a purely theoretical consideration developed by a famous astrophysicist from India, Chandrasekhar Subrahmanyan. Various terms are defined, such as Event Horizon, Schwarzschild radius, Singularity, and Escape Velocity, which are conventionally used to describe characteristics of a black hole. In the same section we derive an expression for the Schwarzschild radius from matter density considerations. Our analysis will exhibit a surprising result about a singularity that has been claimed to exist within a black hole. We study briefly the stages of the life-cycle of Stellar evolution in Section 9.1, and learn about the birth of different types of celestial objects, such as white dwarfs, neutron stars, and black holes. In this chapter we will discuss details on the internal composition of matter in each of these entities. You will discover that black holes are really quark stars, because their formation follows from the compaction of a neutron star as a natural progression of events caused by contraction of self gravitational forces.

The primary goal of **Chapter 11** is to revisit the principles and experiments that founded modern picture of Quantum mechanics. Several pioneer physicists contributed to the growth of this fascinating field of physics. To name a few, the concepts of black body radiation from Max Planck, Erwin Schrödinger's equations for modeling the position of electrons in the atom, and the discovery of particle/anti-particle pairs as a resultant solution proposed by Paul Dirac in his four component wave equations. Despite all these success stories, physicists were unable to fill the gap between Classical mechanics and Quantum mechanics. They could not develop a single framework of science in which all the laws of physics predicted the results with consistency for all matter, objects of astronomical sizes, such as galaxies, black holes, and etc., and for the nanoscopic particles, namely, quarks and neutrinos. Furthermore, as we shall elucidate, some effects, such as Quantum entanglement and the speed at which forces of gravity propagate still remain a mystery.

Early attempts of instigation to make progress in the quantum field of study brought increased confusion about behavior of radiations and of elementary particles. Their nature was hence categorized as of a dual kind, as a particle as well as a wave. In the analysis of the outcome of some experiments, such as Young's Double slit experiment and the Davisson-Germer electron diffraction experiment, physicists neglected to bring into account the effect of gravity on the motion of particles. Therefore, we will specifically revisit those two experiments. This will allow us to critically distinguish particle entities from waves. Then we will derive Schrödinger's equations by using Maxwell's equations governing classical electrodynamics. Our intention is to improve his equations by including the effects of gravity on the work function describing behavior of particle electrons, which incidentally he had neglected. Next, we will elaborate on Paul Dirac's contribution and expound on the importance of his work. Finally, we will discuss the application of the principles of Quantum mechanics to real-life situations. We will also describe the operations of the Quantum entanglement effect, Quantum locking for transportation, and the Scanning Tunneling Microscope. We shall finish the chapter by describing loose ends that prevent the union of classical and quantum theories.

In **Chapter 12**, we will explore the structure of protons and neutrons, the nucleons making up the nuclei of atoms. The nucleons are composed of different flavors of quarks, which are linked conforming to the rules of Quantum Chromodynamics (QCD). We will study the different types of quarks and their properties. We will expound on the Eightfold way and the Tenfold way, patterns in which different quarks join to form families of particles, such as hadrons and mesons. We will define parity and outline the principle of symmetry that governs the rules of Chromodynamics. The QCD rules are more complex than QED because quarks possess color charge along with electric charge. The color charge comes in three flavors and quark/anti-quark pairs exist simultaneously. We will look into these matters as a basis for understanding the behavior and construct of our material universe.

Quarks are united within nucleons by the forces of color charge and binding energy. Quarks are bound by a binding energy that is in excess of 300 MeV. Furthermore, quarks cannot exist in isolation, and therefore identifying different varieties of quarks in particle detectors is a monumental task. We will delineate the procedure that is adopted by the Large Hadron Collider in CERN, Geneva to screen streams of quark jets within their ATLAS detector. Quarks are created by the collision of nucleonic matter at very high energies within a particle collider. At such high energies, streams of ejected quarks are known to materialize into more massive hadrons by a process known as the Drell-Yan annihilation (DYA) mechanism. You will study details of the DYA process. Finally, we will explore features of String theory that claims the existence of even smaller "particles" other than quarks in the composition of matter.

Chapter 13 is about the origin of the universe and its growth to its present observed state. We will seek answers to several intriguing questions in this chapter. Is there a theory that explains the birth of universe without ambiguity? Is the universe really expanding as posited by Hubble in his expanding universe model? Also, we will address the question of what the scope (physical size and dimensions) of universe is and the best current estimate about its age. It is thought that the universe was created from a point source of extremely dense energy of an infinite amount. We will describe and analyze a generally accepted promising theory about the origin of our cosmic universe, the Big-Bang Theory. We will do so because it, too, is based upon the point particle model of the universe that grew to its present size.

Most new theories developed have the handicap of explaining all observations for their own designed purposes. The BBT is not an exception to this rule and has faced severe criticism with regard several issues. We will expose all the problems associated with BBT. Although the theory has many problems, it contrived foundation for advanced theories such as the Inflationary Universe Model (IUM) by Alan Guth and others. Following that we will present two entirely different schools of thought with regard the expansion of the universe, Hubble's uniform expanding space view, and Sky's infinite space view. After that, we will describe the evolution of matter in the universe; the formation of hydrogen and helium atoms from the composition of the elementary particles, baryons and fermions.

The IUM theory requires understanding of several sophisticated concepts such as Classical and Quantum field theory, spontaneous symmetry breaking and phase transition, Higgs field and Mechanism, and False vacuum. Therefore, we will define new terms that are necessary for understanding of novel concepts. Further, we will describe steps in which succession of strange events took place as claimed by the developers of IUM in the section roadmap to IUM. In the same section, we will highlight details of the Higgs Field and invention of Higgs Boson. Finally, we will discuss details of Inflationary Universe model. You will discover that the model answers all questions about the origin of universe with complete satisfaction. We will end this chapter with discussion of Multiverse, which is considered as cornucopia of parallel, concurrent, and alternate universes by Cosmologists. We will describe characteristics of different universes categorized by famous physicists Max Tagmark and Dr. Brian Greene.

The final **Chapter 14**, “Space Exploration,” addresses the most important application of principles developed in this text book for the field of Astronomy. Our universe is composed of billions of stars, thousands of galaxies, and an abundance of black holes. Reception, detection, analysis, and monitoring a wide range of signals received from distant sources in space provide the most promising way to locate and identify many types of celestial entities. It is determined that characteristics of received signals, such as wavelength (frequency) and energy depend on the composition of matter on the surface of the signal-emitting source. Therefore, a variety of techniques are being developed, and telescopes with a plethora of sophisticated instruments are designed for capturing these signals in different wavebands.

We will study characteristics of six entirely different types of astronomical systems, each developed for the detection of signals in the RF, Infrared, Optical, UV, X-ray, and Gamma wave categories. A typical astronomical system for highly accurate measurement of signals consists of a telescope that is a signal receptor with an associated computer hardware/software for post processing of data. In order to improve resolution and clarity of the images that are observed telescopes are built with mirrors and lenses of large diameter. Often the size of a mirror is increased by fabricating several small segments of mirrors mounted on panels. The position of the panels are adjusted by a computerized control drive system for correcting the shape of the composite mirror. We will describe features of six modern telescope facilities; the land based ALMA, KECK and MAGIC, and space assigned telescopes HST, JWST, and the Chandra x-ray observatory.

Astrophysicists have had a great deal of success in detecting Gamma wave radiations generated from extremely high energy particle sources in association with intergalactic nuclear activity amidst interstellar gas. In order to learn more about the particle details involved in these high energy emissions it is imperative that we produce such particles on the Earth. Therefore, particle colliders are employed in an attempt to create these high energetic exotic particles. Particle detectors are an integral part of particle collider, as one would naturally cede. We will study the construction of five different types of detectors, each one designed to detect particles at different energy levels.

Finally, we will study a most valuable section dealing with the Astronomer’s Toolkit. We will explicate important concepts, such as the small angle distance formula, stellar coordinates, and the orbital periods of planets. We will analyze the motions of star and derive an expression for the space velocity of a star in terms of its radial and tangential components. We will outline a procedure to estimate the size of celestial objects, their mass, diameter, absolute brightness and chemical composition. We will introduce to you sophisticated concepts of H-R diagrams and discuss their impetus in Astronomical computations. We will explain the meaning of the most commonly used terms, such as right ascension and declination, angular size and linear size of celestial objects, the magnifying power and light capture ratio for telescopes, and the angular resolution based on Rayleigh’s Criterion. We will end this chapter by suggesting topics for future research.

To the Student

In our opinion, mastering knowledge about the sophisticated concepts of physical phenomena can be an adventure, specifically if you are making a career out of it. Seeking answers of advanced scientific theories, as well as the solutions of complex problems in the field of astronomy is like analyzing a problem in mathematics. We recommend that you should use the "divide and conquer" strategy, because it is known to work. Solutions to any problem in mathematics can be arrived at by breaking down the problem into simple steps. The outcome of each step is evaluated by performing a basic set of operations on known values of variables and the constants using predefined operators. The situation involved in solving any problem in Astronomy is analogous to the above situation in mathematics in the sense that the majority of the problems can be divided into events of elementary, discrete forms.

We have applied the "divide and conquer" strategy and were highly successful in getting answers to questions which had been neglected by many pioneer physicists of the twentieth century. We believe we have solved the mystery with regard the origin and nature of all types of radiations and provided insight into the real cause of the force of gravity between objects. We have unambiguously declared that black holes are composed of quarks, and that singularities, as popularly understood (or not understood), do not exist within the black hole cores. These are a few of the examples of our accomplishments.

We wish to offer you our advice for retrieving information on the internet about the subject matter of this book and for seeking solutions to many problems. First, learn to manage your time wisely by being careful with the time you spend on the internet. There is so much material out there that it is very easy to lose track. Many students, in general, have a tendency to find the answers to posed problems of an assignment using someone else's work to simply to seek a high score. We think it is a better idea to overcome this weakness at the early stages of their student career. Instead of securing a right answer to a problem, it seems to us imperative they should learn and master the skills that will help them on their own, arrive at the acceptable and right answer. The internet may provide answers to nearly all types of problems, and search engines such as GOOGLE make it very convenient to access solutions. It is important to know that the internet is an open domain system. Solutions to many problems that are posted on the internet lack a desired level of accuracy. Further, a great deal of information is not screen by an official agency for verification. Therefore, it is your responsibility for discarding inappropriate information and adapt your problem-solving skills for correct solutions.

We would like to give a brief explanation of the cover of this book. It displays interaction between electrons of an incident beam and a target beam. In space, an electron which has a unit of charge couples through a mediator particle to another electron. Thus, a mediator particle, such as a Z-boson or a **γ**-quantum of light allows an exchange of properties between electrons instantaneously. The purpose of this photo is to demonstrate a possibility that the quantum entanglement phenomenon can be successfully explained on the basis of the Quantum field theory, as depicted on this cover. Please remember, that more details on the information in this book is always available somewhere on the internet. Contact us if you require further information on the topics discussed in this text book. It is our desire to thank you for purchasing this text book, and are wishing you the best in your Astronomy studies as an extraordinary adventure of your life. Feel free to write a blog and communicate with us via any social media channel; Facebook, Twitter, or E-mail, and through our website at **http://www.Skylativity.com.** Also, view our YouTube and write your suggestions that will help us to serve you better in the future.

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About the Author

Shailesh Kadakia, originally from Mumbai, India earned his Master's degree (MSE) with emphasis on Computer technology from the University of Texas at Austin in May of 1981. He earned his Under graduate degree in Electrical Engineering from the University of Mumbai, Bombay India in March of 1975. He was awarded National Science Foundation Scholarship for his research and thesis titled "The reduction of pin connections of a microcomputer system using light-pipes", at the University of Texas. From 1981 to 2001, Shailesh was employed as an Information Technology Engineer in several circuit manufacturing corporations. During his twenty year IT career, he was issued five patents in computer technology (circuits and systems), and had published over 25 reports and papers in journals. He contributed toward the successful execution of VLSI projects at National Semiconductor, Texas Instruments, Cirrus Logic, Motorola Semiconductor, Hewlett Packard, LSI Logic, International Meta Systems, Silicon Graphics, NxtWave Communication and Harris RF Communications.

In April of 2010, Shailesh Kadakia self published his first book, *True Physics of Light, Beyond Relativity*, First Edition, from self-funded company Matrix Writers & Publishers. In May of 2011, he wrote and published Second edition of the same title in print as well as electronic formats. In September of 2011, Mr. Kadakia accepted the position of Visiting Professor at the University of Pittsburgh, Johnstown, PA. There he taught Electric Circuits, Digital System Design, and MATLAB Programming and Applications Classes. In July of 2013, he relocated his company Matrix Writers & Publishers from New York to California. At present, he is employed as an Instructor at Mathnasium, a math coaching facility with offices in San Marcos and Carlsbad CA. There he is teaching mathematics to Middle and High School Students. Outside of the IT Career, Professor Shailesh Kadakia has received numerous awards such as Businessman of the Year 2005 from NRCC and is a lifetime member of Cambridge's *Who's Who*. He is a honorary member of The Boundless Project, an organization which promotes science and technology globally. He has received certificates for presenting seminars "Quantum of Light and Astronomy" at Ho- Chi-Minh City Vietnam, and "Write & Publish Books: A process" at The University of Riverside, Riverside CA. He is enjoying his married life with his wife Carole Kadakia in Escondido, CA near the fabulous city of San Diego. His favorite sports are playing billiard pool, tennis, and bowling.

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1.

An Introduction to Relativity

Isaac Newton (1643-1727)

CONTENTS

For more than a century, scientists and engineers have perceived the dual nature of light, a particle and a wave, with some uncertainty. In this book, it is shown that light strictly behaves as a wave. Ever since Albert Einstein devised his theory of relativity which explicates the phenomenon of light propagation in free space, very little work has been done to resolve this duality [1]. His subsequent work to explain the properties of matter at an atomic level and the energy released during a nuclear reaction, popularly described by equation $\mathbf{E = mc^2}$, ponderously relies on the fact that light behaves as a particle and that the speed of light is a constant **c**. Also, for the computation of important astronomical parameters, such as the distances and the velocities of receding and approaching galaxies, and for the age determination of the Universe, the Hubble time parameter is utilized by astronomers. The formulation that determine these values provides vastly different results, depending on the behavior of the light, whether it is modeled as a wave or a particle. Further, in this effort we have proven that every phenomenon associated with light propagation and its behavior during the physical and bio-chemical reaction can be successfully expounded by modeling it as a wave. The wave nature and wave model for light provide the correct physical description of light.

Another question that has perplexed many physicists was whether or not any particle or object can travel at or above the speed of light. Einstein provided an answer by applying the postulates of the special theory of relativity. The theory stated that it is implausible to attain the speed of light for any object because its relativistic mass rapidly increases toward infinity as the speed of the object approaches the speed of light. By the term “relativistic mass” he meant the total mass of the object. From his view, the total mass of an object consisted of two components. The first component he described as “rest mass,” which he considered the mass of an object measured in a standstill condition. He implied that the rest mass has zero kinetic energy and the mass will generate $\mathbf{mc^2}$ units of energy if transformed into radiation energy. The second component of mass he stated was “kinetic mass,” which was attributed by the motion of the object. It is this component which varied with speed in a way to prevent further acceleration of the mass despite supplying an unlimited amount of energy to the system of the mass.

We have presented a different view than proposed by Einstein. We do not believe that relativistic mass increases rapidly toward infinity as the speed of an object approaches the speed of light. The reason is the rest mass of an object is a measure of the quantity of matter contained in the object. This rest mass should not depend on the frame of reference and the state of kinetic energy contained in the object. Mass gained by an increase in kinetic energy is not a real increase in mass. Ordinarily the gain in kinetic energy of an object results in a change in the potential energy content of the object. Therefore, within practical limits, it should be feasible to accelerate the particles to the speed of light, or even in excess of the speed of light. The particles with speeds beyond the speed of light, at super luminous speeds, are called tachyons. The upper limit of the speed of light is applicable to energy waves, such as visible light, infrared rays, X-rays, gamma rays, and electromagnetic radiation only, and not to objects with real rest mass. Therefore, the principle of the special theory of relativity, the maximum limit on the speed of light **c**, should not be applied to objects and particles with non-zero rest mass.

It is discovered that very tiny particle electrons are accelerated to the speed of light in a particle collider when accelerated under the influence of an electromagnetic field produced by the electric current carrying coils. Usually in a particle collider an electron and a positron, or a proton and an anti-proton are collided at very high acceleration energies. After the collision the residue particles and radiations are examined for determination of speed by detectors. There are several reasons why the speed of particles in an accelerator or collider is restricted below the speed of light. When electrons and positrons are collided, the particles cease to exist. Immediately after the collision, the electron/positron pair lose some energy as they radiate energy in form of vibrations. The loss of radiation energy prevents further acceleration of electrons, and radiation energy waves are produced in the collision process.

In case of proton anti-proton collision event, the particles are smashed and quarks are produced. A huge fraction of proton energy is consumed to overcome binding energy associated with constituent quarks. Also, it is possible that when the accelerating protons attain the speed of light, the particles start radiating vibration energy, and the kinetic energy of the particle is diminished in the process. Specifically, this is true when the molecules of matter are accelerated to the speed of light because the molecules are composed of atoms which consist of many protons and neutrons at the center, and electrons in the orbit. Thus, a further increase in the speed of any object is prohibited when the atoms and molecules of the object start radiating energy waves. In reality, the speed of the molecules or particles is decreased to conserve energy.

Our assertion is that the speed of a particle is decreased below the speed of light as the energy content of the particle is dissipated in emissions of radiation. This fact is consistent with Erwin Schrödinger's findings in 1925. He derived the wave equations to model the behavior of light particles as a wave propagating in one, two, and three dimensions. An elementary analysis of the energy radiation by excited atoms is found in French and Taylor [3]. The analysis, though not rigorous, provides quantitative expressions for irradiative life times and the rate of energy radiation from atoms. Further, the same analysis derives the selection rules for the initial and the final quantized energy states of electrons. The rules govern possibility of an electric dipole transition event when an electron in orbit changes its state.

It is well known that waves are generated when any particle, string, wire, or metal rod vibrates upon the application of stress. The wave produced is characterized by the frequency of the normal oscillation modes of the system. Schrödinger stated that for every wave, there is a particle in motion responsible for its creation. He described this as a wave-particle duality. Clearly, the wave-particle duality is different from the dual nature about the behavior of light, i.e., wave and particle. Waves at any frequency (sound, electromagnetic, X-rays, laser, maser, and visible light waves), are carriers of energy. It is undeniable that sound waves consist of particles of matter.

Let us ask a simple question, why should light waves be treated differently from the sound waves? One of the major difference between visible light waves and sound waves is that light waves are transverse waves and sound waves are longitudinal waves. Transverse waves propagate normal to the direction of vibrations, whereas longitudinal waves travel along the direction of the waves. Another difference is that light waves are of a very high frequency and do not require a medium to propagate. In fact, the light waves in the visible spectrum are released by a process similar to the process involved in the production of lasers and masers. Figure 1.1 illustrates an example of a radiation event caused by light or thermal energy. Typically, wave energy is released in a radiation event by electron excitation, when an electron in the outer shell makes a transition to a lower shell orbit. This transition can occur when thermal energy is applied to matter or when high field strength is induced by applying an electrical potential, as in the case of a solid state laser.

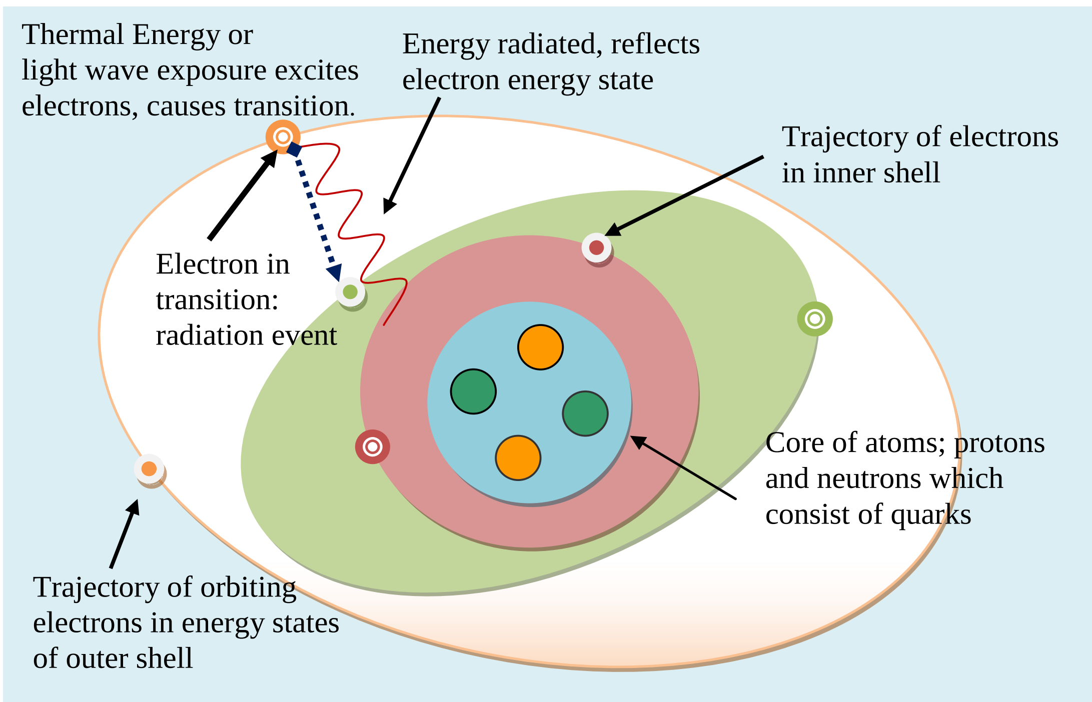


Figure 1.1 Radiation event: An orbiting electron in excited state**.** When orbiting electrons are exposed to the light energy waves, they are excited, triggering an orbital transition event. The electrons radiate energy waves at a frequency that corresponds to the energy difference between the initial and final quantum states.

From our discussion, we infer that all radiation waves are created by dissipation of energy from an electron in an orbit transition event. The loss of energy by electron vibration is manifested in the form of radiation waves. The energy content of these waves are quantized, a fact first discovered by one of the greatest of physicists, Max Planck, in 1900. It is found that the quantized energy wave packets behave identical to particles in a certain sense and obey the laws of the conservation of momentum and the conservation of energy. However, these packets of waves, as described formally by Einstein as photon particles, have suffered a subtle difference in their properties to those of actual particles. They do not exhibit a force of gravity on particles or other waves. Therefore, we identify the photon particles as virtual particles. Particles that show gravity characteristics are known as real particles, in our context. It is clear that Einstein erroneously modeled behavior of light waves as dual, behaving sometimes waves and occasionally as particles. From now on, we will model the behavior of radiation waves as virtual particles and distinguish them from real particles of ordinary matter because of the underlying difference in their natural behavior.

The content of this chapter is organized as follows: In Section 1.1, we succinctly explain why it is important to model the behavior of light very accurately. Then, it is clarified that only the wave model of light makes sense rather than the particle model. The discussion follows to explicate why the absolute speed of light can be attained by particles with non-zero rest mass. In Section 1.2, the example of light trajectory in an accelerating elevator is explained based on a wave model of light. In Section 1.3, we will review basic principles of classical mechanics, motion of particles under constant acceleration, laws of conservation of momentum and conservation of energy. It is important to review these principles because famous physicists have incorrectly applied these laws to create an ambiguous dual model for light behavior, as a wave and a particle.

In Section 1.4, we will discuss why the bending of light arriving from distant stars passing by the Sun is not deflected by the Sun's gravity. Einstein suggested that light rays arriving from a star, positioned behind the Sun with respect to Earth, bent due to the force of gravity from the Sun. He suggested one could test this during a solar eclipse event. It is our conception that the principal cause for starlight bending around the Sun was because of the refraction of this light through the atmosphere of the Sun's corona. We compared the results of the bending of light phenomenon by four methods of computation, Einstein's Formula, Newton's Kinematics, by applying Snell's refraction law and an empirical relationship suggested by physicist from India Dr. R. C. Gupta.

In Section 1.5, the operation of Michelson's interferometer apparatus is described whereby the purpose of whuch was to measure the rotational speed of the Earth's orbit around the Sun. For reasons explained, his attempts to measure the speed were unsuccessful. Further, it is explained why his experiment did not prove that the classic Lorentz length contraction occurs. In Section 1.5.1, we will discuss the assumptions that were made which led to the wrong conclusion which, in turn, emphasized the need for the special theory of relativity postulates proposed by Einstein. In Section 1.5.2, an improved design for Michelson's interferometer is suggested by us. The newly designed apparatus, Sky's interferometer, allows us to precisely measure the orbital speed of the Earth around the Sun. Though Michelson's apparatus did not provide satisfactory results for orbital speed measurements, modified designs of his apparatus are applied to measure speed/wavelength of light and refractive index of gas and glass plates. We will explicate details of the alternate interferometer for the successful application of its measurement in Section 1.5.3.

In Section 1.6, we demonstrate that the conclusions drawn from outcome of the experiments favoring particle theory did not provide sufficient evidence for the particle model of light. Therefore, the results from three experiments, the Photoelectric effect, the Short wavelength limit X-rays, and the Compton effect are investigated in greater depth than prior attempts in Sections 1.6.1, 1.6.2, and 1.6.3 respectively. Our investigation proves that light is a wave as opposed to the claims made by the performers of the experiments, namely a particle. Further, our investigation in this section allows us to distinguish real particle of substances found abundantly in the Universe from virtual particles of light and radiation energy waves.

In Section 1.7, we discuss the details of the single most important effect in physics, the Doppler's shift, to prove that light is a wave. Also in this section, we analyze the results of the rotation of fan blades experiment, to prove that light is definitely a wave. Further, zero shifts between the absorption and emission line spectra of various elements, strictly proves that the radiation from the atoms of the elements is wave. We have included several events associated with light propagation to prove that light behaves as a wave in reality.

1.1 Light: A Wave or a Particle?

According to Einstein's special theory of relativity (STR), light exhibits its behavior as a particle and he named these particles photons. Also, in his general theory of relativity (GTR), he stated that a beam of light will bend and slow down under the influence of a force field, such as gravity. In astronomical measurements, it matters if the path of light from stellar objects such as galaxies, nebulae and stars is straight, as per projections from **Skylativity®** theory vs. if it is curved by force of gravity in accordance with Einstein's GTR. To support Hubble's law for expansion of Universe and for determination of the age and size of the observable Universe, it is assumed that light from distant galaxies have travelled in a straight line. Furthermore, Newton's theory of gravitation estimated the trajectory of objects having non-zero rest mass with high accuracy, so it is important to discriminate the nature of light, whether it is a wave or a particle. A natural characteristic of a particle that distinguishes it from a wave entity is particles have rest mass, a center of gravity, and project a force of gravity on other particles.

Without considering the fact that light waves have no center of gravity, Einstein's GTR predicted the bending of light in the presence of strong gravitational fields. He suggested that the path of entities such as waves and particles will follow a curved, geodesic trajectory, because the space/time of all geometries in a space fabric is curved. Because trajectory of different objects in the same volume of curved space is influenced by factors dominated by other types of phenomena, in particular the refraction effect (Scattering of light by electrons of gas atoms) it is not sensible to apply space/time curvature to fabric of space. According to recent developments, space is composed of quantum fluctuations and possesses ground state energy. The distribution of the energy wave function is only approximately uniform. Therefore, curvature inside the fabric of space is not predictable with a very high degree of accuracy. Our discussion of GTR will intensify this point in Chapter 8. At this juncture we will stick to the notion that light waves travel in a straight line unaffected by gravity because they are not particles.

Since antiquity, people observed that the propagation speed of the light and all radiation waves were considerably faster than the speed of sound and other forms of mobile transportation. A natural question for the scientific community over the past few centuries was whether any object could travel at speeds in excess of the speed of light. Einstein, with his visionary mind, answered the question that no object can travel at speeds faster than the speed of light c. We have taken a different position on the issue. We believe that objects with non-zero rest mass *can* travel at any speed, even above the speed of light, if enough energy is supplied to the object to accelerate it to that speed, and if the object did not consume some energy in the form of radiation.

In the following two sections, we will demonstrate that light does not bend by a force of gravity and that its trajectory is unaffected by gravity, or for that matter any other accelerating force, because light is a wave. Further, in Section 1.3, we will explicate why the bending of light by the force of gravity would provide catastrophic results when one projects the positions of huge celestial objects such as the nebulae and the billions of stars inside neighboring galaxies. In the following section, we will discuss the details of the trajectory of light from a flashlight carried by a person in a moving elevator.

1.2 Accelerating Elevator Experiment

In his example of a man traveling inside a moving elevator, Einstein postulated that a light beam emitted from a flashlight carried by the man in a moving elevator will strike the wall in front of him at a different spot than the spot at a normal angle to the wall. He claimed that this was due to the bending of light caused by the force of gravity on photons. According to our view, the beam will strike at an offset, because of the upward motion of the elevator. Figure 1.2 (a) illustrates how the path of a light beam is traced when an elevator is stationary with respect to the surface of the Earth. In Figure 1.2(b), the path of a light beam, as predicted by Einstein's theory, is shown for the instant the elevator is traveling away from the surface of the Earth. For the same situation, the path projected by new concepts stated by us is illustrated in Figure 1.2(c).

One can determine the position of the light beam when it reaches the other side wall inside the elevator as follows: the light beam will continue to travel in a straight line after it is separated from the light emitting source. It will take **S/c** s for the light to reach the wall. During that elapsed time, the elevator has moved upward by a distance of **(S/c) × V_{avg} m** because it is assumed that it is moving upward at the rate of **V_{avg} m/s**, a motion under constant acceleration. Here, **S** is the spacing of the wall from the flashlight and **V_{avg}** is the velocity of the elevator. Therefore, the observer inside the elevator will visualize that the light ray has bent. Thus, the light will hit the wall at right angle to the wall with an offset distance **D** from the point of the normal incident when the elevator was stationary.

$$\boxed{D = (S / c) \times V_{avg}} \quad (m) \qquad (1.1)$$

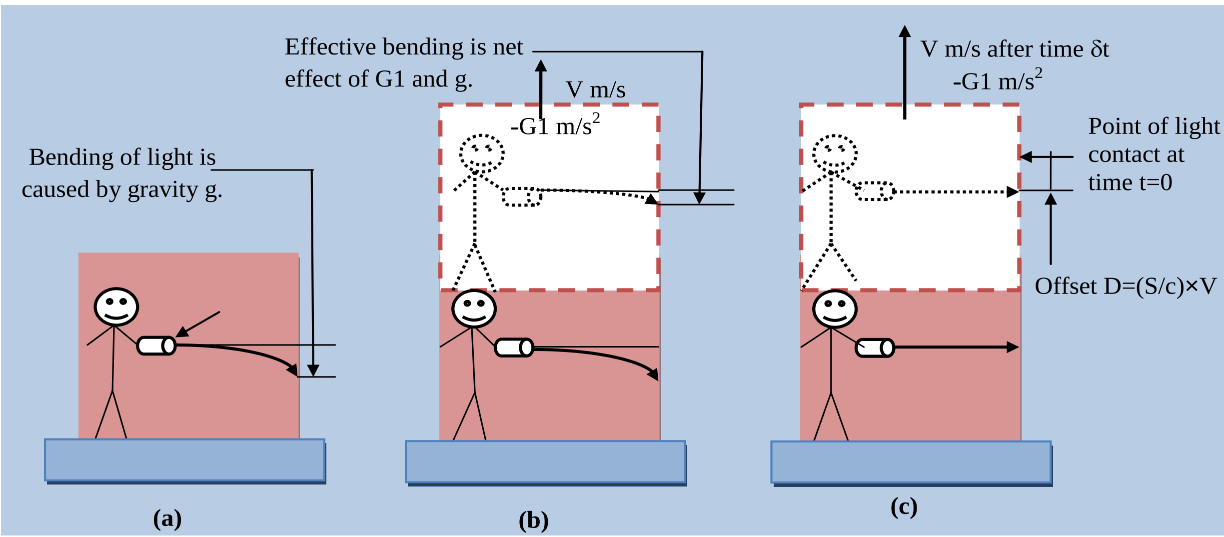


Figure 1.2 Path of light from a flashlight in an elevator**.** (a) The path of light when the elevator is on the surface of the Earth (Einstein's theory of relativity). (b) The path of light when the elevator is moving upward with an acceleration of **-G1** as projected by Einstein's theory. (c) The path of light when the elevator is moving upward with an acceleration of **-G1** as projected by the **Skylativity**® theory. The point of contact of the light to the wall is always at a right angle (90°) in the case of the **Skylativity**® theory.

We are implying that the light wave will reach the other side of the wall at a point at a right angle to the beam, regardless of the motion of the elevator in accordance with the Christian Huygens principle. Huygens' Principle proposed a geometric method and construction for determining the position of a new wave front at some later instant by using knowledge of an earlier wave. Einstein's theory projected that the path of the wave will be curved and will bend by the force of gravity. It is very important to compute the distance between the normal position on the wall and the contact point of the light by the offset method instead of attributing a bending of light by gravity. The main reason for this is that light waves do not have rest mass and a center of gravity. Therefore, the light rays from a flashlight in the moving elevator will not bend by the force derived from the acceleration of an elevator, nor will they bend due to Earth's gravitational field. You will discover in Section 8.6, Quantum gravity, that gravity (or when elevator moves upward at constant acceleration) should change the frequency of light waves emitted from a flashlight.

A direct effect of the finite velocity of light and the Earth's rotation was discovered by James Bradley in 1927 [4]. He found that the position of all stars appeared to execute a common annual motion that is evidently a counterpart to the rotation of the Earth around the Sun. Therefore, a ray of light coming from a star and striking the objective lens of a telescope appears to come from another direction. Because of the Earth's rotation around the Sun, the ray does not reach the eyepiece. Instead, it reaches the wall behind the viewing telescope, as illustrated in Figure 1.3.

Some scientists claimed that the measured displacement of the star was partly due to the bending of light caused by the gravitational field from the Sun. As explained later, the bending of light is primarily because of the refraction of light caused by the change of refractive indices between the vacuum in free space and the air of Earth's atmosphere. The change of the refractive index between atmospheric air and the vacuum in space should result in a measurable difference in the speed of light. In order to observe a fixed star, the telescope needs to be tilted in the direction of the Earth's rotation that compensates for the displacement in the position of the eyepiece. While the light rays arriving from the star traverse the length **L** of the telescope in time **(L/c) s**, the Earth and the eyepiece of the telescope move by the distance **d**, in Figure 1.3. The light rays will strike the eyepiece only if distance:

$$\mathbf{d = v \times (L/c)} \quad \mathbf{(m)} \qquad \mathbf{(1.2)}$$

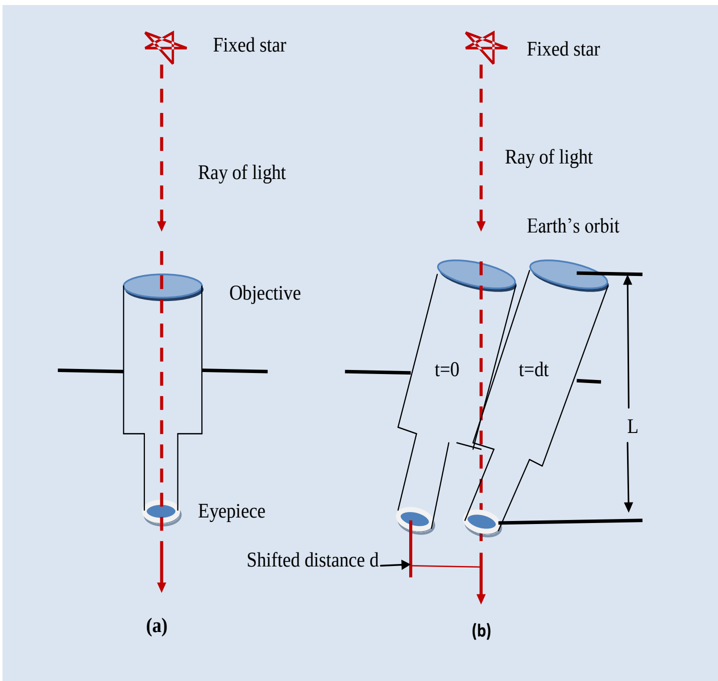


Figure 1.3 Observed position of a star is affected by the Earth's orbital rotation. (a) Observation of a fixed star, the Earth at rest. (b) The telescope is inclined to compensate the Earth's orbital motion. (Courtesy of Max Born, Einstein's theory of Relativity)

The angle of tilt for the telescope is determined by ratio **v/c** where **v** is the speed of the Earth's rotation and **c** is the speed of light which is also equal to ratio **d/L**. The ratio **v/c** is known as the aberration constant **β**. The inclined axial position of a telescope does not point to the true position of the star, but to a point in the sky that is displaced in the direction of **v**. The speed **v** is **30 km/s**, whereas the speed of light is **~300,000 km/s**. Therefore, the tangent of the angle of tilt is **1/10,000**. The value of **β** can be precisely determined by measuring the elliptical motion of a fixed polestar, such as Polaris. This measurement provided a very accurate technique for the computation of the speed of light **c**.

Newton's law of gravitation was initially applied to estimate deflection of star light behind the Sun by its gravitational force. One of the deficiencies of Newton's theory of gravitation is that it did not address the motion of wave entities in the presence of ponderous celestial objects effectively. For objects such as light waves with zero rest mass, Newton's equation did not predict acceleration in steady state because photons of light have zero inertial rest mass and lack a center of gravity. Newton's Universal law of gravitation did not explicate why the gravity of large objects should affect photon particles of light waves. Further, it will be evident from our review of classical mechanics Section 1.3 that Newton's law did not predict acceleration of particles with zero rest mass. Newton's Universal law of gravitation states:

Newton's Universal Law of Gravitation → Every massive particle in the Universe attracts every other massive particle with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between the center of gravity of both masses.

In symbolic notation

Every point particle attracts every other point particle by a force pointing along the line intersecting center of gravity of both point particles. The force is directly proportional to the product of the their masses and inversely proportional to the square of the distance between the masses:

Newton's Universal Law of Gravitation → $\mathbf{F = G \times m_1 \times m_2/r^2}$ **(N)** **(1.3)**

where **F** is the magnitude of the gravitational force between the two point masses, **G** is the gravitational constant, $\mathbf{m_1}$ is the inertial mass of the first particle of nonzero value (mass of photon fails this test as it has zero rest mass), $\mathbf{m_2}$ is the inertial mass of the second point particle, mass of the Sun, and **r** is the distance between the centers of gravity of two point particles.

You will discover in Chapter 8, that Einstein's generalized theory of gravitation did not completely solve the problem either. According to the theory of special relativity, the material mass (rest mass) of a light photon is zero. By definition of real particles, photons are not particles because particles have a finite mass in any frame of reference and a fixed position for the center of gravity. Since a photon does not contain any matter, it has zero rest mass and therefore it should not suffer deflection in the presence of gravity from vastly massive objects.

In this book, we support the viewpoint that a light beam and radiation waves always travel in a straight line unless they are refracted by scattering phenomena in space. The light beam should not bend or deflect, and need not obey Sir Isaac Newton's gravitational laws because gravity does not have any effect on an object with zero rest mass. On the other hand, it is important to note that there has been no event in which the gravity effect from the light waves on other waves or particles has been observed. Meaning, no matter how intense the light wave energy projected from any source may be, there is no force of gravity detected from said incident light affecting objects, particles, or waves. This fact provides further evidence and increases confidence in our proposed theory that light waves do not bend by force of gravity. It is well known that the force on an object mass **m kg** is computed from expression:

Newton's Second Law → $\mathbf{F = m \times a}$ **(N)** **(1.4)**

The gravitational acceleration **a** for photon of mass $\mathbf{m_1}$ kg in the presence of a strong gravitational field from the Sun is computed by equating expressions **(1.3)** and **(1.4)**

$$\mathbf{m_1 a = G\, m_1 m_2/r^2}$$

This equality provides satisfactory and valid results only for the case when rest mass $\mathbf{m_1 \neq 0}$.

Acceleration of photon $\mathbf{a = (G \times m_2)/r^2}$ **(1.5)**

It is found that one can't accelerate or retard speed of light by any means after it is created. The velocity of light is not modified other than the refraction and reflection phenomena. Einstein proposed that a photon has non-zero mass due to its inertia. From his formula, $\mathbf{E=mc^2}$, the rest mass equivalent of **E units** of light energy is:

$$\mathbf{m_0 = E/(\text{Square of the Speed of Light}) = E/c^2} \quad \textbf{(1.6)}$$

$\mathbf{m_0}$ signifies the mass of a photon at rest which is not pragmatic and is unrealistic. Speed of light waves cannot be reduced to zero by any means unless light is absorbed by matter that is exposed to light. We like to name this energy mass of photons as an imaginary mass because it does not exist physically, it is not real. The mass computed from equation **(1.6)** provided the value of hypothetical mass for radiation energy at any frequency. You will learn more about rules of engagement between light and matter in Chapter 6, Quantum Electrodynamics formulated by Richard Feynman.

Later in this Chapter, you will discover that energy **E** in expression **(1.6)** is numerically equal to $\mathbf{h} \times \boldsymbol{\nu}$ units. This expression is very important and you will find it repeated many times in this text book. When it relates to photons, this energy mass $\mathbf{m_0}$ is not concentrated but is distributed with respect to its position. Furthermore, for any trajectory of light, a given photon never repeats its physical location. Therefore, the center of gravity for a photon is not known precisely. Furthermore, as stated by the Heisenberg uncertainty principle, one cannot determine the position and momentum of any particle at the same time with the same precision [3]. Our point is that the center of gravity location for light waves is indeterminate. The Newtonian gravitational force acts between two bodies with a deterministic center of gravity.

Before we discuss bending of light by gravity in great details, it is imperative we review principles of classical mechanics. Therefore in next section we will study motion of particles and objects under constant acceleration in x,y and z directions. Also, we will define conservative and nonconservative forces, and distinguish between isolated and nonisolated systems. Further, we will explicate the law of conservation of momentum during elastic and inelastic collision events. In addition, we will expound the law of conservation of energy in a system of particles and objects. Finally, we will explain the relationship among force, work and energy.

1.3 Classical Mechanics, Review

Classical mechanics deals with the motion of particles in x, y and z directions by treating them as point-like objects. Point-like objects have characteristics of a very large mass (ideally infinite) compared to their size (ideally zero), and compared to the extent of motion under consideration. In mechanics, the motion of objects is classified into three types: translational, rotational and vibrational. In this section our discussion is confined to translational motion only. We will discuss the concepts of position, velocity and acceleration from an instantaneous and average value stand point. Further, we will distinguish between two terms, the displacement and the distance, when a particle traverses paths. Also, we will differentiate between the velocity and the speed of particles.

1.3.1 Displacement, Velocity, and Acceleration

When it comes to position of particles, one is naturally interested in change in position, displacement of a particle over a known interval of time. Another quantity of interest is known as distance parameter which is defined as the length of path traversed by a particle over a time interval. The primary distinction between displacement and distance, displacement is a vector quantity that has magnitude and direction, whereas distance is completely specified by a scalar value and no direction.

Consider a particle whose initial position is x_i at time t_i and its final position is x_f at time t_f. Then the magnitude of displacement Δx over time interval $\Delta t = t_f - t_i$ is given by

$$\mathbf{\Delta x = x_f - x_i} \tag{1.7}$$

The distance traversed by the particle over the same interval of time is given by

$$\mathbf{\Delta d = \sum_{C=0}^{n} \delta x_c} \tag{1.8}$$

where c describes the instant at which the particle's position vector changed it's direction, and δx_c is the path length difference between the successive positions of particles. Also c = 0 corresponds to time t_i and c = n corresponds to time t_f.

In calculus, the rate of change of displacement of a particle with respect to time is defined as the velocity of the particle. The average velocity $\mathbf{v_{avgx}}$ is computed as a ratio of particle's displacement $\mathbf{\Delta x}$ and the interval the displacement occurred $\mathbf{\Delta t}$. i. e.

$$\mathbf{v_{avgx} = (\Delta x/\Delta t) \times i} \quad \mathbf{(m/s)} \tag{1.9}$$

The sign of average velocity is determined by the sign of displacement that is positive if the displacement is increasing in the direction of positive x-axis. Obviously, average velocity is a vector quantity. If velocity is confined to one dimension, its direction is specified by + or – sign. If velocity is confined to two directions, x and y, it is expressed as

$$\mathbf{v_{avgxy} = (\Delta x/\Delta t) \times i + (\Delta y/\Delta t) \times j} \quad \mathbf{(m/s)} \tag{1.10}$$

If velocity is confined to three dimensions, x, y and z, it is expressed as

$$\mathbf{v_{avgxyz} = (\Delta x/\Delta t) \times i + (\Delta y/\Delta t) \times j + (\Delta z/\Delta t) \times k} \quad \mathbf{(m/s)} \tag{1.11}$$

Here, **i, j,** and **k** represent vectors of unit length in the direction of the respective axis, **x, y** and **z**. By convention, all the vector quantities are printed as bold face letter fonts and scalar quantities are printed in normal text fonts. Let us define the scalar quantity of the average speed of a particle. Average speed $\mathbf{v_{avgs}}$ of the particle is computed by the expression

$$\mathbf{v_{avgs} = \Delta d/\Delta t} \quad \mathbf{(m/s)} \tag{1.12}$$

where $\mathbf{\Delta d}$ is the total distance travelled over time interval $\mathbf{\Delta t}$.

To understand the behavior of a particle precisely, often it is important to know its velocity or the speed of a particle at a particular instant in time. For instance, we would like to know what the average acceleration (rate of velocity change) of a particle is between two positions. Therefore, let us define the concept of instantaneous values for velocity and acceleration. Instantaneous velocity of a particle is defined as its average velocity, in the limited case where the time interval Δt shrinks and approaches zero. In differential calculus, this limit is called the derivative of x with respect to t and denoted as such.

$$\mathbf{v_{instx} = \lim_{\Delta t \to 0} v_{avgx} = (dx/dt) \times i} \quad \mathbf{(m/s)} \qquad \mathbf{(1.13)}$$

Corresponding to the instantaneous velocity of particle, the instantaneous speed $\mathbf{v_{speedx}}$ of the particle is defined as the magnitude of the instantaneous velocity, which is a scalar quantity. In vector calculus, the rate of change of velocity of a particle with respect time is defined as an acceleration of the particle. The average acceleration $\mathbf{a_{avgx}}$ is computed as a ratio of particle's differential velocity $\mathbf{\Delta v_x}$ and the interval the displacement occurred $\mathbf{\Delta t}$ i. e.

$$\mathbf{a_{avgx} = (\Delta v_x / \Delta t) \times i} \quad \mathbf{(m/s^2)} \qquad \mathbf{(1.14)}$$

where $\mathbf{\Delta v_x = v_{instxf} - v_{instxi}}$.

The sign of average acceleration is determined by the sign of differential velocity $\mathbf{\Delta v_x}$**,** the value of which is positive, if the acceleration is increasing in the direction of the positive x-axis, and the value of which is in negative if acceleration is diminishing in the direction of the negative x-axis. Now let us explain the concept of instantaneous acceleration. Instantaneous acceleration of a particle is defined as the average acceleration of a particle in the limit case where time interval Δt shrinks and approaches zero. In differential calculus, this limit is called derivative of $\mathbf{v_{instx}}$ with respect to t and denoted as such.

$$\mathbf{a_{instx} = \lim_{\Delta t \to 0} v_{instx} = (dv_{instx}/dt) \times i = d(dx/dt) \times i/dt = d^2x/dt^2 \times (i)} \qquad \mathbf{(1.15)}$$

When the acceleration of a particle varies in time, its motion can be very complicated and difficult to comprehend. Analysis of a situation wherein objects travel with variable attention requires special treatment. Therefore, we will leave the discussion of the topic for more advanced texts [11]. In the next section we will concentrate on the motion of particles under constant acceleration. Specifically, we will describe the events related to the motion of huge celestial objects in the Universe such as stars, black holes and galaxies.

1.3.2 Motion under Constant Acceleration

Since we are interested in understanding concepts related to astronomy and space applications, it makes sense to consider the motion of celestial objects under constant acceleration. From stability considerations, our Universe is very sparsely populated with different types of celestial objects, stars, planets, nebulae, and galaxies. Hence, for the most part, it will suffice to model behavior of astronomical objects under steady state conditions. Therefore, we will limit our discussion for the case of motion at constant acceleration, wherein the value of instantaneous acceleration equals average acceleration. We will also deal with the motion of particles with variable acceleration occurring during a transient phase in Chapter 8, Quantum Theory of Gravitation. You will discover that Einstein's General Theory of Relativity successfully addressed the issue of particles under variable acceleration, which was the greatest triumph of the 20th century, and his contribution. It is unfortunate that his theory failed to unify gravity with quantum forces of fundamental particles in the nucleus of atoms. Now, let us analyze a model for the particle under constant acceleration.

For expression of $\mathbf{a_{avgx}}$ in equation **(1.14)** if we assign $\mathbf{t_i = 0}$ at the start, $\mathbf{t_f = t}$ at any later time, and rearrange terms, we get

$$\mathbf{v_{xf} = v_{xi} + a_x t} \quad \text{(for constant acceleration)} \qquad \textbf{(1.16)}$$

where $\mathbf{a_x}$ is constant acceleration, $\mathbf{v_{xf}}$ instantaneous final velocity and $\mathbf{v_{xi}}$ instantaneous initial velocity.

Thus, we can calculate the final velocity of a particle or an object, given the value of velocity of the particle at the beginning, value of time t, and value of constant acceleration. From equation **(1.16)** it is evident that at constant acceleration, the velocity of any particle varies linearly with time. Therefore, the average velocity of a particle at any time is computed as the arithmetic mean of the initial velocity $\mathbf{v_{xi}}$ and the final velocity $\mathbf{v_{xf}}$

$$\mathbf{v_{avgx} = (v_{xi} + v_{xf})/2} \quad \text{(for constant acceleration)} \qquad \textbf{(1.17)}$$

To obtain the final position of a particle $\mathbf{x_f}$ as a function of time, we substitute $\mathbf{t_i}$ and $\mathbf{t_f}$ values in equation **(1.9)**, given the value of the initial position $\mathbf{x_i}$ and the value of its average velocity. Hence $\mathbf{x_f - x_i = v_{avgx} \times t}$

From equation **(1.17)** for average velocity $\mathbf{v_{avgx}}$ we get

$$\mathbf{x_f = x_i + \tfrac{1}{2} \times (v_{xi} + v_{xf}) \times t} \quad \text{(for constant acceleration)} \qquad \textbf{(1.18)}$$

By substituting the value of $\mathbf{v_{xf}}$ in terms of $\mathbf{v_{xi}}$ and $\mathbf{a_x}$ from equation **(1.16)** into equation **(1.18)** and by simplifying we get

$$\boxed{\mathbf{x_f = x_i + v_{xi} \times t + \tfrac{1}{2}\, a_x \times t^2}} \quad \text{(for constant acceleration)} \qquad \mathbf{(1.19)}$$

This equation provides the value of the final position of the particle at any time t in terms of initial position, initial velocity, and the constant acceleration.

Finally, we can derive an expression which predicts the final velocity of a particle without the appearance of a time variable in the expression. We achieve this by substituting the value of t from equation **(1.16)** into equation **(1.19)**. Upon simplification and rearrangement of terms we get

$$\boxed{\mathbf{v^2_{xf} = v^2_{xi} + 2a_x \times (x_f - x_i)}} \quad \text{(for constant acceleration)} \qquad \mathbf{(1.20)}$$

It is obvious that we can extend the application of the equations developed for the motion of particles in one direction at constant acceleration to model the motion of particles in two directions x, y, and to model the motion of particles in three directions x, y and z. Motion in multiple directions can be analyzed as two or three independent motions in each of the perpendicular directions x, y and z for respective cases. That is, any influence of a direction which is orthogonal to any other direction would not affect the motion of a particle in the direction under consideration, and vice versa. Again, it is assumed that acceleration of particles is constant in each of the different orthogonal directions, yet is of different values. Next, we will explicate the concepts of conservation of momentum and conservation of energy for system of particles undergoing motion at constant acceleration.

1.3.3 Conservation of Momentum and Energy

First, let us comprehend why concepts of conservation of momentum and conservation of energy are important considerations for modeling light behavior as particles. You will discover in Section 1.6 that physicists in favor of the particle model for radiation energy waves performed experiments to justify their premise. The three experiments to validate particle behavior of energy waves, i.e., visible light and X-rays, were the Photoelectric effect, the Short wavelength limit X-rays, and the Compton effect. To analyze details of the results from the experiments, physicists applied the principle of conservation of momentum and conservation of energy to photon particles of light and X-rays. They discovered that the energy of photon particles of light and the energy of photoelectrons were conserved in the Photoelectric effect whereby photons interacted with electrons of a metal target. Also, they found that the momentum of X-ray particles were conserved before and after their interaction with electrons of the target metal in two experiments, the Short wavelength limit X-rays experiment and the Compton effect experiment.

Retrospectively, we wish to define momentum and the work done by forces (conservative and non-conservative, terms explained shortly) in isolated systems of particles and objects. Since Newton's laws of motion provide the definition of force and momentum we will state his three laws.

Newton's First Law → Everybody in this Universe maintains its state of rest or of uniform motion unless compelled by an external entity when viewed from an inertial reference frame.

Quantitatively, Newton's First law defined the mass of an object as an inherent property. He insisted that the mass should be independent of the object's environment and independent of the method used for measure respecting the object. An important conclusion drawn from his first law was the magnitude of the acceleration of an object is inversely proportional to its mass when it is acted upon by a force. In expression form, for a given force

$$\mathbf{m_1/m_2 = a_2/a_1} \qquad \textbf{(1.21)}$$

where $\mathbf{m_1}$ is mass of first object, $\mathbf{m_2}$ is mass of second object, $\mathbf{a_1}$ is acceleration of first object when acted by force $\mathbf{F}$, and $\mathbf{a_2}$ is acceleration of second object when acted upon by the same force $\mathbf{F}$.

Newton's Second Law → The time rate of change of the linear momentum of a particle is equal to the net force acting on the particle of invariant mass with respect to time.

Quantitatively, Newton's Second law defined linear momentum of a particle as a product of its mass and its velocity. Naturally, momentum is a vector quantity which requires magnitude and direction for complete specification. An alternate form of Newton's Second law relates the acceleration of an object with its mass. When viewed from an inertial reference frame, the acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass. Both these definitions are important. From the first and the second definitions we get,

$$\sum \mathbf{F} = d(m \times \mathbf{v})/dt = d\mathbf{p}/dt = m\mathbf{a} \quad \text{(constant mass)} \qquad \textbf{(1.22)}$$

where linear momentum $\mathbf{p} = m \times \mathbf{v}$ and acceleration $\mathbf{a} = d\mathbf{v}/dt$

Newton's Third Law → If two objects interact in isolated system, the force F_{12} exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force F_{21} exerted by object 2 on object 1.

Quantitatively, Newton's Third law implied conservation of momentum, that is, whenever two or more particles in an isolated system interact, the total momentum of system remains constant. From the definition of the third law we get $\mathbf{F_{12} = - F_{21}}$ or in terms of momentum $d/dt\,(\mathbf{p_1} + \mathbf{p_2}) = 0$

Because the time derivative of total momentum is zero, we infer that the total momentum of the isolated system of particles must remain constant before and after interaction of the particles, i.e., initial total momentum = final total momentum

$$\mathbf{p_{1i} + p_{2i} = p_{1f} + p_{2f}} \tag{1.23}$$

where prefixes i signifies momentum condition at the start of interaction between particles and f signifies momentum values at the end of interaction between the particles.

Concerning momentum for a system of particles: When two particles approach their motion's end in a collision event, the collisions between the particles are classified in two varieties, elastic collision and inelastic collision.

A collision between two objects is elastic if the total kinetic energy of the system is conserved as well as the total momentum is conserved, meaning the values of kinetic energy and momentum before and after the collision do not change.

A collision between two objects is inelastic if the total kinetic energy of the system is different before the collision and after the collision, but the total momentum of the system is conserved. When two objects stick together after a collision the collision is called perfectly inelastic.
For elastic and inelastic collision:

$$\mathbf{m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}} \tag{1.24}$$

For perfectly inelastic collision:

$$\mathbf{m_1v_{1i} + m_2v_{2i} = (m_1 + m2) \times v_f} \tag{1.25}$$

where $\mathbf{m_1}$ is mass of first particle, $\mathbf{v_{1i}}$ and $\mathbf{v_{1f}}$ velocity of $\mathbf{m_1}$ before and after the collision, $\mathbf{m_2}$ is mass of second particle, $\mathbf{v_{2i}}$ and $\mathbf{v_{2f}}$ velocity of $\mathbf{m_2}$ before and after the collision, and $\mathbf{v_f}$ is the velocity of the combined mass as both particles joined after a perfectly inelastic collision.

Principle of conservation of energy deals with conservative forces and nonisolated systems. Therefore, we will distinguish between conservative and nonconservative forces. Also, we will understand the difference between isolated and nonisolated systems.

A force is conservative if the work done in moving a particle between any two points is independent of the path **c** taken by the particle and the work done is zero if any path is closed. If the conditions specified for conservative forces are not satisfied then the force is nonconservative.

To expound upon the principle of conservation of energy, it is imperative to learn the details of the relationship between force, work, kinetic energy, and potential energy in isolated system.

If $\Delta \mathbf{r}$ represents the displacement of a particle caused by the application of a conservative constant force $\mathbf{F}$, then work W_c done by the force is given by the product of the magnitude of the component of force in the direction of $\Delta \mathbf{r}$ and the displacement $\Delta \mathbf{r}$.

$$\mathbf{W_c = F\cos\theta \times \Delta r \ (N \bullet m)} \qquad \mathbf{(1.26)}$$

where θ is angle between $\mathbf{F}$ and $\Delta \mathbf{r}$

In the case of a variable force $\mathbf{F(x)}$, the work done by the force on a particle as it moves from distance x_1 to x_2 is obtained by calculating the area under the curve of plot $\mathbf{F(x)}$ vs. $\mathbf{x}$. In calculus, the area is represented by evaluating the integration of the force function over the interval x_1 and x_2. When the displacement of a particle is in the same direction as the force, the potential energy of the particle decreases. Thus we can express the following relationship between the work W_c, the conservative force $\mathbf{F(x)}$ and the potential energy $\mathbf{U}$, if the speed of the particle does not change.

$$\mathbf{W_c = \int_{X1}^{X2} F(x)\,dx = -\Delta U} \qquad \mathbf{(1.27)}$$

In a situation for which the work done by the force is strictly transformed into the variation of speed, the kinetic energy $\Delta \mathbf{K}$ in the system is altered. In that scenario, the work done appears as a change in kinetic energy of the system. Using Newton's second law relation $\sum \mathbf{F} = \mathbf{ma},$ and then performing the chain-rule of manipulation [19], we get.

$$\mathbf{W_c = \int_{X1}^{X2} F(x)\,dx = \tfrac{1}{2}\, m v_f^2 - \tfrac{1}{2}\, m v_i^2 = \Delta K} \qquad \mathbf{(1.28)}$$

Now, let us define isolated systems and nonisolated systems. An energy model of a system is nonisolated if, in the system, energy crosses the boundary of the system during some time interval due to interaction with environment, such that the internal energy of the system (temperature, enthalpy) is modified. This results in a change in the system's total energy.

In isolated systems, energy does not cross the boundary of the system due to interaction with environment. For this system, the total energy of the system remains constant. If only conservative forces act on an isolated system, we can apply the work-kinetic energy theorem only when there is a change in the system's speed.

Work-kinetic Energy Theorem → When work is done on a system and the only change in the system is in its speed, the net work done on the system equals the change in kinetic energy of the system.

In experiments to validate the particle nature of photon, we deal only with isolated systems and conservative forces only. Therefore, our focus is on the conservation of energy theorem restricted to isolated systems. The main reason is that there is no change in the internal energy of the system under consideration during any time interval of interaction.

Conservation of Energy Theorem → If a system is isolated and if only conservative forces are acting on particles or objects inside the system, the total mechanical energy of the system is conserved. i. e.

$$\mathbf{K_f + U_f = K_i + U_i} \qquad \mathbf{(1.29)}$$

If nonconservative forces act between the objects inside a system, mechanical energy is not conserved. In these situations, the difference between the total final mechanical energy and the total initial mechanical energy of the system equals the energy transformed to internal energy by the nonconservative force.

As stated earlier for an elastic collision, not only is the momentum conserved, but the kinetic energy of the isolated system is also conserved. Therefore, for an elastic collision between two particles, in addition to equation **(1.24)**, the following condition must be satisfied:

Initial Kinetic Energy = Final Kinetic Energy

-assuming that potential energy did not change. If the potential energy changes, then we should apply equation **(1.29)**

$$\mathbf{½\, m_1v^2_{1i} + 1/2m_2v^2_{2i} = ½\, m_1v^2_{1f} + 1/2m_2v^2_{2f}} \qquad \mathbf{(1.30)}$$

Our studies of the laws of conservation of momentum and conservation of energy reveal that, at least on the surface, when applying the principles to various experiments to validate particle nature, it appeared that the particle model of the photon made sense. However, contrary to the conclusions made by pioneer physicists, it may be surprising to find that our analysis portrays an entirely different result. The difference in the result is contributed by the fact that, from our view point, there is a subtle difference in the way photons of light interacted with electrons in those experiments as compared to the interaction of point particles with finite masses.

According to our understanding and the strange theory of light invented by Richard Feynman described in Chapter 6, electrons interact with photons in a peculiar fashion. As discussed in chapter 6, during the phenomena of refraction, reflection, and transmission of light from a variety of surfaces, the energy of a photon is absorbed by the electrons of atoms of a material to which light is exposed. The electrons react by re-emitting light in a peculiar, yet deterministic manner, depending on the characteristic of the surface and the concentration of electrons. Therefore, after studying this chapter you will appreciate and be convinced of our viewpoint regarding the wave model for light and radiation energy.

In the next section, we will continue to elaborate our discussion on the bending of light by the force of gravity. In the section, we shall examine the deflection of light arriving from the stars behind the Sun by the gravitational effect and by the refraction effect. Also, we will compute predicted deflection by four different formulations and compare the results.

1.4 Deflection of Light from a Star

According to GTR, in the presence of gravitational fields, the velocity of material bodies or of light can assume any numeric value. In an arbitrary Gaussian coordinate system, not only does the velocity of light become different, but the light rays no longer remain straight [4]. We agree that the speed of light varies. We disagree that the light rays will bend. Einstein tried to explain the bending of light rays from distant stars on the basis of “the gravity effect” of the Sun on rays of light. Two scientists attempted to verify Einstein’s predicted value **1.75 arc s** for the deflection of light arriving from a star at different times in history. One was German mathematician, Johann Georg von Soldner in 1801, and the other was British astronomer, Arthur Stanley Eddington, as late as May 29, 1919.

In the early 1900’s, two British expeditions were sent to observe a total eclipse of the Sun, one to the west coast of Africa in Principe, the other to the north of Brazil in Sobral. They returned with a number of photographs of the stars surrounding the Sun. The results obtained from the photographs were announced on November 6, 1919 [5]. The displacement from the pictures was **1.75 arc s** which was in close agreement with Einstein’s prediction. Many scientists applied the results of this test to conclude that the principles of Einstein’s “theory of general relativity” were validated. Figure 1.4 illustrates the situation in which a ray of light arriving from a fixed star passes close to the Sun and is observed on the Earth. The ray will be attracted toward the Sun by the force of gravity from the Sun, and will create a concave trajectory, as indicated in Figure 1.4.

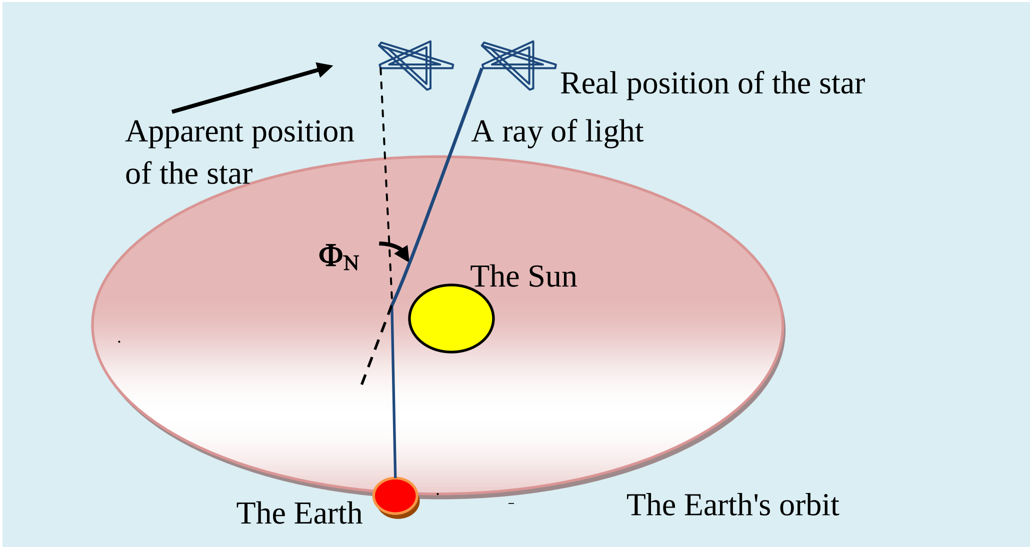


Figure 1.4 Deflection of light arriving from a far away star is effected by the Sun's gravity. Light deflection is calculated by applying Newton's Kinematics.

From our perspective, the light waves followed a curved path for a different reason. The light rays arriving from the distant stars are deflected as they pass by the Sun because they are refracted by the hydrogen gas atmosphere of the Sun. Also, the light rays from the stars are further refracted by the Earth's atmosphere. For centuries, it was evident that all celestial objects were in a constant state of motion and were moving rapidly. For instance, the orbital rotational speed of the Earth is at the rate of **29.27 km/s,** orbiting around the Sun. The tangential velocity of the Sun on the ecliptic is at the speed of **216.48 km/s**. Therefore, the effective gravitational force on the light from the distant stars is variable. The wave model for light and the refraction effect computations allows mapping the position of the moving celestial objects in the sky with very high accuracy than otherwise possible.

Now, let us compare the bending of a light ray arriving from a distant star, considering both the change in the refractive index of the atmosphere from a vacuum (free space), and (possibly) the bending of light due to the Sun's gravity. In the following, we will compare the deflection of light as it passes by the Sun by employing three different theories. First, we will apply Newton's laws to compute the bending of light by the gravitational field. Then, we will calculate bending by the refraction effect in accordance with Snell's law, named for Willebrord Snellius. We will estimate the deflection of light as a result of the transitioning of light through the Sun's atmosphere, as well as its transition through the Earth's atmosphere. Each estimate will be done separately. Next, we will compare our results with a value predicted by Einstein's theory of gravitation. Finally, we will summarize our results, comparing the numbers with experimental data from past and recently measured values of deflection for radio frequency signals.

Computation – Bending of light by gravity vs. refraction of light by Snell's law

A. Bending of light in the proximity of the Sun by Newton's theory of gravitation

Mass of the Sun $\mathbf{M_\Theta = 1.98 \times 10^{30}}$ **kg**, Radius of the Sun $\mathbf{R_\Theta = 6.95 \times 10^{8}}$ **m**
Mass of the Earth $\mathbf{M_e = 5.98 \times 10^{24}}$ **kg**, Radius of the Earth $\mathbf{R_e = 6.38 \times 10^{6}}$ **m**

Universal constant $\mathbf{G = 6.6726 \times 10^{-11}\ m^3/kg\text{-}s^2}$
Average radius for the Earth's orbit $\mathbf{= 1.496 \times 10^{11}\ m}$

Calculate gravitational acceleration constant from the Sun on a ray of light grazing surface of the Sun.

$$\mathbf{G_{sp}} = \mathbf{G \times M_\Theta / (R_\Theta)^2}$$
$$= \mathbf{6.6726 \times 10^{-11} \times 1.98 \times 10^{30} / (6.95 \times 10^{8})^2}$$
$$= \mathbf{273.52\ m/s^2 = 27.882} \text{ times the strength of Earth's gravitational field.}$$

The computed deflection of light due to the Sun's gravity, using Newton's Kinematics, K. Brown [6] is hereby given as,-

Deflection $\boxed{\phi_N = -\,2\,G \times M_\Theta / (R_\Theta \times c^2)}$ **(radians)** **(1.31)**

By substitution of parameter values in the -formula we get

$\mathbf{\phi_N = -0.000004245}$ **radians,** 1 arc s = 4.85×10^{-6} radians gives $\mathbf{\Phi_N = -0.875}$ **arc s.**

B. Bending of light as it travels through the Earth's atmosphere using Snell's Law

Refractive index of vacuum: $\mathbf{\mu_v = 1.0}$ and For atmosphere air: $\mathbf{\mu_a = 1.000293}$
Notice that μ_a could vary a great deal depending on the density of the air. The deflection and the angle of refraction depend on angle of incidence. Let

ϕ_i angle of the incident ray at the vacuum and air interface
ϕ_r angle of the refracted ray received at the observer's telescope

Snell's law→ $\boxed{\mu_v \operatorname{Sin}\phi_i = \mu_a \operatorname{Sin}\phi_r}$ **(1.32)**

For a normal ray: $\phi_i = 0^o$, $\mathbf{Sin\phi_i = 0}$ **which gives** $\phi_r = 0^o$ and deflection is zero.
On the other extreme $\phi_i = 90^o$, $\mathbf{Sin\phi_i = 1}$.
Substituting into the equation **(1.32)** gives $\mathbf{Sin\phi_r = 1/1.000293}$

Since denominator is different by a small amount from 1.0, we can apply Taylor series expansion

$$\mathbf{(1+x)^{-1} = 1 - x + x^2 - x^3 + x^4 - \qquad -1 < x < 1}$$

We can ignore the fourth and higher power terms because their contribution is small enough and do not affect the end-result.

$$\mathbf{Sin\phi_r = 1 - 0.000293 + 8.585 \text{ x } 10^{-8} - 2.515 \text{ x } 10^{-11}}$$

$$\mathbf{Sin\phi_r \approx 0.999707 \text{ or } \phi_r = Sin^{-1}(0.999707) = 88.613°}$$

The deflection ϕ is: **90 – 88.613 = 1.387° = 1.387 × π / 180 = 0.02420 radians**

1 arc s = 4.85 × 10^{-6} radians **gives Φ = 0.02420/(4.85 × 10^{-6})** arc s **= 4991.28 arc s**

This computations revealed that the deflection projected by Snell's law is highly sensitive to the angle of incidence. The computed value will vary from **zero arc s** to **4991.28 arc s** as the angle of incidence varies from 0° to 90°. The angle of refraction and the bending of light in Snell's Refraction law depend on the angle of incidence and, hence, on the time of day the eclipse occurred. In the experimental verification, the deflection of light from a star was measured during a solar eclipse. British astronomer Arthur Eddington took pictures of the star from the Isle of Principe, West Africa on the day of May 29, 1919. The eclipse occurred at **13:08:55** hrs lasting **6 minutes and 51 s**, at which time the test was conducted. From the photographs taken, it was determined that the deflection of the light from the star was close to 1.75 arc s. We have summarized the results in Table 1.1.

Now, let us calculate the deflection effect from the refraction in Earth's atmosphere within the environment the experiment was performed. The angle of refraction corresponds to the time of 1 hr, 8 minutes & 55 seconds and is computed as follows. Since eclipse happened at 13:08:55 hours, the Sun crossed the vertical at the location during noon. Therefore, angle of refraction corresponds to the Earth's rotation by the amount of time 1 hr, 8 minutes & 55 s, assuming that the ray from the star was normal to the objective of the telescope.

$$\mathbf{\phi_r = [(68 \times 60 + 55)/(24 \times 60 \times 60)] \times 360 = 17.229°}$$

Applying Snell's Law again $\mathbf{\mu_v\, Sin\phi_i = \mu_a\, Sin\phi_r}$

$$\mathbf{Sin\phi_i = (1.000293/1.0)\, Sin(17.229°)}$$

$$\mathbf{= 1.000293 \times 0.2962 = 0.2963} \text{ gives } \mathbf{\phi_i = 17.234°}$$

Deflection $\phi_i - \phi_r$ = **0.005° = (0.005 /4.85 × 10^{-6}) × (π/180) arc s = 17.993 arc s**

Notice that **1 arc s = 4.85 × 10^{-6} radians.** The above computations identified that the bending of light arriving from the star is predominantly caused by refraction in the Earth's atmosphere. The computed value is 10 times the value projected by Einstein's formula that was verified experimentally. It is not clear why the refraction of light by the Earth's atmosphere was not considered in Einstein's computations.

An empirical result for the deflection of light arriving from a star by the refraction effect is derived by R. C. Gupta [7]. The formula described in his paper included a fudge factor **k** that allowed one to model the effect of the variation in the index of refraction at different altitudes of the atmosphere of a star. In our case, the atmosphere of the Sun (our star) which contributes to the refraction effect bending light arriving from distant stars. Interestingly, his formula resembles Newton's and Einstein's formula, except for the fudge factor, even though he derived it using entirely different refraction considerations. The deflection formula described in his paper is

R. C. Gupta → Deflection $$\boldsymbol{\phi_G = -2\,k\,G \times M_\Theta / (R_\Theta \times c^2)} \quad \textbf{(radians)} \qquad \textbf{(1.33)}$$

The fudge factor **k** came from the changes in the density of the atmosphere within the corona of the Sun as the light from a star entered different zones of index of refraction and exited. Moreover, the fudge factor also permitted evaluation for bending of RF waves. In modern days, Radio Frequency waves are employed to determine the extent of gravitational bending experimentally. Gupta suggested that factor **k** should correspond to an average coefficient of refraction. Empirical value for **k** in this scenario was found to be somewhere between 1 and 2, which was in complete agreement with measured value of deflection by Eddington.

In nature, the extreme case of refraction of Sunlight at an angle of incidence equal to 90° with Earth's atmosphere happens routinely. Daily, at Sunrise and Sunset, rays from the Sun are refracted. These are parallel to the horizon, and thus create an angle of incidence of 90°. The refraction of a ray from the Sun at the dawn results in an early Sunrise by the time the Earth rotates an angle of 1.387° at the horizon. This time is equal to **(1.387 × 24 × 60) ÷ 360 = 5.548 minutes**

Similarly at dusk, when the Sun sets, due to the refraction effect, the Sun appears to set later by 5.548 minutes. Therefore, at the Sunset and Sunrise points in the mountains, it is advised not to catch the scene at the last minute because the Sun will appear full at Sunrise quite rapidly, and conversely, sunlight will disappear into darkness rather abruptly during Sunset. Therefore, the length of the day is increased by approximately 10 minutes because of the refraction effect at the horizon.

In Figure 1.5 the deflection of light arriving from stars by Earth's atmosphere, and its calculated deflection by Einstein computations, is described in detail. In the extreme case of rays with an incident angle near 90°, the refraction bending of light from Snell's law computations is higher by an order of magnitude compared to the value suggested by Einstein. The fact that energy waves *lack rest mass and a center of gravity* further strengthened our conclusion that light waves should not bend by the force of gravity. Additionally, the star-source of light is constantly in motion and the Sun is not stationary. Therefore, the trajectory of light rays from stars will not be affected by the force of gravity from the Sun. Assuming that Einstein's gravitational effect on light is valid, light from remote stars may then experience gravitational forces from multiple nearby stars.

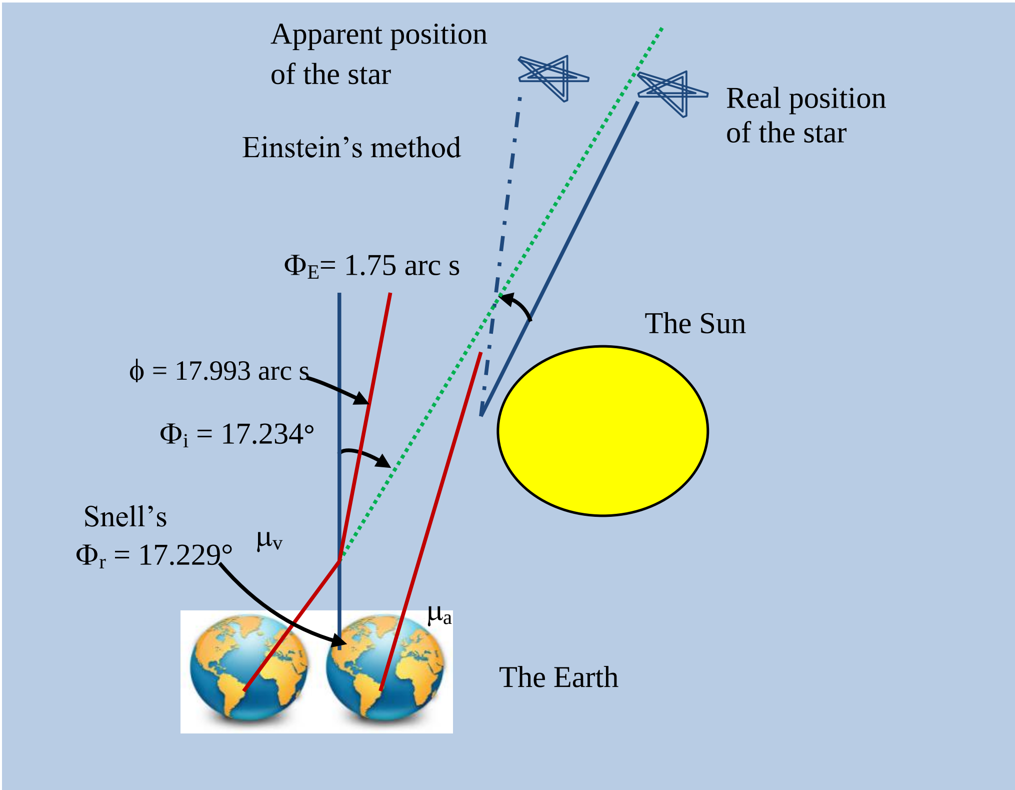


Figure 1.5 Deflection of light arriving from a star by the Earth's atmosphere**.** Light bending computed by applying Snell's Law & Einstein's method.

C. Deflection of Light in curved space time using Einstein's Computations

Einstein's Formula →Deflection $\boldsymbol{\phi_E = -4\, G \times M_\Theta / (b \times c^2)}$ **(radians)** **(1.34)**

where $\mathbf{M_\Theta}$ is Solar mass and **b** is distance a ray of star grazing the Sun. Usually **b** is expressed in multiples of solar radius $\mathbf{R_\Theta}$ [8].

For a ray grazing the surface of the Sun b = $\mathbf{R_\Theta}$, Deflection $\boldsymbol{\phi_E = -4\, G \times M_\Theta / (R_\Theta \times c^2)}$**.**
By substitution of parameter values in **(1.34)** we get $\boldsymbol{\phi_E}$ **= -1.75 arc s**

From these computations, it is evident that the deflection, according to Snell's law of refraction, is **10.282** times greater than the deflection due to the gravitation bending of light from Einstein's computations. The effective bending of light by gravity is much smaller than the accuracy of measurement. To minimize errors caused by the refraction of light through the plasma of the Sun's surface atmosphere, as well as Earth's atmosphere, physicists performed the measurement of the incidental rays from a star near zero degrees to Earth's atmosphere. Recently, to verify the results, they measured the bending of light by employing radio frequency waves. The radio waves measured a deflection value that was **1.66 arc s**, which did not match up with Einstein's prediction. The error between Einstein's prediction and RF wave techniques was more than 5%. It is a disappointing fact that Einstein's formula did not explicate the frequency dependence of the bending of energy waves that was observed in an experiment using RF waves.

In Figure 1.6 values of deflection ϕ_E for rays at various grazing distances is plotted. Also, in Table 1.1, the results of deflection computations are compared against three different effects, with the most recently measured value using RF waves. From the plot it appears that the deflection value drops rapidly for b values between 1 and 3, and then flattens out gradually in the range 3 to 7. Therefore, we are tempted to apply principles of Quantum Electrodynamics from R. Feynman [12] to analyze the refraction of star light in the proximity of the Sun.

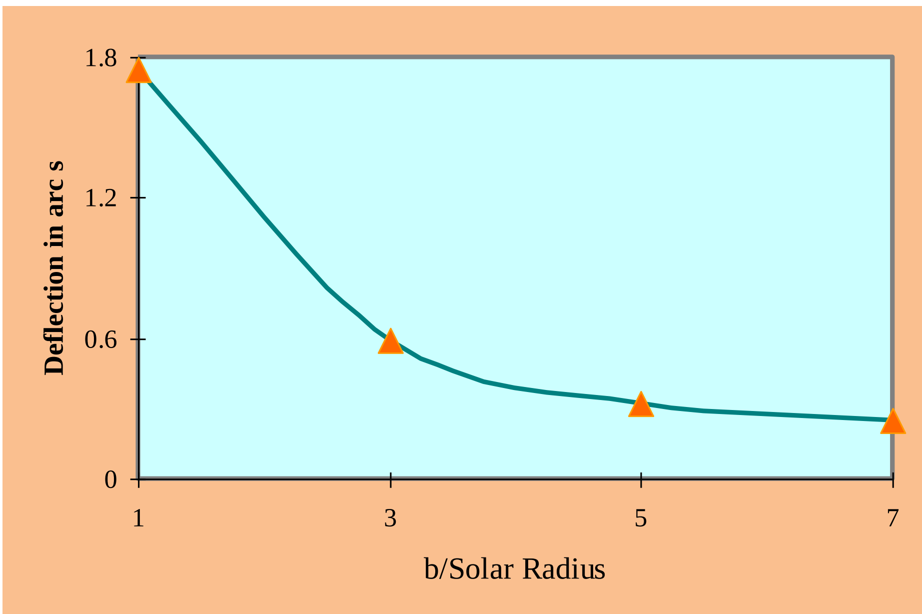


Figure 1.6 A plot of rays grazing distance from the Sun vs. deflection in arc s**.** Light deflection based on Einstein's theory of gravitation. (After H. Ohanian and R. Ruffini, Gravitation and Spacetime.)

From Figure 1.5, it is clear that the bending of star light near the Sun is caused by two effects. Light is refracted as it enters the corona of the Sun, and again as it leaves the corona at its edge. Secondly, star light is scattered by different quantities as it interact with electrons of the hydrogen gas atmosphere, which are under the influence of a different gravitational force, depending on their altitude from the surface of the Sun. It is obvious that Eddington's experiment did not identify the two components involved in the bending effect, instead reported a final result of 1.75 arc s. Our assertion is that the contribution from a gravitational curving of star light is only *half the amount of the measured result.* The computed quantity for ordinary refraction accounts for the other half.

Table 1.1 Computed values of deflection ϕ for three different effects

Measurement Effect	Deflection arc s ϕ measured	Deflection arc s ϕ computed	Comment
Newton's Kinematics		0.87	$\mathbf{2\ G \times M_\Theta / (R_\Theta \times c^2)}$
Snell's Law		17.993	≈ 10.282 times
Einstein's Gravitational	1.61 ± 0.80 WA	1.75	$\mathbf{4\ G \times M_\Theta / (R_\Theta \times c^2)}$
			Principe, West Africa
Einstein's Gravitational	1.98 ± 0.12 SB		Sobral, Brazil (SB)
Using RF Waves	1.66		Error is <5.143%
Gupta R. C. Refraction		0.87-1.75 for $1 \le k \le 2$	$\mathbf{2\ G}\ k \times \mathbf{M_\Theta / (R_\Theta \times c^2)}$

We propose a different test to be set up in order to perform an experiment validating the relativity theory. In this experiment, the photographs of the stars during total solar eclipse should be taken from an orbiting satellite outside of the Earth's atmosphere. The fact that the deflection value is the same within the accuracy of measurements at two different locations, Africa and Brazil, could possibly lead to an incorrect conclusion. One of the difficulties associated with this experiment is that one cannot repeat the measurement frequently. The reasons being, a solar eclipse event does not occur often, it is brief in duration, and good weather conditions are not a guarantee. Physicists who performed the test claimed that the results were arrived at after applying correction factors for refraction effects. The evidence suggests that the value of correction factors from the refraction effect will exceed by an order of magnitude the values measured by the photograph test. Since correction factors are very significant, it was necessary that the index of refraction at both viewing places should have been measured while the photographs were taken. There is no evidence that proves they had applied *accurate correction factors* after measuring the index of refraction for each location.

Let us suppose that a photon is a particle with inertial mass, as proposed by Einstein. With this supposition in mind, light beams bend toward the Earth as they experience force of gravity from the Earth, as posited in the elevator thought experiment. Einstein had stated that photons cannot be accelerated or retarded; they maintain the constant speed of **c** in space. Since our light beam has bent, the specific photon's velocity vector has also changed. This, however, is a contradiction which Einstein's theory cannot explain. He stated that the speed of the celestial stars changes the frequency of the photons arriving from the distant stars. The shift in frequency is toward the blue end of the spectrum for photons from stars approaching the Earth and is shifted toward the red end of the visible spectrum for photons from stars receding away from Earth. Interestingly enough, with this considered Einstein used the terminology associated with light *frequency*, a property associated with *waves* and not particles. Additionally considered under Einstein's supposition, the trajectory of light arriving from any star of another galaxy will suffer multiple bending if it will bend by force of gravity of stars, because it passes by multiple star masses and nebulae.

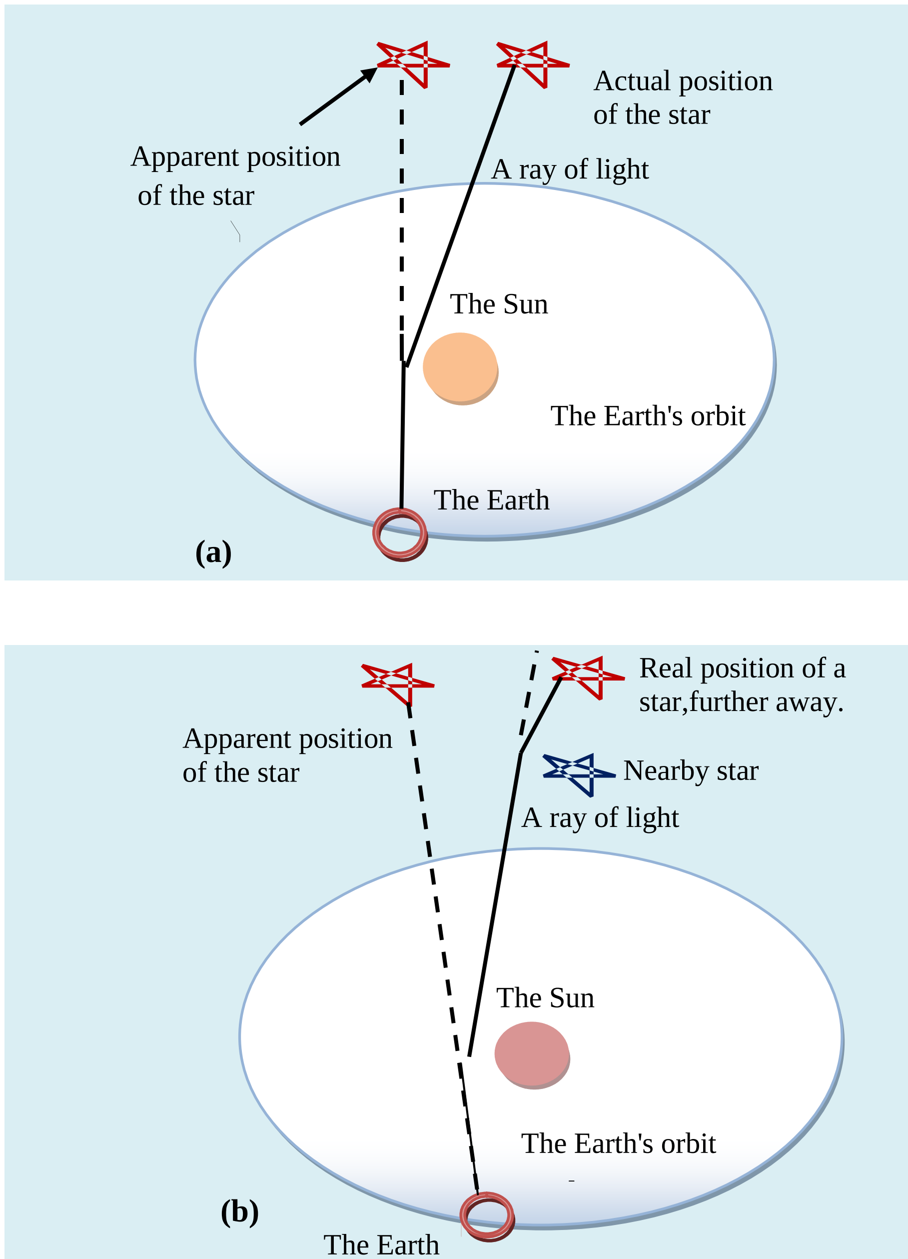


Figure 1.7 Position of the star is affected by the bending of light**.** (a) The deflection of a ray of light from a star by the Sun. (b) The trouble in computations: the bending of light is caused by multiple stars.

The deflection of light by gravity effects could produce disastrous results when they suffer bending, due to multiple stars. The situation in Figure 1.7(a) is described when a light ray arriving from a distant star passes by a star closer to our system before passing by the Sun and is observed on

Earth. With this assumption, the gravitational bending of light by multiple stars will not permit the mapping of the sky with billions of stars in the Universe with any acceptable level of accuracy. The Figure 1.7 (b) illustrates a situation in which light is arriving from a distant star to Earth faces multiple bending effects as it passes by several stars. It is obvious why such deflection of light from other stars before being observed on the Earth would make the task of accurate mapping of the sky from the Earth nearly impossible.

In the next section, we will describe the details of Michelson interferometer. The unusual results from his experiments provided fuel for Einstein to formulate his postulates of STR and GTR. Subsequently, we will show that the incorrect observations made from the outcome of the interferometer experiments led Einstein to discern wrong conclusions. Therefore, we should apply the wave nature philosophy for conducting advanced research in the study of light waves, rather than following the principles of Einstein and others who describe the obscure light behavior as sometimes a particle and, occasionally, as waves.

A primary purpose of the Michelson interferometer experiment was to measure the speed of Earth’s orbital motion around the Sun. To perform this measurement, he decided to compare the light path time delay differences orthogonal to each other. To determine path delays, he was interested in observing the differences in the radii of O-ring patterns created by interference effects of light waves reflected from three mirrors and the source of light. He monitored light arriving from different paths through an eyepiece of a telescope for the purpose of recognizing interference patterns, namely, Newton’s O-rings. To his astonishment, he did not find any rings. We will analyze details of his experiment to explain the reasons for his surprise.

1.5 Michelson Interferometer

In order to measure the speed of Earth’s orbit around the Sun, Albert Abraham Michelson and Edward Morley performed their famous interferometer experiment. For reasons explained later, their measurement did not lead them to determine the speed of the Earth in its orbit. Michelson’s apparatus consisted of: radiation source of a laser beam of a single wavelength (monochromatic light), three mirrors **A**, **B** and **C**, and a means of detection in the form of a telescope for observing the reflected light. Figure 1.8 illustrates a simplified diagram of his arrangement of mirrors, a laser light source, and a telescope. The entire apparatus was designed carefully so that the distances between the mirrors A and B, and A and C can be adjusted to an accuracy of few tenths of a micrometer for mirrors in arm lengths AB and AC separated by a distance of 1 m. The mirror A was covered with a semi-transparent coating to allow portion of light to pass through and some light is reflected as indicated in the Figure.

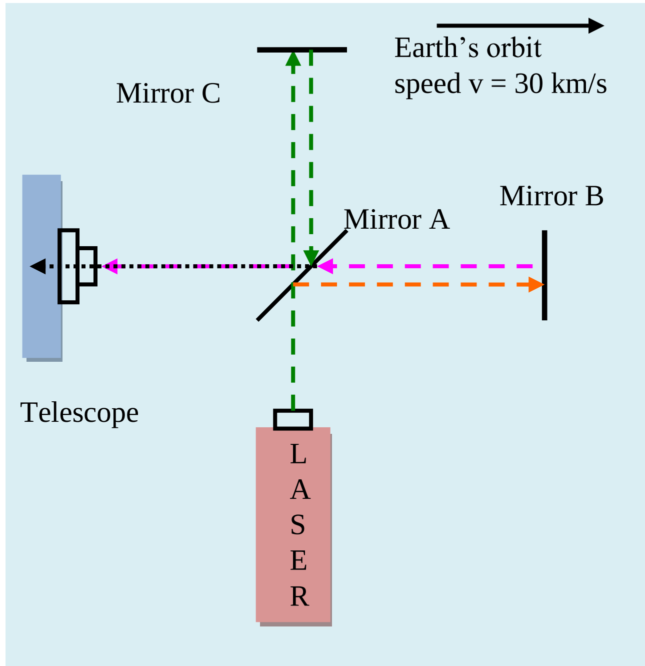


Figure 1.8 Michelson interferometer**.** The difference in delays between two possible light paths may result in an interference pattern. It can be observed by a telescope.

Let us analyze light path delays in Figure 1.8. Classically, the light path lengths **ABA** for mirrors **A** and **B**, and **ACA** for mirrors **A** and **C,** should differ because mirror **B** and the entire apparatus is moving in the direction of the Earth's orbit around the Sun. The position of mirror **C** is normal to the Earth's speed and should move in accordance with mirror **A**. Also, though the Earth rotates on its axis, its rotation should not affect the relative positions of mirrors **A**, **B** and **C**. If the entire apparatus were stationary, that is, if the Earth did not have orbital motion, then the path lengths **ABA** and **ACA** would be equal to **2L**, **L** being the distance between mirrors **A** and **B,** and **A** and **C**.

Michelson expected to find that the distances **AB** and **BA** were travelled by light at different speeds. He thought that the Earth's orbital speed would effect the speed of light in the forward and reflected direction differently. For the forward path **AB,** the mirror B moves in the same direction as the motion of light due to the Earth's orbital motion. For the return path **BA**, the mirror A moves in the opposite direction of the motion of light due to the Earth's orbital motion around the Sun. Therefore, light waves received at **A**, from mirrors **B** and **C**, should be different in time and phase, when observed by the telescope. The measurement of the time difference for determining the speed of Earth's orbital motion was the primary purpose of the experiment. As we will see, Michelson did not find any interference pattern in his experiment and was therefore, unable to achieve the desired result for the following reasons.

Michelson expected that the time difference would show a fringe pattern that would account for the motion of the Earth; instead, he saw no shift and a null result, Robert Mills [9]. Today, we know that the speed of the Earth's orbital path around the Sun is approximately **30 km/s**. Though description of events and the path delay analysis appeared convincing, the details of the experiment, as described by R. Mills, are not accurate. In order to calculate the time delays, he utilized the relative speed of light **c - v** in the forward direction and **c + v** in the reflected direction.

To compute the length of the paths, he applied the constant speed of light **c** in the formulae, which is inconsistent. If we alter the speed of light **c** by applying the Galileo transformation, and apply it consistently in the computations, the sum of the forward and reflected path length will always be **2L**, regardless of the orbit speed. This is a primary reason why Michelson received a null result every time. It is important to note that the speed of light is a constant **c** in a single medium, as long as the source and destination (telescope) are stationary with respect to the frame of reference. In our experiment, the entire apparatus and the Earth (frame of reference) move with the orbit speed. Therefore, the speed of light is constant in the forward and reflected path. According to this assumption, the length of path:

In a forward direction L_{pf} = mirror distance AB + distance moved by B in time for the light to reach AB. Time for light to reach distance **L= L/c**
Forward direction path length $\mathbf{L_{pf} = L + (L \times v)/c = L (c + v)/c}$

Reflected path length L_{pr} = mirror distance BA – distance moved by A in time for the light to reach BA**.** Again time for light to reach distance **L= L/c**

Return direction path length $\mathbf{L_{pr}= L - (L \times v)/c = L (c - v)/c}$
When we add paths $\mathbf{L_{pf} + L_{pr}= L(c + v)/c + L (c – v)/c = 2L}$

Naturally, when the total path lengths **ABA** and **ACA** are equal, there is no phase difference detected by the telescope at any time. Our corrected analysis proves that details provided by R. Mills are not correct. In the formula, we have made an assumption that the path length **AB** is always **L**. This is a correct assumption, because on Earth we cannot design any apparatus which would be stationary with respect to the Sun while the Earth proceeds in its orbit.

Einstein attempted to explicate the null results for the fringe pattern in Michelson's experiment as follows: He stated that the speed of light along the direction of the Earth's orbit, and in the opposite direction for a reflected ray of light, has the same value **c,** a constant. Classically, the speed of light in the forward path will be c **– v** and in the reflected path will be **c + v**. In order to nullify the classical difference in the path lengths and time, he proposed that time would proceed more slowly in the forward path than expected within classical time. Hence, the path length taken by the light would be contracted to value **L**. For the reflected path, according to the classical procedure, the path length would be shorter than length **L**. In order to compensate for the decrease in length, the relativistic length determination should expand the length to **L**. For that, Einstein's postulate required that time speed-up for the return path of the light. Einstein clearly stated that time is always slower for all other inertial systems, as compared to the preferred frame of reference. Therefore, his postulates fail to explain the null result of the experiment.

To defend his position, Einstein suggested that the path lengths in forward path and reflected path will differ in accordance with the rules of Lorentz transformation in Michelson's experiment. You will discover later that the contraction computed by the Lorentz equation is a *virtual* contraction and is not a real event. In Sub-section 1.5.1, we will describe the reasons for which the wrong results in Michelson interferometer experiment were derived.

1.5.1 Light Path: Lengths and Delays

Let us now reexamine and discover why Michelson's conclusion, which implied relativistic contraction of path **ABA** in compensation for the effective increase in path length, was incorrect. Figures 1.9 and 1.10 illustrate the path length in the direction of the motion of the Earth, and the reflected path. We agree that the forward path traversed is longer than length **L** and the reflected path is shorter than **L**. Also, if we assume that the speed of light changes according to the relative speed of light, then the total path length **ABA** will be longer than **ACA**. In that case, the analysis in [9] the path length **ABA**$=2Lc^2/c^2-v^2$ is correct. In the description, the path length **ACA** is $2Lc/(c^2-v^2)^{1/2}$ [9]. We agree that the value of the path length **ABA** is accurate. However, the value of the path length **ACA** is **2L** and not the value of the expression. According to our discussion, **ACA** should be exactly **2L** long, because light is a wave and travels in a normal direction to the surface of mirror **C**, unaffected by the Earth's orbital motion. In essence, the path lengths **ABA** and **ACA** are different, and the difference detected should be attributed to the speed of the Earth.

Let us suppose that the distance **L** in an apparatus is **1 m**. Also, for illustration purposes, we assume that the wavelength of the laser light used is **400 nm**. Then, the difference between the paths **ABA** and **ACA** in our discussion will be:

$$
\begin{aligned}
L_{diff.} &= \text{path length ABA} - \text{path length ACA} \\
&= (2Lc^2/(c^2-v^2)) - 2L \\
&= 2Lv^2/(c^2-v^2)\ \text{m}
\end{aligned}
$$

For $c = 299792458$ **m/s** and $v = 30000$ **m/s**

$L_{diff.} = 20.0277012$ **nm**

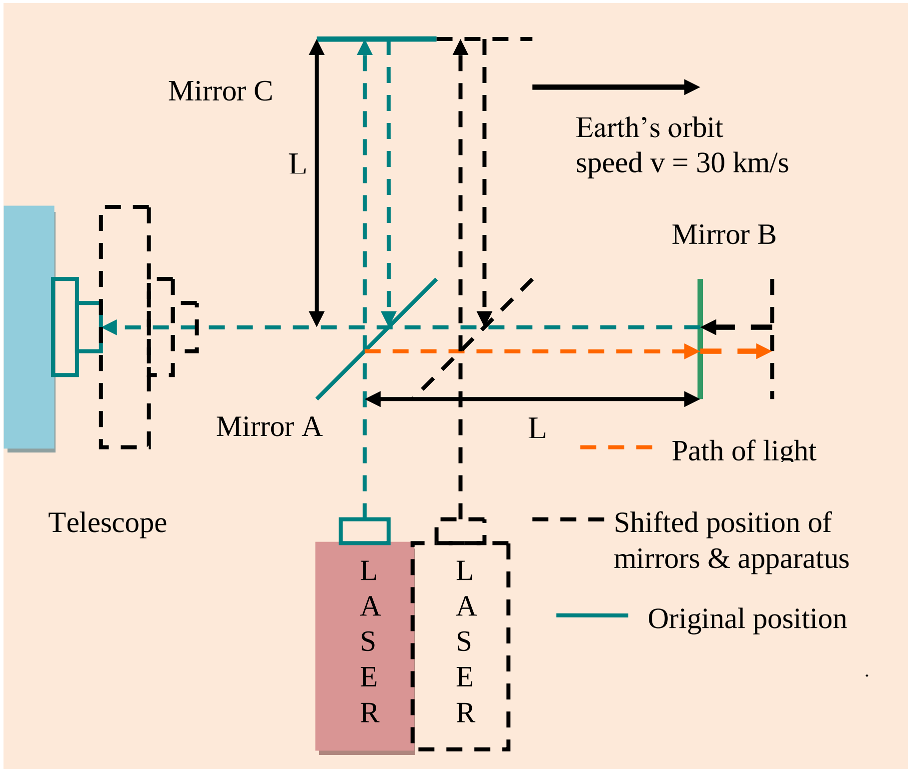


Figure 1.9 Path of light in the direction of the Earth's orbit**.** The path of light is longer when mirror **B** is shifted in the direction of the Earth's orbital motion surrounding the Sun as opposed to the stationary Earth.

The path difference $\mathbf{L_{diff}}$ corresponds to a phase shift of **18.02493108°** and a time difference of $\mathbf{66.81\times10^{-18}}$ **s**. This phase shift should be detected by the telescope. Michelson claimed that his apparatus was capable of detecting the phase shift and the path length of a difference of **1/100** of the wavelength, that is, a distance of **4 nm** in our example of the laser light source. To create a fringe pattern, he would have had to add a length offset of **80 nm**, that is, **4** times the distance he wanted to measure. In order to add a small distance of **80 nm** in **1 m** length by any mechanical means would be a formidable task. Especially, if he is achieving this by the tilting of mirrors, etc. Therefore, he would have failed to see any fringes without adjusting the mirrors.

In this experiment, the path difference should result in an apparent shift in the frequency of the received signal, as suggested by Christian Johann Doppler. In fact, the principle of Doppler's shift is regularly applied to determine the speed of celestial objects. The Doppler shift is also applied in radar computation to determine the location and speed of a mobile target in military applications. However, the Doppler shift can only occur if there is motion between the source and the observer. In this experiment, the source of the laser light, telescope observer, and all mirrors, are moving together with the Earth. Therefore, a Doppler shift cannot be observed in the frequency of the received signal.

According to his analysis, Michelson specified that the path difference and the time delay between **ABA** and **ACA** would be cancelled by the effective decrease in the path length **ABA** caused by relativistic contraction. Obviously, his thoughts were incorrect. If the contraction occurs in two mirrors, the contraction value can't exactly match the difference in the length of the contraction that corresponds to the Lorentz transformation and in accordance with Einstein's theory of relativity. In his apparatus, the greater part of the path traversed by the light is empty space. It does not make sense to say that this space is contracted. He speculated that the mirror **B** experienced contraction because of the Earth's motion. Such a contraction is not realistic for the speed **30 km/s**. The contraction of mirrors **A** and **B** will result in an increase of path length, not a decrease between the forward path **AB** and the reflected path **BA**.

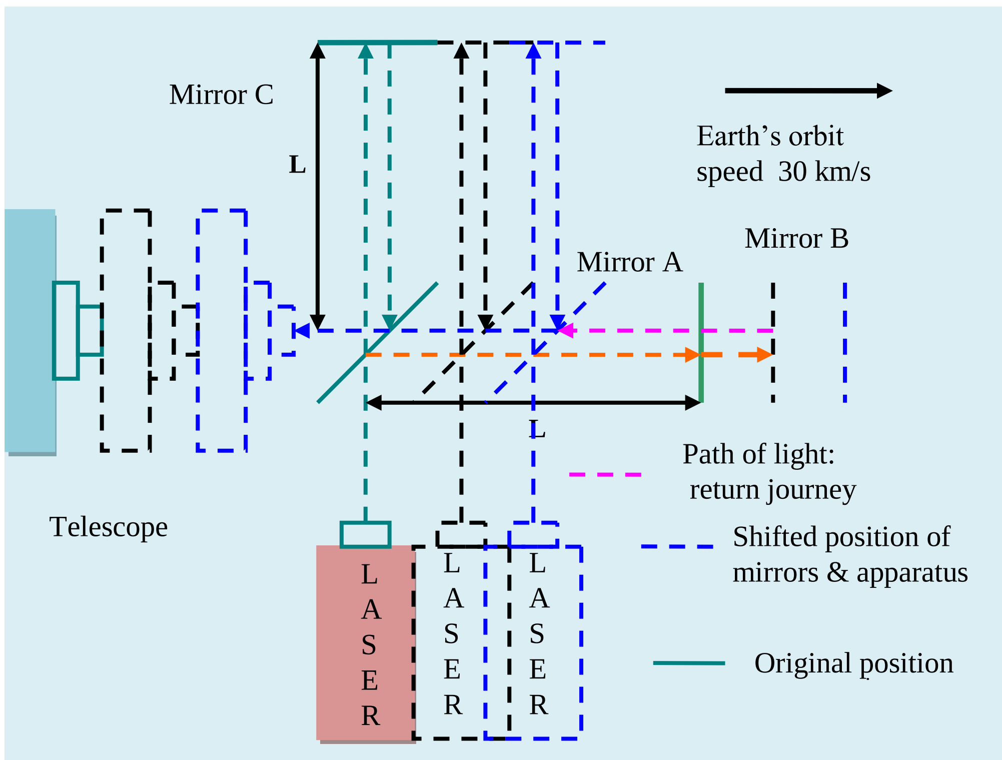


Figure 1.10 Michelson's Interferometer: Reflected Light Path**.** The path of light is shorter when it is reflected as it travels in the opposite direction of the Earth's orbital motion surrounding the Sun

There are many reasons for which the contraction of paths cannot occur in reality. For one, the strong and weak forces in the atom structure play a predominant role for the determination of the volume or size of objects made out of matter. Secondly, the force of gravity from large celestial objects, such as the Earth, have a feeble effect on fundamental particles such as, protons, neutrons, and electrons that form atoms making up the parts of the apparatus. We reason that the apparatus would not be affected by the change in momentum caused by the orbital momentum of the Earth's passage around the Sun. Such a situation could not result in contraction of the apparatus to a precise value. Since the weak force of the gravity, as compared to the strong force of the charge in the nucleus particles, is as small as $\mathbf{10^{-42}}$ [4], the effect of the change of momentum, due to the orbital speed of atoms, cannot be great enough to result in contraction. Specifically, contraction can't be deterministic and accurate to a value precisely predicted by the Lorentz transformation. What is more, we know that one needs to supply or remove an astronomical amount of the thermal energy to a glass or metal surface to cause an expansion or contraction of this proportion.

Further, the different path length **AB** in the forward path and **BA** of the reflected path is not the characteristic of the light signal. The path and the time taken to traverse both paths would be different regardless of what type of signal and sensing mechanism is employed. In addition, the apparatus and the mirrors were under the influence of the motion of the Earth around its own axis. The axial rotation speed of the Earth at the equator is **0.463 km/s**, which is smaller by a factor of **64.66** than its orbit speed around the Sun. When Michelson was looking for fringes caused by the phase shift between the signals of paths **ABA** and **ACA**, the Earth's axial rotation affected his results significantly.

Michelson observed the fringe pattern when he adjusted the tilt angle of mirror **A**. The reason for this result was that he inadvertently changed the length of arm **AB** that caused the phase difference in the signals received by the telescope, from mirror **B**, path **AB**, and mirror **C**, path **AC**. After several hours of discussion with Dr. Amin Jaffer, Engineering Fellow at Raytheon Company, Space and Airborne Systems, we have concluded that the setup of the Michelson interferometer was not the correct method to measure the speed of the Earth's orbital motion around the Sun. It assumes that the reflection of the light from mirror **B** occurs in zero time. As far as we know, the analysis of this experiment by all physicists, to date, has not included any correction factor or the effect of the time of reflection in the computation.

In the next section, we are proposing an improvement to Michelson's interferometer. Our proposed design eliminates the need for multiple reflections of light from mirrors **B** and **C**. Instead, we are relying on a one time reflection event. The light from mirror **A** is sensed by photo sensors. The onset of the change of potential detected by the photo sensors is measured by an oscilloscope. The light rays from the laser source are switched on-off periodically, to create a repeated event at the sensors of the light.

In this new arrangement, the mirrors **B** and **C** in Michelson apparatus are replaced by the photo sensors **B** and **C**. These sensors do not reflect light, a conceptual difference in the design, an obvious advantage over the arrangement described in the previous experiment. As we will discover, this technique does not suffer from any drawbacks of the prior experiment. One need not take into account the time when the light beam is reflected and reversed in its direction from mirrors **B** and **C**. Also, in this method, the classical paradox of the different speeds of light in different directions is eliminated. Though our instruments shows a big promise, it is a novel idea. No one has yet implemented our proposed design and therefore there is no experimental data to validate the results of the experiment.

1.5.2 Sky's Improved Interferometer

In the section 1.5.1, we explained what went wrong in Michelson's interferometer experiment that prevented the successful measurement of the speed of the Earth's orbital rotation around the Sun by capturing the time of the roundtrip for light from a reflected mirror arrangement. The main drawback of the interferometer was that it relied on the assumption that the reflection of the light wave from the mirror occurs in zero time. Also, his apparatus was incapable of discerning the observed time differential between two paths, 66.81×10^{-18} s, one normal to the axis of the Earth's rotation, and the other in the direction of rotation. Moreover, the pattern of the interference of light from both paths is not formed by one wave. The **O** ring interference is observed as a result of the time difference between two paths and is read within a period of several milliseconds, an accumulated result. As explained in the section 1.5.1, the time difference in terms of the wave period, due to Earth's rotation, is only **18°** of the wave period for the laser light source. Therefore, the time of the reflection from the mirrors should not be neglected.

Now that we have addressed the pitfalls of Michelson's interferometer, we will suggest an improved design for the interferometer, and we will designate it as Sky's interferometer. Before we describe the new design and principles, let us propose an alternate method to measure the speed of the Earth's rotation. One way is to use a source of the energy waves that travel in the direction of the Earth's rotation at speeds much slower than the speed of light. The speed of these waves will be nearing the speed of the Earth's rotation, **30 km/s**. One drawback of this method is that it requires control over the speed of the energy waves. Controlling the speed of an energy wave is not a simple concept to comprehend.

To overcome the shortcomings of Michelson's measuring apparatus, we are proposing a different arrangement. Our apparatus relies on the principle of timing a unidirectional motion of a non-reflected laser signal. The time difference is measured between a normal wave and a wave in the direction of the Earth's orbit, a single non-reflected path delay event. By a normal wave we mean a wave that propagates in a direction that is orthogonal to the direction of the Earth's orbit. We will assume that the orbital speed of the Earth's rotation around the Sun is constant over the time frame of measurement. This is a very safe and accurate assumption because the orbital period of the Earth's rotation has not changed to a great extent over the period of a century.

The duration to perform measurements for this experiment is short, only a few minutes. Three events are synchronized by employing common-trigger time-bases. The arrangement is similar to Michelson interferometer. A time-base is used to drive a source of light, a laser onto a transparent mirror **A**. The time delay of light sensed by two identical semiconductor photo electron sensors is measured by two channels on an oscilloscope. One of the sensors is located at a distance of one meter in the direction of the rotation of the Earth's orbit. The other sensor is located in a direction normal (perpendicular) to the rotation of the Earth's orbit at the same distance. The time-base of the oscilloscope, that measure the response from two sensors, is swept by the time-base that drives the laser light source.

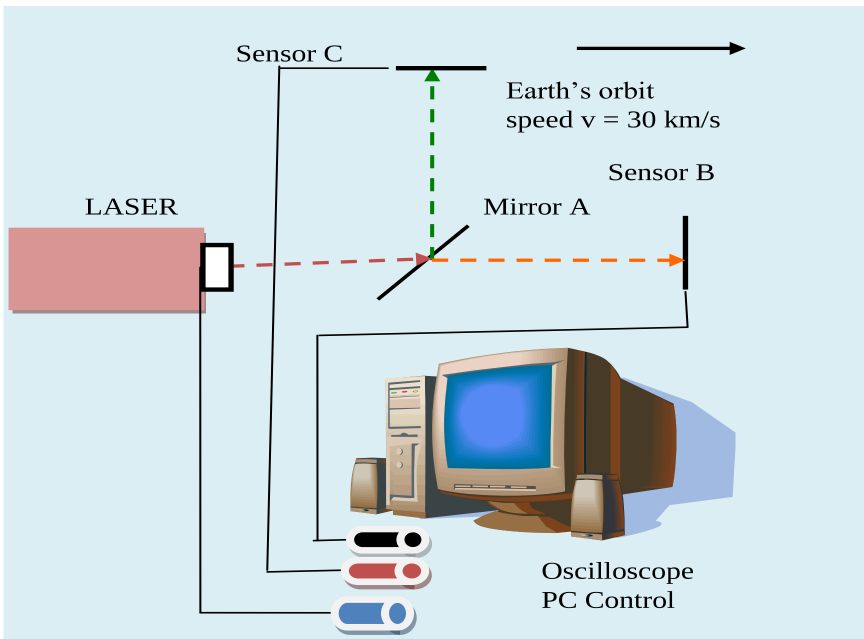


Figure 1.11 Sky's Apparatus: Single Shot Interferometer**.** The method suggested by us relies on the fact that the path delays are measured in one event without reflections from mirrors.

The arrangement of our apparatus is demonstrated in Figure 1.11. The apparatus consists of a laser light source **G**, a transparent mirror **A**, a photo sensor **B**, and an identical sensor **C**. The sensor **B** is located on the right side of **A** at a distance of **1 m** and sensor **C** is located above the mirror A at the same distance of **1 m** from **A**. The signals from both sensors are received at the input terminals of two channels of an oscilloscope, with identical probes and input characteristics. What we are looking for is an indication on the readout of the oscilloscope that detects difference in time between voltage signals from sensors B and C. Since the trigger time-base, the component distances, and all characteristics of measurement can be most accurately tailored to make them identical in all necessary respects, the differential time-delay measurement between sensor **B** and **C** truly reflects the rotation speed of the Earth. To improve the accuracy of measurement, both channels of the scope should be run in a single shot trigger event monitor mode.

Let **t** be the time for the signal to propagate from the laser to sensor **C**, and **δt** be the time difference between the onset of the transition of the signal from sensor **B** and sensor **C**. Thus, the Earth's orbital speed can be computed as:

$$\mathbf{v = c \times \delta t/t} \quad \mathbf{(m/s)} \tag{1.35}$$

After studying the detailed operation of Michelson's apparatus, you may be tempted to think that the whole experiment and effort was in vain. In that case, we will describe some useful applications of his apparatus in Section 1.5.3. You will learn that a slightly modified version of his apparatus can be employed to measure the wavelength λ of unknown light from a source. In this scheme, mirror B is intentionally moved to create a difference in path lengths AB and AC. In another application, the index of refraction μ of a column of gas is determined by counting the number of fringes shifted in relation to following a gradual evacuation of gas from a gas cell.

1.5.3 Applications of the Michelson's Interferometer

Michelson's interferometer is employed to determine wavelengths of a wide range of radiation, including visible light and lasers. The reason for this is that it provides a highly accurate technique to perform the measurement. For instance, an accuracy of 0.0001 nm is reported for a tunable He/Ne laser with a tuning range of 680.4 - 691.0 nm [13]. In Figure 1.12 an arrangement of Michelson's apparatus is displayed that allows us to accomplish our objective of measuring the wavelength of an unknown source of light. Two sets of interference fringe patterns are observed on a screen and compared. For instance, the path lengths AB and AC of light rays of both arms to mirror C and mirror B are unequal. Interference patterns comprising of Newton's O-rings are captured on the screen and stored. Mirror B is then moved by a distance of x mm, let's say 1 mm further away. The interference pattern, the O-rings, are then observed again on the screen and stored for comparison.

It is found that when the distance between mirror B and mirror A in increased, while mirror C remains in fixed position, the number of circular fringes **m** shift inward. This would require bit more explanation. When reflected light from mirror B and mirror C appears on screen, Newton's rings of bright and dark regions are formed due to constructive and destructive interference. The distance of certain maximum (bright ring) from central maxima (brightest spot circle) changes in accordance with the difference in path length light travels from mirror A to B and from mirror A to C. This information is then used to find the wavelength λ of light from unknown source by applying the following formula.

$$\mathbf{2x = m\lambda} \qquad \mathbf{m = \pm 1, \pm 2, \pm 3\ldots\ etc.} \tag{1.36}$$

Alternately, the same implementation of the interferometer can be applied to measure miniscule differences in path lengths AB and AC. The idea is to determine offset error in arms AB and AC. It is possible to detect a difference of a few tenths of a millimeter in arm length of 40m long. In this scenario, light of known wavelength emitted from a source is passed through mirror A. A portion of light is reflected and takes path AC to mirror C. Some fraction of light is transmitted through semi-transparent mirror A and takes path AB. The reflected light rays from mirrors B and C forms an interference pattern on the screen. Newton's rings are observed for two situations, as before. Again, the number of rings **m** shifted is monitored and noted. Now we can compute the value of the moved distance **x** from equation **(1.36)** because we already know the wavelength λ of the light source. Hereby, we have described a procedure that successfully allows Michelson's interferometer to self-calibrate before we can apply it to measure the wavelength of light from an unknown source. Next, we will discuss yet another application of the interferometer, refractive index measurement.

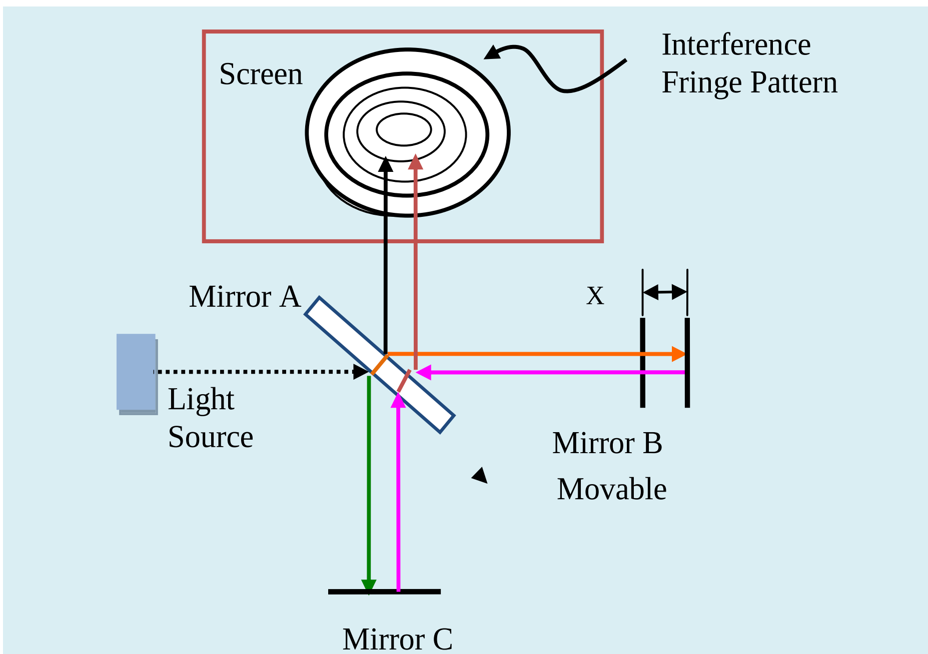


Figure 1.12 Measurement of wavelength of light**,** from an unknown source.

Here, the design of Michelson's apparatus will be modified, namely, a gas cell of length L is introduced along the arm AB comprising part of the path between mirror A and B. The gas cell is filled with a gas (or air if it is desired to measure μ_{air}) at a known pressure. The mirrors are then illuminated by a monochromatic light from a light source. The gas cell is then gradually evacuated and the number of fringes m of Newton's O-rings shifting in is counted. Since the number of fringes moving in depends on the optical path difference (OPD), the path delay of light between arms AB and AC, we can determine the index of refraction of gas [16]. The path delay AB is different when the gas cell of length L is filled with gas verses when the gas is completely evacuated. This is due, of course, to the changes in the index of refraction. A schematic arrangement of the apparatus is detailed in Figure 1.13. By analyzing path delays we can derive the following simplified equation that enables us to calculate the refractive index μ_{gas} of the gas filled in the cell.

$$\mathbf{2L \times (\mu_{gas} - \mu_{vac}) = m\lambda, \qquad m = \pm 1, \pm 2, \pm 3\ldots \text{ etc.}} \qquad \mathbf{(1.37)}$$

where $\mu_{vac} = \mathbf{1}$

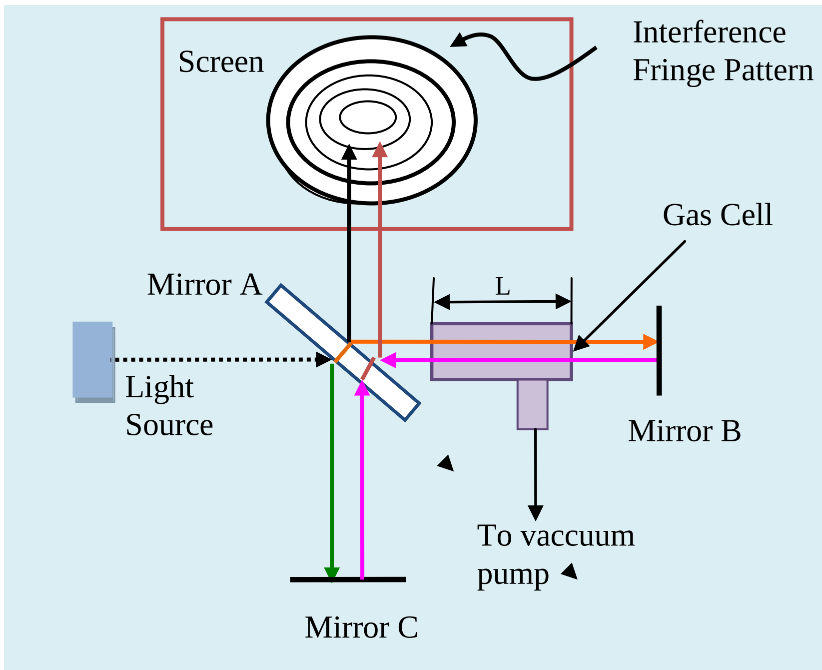


Figure 1.13 Measurement of index of refraction of a gas column. .

Notice that in this application the position of both mirrors, B and C are fixed after the path length difference is adjusted to zero. A critical first step in all these applications is to adjust the path length AB and AC to be exactly equal. By observing through a telescope the fringe pattern contrast between dark rings and lighter rings slowly disappearing, we can discern the path equalization [26]. This arrangement is useful to measure the refractive index of any kind of substance, such as a thin glass plate, or a liquid placed in the cell canister. If white light is used instead of monochromatic light, white light fringes (WLF) are obtained. However, additional complexity arises in calculations because dispersion effects can no longer be ignored [16]. A modified version of the Michelson interferometer and the Rayleigh interferometer is widely used both in research and technology. Applications include Fourier transform spectroscopy, the testing of precision optical components. We also find applications in optical fiber communications.

In section 1.6, we will describe the details of various experiments performed in the past that seemed to verify particle behavior of light in certain events. We will analyze the data from these experiments and prove that the results of these experiments did not provide conclusive evidence in this ostensible verification. Our findings will disclose a rarely accepted fact that the claims of the performers of the experiments were in serious error regarding the nature of light as a particle in those instances.

1.6 Advocates of Particle Theory and Experiments

The proponents of the theory suggested that light has a dual nature, both as a particle and as a wave. They were biased in favor of *particle* nature. Many performed experiments to support a view that light waves behave sometimes as a particle within certain parameters. In other experiments, the results were such that they were led to recognize that light is a *wave*. Einstein and many other physicists used results from several experiments to validate the dual nature of light. Though many prominent physicists have analyzed the results of experiments, which *ostensibly* depicted the particle nature of light, we will investigate the details of three effects: the photoelectric effect, the X-ray emission and the Compton Effect. A closer re-examination of the results from these experiments will reveal that the conclusion that light consists of photon *particles* is not appropriate. Our observation is based on the fact that the resultant outcome of the experiment would not be the same for the wave model of light.

Let us now look at the details of each of the experiments and show why their results provide a contrary conclusion; the conclusion that light is exclusively a wave. Our analysis will have a profound effect on the Science of Light and energy waves. Einstein extended the particle nature of photons to all types of energy waves that included X-rays, ultraviolet, infrared, micro, and gamma rays. From his perspective, each of the radiation waves consisted of photon particles of varying frequencies. Before we investigate the details of the experiments, we will present an equation from Max Planck which characterizes the energy content of light waves. By the 1900's, evidence indicated that energy possessed by individual photons of light waves of frequency $\boldsymbol{\nu}$ is expressed by relation

$$\boxed{\mathbf{E_{photon} = h \times \nu}} \quad \mathbf{(J)} \qquad \mathbf{(1.38)}$$

where **h** is known as Planck's constant and $\boldsymbol{\nu}$ is the frequency of light waves.

Now, we will investigate the details of the following three experiments in great depth in order to correctly understand the behavior of light waves:

1. The Photoelectric effect
2. The Short wavelength limit X-rays and
3. The Compton effect

We shall discover that the evidence from these experiments did not *necessarily* prove that light consists of photon particles. While the laws of conservation of momentum and energy were apparently satisfied for photon particles in these experiments, there were certain subtle but credible differences found in relation to the conservation of the laws for ordinary particles in classical mechanics. Lying within the details of these differences is the substance of our analysis. In fact, our findings will substantiate the wave model for the entire range of radiation energy waves. As a consequence of our critical analysis, we will formally define photon as *virtual particles*, distinguishing them from real particles.

1.6.1 The Photoelectric Effect

In this section, we will discuss the details of an experiment for testing the photoelectric effect. To begin with, we shall describe the experimental set up developed by Hallowach to represent the effect. Based on the observations from the experiment, we shall state the laws of photoelectric emission. Then, we shall derive Einstein's photoelectric equation to characterize the phenomenon. Next, we shall include graphs inferred from experimental data to validate the results. At that point, we will explain why the results from this experiment do not prove that light is a particle.

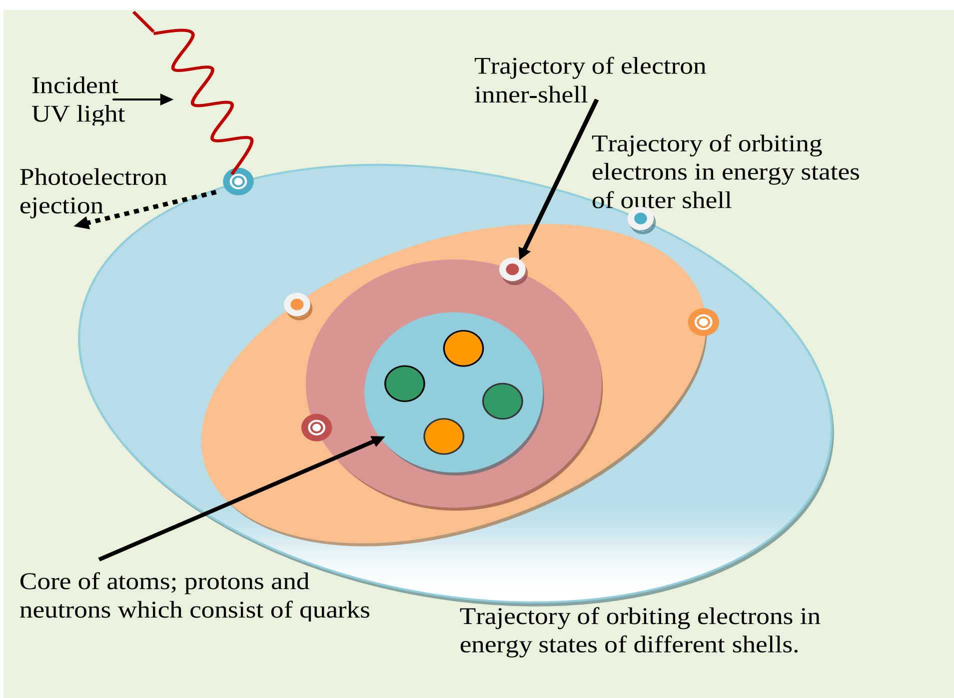


Figure 1.14 Photoelectron emissions by incident light on a clean metal surface**.** When electrons in metal target of an emitter E in Leonard's experiment are exposed to UV light, they absorb a quantum of energy and are ejected from the orbits of atoms for conduction of current to collector C.

Hallowach discovered that an insulated Zinc plate connected to a gold leaf electroscope will lose its charge when it is exposed to a beam of ultraviolet light. The plate in Hallowach experiment held a negative charge at the beginning of the experiment. He suggested that the metal surface started leaking electrons by a process in which they were ejected from atoms of the metal plate by ultraviolet light particles. The effect was termed as the Photoelectric Effect. The ejected electrons were called photoelectrons, which were only observed when the frequency of UV light was above a certain threshold. In Figure 1.14, the photoelectron emission event in a Leonard's apparatus is displayed. This experiment verified Hallowach discovery. Next, we will provide an elaborate explanation of steps which demonstrate the photoelectric effect.

Contemporaneously with Max Planck in the 1900's, Leonard studied the photoelectric effect experimentally [10]. Figure 1.15 shows an experimental arrangement to study the effect. His apparatus consisted of a long evacuated glass tube fitted with two electrodes and a window to expose one of the electrodes to ultraviolet light. The electrodes were an emitting electrode **(E)** anode, and a collector **(C)** cathode. A varying potential difference of a selected value was applied between the two electrodes. When the material from the surface of the E electrode was exposed to UV light of suitable frequency, electrons were ejected from the surface despite the electron charge holding positive potential on the anode plate.

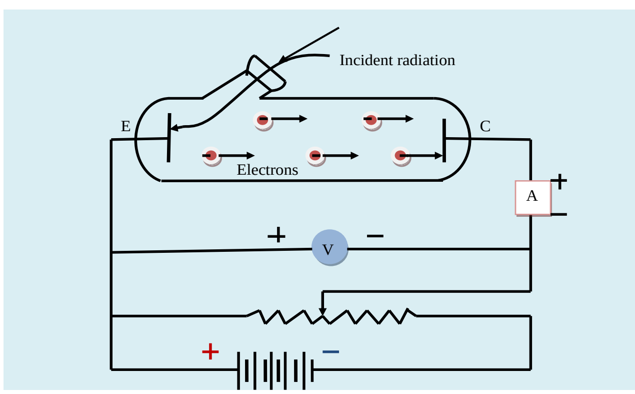


Figure 1.15 Leonard's apparatus to demonstrate the Photoelectric Effect
(Courtesy Satish Gupta," Modern's abc of Physics," 2006)

The ejected electrons with excess kinetic energy moved towards the collecting electrode carrying a negative potential. The electrons, with a negative charge, overcame the negative potential on the cathode. As the value of potential difference increased (more negative), fewer electrons were able to reach the collector and contributed to decreasing the current. An ammeter monitoring the photoelectric current began indicating a decrease in current until it reduced to zero when the voltage of sufficiently high negative value was applied. The voltage at which photoelectric current was reduced to zero was known as *stopping potential*. At the stopping potential, the kinetic energy of electrons will be exactly equal to the work done by the stopping potential to prevent any current flow. Mathematically the relationship is expressed by the following equation.

$$\boxed{eV_0 = \tfrac{1}{2}\, m_e\, V^2_{max}} \qquad (1.39)$$

where $\mathbf{V_0}$ is the stopping potential in kilo volts, $\mathbf{m_e}$ is the mass of electron in kg, $\mathbf{V_{max}}$ is the escape velocity of the electron in km/s, and **e** is electron charge in coulombs.

More experiments were performed by varying the intensity of UV light, varying the retardation potential and changing the frequency of UV radiation. Each time the experiment was run the photoelectron current was recorded. Scientists were able to derive several conclusions from the results of the experiments. The results of the Leonard's experiments were summarized as *the laws of photoelectron emission*

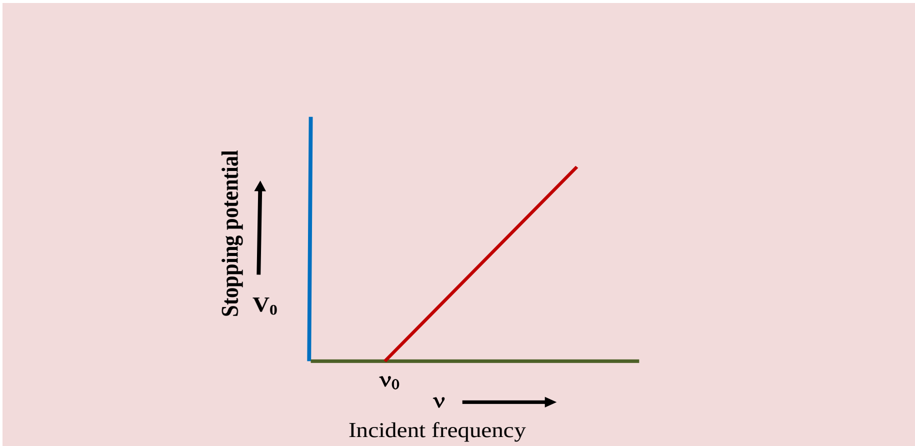


Figure 1.16 Incident frequencies below ν_0 the photoelectric current is 0**.** Stopping potential is in volts numerically equal to the maximum kinetic energy of photoelectrons in **eV** for any intensity.

The Laws of Photoelectric Emission

1. It was discovered that below a minimum threshold frequency $\boldsymbol{\nu_0}$ for the incident light no photoelectrons are ejected *regardless of intensity of light* (Figure 1.16)

2. The threshold frequency $\boldsymbol{\nu_0}$ is the characteristic of the metal being used as a photo-emitter. This fact is true even if the value of the stopping potential is zero. Of course, a higher value of stopping potential will require UV light with a higher frequency than the threshold frequency $\boldsymbol{\nu_0}$, also known as the critical frequency. The UV light of critical frequency is required to initiate and sustain the photoelectric effect (Figure 1.17).

3. It was found that for a given value of frequency $\boldsymbol{\nu}$ or wavelength $\boldsymbol{\lambda}$ for ultraviolet light, there is a spread of photoelectrons energies down to zero. However, the maximum kinetic energy $\mathbf{K_{max}}$ of photoelectrons does not depend on the *intensity* of light, but varies linearly with $\boldsymbol{\nu}$. The energy $\mathbf{K_{max}}$ does depend only on the *frequency* of exposing radiation (Figure 1.16).

4. Experimentally it is verified that high intensity of incident light results in a larger amount of photoelectron ejection and a corresponding increase in the photoelectric current, but not more energy per electron (Figure 1.18).

5. The emission of photoelectrons starts as soon as the UV light is exposed to the metal. It is found that the time lag between UV exposure and emitted photoelectrons is less than 10^{-8} s.

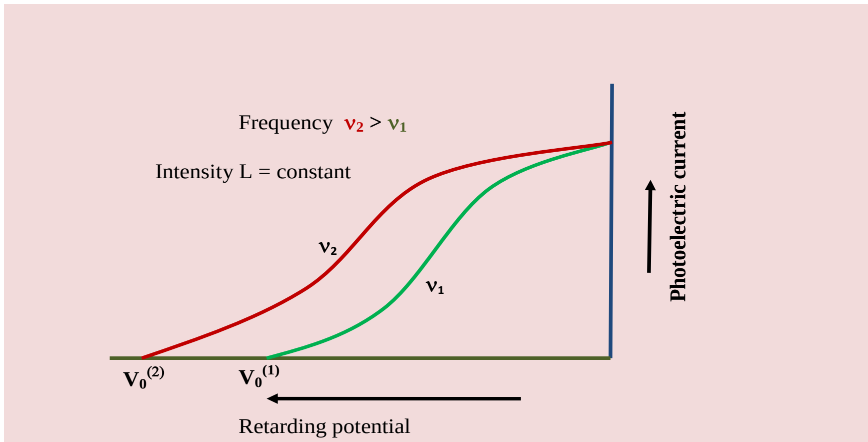


Figure 1.17 Stopping potential vs. photoelectric current**,** varying frequency of incident radiation**.** Higher frequencies of UV light exposure results in higher kinetic energy photoelectrons.

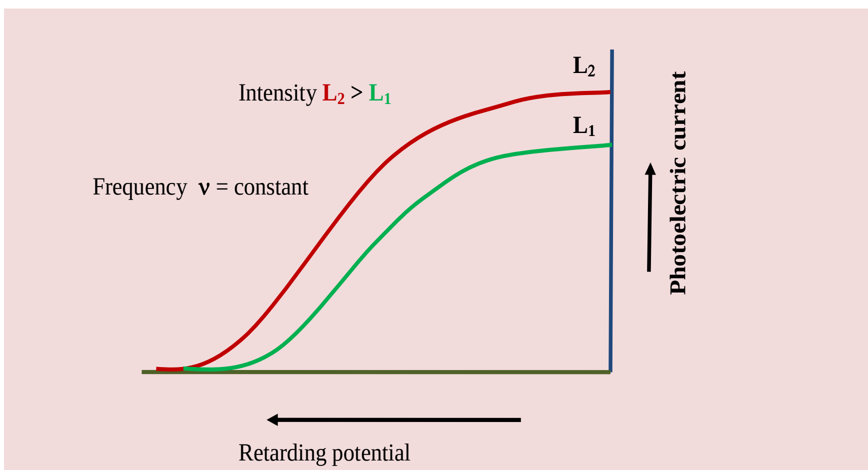


Figure 1.18 Stopping potential vs. photoelectric current at various intensities of radiation. Brighter lights produce more current, not more energy photoelectrons.

1.6.1.1 Einstein's Explanation

To explain the results of the above experiments, Einstein postulated that the energy carried by a photon of radiation of frequency ν is $\mathbf{h} \times \nu$. According to his theory, the emission of a photoelectron was the result of the interaction of a single photon with an electron, where the energy of the photon was completely absorbed by the electron. It is well known that to remove an electron from an atom of metal requires a certain minimum amount of energy ω, called the work function of the metal. Thus, when an electron absorbs energy from a photon, an amount of energy at least equal to ω is used up in liberating the electron, the difference providing energy to accelerate it to speed V_{max}. Thus, the equation

Albert Einstein → $\frac{1}{2} m_e V^2_{max} = h \times \nu - \omega$ **(1.40)**

where m_e mass of electron, V_{max} maximum velocity of photoelectron, ω work function of the metal, h Planck's constant, and ν frequency of UV light.

The work function of the metal is a characteristic of the metal, which does not depend on the frequency or nature of radiation. Sometimes it is called the threshold energy of the metal. If ν_0 is the frequency that corresponds to the threshold energy of the metal, then

$$\omega = h \times \nu_0 \qquad (1.41)$$

Substituting ω in **(1.14)** we get

$$h \times \nu_0 = h \times \nu - \frac{1}{2} m_e V^2_{max} \qquad (1.42)$$

The above relation is called Einstein's photoelectric equation. From his equation, it is evident that the number of photoelectrons ejected will result in large quantities if the intensity of radiation is increased with a corresponding increase in number of light photons. Also, the photoelectric current increased because the photoelectric effect constitutes a one photon, one electron interaction phenomenon. We are in complete assent with Einstein's photoelectric equation and theory. However, we are in dissonance with the fact that energy carried by UV light waves of frequency ν is contained in a *particle* photon because the idea is insensible. This photon particle described by Einstein does not have rest mass and a static center of gravity. Therefore, we believe that a photon is not a real particle, even though photoelectrons absorb energy from UV radiation in precise quantum amounts. It would have made more sense if Einstein had classified photons as a hypothetical imaginary particle and modeled it as such for light as well as all other radiation energy waves.

Our view is that Einstein's equation, in reality, described the steady-state energy transfer behavior between light energy waves and photoelectrons. His analysis lacked the incorporation of transient effects, and therefore could not illustrate what was really happening. It is true that photoelectrons are released when electrons absorb a fixed quantum of energy from a light source instantaneously, as stipulated by physicist Max Planck's quantum particle electron energy model. Einstein deserved credit for discovering the fact that in each occurrence of radiation energy emission event, the energy carried by an emitted electron is equal to the difference between the incident energy and the work function characteristics of the material exposed to the radiation. His work was recognized and earned him a Nobel Prize for the discovery. However this peculiar behavior of electrons erroneously led him to describe radiation energy waves as particles.

In the following, section, we shall investigate photoelectron ejection in more detail. We shall primarily focus on the quantum particle theory proposed by another famous physicist, Max Planck. His pioneer contribution to the Black Body Radiation theory brought him the highest honor in quantum physics, earning him the Nobel Prize in 1918 for revealing the quantum nature of energy waves.

1.6.1.2 Applying Max Planck's Quantum Ideas

We offer the following detailed explanation for the laws of the photoelectric effect. Our analysis is predominantly based upon Planck's model for radiation from quantum particle electron. Plank's hypothesis stated that whenever an electron is involved in any energy exchange process; it will emit or absorb energy making a transition from one quantum state to the other. The entire energy difference between the beginning and the final states in the transition is emitted or absorbed as a single quantum of radiation. The energy of radiation is described by the expression **(1.43).**

$$\boxed{\mathbf{E = h \times \nu}} \quad \textbf{(J)} \qquad \textbf{(1.43)}$$

Thus, the law for energy of radiation came into existence. Max Planck's theory of quantum particle electrons played a very important role in quantum mechanics. Therefore, we have devoted the entire Chapter 11 to discuss his theory having to do with black body radiation and the quantum concepts in much greater details.

We believe that the model of work function difference in Einstein's equation is simplistic in its view. A more detailed analysis reveals that the kinetic energy K_{max} depends on the frequency, not the intensity of incident light. The reasoned explanation for this is that the ejected electron from a specific orbit can *absorb* light energy in a quantized maximum amount that corresponds to the frequency of light to which it is exposed. The quantity of energy absorbed by an orbiting electron is a function of de Broglie wave length (1.23 nm), representing the electron in specific orbit. In correspondence to the frequencies of light having a value at or below the de Broglie wave length, the electron will absorb sufficient energy as a requisite to alter its quantum state. The energy corresponding to the de Broglie wave length will constitute the concept of the work function for the metal.

We conceive that the upper ranges of high-frequency high-energy radiation waves penetrate deeper to the inner shells of atom's orbit, detaching electrons from their interior orbits. These inner electrons are not affected by light propagated at low frequencies, but they absorb energy from light propagated at high frequencies only. The kinetic energy of electrons within the inner orbits is higher than the electrons in outer orbits. This is because the orbital speed of electrons in their interior orbits is higher than the speed of electrons in their exterior orbits. Light propagating at a frequency below the threshold ν_0, will not cause the ejection of an electron, regardless of its intensity. This proves that at low frequencies, light energy is not being absorbed by electrons in any orbit. Therefore, the results of this experiment *do not prove* that light consists of photon particles.

In Chapter 2 you will discover that all radiation energy waves are created by vibrations of electrons in their orbits during an orbital transition event. The energy released in this process satisfy the electron energy level requirements imposed by Bohr's theory, and obey the rules stated by Max Planck for energy-state transitions of discrete quanta [3]. For a rigorous analysis and a model for the photoelectric effect, it is imperative to employ Schrodinger's equations in order to accurately characterize the energy transfer between radiation energy waves and photoelectrons in its time-dependent form. This treatment is outside the scope of this effort. However, in the next section, we will analyze experimental data to fortify the concepts introduced by us.

1.6.1.3 Analysis of Experimental Data

As stated in Leonard's experiment, free electrons are ejected from a clean metal surface when exposed to light and UV energy. These electrons are called photoelectrons. The ejection of these photoelectrons by light is known as the photoelectric effect. It is determined, that for a given value of frequency ν or wavelength λ for incident light, there is a spread of photoelectron energies down to zero. However, the maximum kinetic energy K_{max} of photoelectrons is sharply defined and varies linearly with ν. The energy K_{max} did not depend on the *intensity* of light, but only on its *frequency*. We saw in section 1.5.1.2, experimentally, the verification that the high intensity of incident light resulted in increased *numbers* of photoelectrons ejection, but not increased *energy* per electron. Further, below a minimum threshold frequency ν_0 for incident light, no photoelectrons were ejected, regardless the intensity of incident light. The threshold frequency ν_0, was the characteristic of the metal being used as the photo emitter.

In Table 1.2, the maximum kinetic energy of photoelectrons vs. the frequency of incident light rays is summarized, and the data is plotted in Figure 1.19. We provide the following explanation for our conclusion in favor of the wave nature of light accounting for the energy incident to the ejection of electrons from their orbits. The data was reproduced courtesy of Milikan, phys. Rev. 7, 355 (1916) [3].

The energy $\mathbf{K_{max}}$ depended on the frequency, and not the intensity of the incident light, because the ejected electron from a specific orbit absorbed the light energy of a quantized maximum amount at the frequency of incident light. The quantity of energy absorbed by an orbiting electron is a function of the de Broglie wavelength representing the electron in orbit. At the frequencies of the incident light, corresponding to at or below the de Broglie wavelength, the electron absorbed adequate energy required to alter its quantum state. At higher frequencies light waves penetrated to the inner shells, removing the electrons from their interior orbits as the electrons absorbed the penetrating light.

Table 1.2 Frequency of light vs. Maximum KE of electrons

Frequency of light inTera Hz	Maximum kinetic energy in eV
48.5	-2.33
55	-2.03
69	-1.5
74	-1.3
82	-0.94
96	-0.38
118	0.50

Obviously, the light of lower frequencies with low energy cannot penetrate to the electrons in inner orbits. The kinetic energy of electrons in the inner orbits is higher than the kinetic energy of the electrons in the outer orbits. This is because the *potential* energy of electrons is higher (smaller negative) in the exterior orbits than in the interior orbits. To prevent escape of electrons, the kinetic energy and the speed of electrons is balanced against their potential energy. The fact that incident light having a frequency below threshold $\boldsymbol{\nu_0}$ does not produce electron ejection, regardless of its intensity, proves that any incident light energy propagating below that frequency will not be absorbed by electrons in any orbit. Therefore, the results of this experiment did not prove that light consists of photon particles.

It was determined that the photoelectric current was directly proportional to the intensity of the incident light. The higher the intensity of light the more photoelectrons are ejected provided that the frequency of light was above the threshold frequency. However, this linear relationship did not provide a solid proof that light is indeed a particle. A larger *number* of electrons on the metal plate had absorbed the increased amount of energy from the light waves when the intensity was increased, which also increased the number of interacting photons. Thus, light waves with high intensity ejected more photoelectrons and increased conduction. It is not a surprise that Einstein's photoelectric effect equation works equally well whether light is modeled as a wave or a particle. Thus, a photoelectron is emitted if an electron on a metal anode absorbs a quantum of energy, despite whether light is modeled as a particle or a wave.

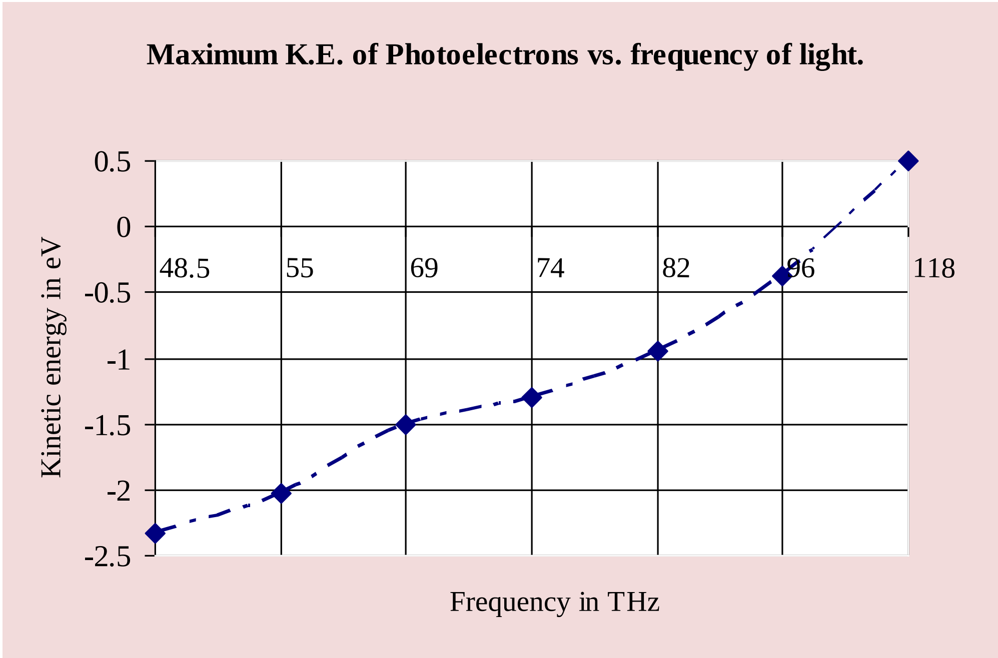


Figure 1.19 Maximum KE of photoelectrons vs. frequency of incident light**.** The maximum kinetic energy is proportional to the frequency and not related to the intensity of light incident because high frequency light waves affect the electrons of the inner shell orbits. [Figures from R. A. Milikan, Phys. Rev. 7,355 (1916)].

Another dilemma that favored the particle nature of light was the time delay observed between the instant of exposure of radiation and the emission of ejected photoelectrons. It was claimed that the time delay between initial light illumination and the onset of photoelectron ejection current was so short $\mathbf{3 \times 10^{-9}}$ **s (<** $\mathbf{10^{-8}}$ **s)**, that it could not be explained with the wave model of the light. According to this claim, if light were waves, it would take about a year to eject a photoelectron out of the metal surface. The reason for this thinking was developed from the idea that the wave model impose a requirement, an electron must absorbs a small amount of energy from each wave-cycle of incident light. However, the onset time delay is still very high, compared to the period of the incident light wave, which is a few femto seconds (**1.25-2.5 Fs**, see Table 1.3 for the visible light range). On the basis of QED principles developed by Richard Feynman discussed in Chapter 6, we presume that the photoelectrons are ejected after the electrons in their orbits absorb wave energy from several cycles of light waves. A limitation of wave model was it could not explicate the quantum nature of energy transfer between an electron and the emitted radiation. We will learn more about quantized energy of radiation in Chapter 2, when you will study the details of origin of radiation from inner space of atoms.

Table 1.3 Light wavelength λ (10^{-9} m), frequency ν (10^{12}), period (10^{-15}) & coeff. σ_{water}

COLOR	WAVE-LENGTH λ		PERIOD	FREQUENCY ν	REFRACTIVE INDEX σ OF WATER	
	Angstroms	Nano m.	Femto sec.	Tera Hertz	Real Part	Orthogonal
Violet	3800-4300	380-430	1.266-1.429	790-700	1.345	2.11 e $^{-10}$
Blue	4300-5000	430-500	1.429-1.667	700-600	1.342	3.30 e $^{-10}$
Cyan	5000-5200	500-520	1.667-1.724	600-580	1.339	4.31 e $^{-10}$
Green	5200-5650	520-565	1.724-1.887	580-530	1.337	8.12 e $^{-10}$
Yellow	5650-5900	565-590	1.887-1.961	530-510	1.335	3.53 e $^{-09}$
Orange	5900-6250	590-625	1.961-2.083	510-480	1.333	1.41 e $^{-08}$
Red	6250-7400	625-740	2.083-2.469	480-405	1.331	3.48 e $^{-08}$

Einstein and the proponents of the particle theory of light claimed that photoelectrons were ejected by the energy absorption from exactly one quantum of photon. He proposed that the photoelectric effect is a one electron-one photon interaction phenomenon. According to his theory, one photon could not eject more than one photoelectron. From our elucidation, however, one may begin to realize that the observation seems correct, but it does not support the notion that a photon is a particle. Our conviction is that particles have rest mass and a fixed center of gravity [25]. Hence, the evident short delay for electron ejection in the photoelectric effect does not prove that light consists of photon *particles*. An interesting analysis of wave and particle theory of light applied to the photoelectric effect is described in a white paper from Dr. Thomas Smid [E].

In 1905, Einstein proposed that quantization was a fundamental property of light and radiation. It was this that led to the concept of the photon particle. From our school of thought, this was an error, because Einstein failed to realize a fundamental property of real particles; the unique position of a *center of gravity* for the particle. As stated before, particles project an attractive force of gravity upon other particles. Remarkably, this constitutes a major consideration that Einstein and many other physicists did not take into account. We do believe quantization is a fundamental property of quantum real particle electrons. The radiation of every type of energy inherits this property from its creator parent particle electron. Regardless the quantized nature of radiation interaction with particles, we prove that the lack of mass and a center of gravity, being necessary properties of matter, restricts us from qualifying radiant energy as particulate. Therefore, we qualify the photon as an *imaginary* particle which does not exist in reality. It is imperative that physicists recognize this fact and invent special rules to handle interactions between actual particles and wave entities.

In section 1.6.2, we will discuss the details of the short wavelength limit X-ray experiment. We shall persist to show that the results and conclusion of the experiment did not prove that light consists of particles. On the contrary, you will be convinced that the results of the experiments prove that light and radiation energy are exclusively waves.

1.6.2 Short Wavelength Limit X-rays

The focus of this section is to describe details of the short wave-length-limit X-rays experiment. In this experiment, usually a metal target is struck with high energy accelerated electrons within the range of 5-50 KV for the purpose of obtaining what is called a *Bremsstrahlung* (German for “deceleration radiation”) *spectrum* [3]. It has been observed that the spectrum was continuous, and covered a wide range of wave lengths. The energy from the colliding accelerated electrons had been absorbed by electrons in their orbits and re-emitted in the form of x-rays. In Figure 1.20 the concept behind this radiation event is displayed. A fact that was not explained by classical mechanics was that X-ray emissions were sharply cut-off at a certain minimum wavelength, or a corresponding maximum frequency (we have avoided the “photon” use intentionally). The cut-off frequency of X-rays only depended on the accelerating potential and did not depend on the type of metal used as a target. The minimum wavelength λ_m corresponding to maximum frequency of the X-ray was the same for all metals and varied linearly with the accelerating potential of colliding electrons in accordance with a law verified by Duane and Hunt [3].

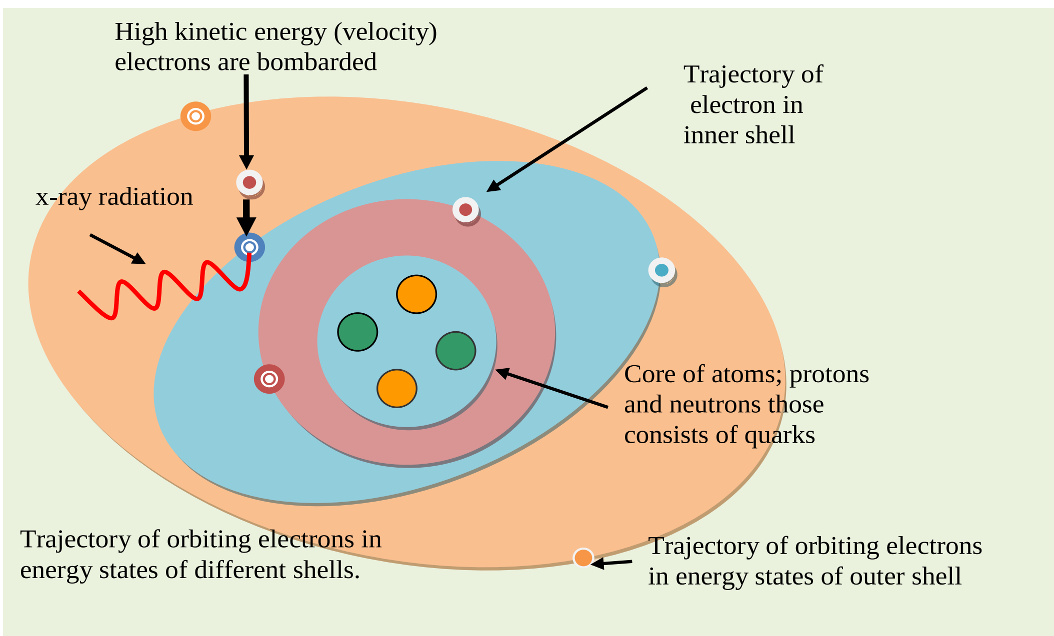


Figure 1.20 Radiation event caused by collision of high energy electrons**.** Here it is demonstrated that electrons with high accelerating potential may trigger an orbital transition event and release X-rays.

The radiation event in which high energy electrons were bombarded, resulting in the emission of X-rays is displayed in the Figure 1.18

$$\boxed{1/\lambda_m = [e/(h \times c)] \times V_0} \qquad \mathbf{(1.44)}$$

Define $\nu_m = c/\lambda_m$, we have $h \times \nu_m = e \times V_0$ **(1.45)**

Maximum energy of x-ray emission = Kinetic energy of incident electron

Notice that the work function does not appear in this equation **(1.44)** because it is almost negligible in comparison to the electrons and the photon energies involved (order of 0.1 percent). In Figure 1.21 the relative intensity of x-ray emission vs. wave length for varying electron potentials are plotted. The corresponding numerical data is included in Table 1.4. In Figure 1.22 a graph of maximum frequencies vs. accelerating voltage is displayed and the corresponding numerical data is summarized in Table 1.5.

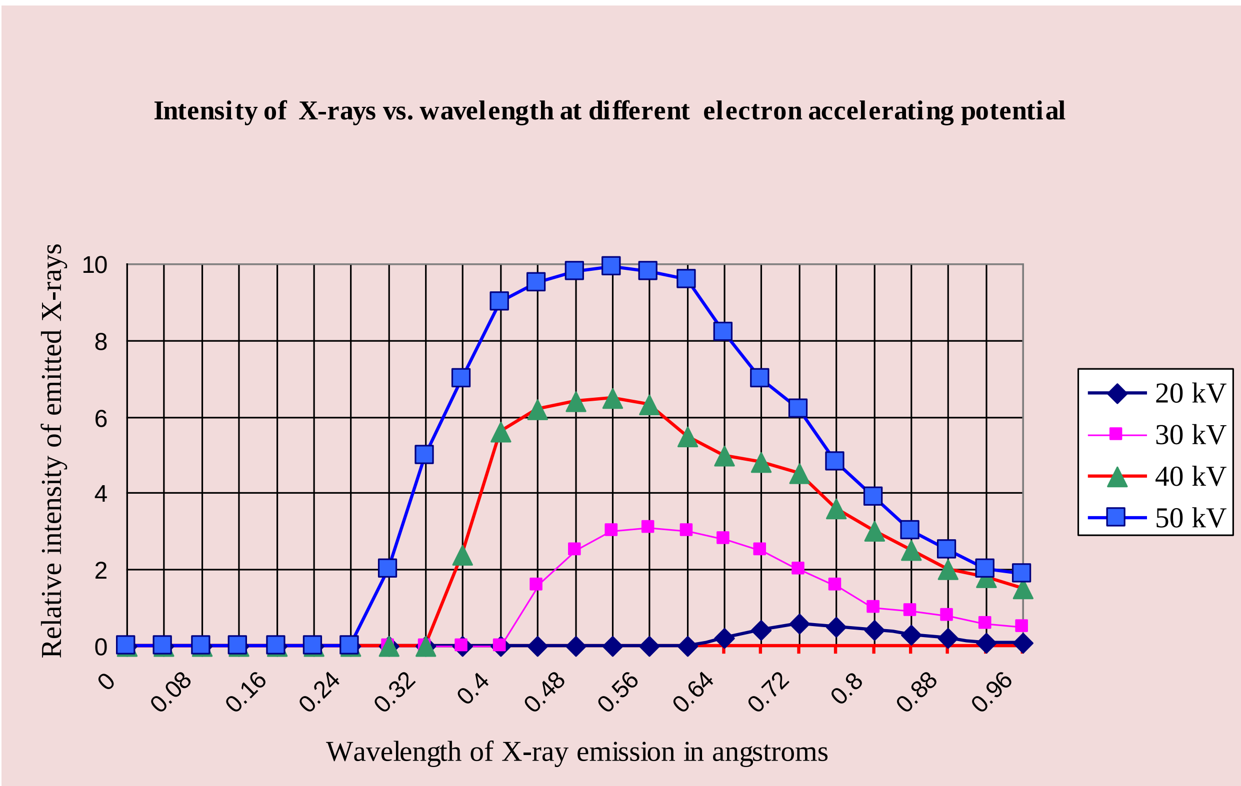


Figure 1.21 Bremsstrahlung spectra**:** x-rays are emitted when electrons with high acceleration potential strike a metal target [Data of C. T. Ulrey, Phys. Rev. 11, 401 (1918)].

Let us dig deeper into the exercise to understand the x-ray emission phenomena. It was claimed that the maximum possible frequency of X-rays corresponds to the difference between the kinetic energy of an incident electron and the energy of the electron when it occupied a vacant state in an orbit shell. This differential, it was claimed, was converted into the energy of a single X-ray photon. Hence, it was interpolated that X-ray photons are particles. However, the emitted X-ray lacks rest mass and center of gravity. Therefore, we repeat, X-ray photons are *not real particles* in our concept or terminology.

Table 1.4 X-ray emissions vs. cutoff frequencies at different eV acceleration.

Wavelength X-ray Ang.	Relative Intensity at 20 kV Acc.	Relative Intensity at 30 kV Acc.	Relative Intensity at 40 kV Acc. .	Relative Intensity at 50 kV Acc.
0.0 – 0.24	0	0	0	0
0.28	0	0	0	2
0.32	0	0	0	5
0.36	0	0	2.4	7
0.4	0	0	5.6	9
0.44	0	1.6	6.2	9.5
0.48	0	2.5	6.4	9.8
0.52	0	3	6.5	9.9
0.56	0	3.1	6.3	9.8
0.6	0	3	5.5	9.6
0.64	0.2	2.8	5	8.2
0.68	0.4	2.5	4.8	7
0.72	0.6	2	4.5	6.2
0.76	0.5	1.6	3.6	4.8
0.8	0.4	1	3	3.9
0.84	0.3	0.9	2.5	3
0.88	0.2	0.8	2	2.5
0.92	0.1	0.6	1.8	2
0.96	0.1	0.5	1.5	1.9

Another plausible explanation is that the highest potential electrons had produced the highest frequency x-rays; such occurring when the accelerated electrons bombarded the inner orbital shells. The electron exchanged energy with an electron in an orbit closer to the nucleus. These have a higher speed and spin momentum than the electrons in the outer shell orbits, we recall. As indicated in Figure 1.18, the excited electron absorbed energy from a colliding electron and re-emitted the excess energy in the form of X-rays. The maximum frequency of the X-ray was the function of the excess energy and the quantum state (spin momentum and speed) of the electron from which the energy was released. The fact that this maximum frequency was linearly increasing with the accelerating potential of the electron did not prove that the released X-ray was a photon particle. The energy content of a wave can also be a quantized number just as well as a particle can be quantized. Also to be considered as well was the fact that the spectra of the various wavelengths were emitted in this event. Furthermore, emitted X-rays also lack a center of gravity and a rest mass, which are crucial identifying characteristics of real particles.

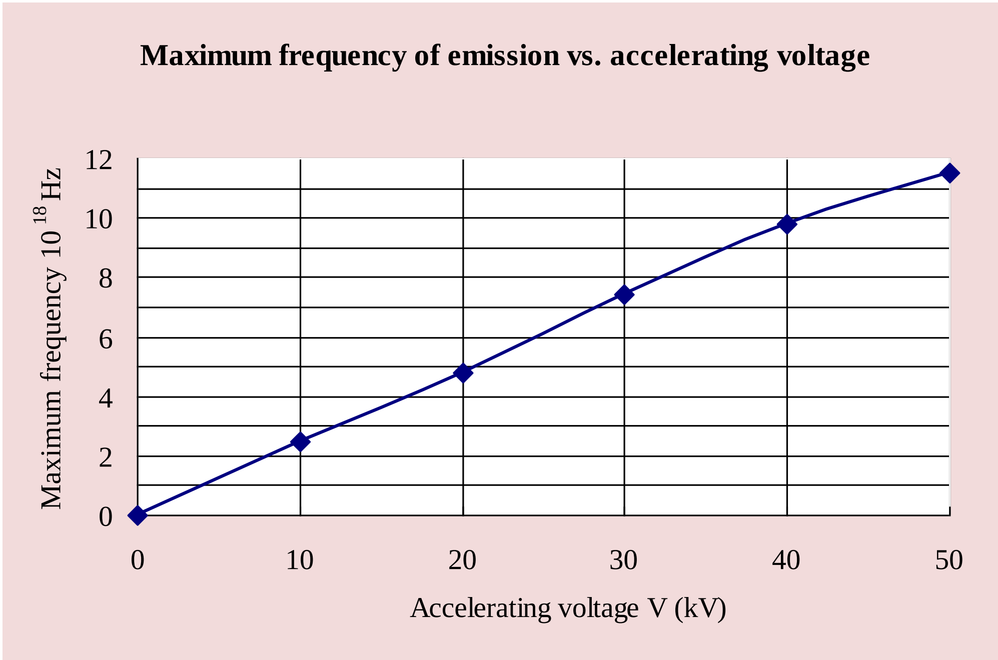


Figure 1.22 Maximum frequency of X-rays vs. accelerating voltage**.** The frequency emitted is directly proportional to the potential of bombarding electrons. [Data of C. T. Ulrey. Phus. Rev. 11, 401 (1918).]

The phenomena described in charts of the Figure 1.21 and the Figure 1.22 resembles the photoelectric effect in reverse. This is derived from the point of view that the kinetic energy of colliding electrons had been transformed into X-ray radiation. It was discerned, that the maximum possible frequencies of X-rays *correspond to the kinetic energy of an incident electron* that had been converted into the output energy of a single photon of corresponding frequency. Put simply, the energy from a bombarding electron is absorbed by an electron in orbit, re-emitting this energy in the form of X-rays. Therefore, for a given accelerating potential, the intensity of X-rays peaks at a limited corresponding wavelength, its cut-off frequency. This frequency, at which peak intensity occurred, increased with an increase in the accelerating potential of the incident electrons. Moreover, the cut-off frequency increased also.

From our perspective, the emitted X-rays waves do not possess rest mass and a unique position of center of gravity [25]. Therefore, it is an unfortunate prevarication to classify radiated energy X-rays being comprised of particle photons, but manifesting themselves as waves with a frequency corresponding to X-ray energy spectrum. The distribution of the rest mass of a particle system defines an instantaneous position of center of gravity for the mass in the steady state. Moreover, real physical particles with nonzero rest mass exhibit force of gravity on other particles and objects. Thus, it is imperative to state that wave entities such as light waves, infrared energy waves, X-rays, Cosmic rays and Laser or Maser waves are comprised of *imaginary* particles and we should distinguish them from real physical particles.

Table 1.5 Maximum frequency of X-ray vs. the accelerating potential.

Accelerating Voltage V (kV)	Max. Frequency 10 ** 18 Hz
0	0
10	2.5
20	4.8
30	7.4
40	9.8
50	11.5

In the next section, we will illustrate the details of the experiment of the Compton Effect**,** discovered by and named for its inventor, Arthur Holly Compton. The Compton Effect demonstrated that photons carried kinetic energy and a linear momentum. Collision events between X-ray photons and free electrons were analyzed using the energy and momentum conservation laws of relativistic particle dynamics. In 1919, Einstein concluded that a photon of energy E travelled in a single direction and carried a momentum **= E/c = hf/c.** In 1923, Compton (1892-1962) and Peter Debye (1884-1966) independently extended Einstein's idea of photon momentum. Compton showed that when X-ray photons collide with free electrons the X-ray photon suffered a loss of energy. The loss was manifested as an increase in the wavelength of the X-ray by precisely the amount corresponding to an elastic collision between two particles. The resulting scattering of X-rays and the recoil of the electron, an effect resembling a collision between two particles, is known as the Compton Effect. Although many physicists thought that the ideas developed from the results of the Compton Effect experiment were sufficient to prove particle nature of light, we think the truth to be something else.

1.6.3 The Compton Effect

In this section, we will discuss the details of the experiment that describe the Compton Effect. The Compton Effect demonstrated that a photon carried radiant energy and possessed linear momentum. The collision event occurring between photons and free electrons were analyzed using the energy and momentum conservation laws. Compton showed that when the X-ray photon collided with the free electrons, the X-ray photon suffered a loss of energy. The loss was manifested as an increase in the wavelength (a decrease in frequency) of the X-ray by the precise amount that corresponded to momentum and energy conservation changes in an elastic collision between two particles. Here, Compton faced a dilemma. He stated that the X-ray was a particle. He also said that an elastic collision between the X-ray and the electron particle resulted in the increase of the *wavelength* of the X-ray. He implied that the particle X-ray was *analogous to the wave* X-ray, with a difference in wavelength caused by the conservation of momentum.

Compton's observation was interesting, but it did not prove that the X-ray was a photon particle. It was a hypothetical situation in which the X-ray photon collided with an electron. Therefore, it is more appropriate and accurate to specify that the X-ray *radiation* encountered a free electron. The electron absorbed the X-ray *energy* and re-emitted the energy at a lower wavelength. We say again: our proposition is that the X-ray is an emitted *wave* that carries energy, but has no rest mass [25]. Therefore, radiation waves such as X-rays do not have a center of gravity. Hence, this experiment failed to prove that light or X-rays consist of photon particles. In 1922, Compton and his coworkers realized that the *classical* wave theory of light failed to explain the scattering of X-rays from electrons. According to classical mechanics, electromagnetic waves of frequency $\mathbf{f_0}$ incident on electrons should have two effects:

1. Radiation pressure should cause acceleration of electrons in the direction of the radiation.

2. The oscillating field of X-rays should set electrons in oscillation at frequency **f** , where **f** is the frequency within the frame of the moving electron.

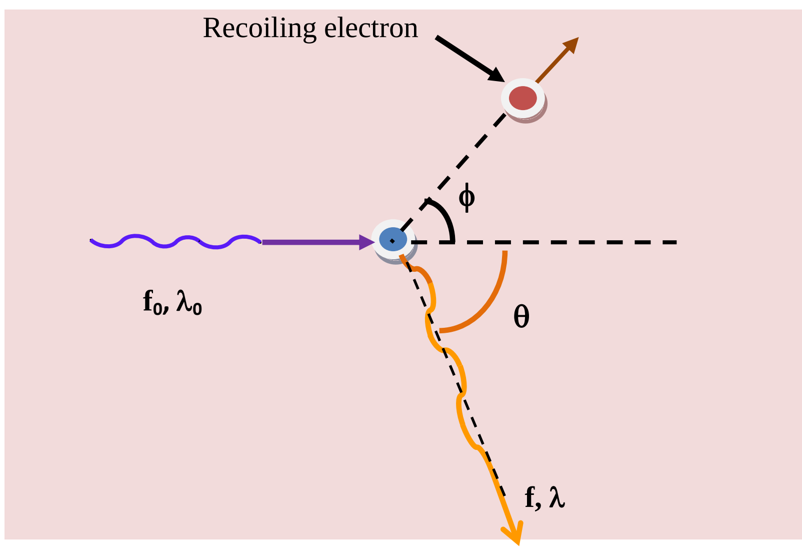


Figure 1.23 Collision between X-rays with an electron deflects them and the electron **recoils.**
(Courtesy of Serway & Jewett, Physics for Scientist and Engineers).

The apparent frequency **f** of the electron is different than $\mathbf{f_0}$ because of Doppler's Shift. Each electron moving in its orbit first absorbs radiation energy, gaining momentum, and then reradiates its energy, losing momentum, thereby exhibiting two Doppler shifts. Different electrons will move at different speeds after interaction. This is because its speed is dependent upon the amount of energy absorbed from the incident electromagnetic waves. The scattered wave frequency should show a distribution of Doppler shifted values in relation to the angle of incidence. Instead of observing, as he expected, *varying* energy signatures distributed throughout the scattered x-rays, Compton discovered that at a given angle of approach, only *one frequency of radiation* was observed in the scattered spectrum. Compton explained this observation by stating that the EM waves were behaving like photon particles having energy **hf** and momentum **hf/c**. Figure 1.23 shows the quantum picture of the collision between the X-rays and electrons. In this model, the electron is recoiled after the collision by angle ϕ**,** in a "billiard ball" fashion with respect to approaching radiation, while the frequency shifted radiation is scattered at an angle θ.

Compton plotted the data and the results of the measurements from his experiment. The X-rays, scattered from a graphite target, were analyzed by a rotating crystal spectrometer. The intensity was measured using an ionization chamber that generated a current proportional to the intensity. The incident beam consisted of a monochromatic X-ray of wavelength λ_0 **= 0.071 nm**. The current values were plotted vs. the wavelength for different values at a scattering angle θ. The graphs showed two peaks, one at λ_0 and other at λ. Based on these data, Compton derived the following relationship between differences in the wavelengths, at which the peak occurs at the scattering angle θ.

$$\lambda - \lambda_0 = [h/ (m_e \times c)]\ (1- \cos \theta) \qquad (1.46)$$

where m_e is mass of the electron and other symbols have the same meaning as before.

This expression is known as the Compton Shift Equation. The factor $h/(m_e \times c)$ is called the Compton wavelength of the electron, which has a current value of **0.00243 nm**.

At this time, let us analyze the details of the physical facts behind the effect. We do not contest Compton's equation and his theory behind it. However it is important to note that in the specialized case of a graphite target, the electron wavelength and the velocity of recoil is characterized by **0.00243 nm**. Further, according to quantum electron particle theory, electrons are orbiting in many different orbits in each atom of a graphite target, doing so at different speeds--and not always at **c,** as quantified in the equation **(1.46).** Even though the change in the wavelength of scattered X-rays corresponded to the difference between electron energies at the start of collision, as well as the kinetic energy of the recoil electron, it did not necessarily prove that X-ray radiation consists of *particle* photons. Once again our conviction is that an X-ray *wave* carried energy, but itself has no rest mass and does not exhibit the force of gravity on other particles. Additionally, the radiated X-ray waves did not have a center of gravity. Hence, this experiment failed to prove that light and X-rays consist of photon particles.

The analogy made between the X-ray and electron collision event in Compton's Effect with billiard balls colliding is not a perfect one. In the X-ray collision event, the magnitude of components of momentum vectors in Y-direction for the recoil electron and the scattered X-rays are non-zero, though the magnitude of component of momentum vectors for the electron and the X-rays in Y-direction at the start were zero. In a billiard ball collision event, if a cue ball had zero momentum in Y- direction, normal to the travel, the momentum component of the target ball in Y-direction, normal to the motion will have zero value if the cue ball collides with the target ball in X-direction. In this sense the motion of billiard balls completely obeyed rules of Newtonian classical mechanics while X-ray collision event in Compton's Effect did not obey the rules in strict sense.

Our explanation about the results of these experiments showed that their results did not necessarily prove that light energy consisted of photon *particles*. In fact, the entire spectra of signals (radiation) uniformly consist of waves with different wavelengths and are completely characterized by the wave properties. Our extensive analysis of the results of three experiments provides compelling evidence that the particle model of light and radiation waves is a convenient inference and is correct only from the point of a false inferential premise. The photon particles described by Einstein and other physicists are *hypothetical* particles. We will call the hypothetical particles virtual particles because they are imaginary particles, not real particles. As per our explanation we provide the following definitions of a real particle and a virtual particle.

A real particle is characterized by definite rest mass $\mathbf{M_o}$, occupying a definite volume of non-zero value, possesses a unique center of gravity position, and it exerts a force of gravity on other particles with rest mass **M kg**, that leads to its acceleration $\mathbf{a\ m/s^2}$, that has value as described by relation $\mathbf{a = G \times M/ r^2}$, where **G** is the Universal constant of gravitation and **r** is the separation distance between those particles.

A virtual particle is an entity which possesses energy, lacks rest mass, occupies an indefinite volume in space, and does not impose a force of gravity, but may or may not impose other types of forces such as magnetism.

From our definition it is obvious that virtual particles lack a static center of gravity. Further, light and radiation waves are continuously propagating in space. It is not feasible to prevent propagation of light and radiation waves in space. A light photon cannot be brought to rest. As a consequence of the particle definition stated, all energy waves in the spectrum are classified as virtual particles. We shall also declare virtual particles as quanta (singular quantum) of radiation waves and suitably characterize them as wave entities. We will purposely use different terms other than Einstein's "photons"; he called them photons without distinction whether they were real or imaginary particles. He confused the world physics community by declaring the dual nature of light as a particle and a wave. According to the equation **(1.43)** each quantum of radiation possesses $\mathbf{h \times \nu}$ Joules of energy. Therefore, we conclude that all types of radiation energy waves, including visible light waves, are not real particles and are not influenced by the force of gravity.

In the following section, we will focus on experiments that will demonstrate that light is indeed a form of energy waves. In particular, our focus will be to characterize Doppler's Shift Effect as it relates to sound and radiation waves. Furthermore, we will analyze the motion of fan blades while they are exposed to light. The advocates of the corpuscular theory of light used this experiment to establish particle nature of light. We will show that their effort did not serve its purpose.

1.7 Wave Nature of Light:Experiments

In section 1.6, we proved that the experiments that were performed to verify that light exhibited particle behavior in certain situations did not provide convincing results. Instead, we were able to prove that the wave model for the behavior of light better represents the nature of light than does the particle model. In next subsection, we will describe the facts and experimentation that prove that light behaves as a wave in all instances. Specifically, we will consider the effect of Doppler's Shift. Doppler's shift has important applications in astronomy, daily commerce, and national defense. In astronomy, it is utilized to estimate distances of remote galaxies and determination of the size and the age of Universe. In routine commerce, it is employed by traffic police to catch drivers speeding on highways and streets. It is used by flight control towers to navigate air traffic using radar. In military defense, its principles are applied for the locating and determining the aspects of mobile enemy targets using *radar* systems on aircraft, as well as surface ships at sea. Furthermore, we also see the use of *sonar* by surface ships and submarines. We will also describe the details of the rotating fan blades experiment. We will then validate our conclusion by citing examples of several interesting phenomena to support our argument cogently.

1.7.1 Doppler's Shift

The most remarkable distinction between waves and particles is that particles cannot exhibit Doppler's shift. It is well known that a reflected signal from a mobile target has a phase shift, being shifted in *frequency* compared with the frequency of the original output signal. This fact was first discovered by an Austrian physicist Christian Johann Doppler in 1842. He observed that the sound (waves) emitted from a receding and approaching train had a different pitch when heard by a stationary observer. The pitch was higher when the train was approaching the observer and became lower when it was receding away. A similar phase and frequency shift behavior was also detected for the entire electromagnetic wave spectrum. There are two important aspects of Doppler's principle. We would like to point out that the shift of the radiating signal occurs only when the distance between the source and the observer is changing. Secondly, the shift in the frequency observed is an *apparent shift*, but in reality, *the wavelength of emitted and received signal has not changed*.

The Doppler's effect is consistently being observed for signals in transit, whether they be sound energy, light wave energy, x-rays, or infrared signals. A common misconception about Doppler's shift is that the wavelength of the reflected signal is deviated by relative motion between the source and the observer. In reality, only an *apparent shift in frequency is occurring*. The wavelength of the reflected signal does not change. It is well known that the frequency shift is directly proportional to the velocity of the target. This is Doppler's popular principle that allows one to measure the velocity of a target object by measuring the frequency shift. Doppler developed following expression to compute the speed of a target (or source, should the target be stationary) by measuring the shift in frequency in the sound wave at the observer site.

Doppler's shift formula → $\mathbf{f_o = f_s \times (v + v_o)/(v - v_s)}$ **(Hertz)** **(1.47)**

where $\mathbf{v}$ speed of sound waves or sensed signals, $\mathbf{f_o}$ shifted frequency, $\mathbf{v_o}$ observer speed (+ve toward and negative away from source), $\mathbf{v_s}$ source speed (+ve if toward and negative away from observer), and $\mathbf{f_s}$ source frequency of sound or sensed signal

According to Doppler, the frequency or tone originating from the whistle of a moving train was sharper than when it was at a standstill. He measured the shift in frequency and determined that it is proportional to the speed of a train. This shift is popularly known as the Doppler shift. We believe that the Doppler's effect should not affect the wavelength because the same shift in frequency should occur if the train is standing still and the observer is moving toward the train. Therefore, the Doppler's effect results in the change of the *relative* speed of the traveling wave front. The sound *appears* to be arriving at a higher speed and with a sharper tone, than if both the observer and the train were not moving.

Radar technology is a prime example of the application of the principle of Doppler shift. Scientists measure the shift in the frequency of the reflected signals returning from a mobile target and the time of flight of a **~50GHz** radio frequency signal in order to determine the exact location and aspect of the target. The Doppler shift noted in frequency is directly proportional to the velocity of the moving target from the perspective of a static source. Scientists typically assume that the wavelength of the returned signal remained the same (second order effect on the computation). The Doppler Effect is applied by radar systems to determine whether the speed of drivers is in violation of the speed limit. Astrophysicists use the effect to measure the velocities of receding and approaching stars, galaxies, supernova and other celestial objects relative to the Earth.

For light waves, the Doppler shift is characterized as either blue shift or red shift, depending on whether the source of the wave is approaching the observer (an increase in frequency, a blue shift) or receding from the observer (a decrease in frequency, a red shift) [20]. Also, the fact remains that the measured Doppler shift has two values, depending on the direction and the speed of the source in relation to the observer. A source of signal cannot create signals of two distinct frequencies at one instant which differ by $\mathbf{2\delta}$. According to Einstein's theory, the measured lengths of rods in inertial systems is always smaller than the measured length of rods in a base reference system. As explained, Doppler's effect predicts the high and low frequency values. Therefore, STR is not consistent with Doppler's effect. Furthermore, presently, to determine Doppler shift for light signals, the relativistic frequency shift formulae is used based on the assumed *constant* of the speed of light, as proposed by Einstein's STR principles. Since we proposed a *varying* speed of light (VSL) within the body of the Skylativity® theory, the formula expressing the Doppler shift for light and radiation waves is the same as expressed for sound waves **(1.47)**.

This is a very important observation for light and other radiation energy waves; the fact that the Doppler shift affected the wavelength reveals a significant error in what was proposed by STR. The proposed process for a source of radiant energy (light) is the vibrations of electrons emitting energy when the electrons are transitioning from one quantum state to another, from an unstable high energy state back to its ground state. According to Niels Bohr's atomic model, these changes in energy were quantized according to each element and the shell to which the electron belongs.

We will continue our discussion of radiation frequency variation with the presence of gravity in Chapter 8. At present, it will be sufficient to state that the wavelength of light waves are created due to the disturbance of the state of fundamental particles, and should not be affected by the macroscopic Newtonian motion of the molecules. Furthermore, the classical Doppler shift $\boldsymbol{\nu^*}$ of a light wave of frequency $\boldsymbol{\nu}$, traveling at an angle $\boldsymbol{\alpha}$ to the direction of motion for two inertial systems moving with the speed $\mathbf{v}$ with respect to each other [4], is expressed by

$$\boldsymbol{\nu^* = \nu\,(1 - \cos\alpha(v/c))} \tag{1.48}$$

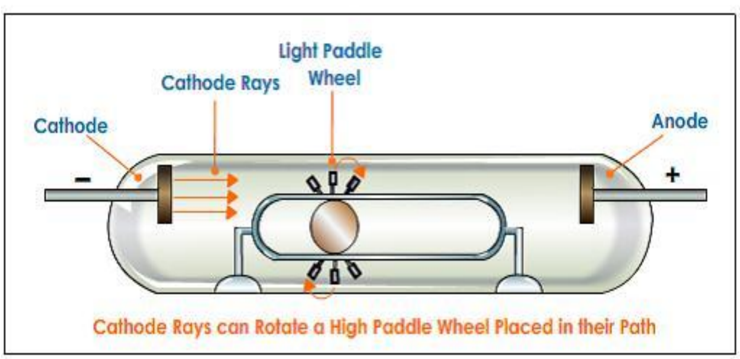
where $\mathbf{v}$ is the speed of object in an inertial system and $\boldsymbol{\alpha}$ is the orientation of the velocity vector.

One of the common mistakes made is that it is presumed that the wavelength of a travelling wave changes when the signal is propagating with a mobile medium. In general, the wavelength of any type of signal produced is the function of the spatial dimensions of the source. For instance, sound waves are produced by vibrations of gas molecules, strings, and tuning forks. Light and radiation energy waves of x-rays, Lasers and infrared rays are created by oscillations of electrons in the atoms of the source. We are implying that the motion of source will only affect the *frequency* of the signal and not the *wavelength*. The wavelength of travelling waves is only changed if the characteristics of the *medium* are altered. For instance, the speed of sound waves and the wavelength of a sound signal in water is different from the wavelength in air. Similarly, the transitional wavelength of light differs through air than through glass, and still differently through water. This is because the medium of glass and water have different indices of refraction than does air. It is interesting to note that, generally, the speed of sound waves increase in a denser medium than a rarer medium. It is found that the speed of light waves decreases in a medium with a higher refractive index than air. The wavelength of light in a medium with a high index of refraction is shorter, and its speed is less than in the vacuum space.

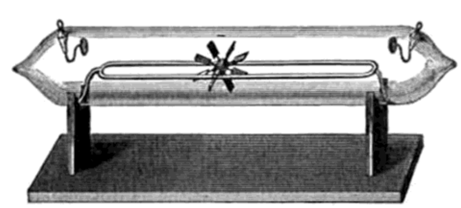
The proponents of the particle nature of light suggested yet another experiment to justify that light behaved as a particle. They performed an experiment in which blades of a miniature fan were exposed to light. The idea was to demonstrate that light photon particles actually transferred their momentum to fan blades when the blades were struck by light waves. Their intention was to show that the blades were rotated by the impact, the transfer of momentum. Therefore, in Section 1.7.2, we will explicate the reasoning and the result of the experiment, which involved the rotation of fan blades coated with a semiconductor, a photosensitive material. The fan blades were exposed to light waves, showing how it *actually* proved that light is comprised of *waves* rather than particles.

1.7.2 Rotation of Fan Blades

The idea of rotating fan, an early experimental discharge tube “Crookes tube” to study characteristics of rays was not new. It was originally invented by an English physicist William Crookes and others around 1869-1875, who discovered that streams of cathode rays were indeed particles, electrons. A schematic arrangement of Crookes apparatus and a photograph of his tube are displayed in Figure 1.24. Cookes placed tiny vane blades on a light paddle wheel in the path of the cathode rays, and found that it rotated when the rays hit it. The paddle wheel turned in a direction away from the cathode side of the tube, validating that the motion of the wheel was caused by particles coming from the cathode. Crookes concluded at the time that cathode rays have momentum, so the rays were likely particles of matter. It was not known that cathode rays were electrons at that time. However, later it was concluded that the paddle wheel turned, not due to the momentum of particles hitting the paddle wheel, but due to the radiometric effect.



(a)



(b)

Figure 1.24 Schematic arrangement of Crookes tube (a) Essential components; Cathode, light paddle wheel, anode and a vacuum tube (b) An actual photograph of the apparatus

The radiometric effect was proven by J. J. Thomson in 1903. He calculated that the momentum of electrons hitting the paddle wheel would be small enough to turn the wheel at the rate of only one revolution per minute. Therefore, he suspected there must be another reason for the motion of the paddles. He figured that when the rays hit the paddle surface they heated it, and the heat caused the gas near it to expand, pushing the paddle. We illustrated this experiment to show that it is very easy to draw incorrect conclusions in delicate experiments involving miniscule amounts of force.

The supporters of the particle theory designed a similar experiment with an intention to demonstrate that mechanical pressure from light waves transferred a momentum and a force to the blades of a fan. They specifically prepared the fan with very thin (light weight) blades so that it will move with as small a force as possible. The blades were coated with a thin layer of photosensitive material, and the fan was exposed to light rays. They discovered that the blades started rotating in a direction that would indicate that photon particles from the light transferred linear momentum into a torque. A construction of this fan and the apparatus is illustrated in Figure 1.25.

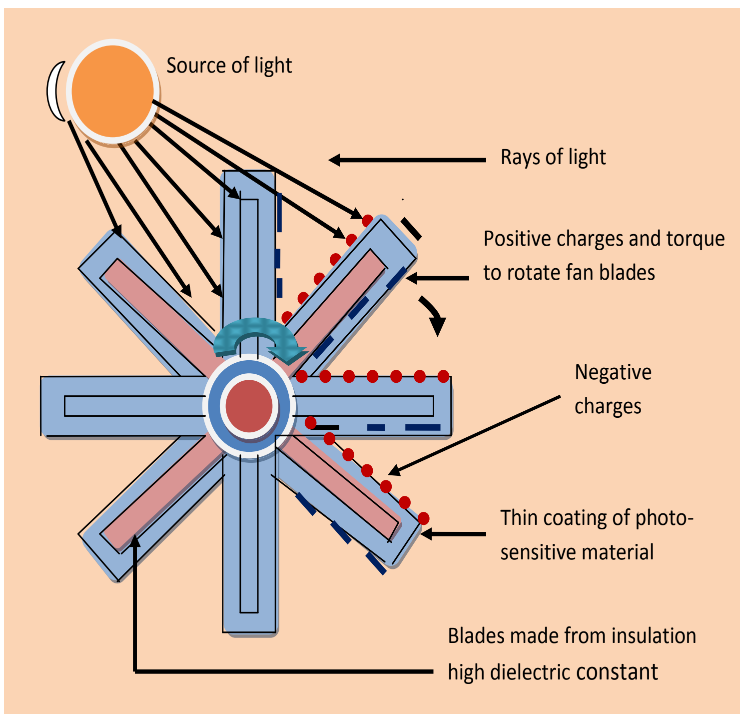


Figure 1.25 Rotation of fan blades coated with photo-sensitive material. Fan starts rotating as it’s blades experience charge force from electrons and holes charges on different blades created by exposure of semiconductor material to light.

Our view about the results from this experiment is that it did not prove that light waves are particle photons. The reason is simple; the size of photons possessing zero rest mass is very small compared to the mass and the momentum change associated with the blades. Further, the fan blades would not rotate if they were not coated with photosensitive material. The performers of the experiment erroneously concluded that photons were impinging upon the blades, transferred their momentum. Therefore, we conclude that a closer examination is necessary to analyze the rotation of fan blades by light.

Figure 1.26 illustrates a detailed view of a pair of blades. The blades were made out of a very thin film of ceramic, which has very high dielectric constant compared to air. Also, the thin film decreased the weight of the film, and the whole fan weighed less than an ounce. These blades were coated with photosensitive material. When the blades were exposed to an intense light beam, many electrons in the outer shell of the photosensitive material absorbed the light wave energy. They jumped to a conduction band, became free electrons, and left behind holes in the bound state of the surface atoms. The free electrons accumulated on the surface of the blade.

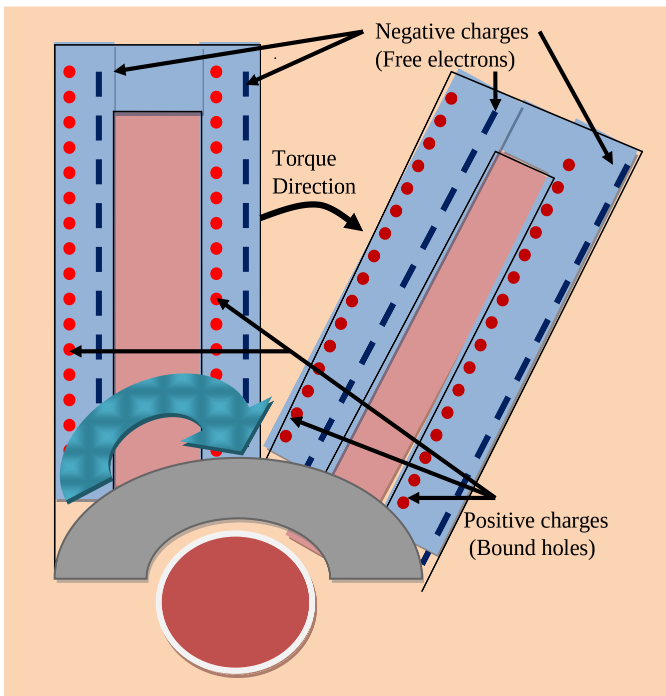


Figure 1.26 Details of the charges on a pair of fan blades exposed to a beam of light. A torque is developed when the thickness of the film that is pasted, is larger than the thickness of the fan blades.

The peculiar ways electrons emit and absorb light, as well as other non-electromagnetic waves classed such as infrared, x-rays and gamma rays are of significant interest to us. We shall show that these classes of waves are distinct from electromagnetic radiation. We will categorize them as Planck waves. In fact, based on this new classification, we shall develop a new chart of frequency spectrum in Chapter 2. At the moment, we shall continue our discussion on why the thin semiconductor-coated fan blades were set in motion by incident light. One can relate this situation with the creation of static charges built-up on silk when it is rubbed with fur. We observe that a body with charge buildup can set in motion charge free matter, such as human hairs that repel one another.

As we will notice, the unbalanced charges on the polarized blades have potential to create a torque that sets the wheel in motion. Let's examine the details more closely, inasmuch as this is exactly what happened in this situation.

When the light waves hit the blades with a photosensitive material coating, many (valance band) electrons and "hole" counterparts were created. This is the result of electrons absorbing the energy from the incident light. The freed electrons are in the conduction band and charge the surface of the blade negatively, while the other side of the blade is positively charged because "holes" are created in the outer orbits of surface atoms, being less one electron. The negative charge on one-half of one blade is attracted to the positive charge on the adjacent blade. The force of attraction between the polarized, charged blades created a momentum realizing torque that resulted in the rotation of the fan blades.

Thus, this experiment did not prove that light is comprised of photon particles. Instead, it proved that it is a wave. In sections 1.7.3 and 1.7.4, we will show more examples that strengthen our conclusion that light always behaves as energy *waves*, and never as particles. The nature of examples stated in these sections are is such that one cannot provide experimental evidence to prove wave nature of light.

1.7.3 Bright and Dark Sides of the Earth

We all know that the side of the Earth facing the Sun is illuminated during the daytime for that region of the Earth. On the other side of the Earth, it is dark and is nighttime for that part of the Earth. If light is comprised of photon particles, as described by Einstein, it should be possible, let's say, to bend rays of light by the influence of some kind of force field in order to illuminate a small part of the dark side, a very tiny fraction, such as, a few feet. This is an extremely difficult experiment to perform. There is no such evidence that this experiment has ever been performed.

A major deficiency of the particle model for light stems from the fact that white light from the Sun consists of the seven primary colors of the rainbow. There is no explanation from Einstein's theory of relativity about how the photons corresponding to various colors of different frequency and that the wavelengths are somehow combined into photons of white light. Also, it is difficult to explain, based on the particle theory, how the photons of white light, when passed through a prism, can be split into photons of different colors, a dispersion phenomenon. Splitting white light into different colors due to the dispersion effect is very easy to observe naturally. For instance, daily at Sunrise (dawn) and Sunset (evening), we see the red colored light more distinctly than the other colors. The index of refraction is different for the red color than the blue color. An interesting fact is, in the morning at sunrise, and during sunset in the evening, we see red color in the sky. But during the day we see a blue-colored sky. The reason for the different colors is that the light waves are preferentially scattered by the Earth's atmosphere, depending on the angle of incidence of the rays of sunlight relative to the surface of the Earth's atmosphere. During sunrise and sunset the angle is such that blue rays are scattered to a minimum extent and red colored light is scattered to a maximum extent. During the daytime the angle of incidence of sunlight is such that the atmosphere scatters the bluish spectrum of color to a greater extent. The preferential scattering of light is more easily explained by the wave theory of light than the corpuscular particle theory in its attempt.

From our extensive discussion in this chapter, you will have been convinced that all of the chemical and electrical properties of events related to light can be explained by strictly stating that light is a wave similar to x-rays and infrared waves. The bending of light through the atmosphere and through high density materials, such as fluids like water and oil, or solids like glass and the human body, etc., can be more easily explained by theorizing it as being a wave. The same is true for the reflection of light from shiny surfaces. Another example is seen by the behavior of light propagating through a fiber optic cable. Light can travel through the curves and angular bends of a fiber optic cable. A wave can create a curved path by what is described as multiple internal reflections phenomena. If light was a particle, or corpuscular in form, it would not appear at the end of the tunnel of the fiber optic cable. In Section 1.7.4, we will address more examples that provide proof that light behaves and therefore exists as a wave and not a particle.

1.7.4 More Examples

Several phenomena have been investigated to explain the dual behavior of light being a wave or a particle. For instance, one of the controversies in the earlier years, that light is a particle, was from photo voltaic cells which were producing an electrical voltage difference by exposing these cells to the sunlight. When the semiconductor material of photovoltaic cell is exposed to light, electrons in the atoms of the material absorb light wave energy. The electron's energy state changes to the conduction band. The charges complete the circuit of a power source, and current flows. Previously, this effect was classified as being caused by the particle nature of light. This, however, is not a correct classification, because wave energy can dislodge the electrons from the photosensitive material to create the potential differences between the electrodes of the photocells, causing a current flow.

The second example is the use of monochromatic light beams to etch film processing; light sensitivity. The etching of thin films is very commonly utilized in the fabrication of semiconductor circuits. With the advent of ultra large scale integration (ULSI) technology, it is possible to analyze the nature of etched surfaces, using various techniques. The photographs taken by SEM, TEM, AES, and other means, distinctively show the side encroachment (under and over) in the etching processes. The surfaces etched are very much an analogue in nature, or continuous, from the defect point of view, and are smooth and round shaped. If the nature of light was corpuscular, the edges would be rough, being made a microscopically corrugated surface by the indiscriminate impact of supposed particulate photons.

Finally, let us state an example provided by popular shows that integrates music and dancing laser beams, whereby the light beams intersect in the sky, on streets, or inside an auditorium. If one carefully observes, the path of each light beam, after the intersection of another beam, does not alter it in any way. The beam continues to travel in a straight line. Moreover, the color characteristics of the beam remain the same. If the light, or photons, were particles, the trajectory of the intersecting beams should be affected, at least by some percentage. We are suggesting that an experiment be conducted in which one would analyze the wavelength of the beam of light after an intersection to observe if any alternative interaction occurs. Our assertion is that the wavelength of the light beam will be the same as that emitted from the source when measured after the point of intersection. To improve the contrast and facilitate the measurement, two different colored sources of the light beam should be used.

WHAT IS NEXT? CHAPTER 2: Quantum Theory of Radiation (QTR)

- Distinguish radiation energy waves (visible light, X-rays, infrared, microwaves) from radio frequency electromagnetic waves.
- Define a meaning to true speed of light **c** and sense of absolute time.
- Discuss path of light through a pair of Newton prisms, entropy considerations.
- Dispersion and deviation of light through prism.
- Differentiate properties of waves from particles.
- Origin of radiation waves: a quantum phenomenon
- Establish quantum nature of radiation waves and identify them as Planck waves.
- Describe energy content of RF EM waves and Planck Waves.
- Michael Faraday's experiment, investigating EM nature of light.
- Polarization characteristics of light and EM waves.

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1.8 Summary

DEFINITIONS

Real particle: It is characterized by definite rest mass $\mathbf{M_o}$, occupies definite volume of non-zero value, possesses an unique center of gravity and exerts a force of gravity on another particle with rest mass **M kg** that leads to its acceleration **a** m/s^2 whose value is described by the relation

$$\mathbf{a = G \times M_0 / r^2}$$

where **G** is universal constant of gravitation and **r** is the separation distance between two particles.

V**irtual particle:** It is an entity which possesses energy, lacks rest mass, occupies indefinite volume in space, and does not project force of gravity, but may or may not project other types of force such as the magnetic force. We classified light energy as **virtual particles** and as **quanta** of radiation.

Obviously, virtual particles lack center of gravity. As a consequence of particle definition described here, all energy waves in the spectrum are classified as **virtual particles**, and are most suitably characterized as **wave entities**. Also, energy and light waves are not deflected by force of gravity.

Isolated system: In an **isolated** system, energy does not cross the boundary of the system due to interaction with an environment. For this system, the total energy of the system remains constant. If it were the case that only conservative forces acted on an isolated system, we can apply the work-kinetic energy theorem if the only change in the system is in its speed.

Integrated system: An energy model of a system is **integrated** if, within the system, energy crosses the boundary of the system during some time interval due to interaction with the environment, such that the internal energy of the system (temperature, enthalpy) is modified. This results in a change in the system's total energy.

Elastic collision: A collision between two objects is deemed as **elastic** if the total kinetic energy of the system as well as the total momentum of the object is conserved, meaning that the values of kinetic energy and momentum before and after the collision will remain constant.

Inelastic collision: A collision between two objects is **inelastic** if the total kinetic energy of the system shows difference following the collision, but the total momentum of the system is conserved. When two objects stick together after the collision, the collision is called **perfectly inelastic**.

Space: It is a physical entity that exists which is capable of storing and transporting other physical entities such as matter, energy and information without resistance or with least obstruction.

CONCEPTS AND PRINCIPLES

- Light rays arriving from the distant stars behind the Sun are refracted by the Sun's hydrogen atmosphere and not deflected by the Sun's gravitational field. The effective value of angle of deviation of star light rays is computed by a relation from R.C. Gupta.

$$\mathbf{2\,G\,k \times M_{\Theta} / (R_{\Theta} \times c^2)}$$

where **G** is the Universal constant of gravitation, $\mathbf{M_{\Theta}}$ solar mass, $\mathbf{R_{\Theta}}$ solar radius, **c** is speed of light and $\mathbf{1 < k < 2}$ is a factor that depends on the density of hydrogen atmosphere in the proximity of rays.

- Michelson-Morley experiment was designed to measure velocity of the Earth with respect to a hypothetical ether frame, but failed to show the fringe shift in the interference pattern and corresponding Newton's rings. This is because the speed of light is invariant if the distance between the light source and the observer is not altered during the experiment. The experiment setup does produce fringes if mirror B is moved by distance **x m**. The arrangement can be used to measure and calculate the wavelength of light from a source that is unknown by the equation $\mathbf{2x = m\lambda}$ where **m** is the number of circular fringes shifted and λ is the wavelength of the light source.

  A slightly modified arrangement can be employed to measure the index of refraction μ of a gas column if the wavelength of light λ_k is known by using the expression

$$\mathbf{2L \times (\mu - 1) = m \times \lambda_k}$$

- Review of particle motion in one dimension **under constant acceleration** in Cartesian coordinate system.

$$\mathbf{v_f = v_i + a \times t}$$

$$\mathbf{v_{avg} = (v_i + v_f)/2}$$

$$\mathbf{x_f = x_i + v_{avg} \times t}$$

$$\mathbf{x_f = x_i + v_i \times t + \tfrac{1}{2}\, a \times t^2}$$

$$\mathbf{v_f^2 = v_i^2 + 2a \times (x_f - x_i)}$$

where $\mathbf{v_f}$ is the final velocity, $\mathbf{v_i}$ is the initial velocity of particle, $\mathbf{v_{avg}}$ is the average velocity of particle, $\mathbf{x_f}$ is the final position, $\mathbf{x_i}$ is the initial position, and a is the constant acceleration. These formulae hold well for motion in multi-dimensional systems, and for the polar and the spherical coordinate systems.

ANALYSIS MODEL FOR PROBLEM SOLVING

- Einstein modeled the maximum kinetic energy of electrons emitted during the **photoelectric effect**. This is a process in which electrons are ejected from a shiny metal surface when it is exposed to a light of frequency corresponding to a wavelength below threshold value. The kinetic energy of emitted electrons is obtained by Einstein's equation

$$\frac{1}{2} m_e V^2_{max} = h \times \nu - \omega$$

where m_e is the mass of electron, V_{max} is the maximum velocity of photoelectron, ω is the work function of the metal, **h** is known as Planck's constant, and ν is the frequency of UV light. The work function of the metal is related to the threshold frequency by expression

$$\omega = h \times \nu_0$$

- When high energy accelerated electrons are collided with a metal target, the **Bremsstrahlung** spectrum of x-ray is obtained, a **short wavelength limit x-ray** event. This x-ray emission was sharply cut-off at a certain minimum wavelength (or corresponding maximum frequency) which was only dependent upon the accelerating potential. According to a law validated by Duane and Hunt, the minimum wavelength λ_m varied linearly with the accelerating potential and is evaluated by the expression

$$1/\lambda_m = [e/(h \times c)] \times V_0$$

where **e** is the charge on an electron, V_0 is the accelerating potential, **h** is known as Planck's constant, and **c** is the speed of light.

- X-rays are scattered at various angles of different wavelengths than incident wavelength by electrons in a target. In such a scattering event, a shift in wavelength is observed for the scattered x-rays for each angle, a phenomenon known as the **Compton Effect,** in which x-ray intensity at a scattered angle peaks. It was discovered that if the system of x-rays and electrons is treated as a collision between virtual particle x-ray and real particle electron, conservation of energy and linear momentum is applied, yielding the computation of Compton shift from the relation

$$\lambda - \lambda_0 = [h/(m_e \times c)] (1 - \cos \theta)$$

where λ_0 is the wavelength of incident x-ray, m_e is the mass of an electron, θ is the scattering angle, **h** is known as Planck's constant, λ is the wavelength of scattered x-ray, and **c** is the speed of light.

APPLICATIONS

- The change in frequency of a wave signal sensed by an observer whenever there is a relative motion between a source of the wave signal (audio, video and EM) and the observer is called the **Doppler Effect**. The observed frequency is related to the source frequency

  $$\mathbf{f_o = f_s \times (v + v_o)/(v - v_s)} \quad \textbf{(Hertz)}$$

  where **v** is the speed of sound waves, or sensed signals**,** $\mathbf{f_o}$ is the shifted frequency**,** $\mathbf{v_o}$ is the observer speed (positive toward and negative away from source)**,** $\mathbf{v_s}$ is the source speed (positive toward and negative away from the observer), and $\mathbf{f_s}$ is the frequency of source.

- Rotation of the fan whereby blades were coated with photo-sensitive material; did not prove the particle nature of light. The fan was rotated by torque generated by the Coulomb force between charge particles. An opposing local concentration of charges was created on the blades by the absorption of energy from the incidental light waves.

Exercises

Questions

A heart (♥) denotes objective question and a question with a diamond (♦) requires analysis.
Answers to all questions (♥) and (♦), and problems (♠) and (♣) are included at the end of exercises.

1. Discuss succinctly the three most controversial aspects of Special Relativity Theory principles as postulated by Albert Einstein.

2. Explicate briefly why light is not a particle by stating at least three reasons. Substantiate your reasoning with diagrams describing light as mass-less energy waves.

3. Expound statement “Trajectory of Star light passing by the Sun is refracted by the hydrogen atoms in its atmosphere and not deflected by its gravity” using Snell’s law.

4. Explain controversial aspects of General Relativity Theory postulated by Einstein.

5. What are the causes for failure of Michelson’s apparatus which did not allow him to measure the orbital speed of the Earth around the Sun. Give reasons why he did not observe Newton’s ring through an eyepiece of the telescope in the apparatus.

6. ♥ A spring-mass system is suspended from the ceiling of an elevator. When the elevator is at rest, the system oscillates with period T. The elevator then starts to move upward with an acceleration of a = 0.2g. During this constant acceleration phase, what will be the period of the spring-mass system?

(A) $\sqrt{0.2}$ T.
(B) $\sqrt{5}$ T
(C) T
(D) 25T
(E) .05T

7. ♥ A block of mass m at rest on the horizontal bed of a truck is accelerating at a m/s^2. The coefficient of static friction between the truck and the block is μ_s. The force of friction acting on the block is

(A) Zero
(B) $\mu_s \times mg$
(C) μ_s
(D) ma
(E) $\mu_s \times ma - \mu_s \times mg$

8. ♥ Which of the following defines a conservative force?

(A) $\oint \mathbf{F} \bullet \mathbf{dA} = 0$ or $\nabla \bullet \mathbf{F} = 0$
(B) The force must be frictional.
(C) $\oint \mathbf{F} \bullet \mathbf{dr} = 0$ or $\nabla \times \mathbf{F} = 0$
(D) The force must be nuclear.
(E) The force must be strong. C

9. ♥ What is the fundamental physics basis of Snell's law?

(A) The first postulate of special relativity
(B) Fermat's principle of least time
(C) The uncertainty principle
(D) Newton's first law
(E) The Pauli Exclusion Principle

10. ♥ Which of the following is NOT a correct statement about the photoelectric effect? Assume ν_0 = threshold frequency of a metal and ν is incident frequency.

    (A) There is no photocurrent unless $\nu_0 > \nu$.
    (B) ν_0 is characteristic of the cathode material.
    (C) Above ν, the flux of electrons per second increases as the intensity of incident light.
    (D) The stopping potential V_0 is proportional to ν^2.
    (E) The stopping potential is directly proportional to ν.

11. ♥ In a Coolidge tube, electrons are accelerated to energy of 10 keV for x-ray production. What is the energy for x-ray quantum produced?

    (A) from 0-1 keV
    (B) from 0-5 keV
    (C) at 10 keV
    (D) 10 keV and higher
    (E) from 0-10 keV

12. ♥ Which of the following most correctly describe Mosley's law of x-ray emission (here ν is the x-ray frequency)?

    (A) ν is proportional to Z for x-rays.
    (B) ν is proportional to Z^3 for x-rays.
    (C) ν is independent of Z.
    (D) ν is proportional to $1/Z^2$ for x-rays.
    (E) ν is proportional to Z^2 for x-rays.

13. ♥ Which of the following is NOT a true statement about the fluorescence?

    (A) It is the emission of electromagnetic radiation.
    (B) The process takes place in about 10^{-8}s.
    (C) A quantum of light is scattered elastically
    (D) Ultraviolet quanta may thereby be converted to visible quanta.
    (E) Often fluorescence is quenched by collisions.

14. ♥♦ A stretched string is vibrating with four loops. If the frequency is increased by a factor of four, the number of loops formed would be (A) 1, (B) 2, (C) 16, (D) 4, and (E) 8

Problems

A spade (♠) indicates that solution of the problem demands research outside this text book.
A club (♣) denotes that solution of the problem requires substitution of values in a formula.

1. ♣ A metal ball is dropped into a deep well with water on the very bottom. The time taken between dropping the ball from rest to hearing it splash into the water is 6.0 s. What is the depth d of the well? Assume speed of sound in air V_s = 330 m/s.

2. ♣ Consider a coin is being dropped into a wishing well. Determine the depth d of the well if the time T between releasing the coin and hearing it hit the bed of the well is 2.0 s. The speed of sound in air is 330 m/s.

3. ♠ In a ballistic pendulum shown in figure P1.3 a bullet of mass m = 10 g hits and becomes embedded in the pendulum's block of mass 2.0 kg. Given that the initial velocity of the bullet is 201 m/s, determine the height the ballistic pendulum is raised by the impact.

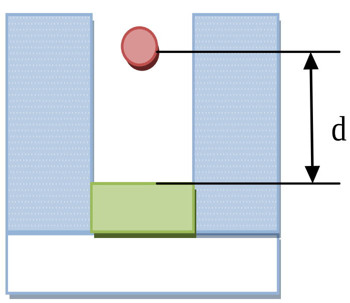


Figure Problem 1.1 & 1.2

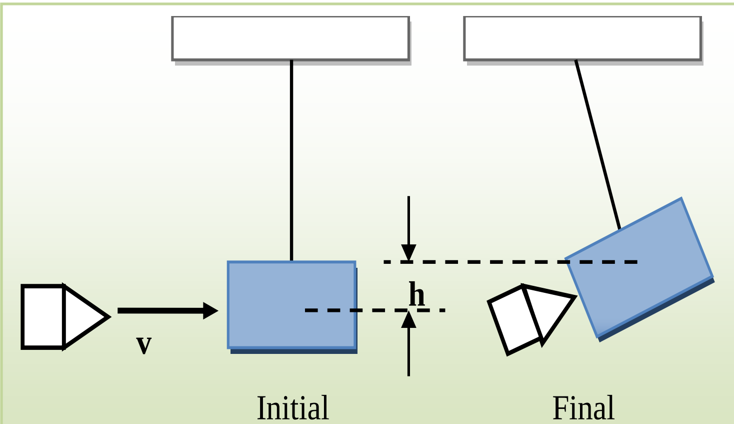


Figure Problem 1.3 & 1.4

4. ♠ A 10g bullet is fired into a 2 kg ballistic pendulum similar to problem 3. The bullet remains in the block after the collision, and the system rises to a maximum height of 36 cm. find the initial speed of the bullet.

5. ♣ A man jumps off a building 202 m high on to cushions having a total thickness of 2 m. If the cushions are crushed to a thickness of 1.0 m, what is the man's average acceleration as he slows down?

6. ♠ A pendulum of length l is attached to the roof of an elevator near the surface of the Earth. The elevator moves upward with an acceleration a = 1/2g. Determine the linear frequency of the pendulum's oscillation.

7. ♣ A simple pendulum of length 1 m is suspended from the ceiling of a train compartment. If the train accelerates at three-fourths the acceleration of gravity, determine the height of the bob vertically below the ceiling under equilibrium condition.

8. ♣ For Atwood's machine where the one hanging mass is four times the other on a pulley, find the acceleration of lighter mass.

9. ♦ An object is projected upward near the surface of the Earth, but is also subjected to a resistive force βv. Determine the time taken to reach the maximum height. Define $\gamma = \beta/m$ for simplicity.

10. ♠ Determine the value for the time of flight of a projectile near the Earth's surface subject to a resistive force $F_R = -\beta v$. Let $\gamma = \beta/m$ and V_{0y} vertical component of launch velocity at t = 0.

11. ♠ What is the vector force due to potential energy $U = kr^n$

12. ♠ The potential energy of a particle moving in one dimension is $U(x) = ½ \alpha x^2 + ¼ \beta x^4$. Calculate the force projected by the particle.

13. ♣ A particle of mass m moves in one dimension subject only to a resistive force $F_R = -bv$. Let $\gamma = b/m = 2.0\ s^{-1}$ and the initial speed be 100 m/s. What is the distance travelled by the particle at t = 0.5 s?

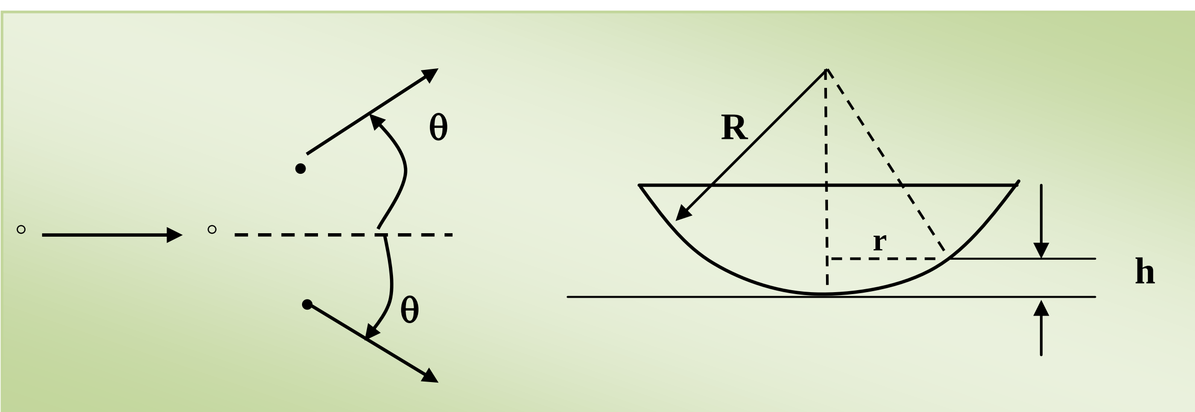


Figure: Problem 1.14 Figure: Problem 1.15

14. ♣ A neutron of kinetic energy T = 1876 MeV is incident on a neutron at rest. The neutron scatters at an angle θ during an elastic collision event with another neutron. Given that mass of a neutron m_n = 938 MeV/c^2. Determine θ.

15. ♠ Newton's rings are observed with a Plano-convex lens resting on a plane glass surface. If R is the lens radius or curvature, m is the order number, and λ is the incident light wavelength, then find the expression for the radii of dark interference rings r, in terms of m, λ and R such that r << R.

16. ♣ A Michelson interferometer is used to measure the wavelength of a monochromatic light. When the movable mirror is displaced by a distant 0.1 mm the number of fringes moving into the center of Newton's ring pattern is 400. Computer the wavelength of light.

17. ♣ A Michelson Interferometer with light of vacuum wavelength 580 nm is used to determine the index of refraction of air. A cell of length 20 cm is placed in the path of one of the beams and air is pumped out. The air is then let in slowly through a valve and the numbers of circular fringes moving in at the center are counted. When all the air is in, the number of fringes counted is 200. Determine μ the index of refraction of air by this measurement.

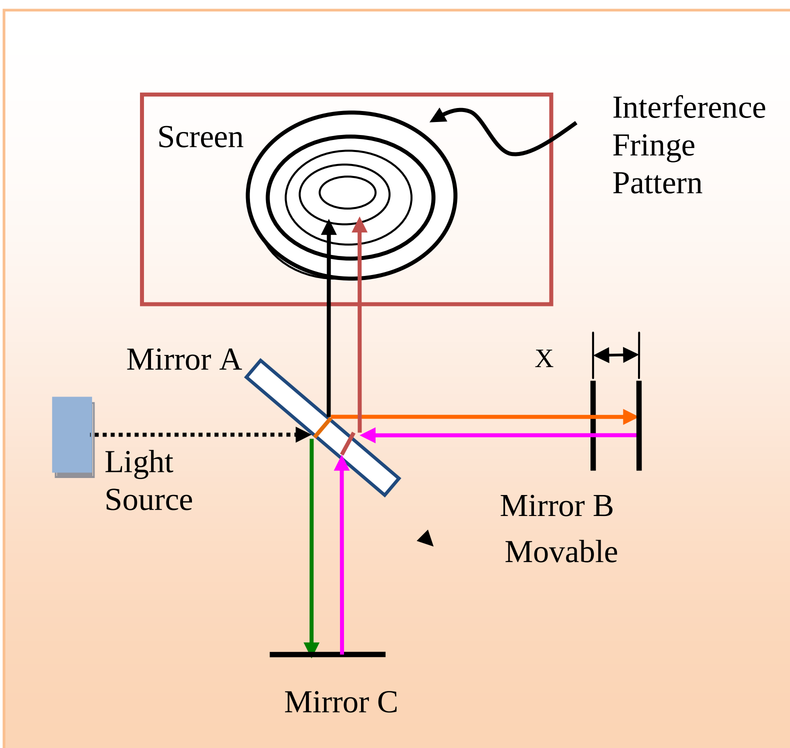


Figure Problem 1.16: Michelson Interferometer, Measurement of Wavelength

18. ♣ Light of wavelength 450 nm is incident on a surface of a magnesium strip for which the threshold wavelength of the photoelectrons is 3370 nm. Calculate the work function ϕ of magnesium.

19. ♣ Photoelectrons are found to be ejected from gold surface when the wavelength of incident light is below 243.1 nm. If the wavelength of incident photon is 150 nm, then what must be the stopping potential V_0 to stop ejection of photoelectrons?

20. ♣ What is the speed of the photoelectron ejected from silver surface? Given that the threshold wavelength is 263.8 nm and the wavelength of incident light is 160 nm.

21. ♣ If radiation of wavelength 5000 A° is incident on a surface of work function 1.2eV, find the value of stopping potential. Assume 1 eV = 1.6×10^{-12} erg and h = 6.62×10^{-27} erg s.

22. ♣ The energy of photoelectrons emitted from a photo-sensitive plate is 1.56 eV. If threshold wavelength is 3500 A°, calculate the wavelength of incident radiation and describe the energy form. Given that 1 eV = 1.6×10^{-12} erg and h = 6.62×10^{-27} erg s.

23. ♣ A metal has a work function of 2.0 eV. It is illuminated by monochromatic light of wavelength 500nm. Calculate
    a) The threshold wavelength,
    b) The maximum energy of photoelectrons, and
    c) The stopping potential.

Given, Planck's constant, h = 6.6×10^{-34} J s, Charge on electron e = 1.6×10^{-19} and 1 eV = 1.6×10^{-19}

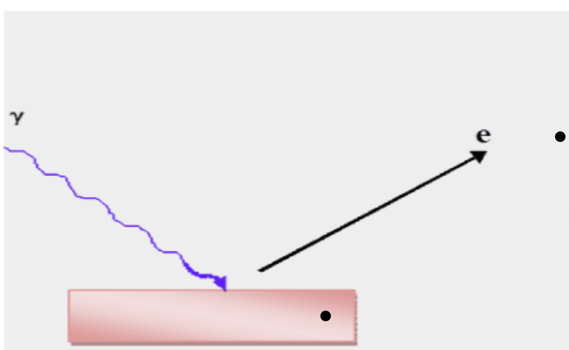


Figure: Problem 1.25

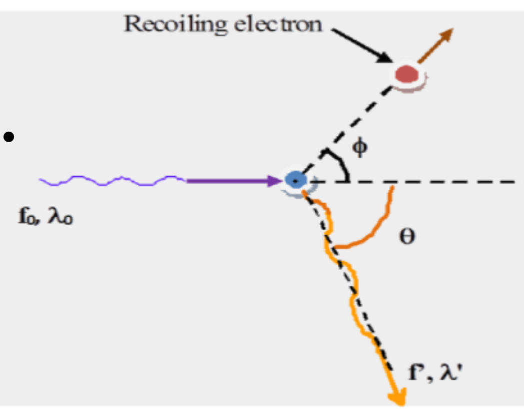


Figure: Problem 1.26

24. ♣ In the photoelectric effect, the threshold wavelength is 275.6 nm. If light of wavelength 170 nm is incident on a metal substance, what is the value of the kinetic energy of the photoelectrons?

25. ♣ X-rays of wavelength 3×10^{-10} m are incident on a material. The scattered X-rays observed at 45° have wavelength shift due to the Compton Effect. Calculate the scattered wavelength.

26. ♣ X-rays with an energy of 50 keV undergoes Compton scattering from a target. If the scattered rays are detected at 45° relative to incident rays, find the energy of scattered X-ray.

27. ♣ X-rays of wavelength 1.50×10^{-10} m are scattered by a metal through an angle of 90°. What is the kinetic energy of the recoil electrons? (See figure problem 1.27)

28. ♣ Electromagnetic radiation of wavelength 6.20×10^{-10} m is incident on a substance and backscattered at an angle of 180°. Calculate the Compton energy shift of radiation.

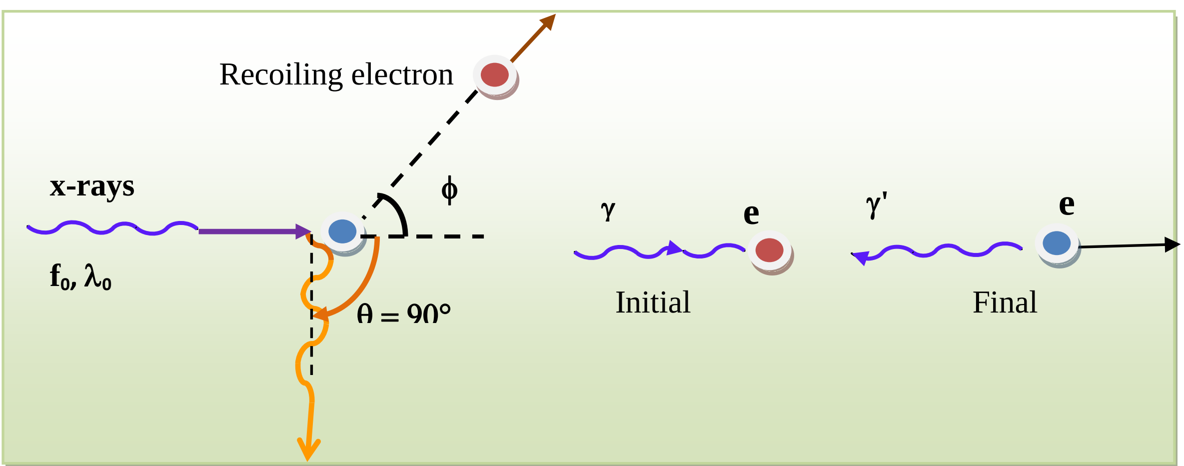


Figure Problem 1.27 Figure Problem 1.28

29. ♠ A K_α x-ray emitted by one hydrogen atom strikes a second hydrogen atom and undergoes photoelectric absorption with an L shell electron. What is the energy of the ejected electron?

30. ♠ Consider that the energy of an incident quantum of light is huge. The quantum is scattered by an electron as it proceeds for a head on interaction. What is the upper limit of energy for the Compton scattered quantum.

31. ♠ A variable length tube closed at one end is used to determine the speed of sound by producing standing waves with a 1000-Hz tuning fork. As the length of the tube is increased, the change in the length of the tube between the fundamental and first overtone is 0.175m. What is the speed of sound in air if the tube is filled with an air column?

32. ♣ An observer and a source of a sound are moving in the same direction with ½ the speed of sound. The source is emitting sound of a frequency of 1000 Hz. The speed of sound in air is 343 m/s. Compute the frequency of the sound heard by the observer and the wavelength of the sound received.

Problems for Exploration

33. ♠ In one version of Millikan oil drop experiment, oil droplets of radius R are allowed to achieve terminal speed (V_d) with a downward electric field and terminal speed (V_u) with an upward electric field. Let η be the viscosity of oil in air and E be the intensity of the electric field. Find the electronic charge q. Assume viscous force = $6\pi\eta v$ where V_x is the terminal velocity. hint: $V_d > V_u$

34. ♠ In a realistic fall of a spherical droplet of water in fluid air, calculate the magnitude of the viscous force. Given that the Reynolds number is $R_e = 0.5$, the kinematic viscosity is 0.149 cm^2/s, the radius of the water droplet is 0.005 cm, and $\rho_{air} = 1.22 \times 10^{-3}$ g/cc. Assume viscous force $F_v = 0.5\pi r^2 \rho_{air} v^2 C_d$.

35. ♠ A charged pin ball of mass 2 grams is suspended on a mass-less string in an electric field $E = (3\mathbf{x} + 4\mathbf{y}) \times 10^5$ N/C. If the ball is in equilibrium at $\theta = 57°$, find the tension in the string.

36. ♠ The executive toy in its simplest form is made of two identical masses hanging from a pivoting rod. If each mass is m kg and the lengths are L m for each arm and p m for the pivot, derive the condition under which the toy is stable.

37. ♠ A block of mass m kg is moving at speed v km/s collides with a spring of restoring force $F = -k_1X - k_2X^3$ on a frictionless surface. Find the maximum compression of the spring. Hint: Define $\alpha = k_1/k_2$.

38. ♠ Imagine that an object of mass 1 kg has a position vector $\mathbf{r} = (3t + 5t^3)\mathbf{x}$. Calculate the work done on the particle over the interval from 0 to 1s.

39. ♠ A disk of mass M kg and radius R shown in Figure Problem 1.39 is in equilibrium. It is given that the incline has coefficient of static friction μ. Find the tension in the chord.

40. ♣ A skier leaves a ski jump ramp at an angle of 45° with an initial speed of 20 m/s. Later he lands down the slope a distance L from where he started the jump. If the slope is inclined at 30°, then find L.

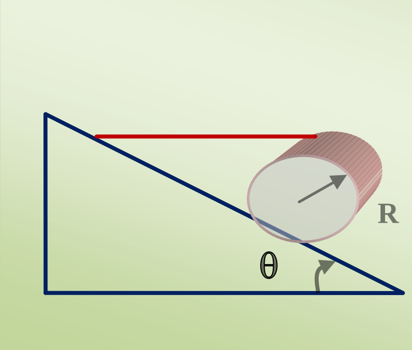


Figure Problem 1.39

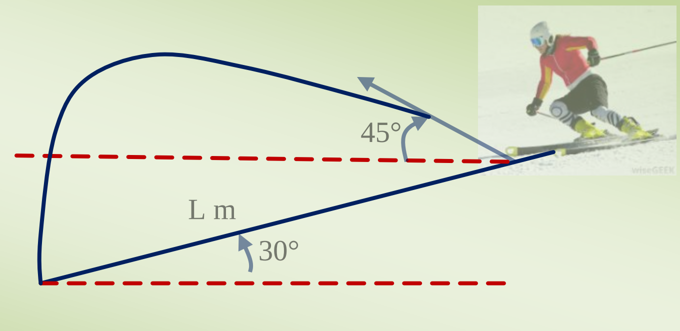


Figure Problem 1.40

41. ♣ A ball is thrown horizontally from the top of a tower 50 m high. The ball strikes the ground at a point 100 m from the base of the tower. Find the angle that the velocity vector makes with the horizontal just before the ball hits the ground.

42. ♠ A mass M_1 kg is subject to the gravitational force and is attached by a string to a second mass M_2 kg on a pulley of radius R m. Suppose that the pulley has a finite moment of inertia I, find the acceleration of mass M_1. Neglect the effect of friction on M_2 which is resting on a plane that has smooth surface.

43. ♠ Consider two masses M_1 and M_2 moving on a frictionless surface. The first mass is moving at a speed of V_1 km/s and the second mass that is attached to a spring is moving at a speed of V_2 km/s. Find the distance x of maximum compression of the spring. Assume $V_1 > V_2$ and they are in the same direction, k is spring constant. Hint: Define $\mu = M_1 \times M_2/(M_1+M_2)$

44. ♣ Two balls are thrown vertically upward at the same time. Suppose that the balls have initial velocities $v_1 = 20$ m/s and $v_2 = 25$ m/s, respectively. Find the distance between the two balls when ball one is at its maximum height.

45. ♠ Ashley, a physics student, stands on top of a 50 m cliff. She releases one stone with a downward speed of 1.0 m/s. With what speed must she project a second stone 0.5 s later at 35° angle if both stones are to hit the bottom at the same time?

46. ♣ Let the point of application of a force $\mathbf{F} = (6, 4, -1)$ N be at position $\mathbf{r} = (-4, 1, -5)$ m. Compute the torque τ due to this force.

47. ♠ An electron is projected at an angle of 30° with respect to x-axis with a speed of 4×10^5 m/s. The electron moves in a constant electric field E = 100 N/C which is directed to y-axis. At what time after t =0 will the electron again cross the x-axis?

48. ♠ A right circular cylinder of radius r rolls down an incline from height h. Determine the ratio of its speed at the bottom to the speed of a point object following the same path. Assume rolling friction, but negligible sliding friction.

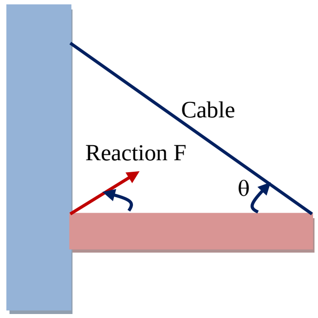


Figure Problem 1.49

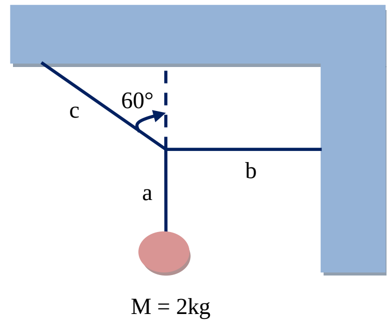


Figure Problem 1.50

49. ♠ A boom is suspended by a cable as shown in Figure Problem 1.49. Given that angle θ = 45° and the weight of the boom is W = 1000N. Find the reaction force F.

50. ♠ Find the tension T_b in cord b for the system displayed in Figure Problem 1.50. The system is in equilibrium.

51. ♣ A horizontal beam of length 10 m and weight 300 N is attached to a wall. The far end is supported by a cable which makes an angle of 60° with respect to the beam. A 400N person sits 6 m from the wall on the beam (see Figure Problem 1.51). Determine tension in the cable.

52. ♣ A pendulum bob of mass M is raised to a height h m and released. It hits a spring of non-linear force law F = -kx –bx3. Calculate the compression distance x of the spring.

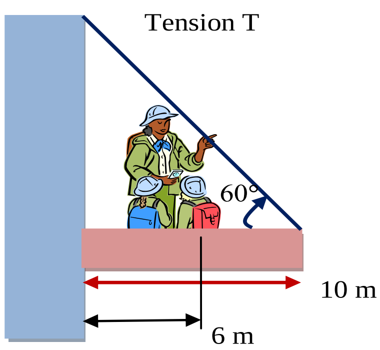


Figure Problem 1.51

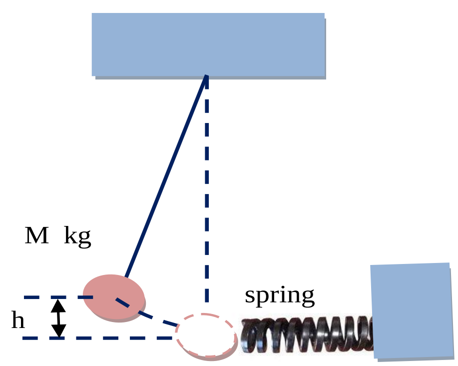


Figure Problem 1.52

53. ♠ A spherical mass m kg is dropped off of a building from rest. Determine the position y = y(t) if the mass experiences a resistive force F_R = -bv. Take the starting point, rest position to be the origin y = 0. Let $\gamma = b/m$.

54. ♠ A wedge-shaped block of mass 2M is placed on a horizontal surface and a small block of mass M is placed at the top of the wedge at a height h. Assume all surfaces are frictionless. The small block is released and it slides down the wedge on to the horizontal surface. Calculate the speed of the small block at the bottom- of the wedge on the horizontal surface.

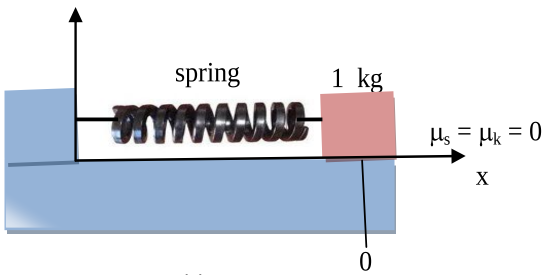


Figure Problem 1.55

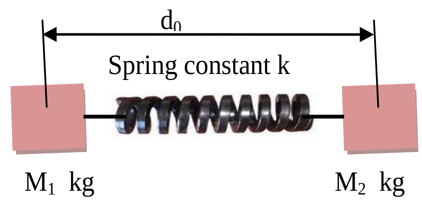


Figure Problem 1.56

55. ♣ A 1.0 kg mass attached to a spring moves on a horizontal frictionless table in simple harmonic motion with amplitude 0.2 m and period 5 s. Assuming that the mass is released from rest at t = 0s and x = -0.2 m, find the displacement as a function of time.

56. ♠ Two equal masses $M_1 = M_2 = M$ kg are connected by a spring having Hooke's constant k. If the equilibrium separation is d_0, and the spring rests on a frictionless surface, then derive an expression for angular frequency ω_0 for the oscillatory motion of masses.

57. ♣ When a 5 kg mass is hung vertically on a light spring that obeys Hooke's law, the spring stretches 5 cm. How much work must an external agent do to stretch the spring 10 cm from its equilibrium position.

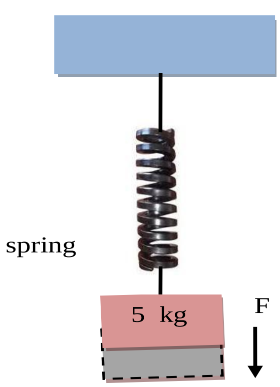


Figure Problem 1.57

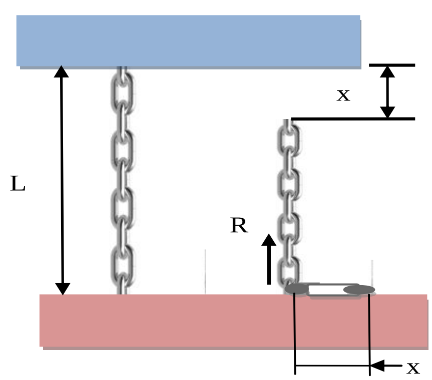


Figure Problem 1.58

58. ♠ A metallic chain of length L and mass M is vertically hung above a surface with one end in contact with it. The chain is then released to fall freely. If x is the distance covered by the end of the chain, how much reactionary force R (exerted by the bottom surface) will the chain experience at any instant during the process? What is the loss of potential energy and gain in kinetic energy when x = L, i.e. the whole chain lays flat on the surface?

59. ♠ In the Rutherford scattering of p + $_{92}$U, the differential cross section at angle θ is measured to be 20 barns. The kinetic energy of the incident proton is 10 MeV. Find θ.

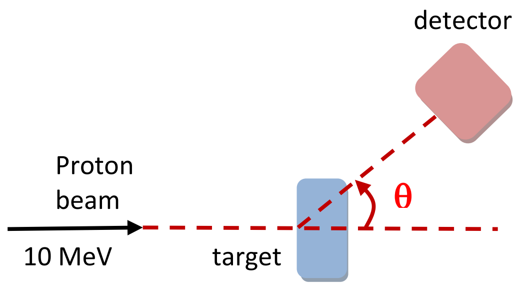


Figure Problem 1.59

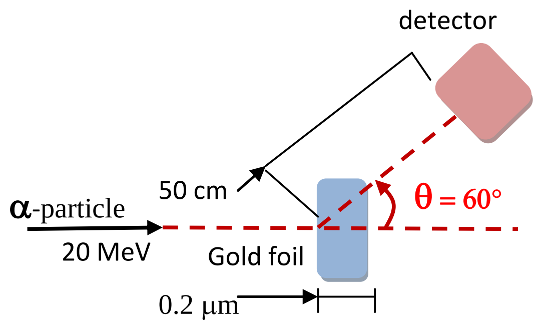


Figure Problem 1.60

60. ♠ In a Rutherford scattering experiment, 20 MeV particles are scattered by a gold foil 0.2μm thick into a detector whose sensitive area is 10 cm^2 which is placed 50 cm from the target and makes an angle of 60° with the incident beam. Calculate the differential cross section in the center of the mass system in barns(b) per steradians(sr).
(1 millibarn = 10^{-28} square meters.)

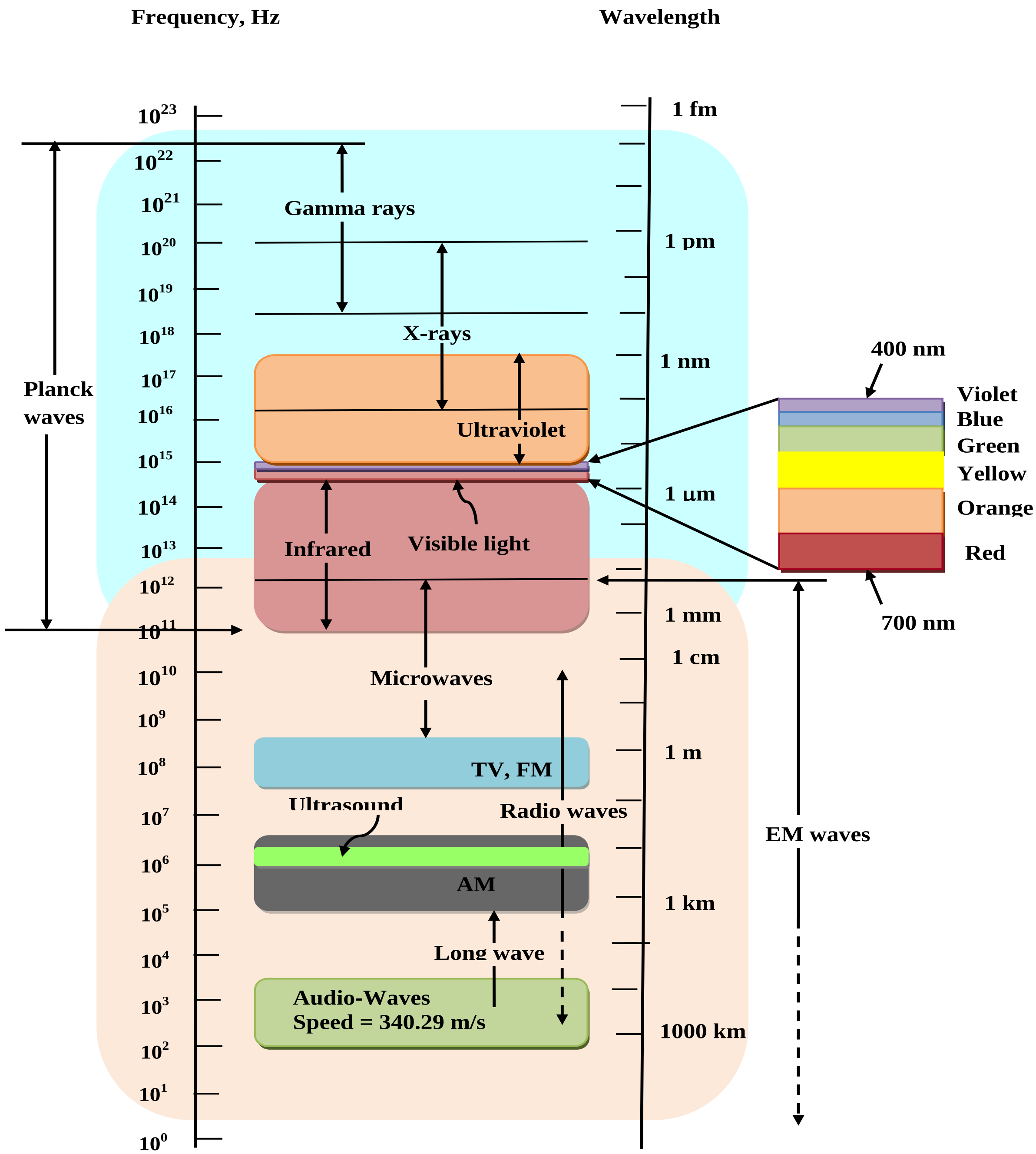
Answers to objective questions

6.	(C)	7.	(D)	8.	(C)	9.	(B)	10.	(D)	11.	(E)
12.	(E)	13.	(C)	14.	(E)						

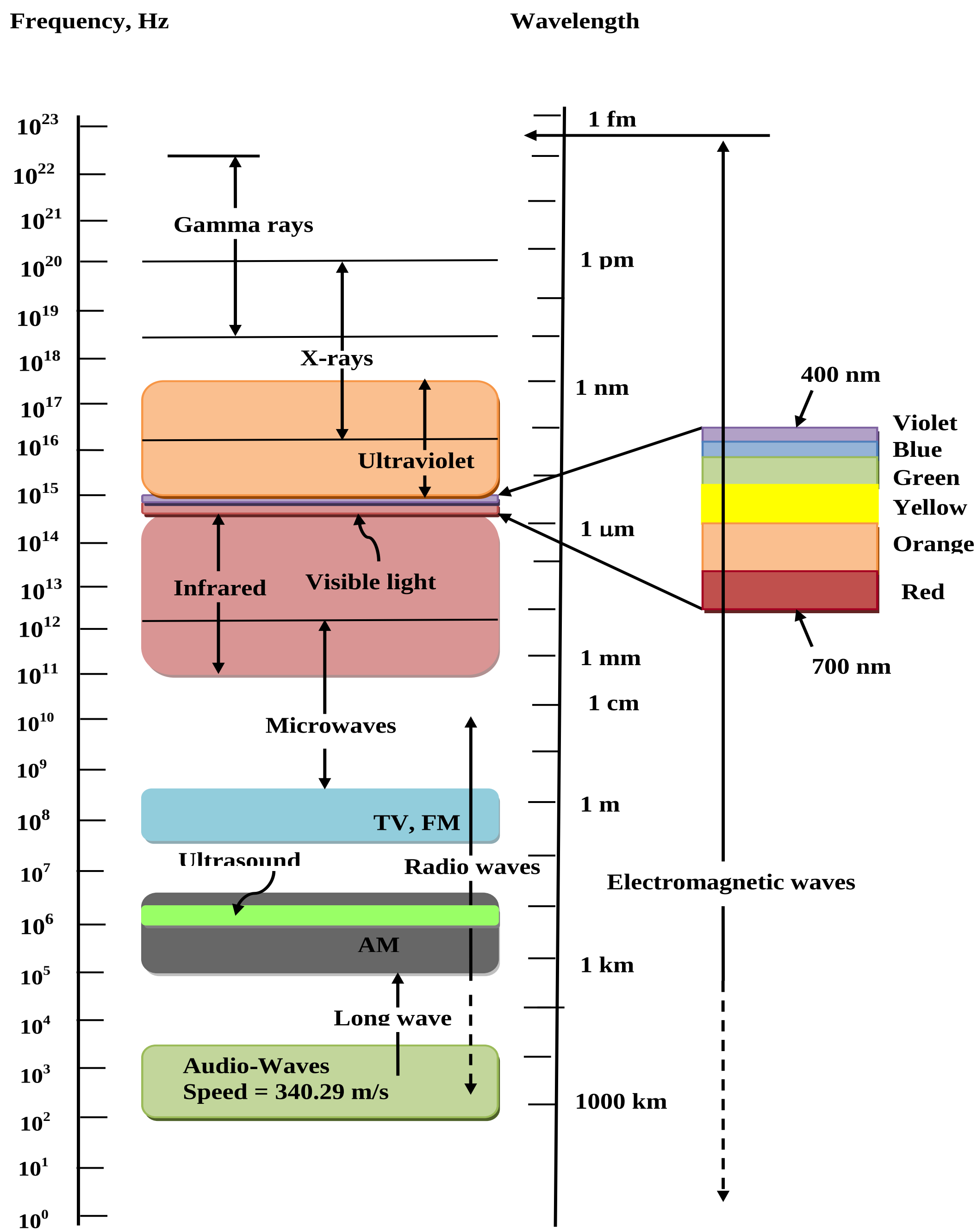
Answers to selected problems

1.	150.75 m	2.	18.5 m	3.	5.1 cm	4.	533.9 m/s
5.	1960 m/s^2	6.	$1/(2\pi)\ [3g/2l]^{1/2}$	7.	80 cm	8.	Accl. a =3g/5
9.	$(1/\gamma)\ \ln(1 + V_0\gamma/g)$			10.	$(2V_{0y}/g)(1- \gamma\ V_{0y}/3g)$		
11.	$-knr^{(n-2)}\ \mathbf{r}$	12.	$- \alpha x - \beta x^3$	13.	31.6 m	14.	70.6°
15.	$(m\lambda R)^{1/2}$	16.	500 nm	17.	$\mu = 1.00029$	18.	$\phi = 3.68$
19.	3.17 eV	20.	1.04×10^6 m/s	21.	1.28 V	22.	2431.4 A° UV
23.	(a) 618.75 nm	(b)	0.76×10^{-19} J	(c)	0.475V	24.	2.79 eV
25.	3.07 A°	26.	48.6 keV	27.	131.8 eV	28.	15.5 eV
29.	6.8 eV	30.	½ m_ec^2	31.	350 m/s	32.	1000 Hz & 0.172m
33.	$3\pi R\eta(V_u+V_d)/E$	34.	0.128 m dynes	35.	0.0125 N	36.	$L\cos\theta > p$
37.	$X=\alpha^{1/2}[(1+2mv^2/(\alpha k_1))^{1/2}-1]^{1/2}$			38.	157.5 J	39.	$Mg\sin\theta/(1+\cos\theta)$
40.	74.24 m	41.	$\theta = 315.1°$	42.	$M_1g/[(I/R^2)+ M_1+M_2]$		
43.	$x = (\mu/k)^{1/2}(V_1-V_2)$			44.	10.2 m	45.	8.6 m/s
46.	$\tau = 19\mathbf{x}+34\mathbf{y}-22\mathbf{z}$ N-m			47.	23 ns	48.	$(2/3)^{1/2}$
49.	F = (707N, 45°)	50.	33.9N	51.	450.35 N		
52.	$x = [(4Mgh/b+k^2/b^2)^{1/2} - k/b]^{1/2}$			53.	$y = (g/\gamma)[t-(1-e^{-\gamma t})/\gamma]$		
54.	$(4gh/3)^{1/2}$	55.	$x=20\cos[(2t\pi/5) + \pi]$			56.	$\omega_0 = (2k/M)^{1/2}$
57.	4.9 J	58.	R = (3M/L)gx and 3MLg/2			59.	$\theta = 73.34°$
60.	129.41 b/sr						

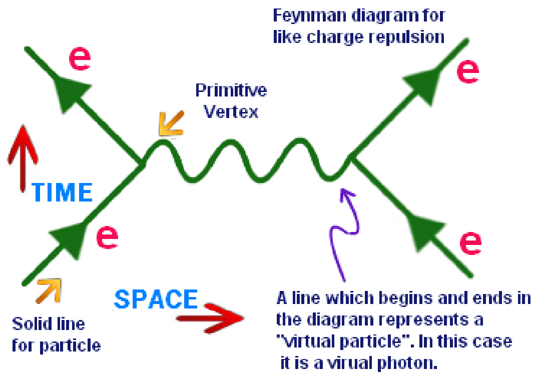
APPENDIX - A: Complete Energy Spectrum (Planck Wave Model)



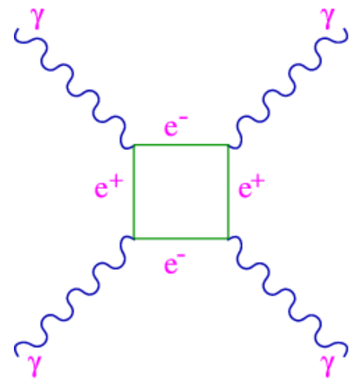
APPENDIX - B: EM Spectrum Frequency Chart (Classical Model)



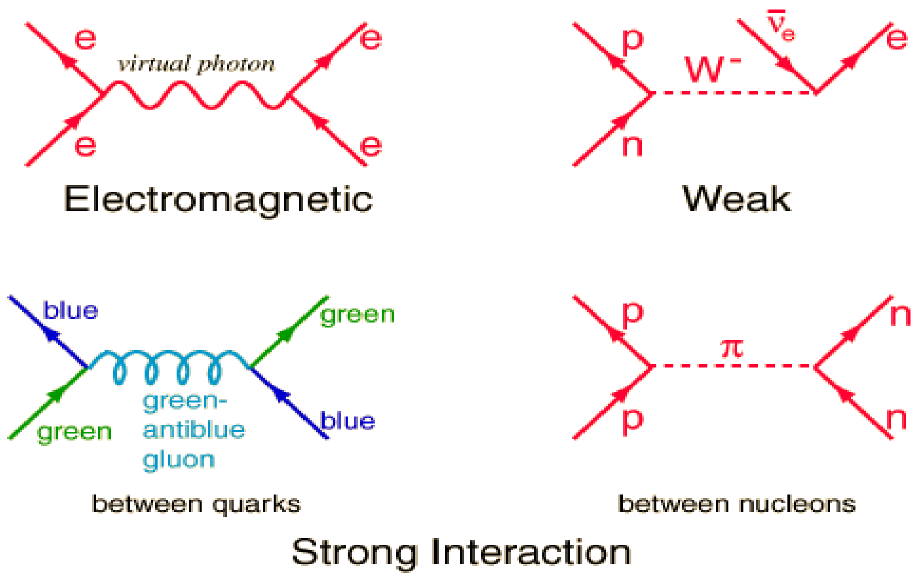
APPENDIX - C: Feynman Diagrams (FD), Standard Forms



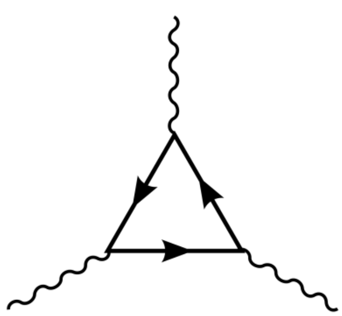
(a) Essential elements of a FD

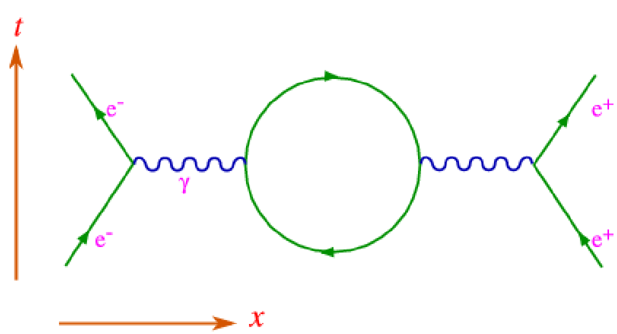


(b) Scattering of light by light (Delbruck Scattering)



(c) FD for different interactions require at least two vertices

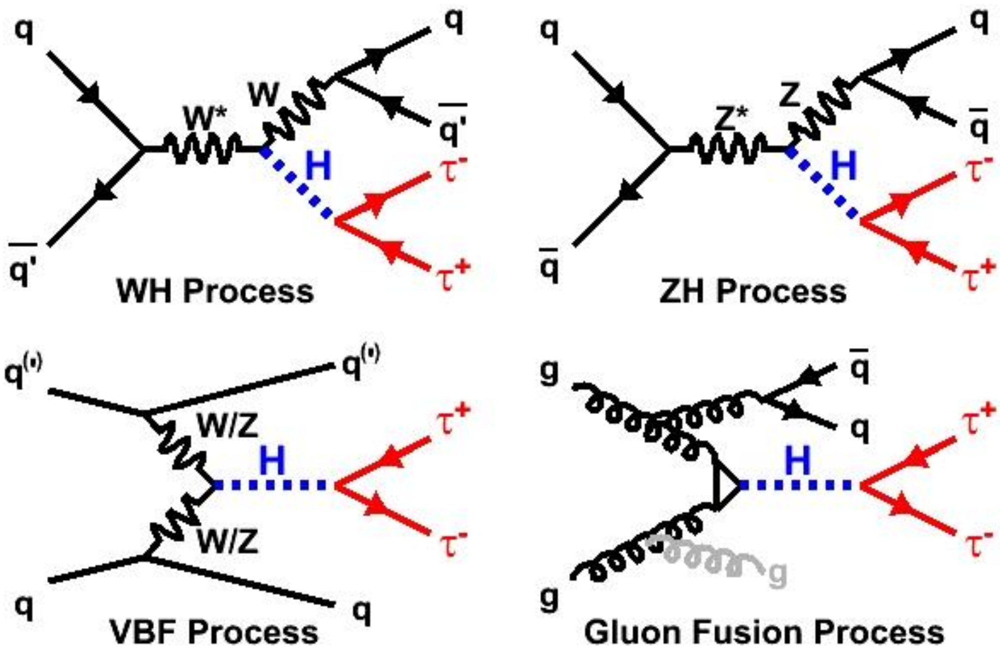




(d) One loop diagram for Uni-cycle events. Ex. Hawking radiation, lamb shift, and anomalous magnetic dipole moment.

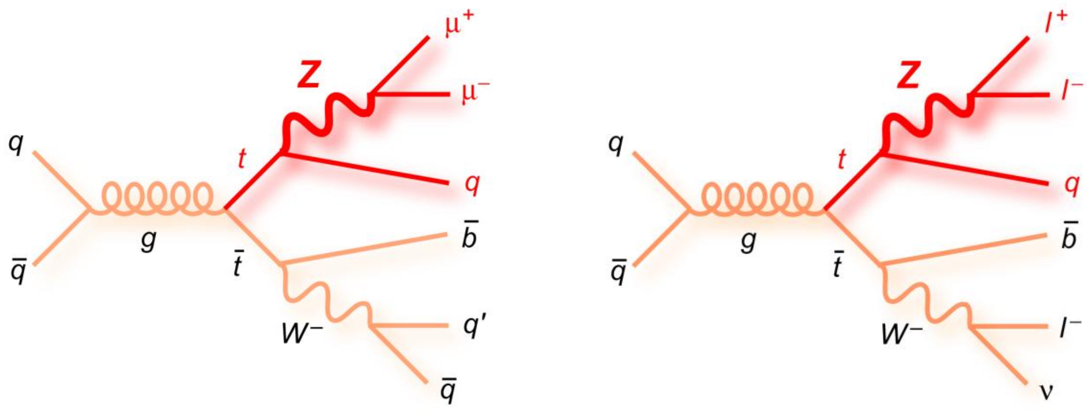
(e) Loop diagram representing fluctuations in vacuum. Electron positron pair annihilate and rematerialize through quark fragmentation.

APPENDIX - C: Feynman Diagrams (FD), Fusion processes



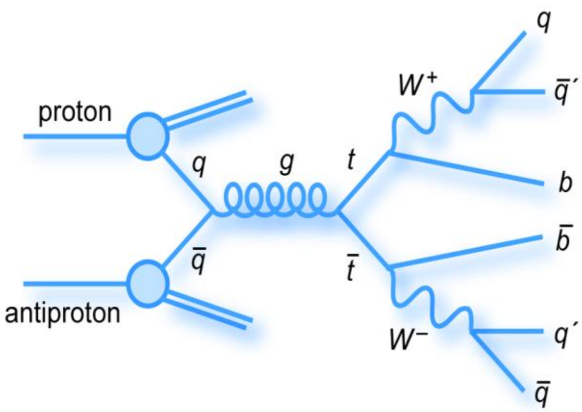
Above sets of FD represents every possible way Higgs boson of Standard Model may have been produced at Tevatron collider, Fermilab and at LHC, CERN. Each diagram is identified by particles participating in the fusion process. For instance WH means fusion of W and H bosons, and etc. From the details of FD, physicist estimated mass of Higgs boson 126 GeV/c^2.

More examples.

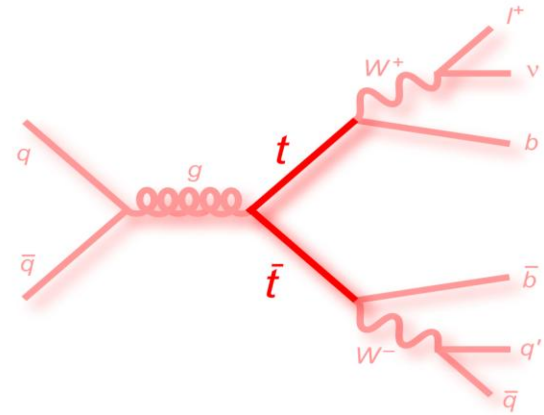


Beyond the Standard Model, Top Decays into muon and leptons

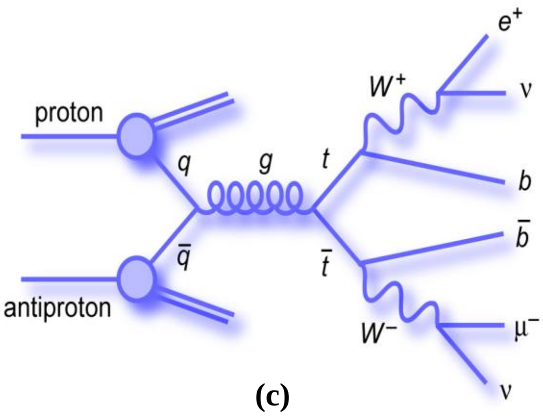
APPENDIX - C: Top pair production and decay [Examples (a) to (d)]



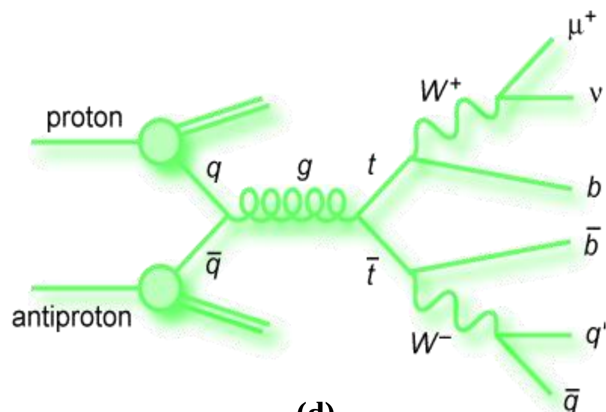
(a)



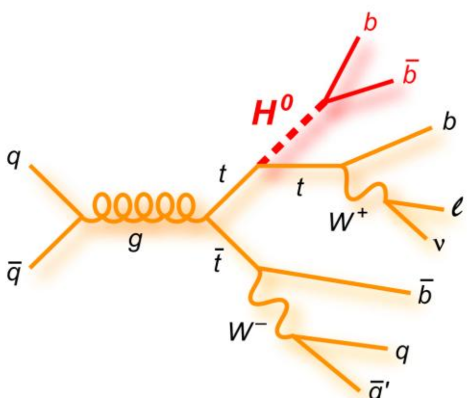
(b)



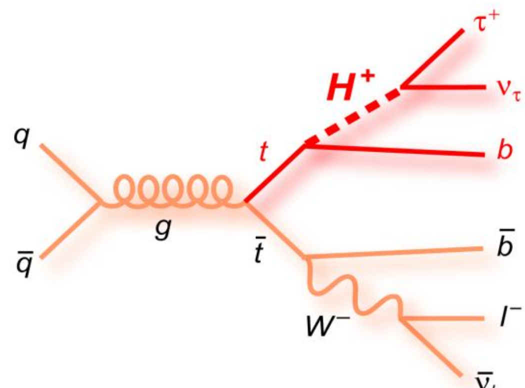
(c)



(d)



(e)



(f)

Beyond the Standard Model Top Processes [Examples (e) and (f)]

APPENDIX - D: Glossary

Aberration constant: The ratio of velocity of an inertial frame moving at v m/s with respect to a reference frame at rest and the absolute speed of light c is defined as the aberration constant. It is denoted by $\beta = v/c$, where c is speed of light that has a constant value for both systems.

Absolute Stationary Frame (ASF): A frame of reference is ASF if and only if in any pair of inertial systems, the distance between the point of interest and the observer is invariant with respect to time.

Absolute Standard Time (AST): It is defined as time period of one cycle (1/frequency) of a wave signal emitted from an atomic clock's electron resident in the outer most orbit of a cesium atom maintained in undisturbed state and in the absence of gravity effects from other objects.

Absorption Spectra: Dark lines superimposed on a continuous spectrum.

Accretion: The gradual accumulation of matter in one location, typically due to the action of gravity.

Accretion disk: A disk of interstellar material surrounding a celestial object with an intense gravitational field, such as a black hole. The matter in the accretion disk eventually spirals into the attracting black hole and adds to its mass.

Accelerator: A machine used to accelerate particles to high the speeds (and thus high energy, as compared to their rest mass energy)

Alpha decay: A radioactive substance with rich proton nuclei if unstable it decays by emitting an alpha particle, ${}^{4}He_{2}$ nucleus into daughter nuclei whose mass number A is lowered by 4 and atomic number Z is lowered by 2.

Alpha particle: The nucleus of a helium atom, consisting of two protons and two neutrons.

Angular frequency (ω): It is defined as the rate at which a phase of a rotating vector is advancing per unit of time that is measured in rad/s.

Angular momentum: Angular momentum is a conserved quantity, which is used to describe rotational motion much like momentum for linear motion. Rotational motion can be orbital motion of two bodies around one another or the rotation of a rigid body. The intrinsic angular momentum of a particle is called "spin." In quantum mechanics, angular momentum and spin are quantized quantities: They can only have certain discrete values measured in multiples of $\hbar$, which is Dirac constant numerically equals Planck's constant h divided by 2π.

Angular Resolution: Angular resolution or spatial **resolution** describes the ability of any image-forming device such as an optical or radio telescope, a microscope, a camera, or an eye, to distinguish small details of an object, thereby making it a major determinant of image **resolution**.

Angular wave number (k): It is defined as the number of waves that can be circumscribed on the perimeter of the circle in space domain.

Angular size: Angular diameter or apparent size is the angle through which an eye or a camera lens must rotate to look from one side of circular object in the sky to the other side from a given point of view. Angular size is measured in radians or degrees. The most common unit is arcseconds.

Annihilation: A process in which a particle meets its corresponding antiparticle and both disappear. The energy appears in some other form, perhaps as a different particle and its antiparticle (and their energies), perhaps as many mesons, and perhaps as a single, neutral boson, such as a Z^0 boson. The produced particles may be any combination allowed by conservation of energy, momentum, electric, magnetic and other charge types and by other rules.

Antifermion: The antiparticle of a fermion. See also antiparticle.

Antimatter: Material made from antifermions. We define the fermions that are common in our Universe as matter and their antiparticles as antimatter. In the particle theory, no a priori distinction exists between matter and antimatter. The asymmetry of the Universe between these two classes of particles is a deep puzzle for which we are not yet completely sure of explanation.

Antiparticle: A charged particle and its antiparticle have the same mass but opposite charge, spin and other properties such as lepton number and baryon number.

Antiquark: The antiparticle of a quark. An antiquark is denoted by putting a bar or apostrophe over the corresponding quark symbol (d', u', s' etc.).

Approachin systems: Two inertial systems are defined as approaching systems if displacement between the two systems is decreasing with time at a constant rate.

Atom: Fundamental building block of matter, consisting of a nucleus (comprising protons and neutrons) and an orbiting swarm of electrons.

Astrophysics: The physics that studies astronomical objects such as stars and galaxies.

Astronomical Unit (AU): It is average distance of the Earth from the Sun which is exactly equal to 149.5979 million kms or 93 million miles. The maximum distance of the Earth's orbit from the Sun (at aphelion) is 152.1 million kms and the minimum distance of the Earth's orbit from the Sun (at perihelion) is 147.1 million kms. The AU is primarily used as a convenient yardstick to specify distances within our solar systems.

Autumnal Equinox: The point at which the Sun's path crosses the celestial equator moving from north to south and when day and night are of equal length is called the **autumnal equinox** as it occurs about September 22.

BASS: Boulder Astronomical Space Society

B Factory: An accelerator designed to maximize the production of B mesons. The properties of B mesons are then studied with specialized detectors.

Balmer Series: The wavelength of emitted spectral lines from hydrogen atoms is called Balmer lines or Balmer Series. The emission takes place corresponding to electron orbit transition from any state for principal quantum number $n > 2$ to $n = 2$. For values of n from 3 to 6, lines in visible light spectrum are emitted. For values of n larger than 6, lines in ultraviolet region of spectrum are emitted.

Baryogenesis: In physical cosmology, baryogenesis is a generic term for the hypothetical physical processes that produce an imbalance between matter and antimatter thus creating abundant amount of matter in the very early universe.

Baryon [BARE-ee-on]: A hadron made from three quarks. The proton (uud) and the neutron (udd) are both baryons. They may contain additional quark-antiquark pairs.

Baryon-antibaryon asymmetry: The observation that the Universe contains many baryons but few antibaryons: a fact that needs explanation.

Baryon number: It is a quantum number assigned to elementary particles that is equal to the sum of baryon numbers in a system of subnucleonic particles. Baryons have a baryon number of +1, while antibaryons have a baryon number of -1. Quarks and antiquarks have baryon numbers of + $^{1}/_{3}$ and -$^{1}/_{3}$, respectively (baryons consists of three quarks). Leptons and mesons have baryon number zero.

Beam: The particle stream produced by an accelerator usually clustered in bunches.

Beta decay: A radioactive substance if unstable it decays by emitting a beta particle, a positron or an electron into daughter nuclei whose mass number A is unchanged and atomic number Z is increases by one if electron is emitted and decreases by one if positron is emitted.

Big Bang Theory: The theory about origin of universe that has been generally accepted since the 1960's. The theory claims that the universe began approximately 10 to 20 billion years ago in a state of enormous temperature and energy density. It has since expanded, and cooled to its present state, and continues to expand.

Binary system: Two stars orbiting each other.

Binding energy: It is the energy required to disassemble a whole system of particles into parts.

Black body: A hypothetical perfect radiator that absorbs and re-emits all radiations falling upon it.

Black body radiation: A type of energy radiation within or around a body in thermodynamic equilibrium with its environment, or emitted by a black body held at a constant temperature.

Black hole: An object whose immense gravitational field (belief) entraps anything, even light, that gets too close (closer than the black hole's event horizon).

Blueshift: A decrease in the wavelength of radiations emitted by an approaching source of light.

Bohr orbits: In the model of the atom described by Niels Bohr, the only orbits in which electrons are allowed to move about the nucleus.

Boson [BOZE-on]: A particle that has integer intrinsic angular momentum (spin) measured in units of h' (spin = 0,1,2…..). All particles are either fermions or bosons. The particles associated with all fundamental interactions (forces) are bosons. Composite particles with even number of fermion constituents (quarks) are also bosons.

Bottom quark (b): The fifth flavor of quark (in order of increasing mass), electric charge -1/3

Brane: Any of the extended objects that arise in string theory. A one-brane is a string, a two-brane is a membrane, a three brane has three extended dimensions, etc. More generally, a p-brane has p spatial dimensions.

Brewster's angle: The angle of incidence on a glass surface at which unpolarized light from a non-coherent source is reflected to produce polarized light.

Bright fringe: When a beam of monochromatic light is passed through two narrow slits the out coming beam projected on a screen forms bands of lighted and darkened regions. The bright bands (fringes) are the places on the screen where the beams are in phase and enhance intensity due to superposition of crests in the waves.

Brightness or Apparent Magnitude: It is measure of brightness of celestial entity as seen by an observer on Earth adjusted to a value it would have in the absence of atmosphere. The brighter the object appears the lower the value of its magnitude.

Calorimeter: A device that can measure the energy deposited in it (originally, devices to measure thermal energy deposited, using change of temperature; particle physicists use the word for any energy-measuring device).

Celestial Sphere: The **celestial sphere** is an imaginary **sphere** of radius 1 AU with the Earth located at its center. The poles of the **celestial sphere** are aligned with the poles of the Earth. The **celestial** equator lies along the **celestial sphere** in the same plane that includes the Earth's equator.

Centrifugal force: It is the inertial force that drives object in UCM away from center of circle in the absence of centripetal acceleration. The magnitude of centrifugal force is equal to centripetal force but its direction is opposite.

Centripetal acceleration: For object performing UCM, a constant centripetal acceleration is supplied by centripetal force towards the center of circle to prevent the object from leaving the orbit.

Cepheid Variable: A type of yellow, supergiant, pulsating star.

CERN: The major European international accelerator laboratory Center for Electronics Research in Nuclear Physics which is located near Geneva, Switzerland.

Cerenkov cone: It is caused by particles entering the water (any liquid) at speeds greater than the speed of light in water (the liquid). As the particles slow down to the local speed of light, they produce a cone of light similar to a sonic boom created by an aircraft travelling at supersonic speeds.

Cesium beam tube (CBT): The housing for QTS which utilizes the principle of hyperfine splitting of electron energy states in isotopes of Cesium-133 atoms

Cerenkov radiation: When highly radioactive objects are observed under water reactors, they appear to be layered with an intense blue light called Cerenkov radiation.

Chandrasekhar limit: The maximum mass of a white dwarf. Scientist from India invented a concept that progenitor stars with less than 1.4 solar mass will collapse to White dwarf star..

Charge: A quantum number carried by a particle. This quantum number determines whether the particle can participate in an interaction process. A particle with electrical charge has electrical interactions; one with strong charge has strong interactions, etc.

Charge conservation: The observation that electric charge is conserved in any process of transformation of one group of particle into another.

Charm quark (c): The fourth flavor of quark (in order of increasing mass), electric charge +2/3

Chirality: Feature of fundamental particle physics that distinguishes left from right-handed, showing that the Universe is not fully left-right symmetric. This feature occurs as a result of random law of nature and entropy of random process is always increasing.

Circumpolar: The stars form an observer at given latitude in one of the Earth's polar region does not appear to move below the horizon during its diurnal motion.

Classical Field Theory: The study of distribution of energy, matter, and other physical quantities under circumstances where the discrete nature is unimportant and may be regarded as continuous function of position.

Closed Universe: A universe with positive curvature, so that its geometry is analogous to that of the surface of a sphere. On this type of surface the shortest distance line is not straight.

CMB: The **Cosmic Microwave Background** radiation, or **CMB** for short, is a faint glow of light that fills the entire universe, falling on Earth from every direction with nearly uniform intensity.

CNO cycle: A series of nuclear reactions in which carbon is used as a catalyst to transform hydrogen into helium.

Coherent sources: Two sources of light are coherent if the phase difference between their waves is constant.

Collider: An accelerator in which two beams travelling in opposite directions are steered together to provide high-energy collisions between the particles in one beam and those in the other.

Colliding-beam experiments: Experiments done at colliders.

Comet: A small body of ice and dust in orbit about the Sun. While passing near the Sun, a comet's vaporized ices give rise to a coma and a tail.

Color: A property possessed by quarks and gluons. A 'threefold type' of charge similar to electric charge, believed to be the source of strong force between quarks described by QCD theory.

Color charge: The quantum number that determines participation in strong interactions; quarks and gluons carry nonzero colour charges.

Color matter: Essentially, any matter that provide response to some kind of radiation in the form of reflection and refraction is classified as color matter which is relatively easy to observe and detect.

Color neutral: An object with no net colour charge. For composite made of colour-charged particles, the rules of neutralization are complex. Three quarks (baryon) or a quark plus an antiquark (meson) can both form colour-neutral combinations.

Complex mass (Skylativity® Theory): The total mass (M_t) of a particle or an object is characterized by a quantity called Complex mass that is based on its energy content.. It is represented by a complex phasor with a static or fix component, eternal mass corresponds to intrinsic energy known as rest mass M_r. The imaginary component M_i that is descriptive of state of kinetic and potential energy associated with the mass is called virtual mass. Symbolically

$M_t = M_r + j\ M_i$

The real mass defines the current location of center of gravity for the mass and the imaginary mass determines the future position of the center of gravity.

Complex dimensions: Four new dimensions, it, ix, iy, and iz are created from known dimensions, a temporal dimension time and spatial dimensions x, y, and z based on probability of finding particle at an imaginary location. Complex dimensions are the sum of real dimension and imaginary dimensions.

Compound (Concomitant) event: It is an event that can be broken down into several steps of simple independent events that are possibly simultaneous.

Confinement: The property of the strong interactions by which quarks or gluons are never found separately but only inside color-neutral composite particles, protons and neutrons.

Conservation: When a quantity (eg. Electric charge, energy, or momentum) is conserved; it is the same after a reaction between particles as it was before.

Constellation: A configuration of stars in the same region of the sky.

Constructive interference: The interference is constructive if two waves are in step with each other and combine to reinforce. In that case amplitude of the resulting wave is the sum of amplitudes of the combining waves.

Cosmic microwave background radiation: Microwave radiation suffusing the Universe, produced during the Big Bang and subsequently thinned and cooled to 2.7K temperature as the Universe expanded.

Cosmology: The study of the history of Universe.

Coupling: In physics two systems are coupled if they are interacting with each other. Usually, when a particle interacts with another particle or a field some characteristics of the particle are changed. The extent of alteration in characteristic of a particle due to its motion in a field depends on the coupling between the field representing the particle and the interacting field.

Coupling constant j: It is a number which is the probability amplitude for an electron to emit or absorb a quantum of radiation. The value of this number is -0.1, a shrink to about one tenth and half a turn of rotation. Its value measured by an experiment is referred as the "charge" of electron e.

Crystal: A material in which atoms are arranged in orderly rows.

Curled-up dimension: A spatial dimension that is crumpled and wrapped into a tiny size, thereby inhibiting direct detection and therefore does not have an observably large spatial extent.

Dark energy: Briefly, it is a theoretical repulsive force that counteracts gravity and causes the expansion of universe at an accelerating rate. In essence, dark energy is a hypothetical form of energy that permeates space of universe and exerts a negative pressure, which would account for the differences between the theoretical and observational results of gravitational effects on color matter.

Dark fringe: The dark bands (fringes) are the places on the screen where the beams are out of phase and reduce intensity to zero due to superposition of crests and troughs in the waves by interference.

Dark matter: Dark matter is matter that neither emits nor scatters light or other electromagnetic radiation, and cannot be directly detected by electro-magnetic sensors. We suspect that dark matter does not have electrons. The matter inside black hole is this type which makes them unobservable. Dark matter is particularly elusive as it does not emit, absorb or reflect light, but makes itself apparent only through gravitational attraction.

De Broglie wavelength: Louise de Broglie hypothesized that every object of mass m and momentum p = mu has wave properties, with a de Broglie wavelength given by $\lambda = h/p$. Davisson and Germer measured wavelength of an electron in their famous electron diffraction experiment.

Decay: A process in which a particle disappears and in its place two or more different particles appear. The sum of the masses of the produced particles is always less than the mass of the original particle. (The mass-energy is conserved, however.)

Decay rate R: It is defined as the number of disintegrating nuclei of a radioactive substance at any time after the commencement of the decay process. It is an exponential process and it is proportional to the number of undecayed nuclei present at some time.

Declination: In astronomy, **declination** (abbreviated dec; symbol δ) is the angular distance expressed in degrees, of a star, planet, and etc, from the celestial equator measured north (positive) or south (negative) along the great circle passing through the celestial poles and the body.

Degeneracy: The phenomenon, due to quantum mechanical effects, whereby the pressure exerted by a gas or a particle does not depend on its temperature.

Degenerate electron pressure: The pressure exerted by degenerate electrons.

Destructive interference: The interference is destructive if two waves are out of step and combine to cancel each other. In that case amplitude of the resulting wave is the difference of amplitudes of the combining waves.

Detector: Any device used to sense the passage of a particle. Also, the word detector is used for a collection of such devices designed so that each serves a particular purpose in allowing physicists to reconstruct particle events.

Diffraction: When light passes through a narrow slit, it deviates from a straight line path and enters the region that is ordinarily forbidden. This divergence of light path from its initial line of travel is known as diffraction. This does not violate Huygens's principle.

Dimension: An independent axis or direction in space or spacetime. In a broader sense it represents a property of an entity that elicit its uniqueness, such as mass, length, time, charge, and etc. The familiar space around us has three dimensions (left-right, back-forth, up-down) and the familiar spacetime has four (the previous three axes plus the past-future axis). Superstring theory requires the Universe to have additional spatial dimensions.

Dirac's Equation: Paul Dirac derives an equation that combines quantum mechanics and special relativity to describe the electron; it is found to also require the existence of corresponding positively charged particles. Dirac, together with Schrödinger, is awarded Nobel Prize in 1933.

Dirac, Paul : See Dirac's equation.

Distance Modulus: It is the difference between brightness (ideally corrected from the effects of interstellar absorption) and the luminosity of astronomical object. It is related to distance in Parsec.

Diurnal Motion: Diurnal motion is an astronomical term referring to the apparent daily **motion** of stars around the Earth, or more precisely around the two celestial poles. It is caused by the Earth's rotation on its axis from west to east, which results into apparent motion of celestial bodies in night sky from east to west so that every star moves on a circle called diurnal circle.

Down quark (d): The second flavor of quark (in order of increasing mass), electric charge -1/3

Doppler effect: The apparent change in wavelength of radiation due to relative motion between the source and the observer along the line of sight.

Drell Yan annihilation: Collision of matter and antimatter particles; electron and positron, and quarks within proton and antiproton, thereby producing a high energy and high momentum photon, and W or Z boson through annihilation and quark fragmentation process.

Dynamic mass: The portion of mass of an object that represents quantity of energy contained in the object because of dynamics. This is a fictional or imaginary component of the total mass of the object. (See also eternal mass.)

Ecliptic: The apparent trajectory of the Sun on celestial sphere due to Earth's orbit around the Sun leading to virtual motion of stars in the background sky. It forms basis for an unique ecliptic space coordinate system. It is an imaginary line of intersection between Earth's orbital plane and celestial sphere.

E_d Diameter of the Earth: Equatorial diameter of Earth used to express sizes of other members of solar system. 1 E_d = 12756 km = 7927.91 miles

Eigenvalue: The angular momentum of a particle along Z axis is known as the eigenvalue.

Eightfold way and Tenfold way: Classification scheme for elementary particles baryons and mesons collectively called hadrons, established in 1960, forerunner of quark model.

Einstein rings: Sometimes multiple images of a star are observed which form a ring of four images. It was believed that multiple images are created due to bending of light caused by the effect of gravity from a nearby black hole on light from the star. Einstein discovered the rings and hence the name.

Electromagnetic interaction: The interaction due to electric charge; this includes magnetic effects, which have to do with moving electric charges.

Electron [e-LEC-tron] (e): The least-massive electrically charged particle, hence, absolutely stable. It is the most common lepton, with electric charge -1.

Electron Volt (eV): Unit of energy. Typically 1- 10eV is the amount of energy per atom involved in chemical reactions. 1 eV is the energy gained when an electron is accelerated by a potential of one volt.

Electroweak interaction: In the standard model, electromagnetic and weak interactions are related (unified); physicists use the term electroweak to encompass both of them.

Elastic collision: A collision between two objects is deemed as elastic if the total kinetic energy of the system as well as the total momentum of the object is conserved, meaning that the values of kinetic energy and momentum before and after the collision will remain constant.

Entanglement: The impossibility of expressing certain quantum mechanical states of a system with two or more parts as a conjunction of definite quantum states of separate parts.

Entropy: A measure of the disorder of a physical system, the number of rearrangements of the ingredients of a system that have its overall appearance intact.

EPR: Abbreviation of A. Einstein, B. Podolsky and N. Rosen, who presented an argument in 1935 that the quantum mechanical description of certain composite physical systems cannot be complete.

ESRO: European space research organization.

Escape speed: It is the minimum speed at which an object must be launched from the surface of a planet that allow its exit from the planet's gravitational field to infinite distance. The definition implies that if launch speed is lower than escape speed the object will orbit the massive planet. Also higher the launch speed larger is the orbit radius.

Euclidean Topology: A geometrical surface with property that the shortest distance between two points on the surface is a straight line. It is based upon postulate of mathematician Euclid which states that only one line can be drawn through a given point which is parallel to a given line. For a Non-Euclidean surface the shortest distance is a curved line.

Eternal mass: That portion of mass of an object that determines the position of center of gravity for the object. (See also rest mass.)

Event: What occurs when two particles collide or a single particle decays? Particle theories predict the probabilities of various possible events occurring when many similar collisions or decays are studied. They cannot predict the outcome for any single event.

Event horizon: It is a spatial boundary of an imaginary surface around a black hole, enclosing the space from which no light or other radiation can escape a black hole's gravitational grip.

Exclusion principle: Wolfgang Pauli's principle which states that no two fermions can exist in the same state at the same place and time. Many of the properties of ordinary matter arise because of this rule. Electrons, protons, and neutrons are all fermions, as are all fundamental matter particles, quarks and leptons.

Far Infrared: The part of the infrared spectrum most different in wavelength from visible light.

Fermilab: Fermi National Accelerator Laboratory in Batavia, Illinois (near Chicago). The lab oratory was named after particle physics pioneer Enrico Fermi.

Fermion [FARE-mee-on]: Any particle that has odd, half-integer (1/2, 3/2,….) intrinsic angular momentum (spin), measured in units of h. As a consequence of this peculiar angular momentum, fermions obey a rule called the Pauli Exclusion Principle, which states that no two fermions can exist in the same state at the same place and time. Many of the properties of ordinary matter arise because of this rule. Electrons, protons, and neutrons are all fermions, as are all fundamental matter particles, quarks and leptons.

Feynman diagrams: Pictorial representations of mathematical expressions for the quantum field theoretic predictions of the scattering of elementary particles. Broadly speaking, the lines in a diagram describe the path of a particle and the vertices correspond to particle interactions that are located at a space-time point.

Field particles (virtual): The virtual particles which mediate interaction through forces to real particles are known as field particles. Four fundamental forces in nature are identified, the nuclear strong color charge, the electromagnetic strong, the weak residual, and the weakest gravitational. Corresponding mediating particles are gluons, photons, W and Z bosons, and graviton.

Fission: A nuclear reaction in which nucleus of heavy atom of radioactive matter splits into nuclei of atoms of light matter.

Fixed-target experiment: An experiment in which the beam of particles from an accelerator is directed at a stationary (or nearly stationary) target. The target may be a solid, a tank containing liquid or gas, or a gas jet.

Flavor: The name used for different quark types (up, down, strange, charm, bottom, top) and for the different lepton types (electron, muon, tau). For each charged lepton flavor, a corresponding neutrino flavor exists. In other words flavor is the quantum number that distinguishes the different quark/lepton types. Each flavor of quark and charged lepton has a different mass. For neutrinos, we do not yet know if they have a mass or what the masses are.

Flatness Problem: It is a cosmological fine tuning problem within the BBT model of the universe. The problem arises from the observation that some of the initial conditions of the universe appears to be fine-tuned to 'special values', parameters such as critical density of matter and energy very close to unity, departing from one by one part in 10^{62} parts at the time inflation began. Small deviation from this value would have had massive effects on the flat nature of universe at current time.

Freeze out: As the Universe expands and cools, the probability of any collision-driven process decreases, because the rate of necessary collision decreases. A process can be ignored when the average time between collisions is long compared to the age of Universe at that time. Such a process is then said to have frozen out.

Frequency (ν): It is defined as the number of the crests or the troughs that are passing through a point in space domain per unit of time interval. Maximum displacement of an electron (particle causing the radiation wave) relative to its mean position is called its amplitude A.

Fundamental interaction: In the Standard Model, the fundamental interactions are the strong, electromagnetic, weak, and gravitational interactions. At least one more fundamental interaction (Higgs) is in theory; it is responsible for fundamental particle masses. Five interactions types are all that are needed to explain all observed physical phenomena.

Fundamental particle: A particle with no internal substructure. In the Standard Model, the quarks, leptons, photons, gluons, W^+ & W^- bosons, and Z^0 bosons are fundamental. All other objects are made from these.

Galaxy: A collection of stars held together by gravitational forces.

Gamma decay: Often a nucleus which undergoes radioactive decays, the alpha and the beta decays leaves the nucleus in an excited state. Subsequently the nucleus experience a transition to an intermediate lower energy state. During this transition a high energy gamma ray quantum is emitted.

General relativity: The theory of gravitation formulated by Einstein.

Generation: A set of one of each charge type of quark and lepton, grouped by mass. The first generation contains the up and down quarks, the electron, and the electron neutrino.

Geodesic: A path or a line of shortest distance joining two points in space (or space-time) is a geodesic. A geodesic is a straight line if the surface is flat. A geodesic on the surface of a sphere is a great circle. In General theory of relativity, freely falling particles follow geodesics paths in space-time.

Gluon [GLUE-on] (g): The carrier particle of strong interaction.

Greenhouse effect: The trapping of infrared radiation near a planet's surface by the planet's atmosphere.

Grand unified theory (GUT): Any of class of theories that contain the Standard Model, but go beyond it to predict further types of interactions mediated by particles with masses of order 10^{15}GeV/c^2. At large energies compared to this mass (times c^2), the strong, electromagnetic, and weak interactions are seen as only different aspects of one unified interaction.

Gravitational interaction: The interaction of particles due to mass-energy.

Gravitational redshift: The increase in the wavelength of a virtual particle photon as it climbs upward in a gravitational field.
Graviton: It is a hypothetical particle that is mediating force of gravitation among all objects in real Universe. Physicist predicted this particle's existence and included in Standard Model of Fundamental Particles and Interactions to unify five forces of nature and formulate TOE.

Ground state: The state of an atom, ion, or molecule with the least possible energy.

Group speed of a wave (v_g m/s): It is defined as the speed at which the crest or the trough on an envelope wave moves in relation to space that is formed on a single wave packet constructed by superposing many waves in space domain.

GTR: Einstein's general theory of relativity.

H-R Diagram: The Hertzsprung–Russell **diagram**, abbreviated as H–R **diagram** or HRD, is a scatter graph of stars showing the relationship between the stars' absolute magnitudes or luminosities versus their spectral classifications or effective temperature.

Hadron [HAD-ron]: The composite particles other than field particles are classified as hadrons. They interact with all four fundamental forces and are of two types, baryons and mesons. Hadrons are made up of real particles, quarks and virtual particles gluons, which determine properties of hadrons. They are not elementary.

Half-life: The half-life of a radioactive substance is defined as the time interval during which half of a given number of radioactive nuclei randomly disintegrate.

Hawking radiation: A form of radiation believed to emanate from black holes, emerging from the region just beyond the black hole's event horizon. Pairs of virtual particles and antiparticles, created naturally in the vacuum fluctuation near the black hole, are split apart, one particle falling into the black hole and the other radiating away.

Heisenberg uncertainty principle: In quantum mechanics, the position x, and the momentum, p, of a particle do not have well defined values simultaneously. The uncertainty, or statistical spread, in their measured values satisfies the relation $\Delta x \times \Delta p \geq \hbar/2$.

Heterogeneous or non-linear: At affine scale universe is heterogeneous (not uniform) in which trajectory of a particle and a wave entity follow a geodesic based on Einstein's principles of GTR.

Hidden variable theory: One of the class of physical theories which deny that the quantum state of a physical state is a complete specification. The hidden variables are those components of the hypothetical complete state which are not contained in the quantum state.

Hierarchy problem: On microscopic scale it is found that gravity is 10^{40} times weaker than electromagnetism. The roots of weakness of gravity can be traced to the large value of Planck mass or the smallness of Newton's gravitational constant relative to the characteristic strength of weak interactions which set the energy scale of particle physics. Also, strong force is 10^{32} stronger than weak force, why? The disparity of scale of particle physics and gravity is known as hierarchy problem. The modern particle physicists solved the problem through Higgs Mechanism.

Higgs boson: It is a native particle to Higgs field which interacted with the field in primordial times during exponential inflation of the universe after big bang that left the Higgs field in an excited state.

Higgs field: The Higgs field is an energy field that exist everywhere in the universe which gives mass to a particle or an object when it interacts with the field.

Higgs Mechanism: The revolutionary idea from Peter Higgs that all particles in universe acquire their mass property as they interact with Higgs field. The quantity of mass associated is determined from the extent of coupling between the Higgs field and the interacting particle. The idea was validated when CERN confirmed existence of Higgs boson in March of 2013.

Horizon problem: It is a problem with standard cosmological model of big bang about large scale uniformity observed in the universe today. It points out that different regions of space were causally disconnected because of exponential inflation and information transfer rate is limited by the speed of light. BBT model did not explain uniformity of temperature, Cosmic Microwave Background radiation from different regions of space separated by vast distances. Varying Speed of Light theory
Skylativity® solves this problem.

Hubble's law: The observation, first made by E. P. Hubble in the 1920's, that distant galaxies are receding from us with a velocity proportional to their distance; one infers that any two galaxies are receding from each other with a velocity proportional to their separation.

Hyper-space: It is defined as the n dimensional coordinate system that is occupied by imaginary Universe (time travel related) in the imaginary space-time domain.

Imaginary time: The imaginary component of time t_i is defined as the probability of finding a particle P_i at the event of interest in the locality of the region Δx_i corresponding to x_r where the particle was found after imaginary time t_i multiplied by the time for which the probability was projected i. e. t_r.

Imaginary Multiverse: It is defined as the state of all objects inside several imaginary Universes which are intangible and occupy imaginary (probabilistic) space-time coordinates. Trajectory of all objects in imaginary Universe are probabilistic in nature.

Inelastic collision: A collision between two objects is inelastic if the total kinetic energy of the system shows difference following the collision, but the total momentum of the system is conserved. When two objects stick together after the collision, the collision is called perfectly inelastic.

Incoherent sources: Two sources of light are incoherent if the phase difference between their waves changes at random.

Inflationary Universe Model: According to the theory of inflation, the early universe expanded at an exponential rate for a fraction of a second after the Big bang. Cosmologist believes that the most of the matter in the universe was created during this period. This model solved all problems of BBT.

Infrared STM: Infrared spectroscopy is utilized to determine type of molecules of a substance by observing reflected infrared spectrum as lasers are fired on crystals of a sample. Differences in the frequency of reflected signals reveal the type of material. The method cannot discern the details on the atomic structure of molecules. A technique in which the STM is combined with Infrared spectroscopy that monitors current variation (peak) by the measurement of reflected infrared radiation from a crystal surface that is in turn effected by a resonating frequency of a tunable laser.

Inner-space: It is defined as the space within atom's nucleus where protons and neutrons reside that is under the influence of strong fundamental force which bind quarks and gluons to form the baryons.

Inertial frame: A frame of reference is defined as an inertial frame if and only if worldlines of all particles in the frame vary linearly in all four dimensions. All inertial frames are considered to be moving at constant velocity with respect to each and have zero acceleration.

Infrared radiation: Electromagnetic radiation of a wavelength longer than visible light but shorter than radio waves.

Integrated system: An energy model of a system is integrated if, within the system, energy crosses the boundary of the system during some time interval due to interaction with the environment, such that the internal energy of the system (temperature, enthalpy) is modified. This results in a change in the system's total energy.

Interaction: A process in which a particle decays or annihilates or it responds to a force due to presence of another particle (as in a collision). It is a particular way in which matter, fields, and atomic and subatomic particles affect each other through a reciprocal action. Word interaction refers to any process that elementary particles can undergo which may involve scattering, decay, annihilation, and particle creation in presence or occasionally in the absence of a field.

Interference: It is a process in which two or more energy waves of the same type (sound, light, electromagnetic, and etc.) and equal frequency combine to form a resulting wave.

Interference pattern: Wave pattern that emerges from the overlap and the intermingling of waves emitted from different locations.

Isolated system: In a isolated system, energy does not cross the boundary of the system upon interaction with its environment. For this system, the total energy of the system remains constant. If it were the case that only conservative forces acted on an isolated system, we can apply the work-kinetic energy theorem if the only change in the system is in its speed.

Isotope: Any of the several forms for the same chemical element whose nuclei all have the same number of charges protons but different number of neutrons.

ITU: International Telecommunication Union Standards, formerly CCITT, produces global telecommunication standards and defines tariff & accounting principles.

Jet: Depending on their energy, the quarks and gluons emerging from a collision will materialize into 5-30 particles (mostly mesons and baryons). At high momentum, these particles will appear in clusters called "jets" that is, in groups of particles moving in roughly the same direction, centered about the path of original quark or gluon.

JPL: Jet Propulsion Laboratory

Jovian Planets: The gas giant planets whose surface is mostly composed of thick cloud of gases are called Jovian planets. Four planets Jupiter, Saturn, Neptune and Uranus falls into this category.

Kaon (K): A meson containing a strange quark and an anti-up (0r an anti-down) quark, or an anti-strange quark, and an up (or down) quark.

Keppler laws: Relationships between motion of the planets and the location of the Sun. 1) Planets move around the Sun in an elliptical orbits with the Sun at one focus, 2) Planets sweeps out equal areas in equal times as they orbit the Sun and 3) The orbiting period of a planet is proportional to $a^{3/2}$, where a is the semi-major axis of the elliptical orbit.

Laplacian determination: Clockwork conception of the Universe in which complete knowledge of the state of the Universe at one moment is completely determines its state at all feature and past moments.

Laser: Light amplification by stimulated emission of radiation (LASER or laser)

Length contraction: It is related to the reduction in length of rods in different inertial frames. Measured length of a rod by a ruler in the first inertial frame appears to be longer than that measured in the second inertial frame by the same ruler and vice versa. This effect is known as Length contraction.

Leptons: The elementary particles without structure and composition are called leptons. They interact via only three forces, electroweak, electromagnetic strong, and gravitational weak. Six kinds of leptons exist: the electron, the muon, and the tauon, and three corresponding neutrinos. Among six leptons, three neutrinos are considered truly elementary.

Light clock: A hypothetical clock that measures elapsed time by counting the number of round trip journeys completed by a single photon (hypothetical particle) between two mirrors.

Lightlike displacement: A displacement in relativistic spacetime interval is Lightlike if the spacetime interval of relativistic geometry has a zero value. The displacement of a particle travelling at the speed of light remains invariant in relation to time.

Light Gathering Power: A telescope's **light gathering power** is directly related to the diameter (or aperture) of its objective (the primary lens or mirror that collects and focuses the **light**). The larger the area of objective, the more **light** the telescope collects.

Linear size or Small Angle Distance formula (SAF): It is very simple formula that relates to actual diameter of a celestial object with observed angular size and its distance from an observer on the Earth.

Longitudinal wave: When the vibration plane of an energy carrier wave is in the direction of propagation of the wave, it is called a longitudinal wave.

Lorentz transformations: Equations that relate the measurements of different observers who are moving relative to each other at high speeds.

Lorentz contraction: Feature emerging from the special relativity, in which a moving object appears shortened along its direction of motion.

Lepton (LEP-tahn): A fundamental fermion that does not participate in strong interactions. The electrically charged leptons are the electron (e), muon (μ), tau (τ), and their anti-particles. Electrically neutral leptons are called neutrinos (υ).

LHC: The Large Hadron Collider at the CERN laboratory in Geneva, Switzerland. LHC collide protons with protons at a center-of-mass energy of about 14 TeV. When completed in year 2005, it will be the most powerful accelerator in the world. It is hoped that it will unlock many of the remaining secrets of particle physics.

Light year: It is a unit of length that is most frequently used to measure distances of stars and other celestial entities on a galactic scale. International Astronomical Union had defined a light year as the distance traveled by light in vacuum in a Julian year (365.25 days or 31.5576×10^6 s) which is equal to 9.461 trillion kms or 5.8786 trillion miles. 1 ly = 63,421.077 AU

Lifetime: The time between the creation and the decay of a type of particle. The lifetime of an individual particle cannot be predicted. We can just measure an average (or mean) lifetime by observing the random decay in a sample of a given type of unstable particles.

Linac: An abbreviation for linear accelerator, that is, an accelerator that is straight.

Luminosity or Absolute Magnitude: Absolute magnitude is a measure of a celestial object's intrinsic brightness, its luminosity. It is a hypothetical apparent magnitude of an object at a standard distance of exactly 10.0 parsec from the observer, assuming no astronomical extinction of starlight.

Magnetic moment: It is defined as the response of an electron to the external magnetic field. The theoretical value derived from QED considerations is designated by letter μ_s and the experimental value is called μ_e. The best value for μ_s today is 1.001 159 652 181 13 (±86) and value for μ_e is 1.001 159 652 180 73 (±28).

Magnifying Power (Magnification): The **magnifying power**, or extent to which the object being viewed appears enlarged, and the field of view, or size of the object that can be viewed, are related by the geometry of the optical system. For telescopes Magnification = F_o/F_e

Main sequence lifetime: The total time that a star spends burning hydrogen in its core, and hence the total time that it will spend as a main sequence star.

Magnetic Monopole Problem: A magnetic monopole is a hypothetical particle that is an isolated magnet which exhibits the effect of only one magnetic pole either North or South. Current understanding of elementary particle physics indicates that inflationary universe model and theory should have produced very massive magnetic monopoles, yet magnetic monopoles are not found. The disappearance of monopoles in the modern universe is called magnetic monopole problem.

Maser: Microwave amplification by stimulated emission of radiation (MASER or maser)

Mass (Current Theory): The mass (m) of a particle is the mass defined by the energy of the isolated (free) particle at rest, divided by c^2. (This is very slightly correct. The majority of particle mass consists of protons and neutrons. Baryon rules states number of protons and neutrons is unaltered in any mass to energy conversion process.) When particle physicists use the word "mass" they always mean the "rest mass" (m) of the object in question. The total energy of a free particle is given by $E = (p^2c^2 + m^2c^4)^{1/2}$

where p is the momentum of the particle. Note that for p = 0 this simplifies to Einstein's $E = mc^2$. For a general particle with mass and momentum it can also be written as $E == \gamma mc^2$, where $\gamma = (1-v^2/c^2)^{-1/2}$.

M_E mass of the Earth: It is used to express sizes of other members of solar system. 1 $E_m = 5.9724\times10^{24}$ kg

Maxwell's electromagnetic theory: Theory uniting electricity and magnetism, based on the concept of the electromagnetic field, devised by Maxwell in the 1880's; shows that visible light is an example of an electromagnetic wave.

Meson [MEZ-on]: A hadron made from an even number of quark constituents. The basic structure of most mesons is one quark and one anti-quark; some of multiples of this.

Meissner effect: The phenomenon in which a metal cooled through its superconducting transition temperature in the presence of a magnetic field completely expels the field.

Metric: Mathematical variable that captures all the geometrical and causal structure of spacetime which is used to define notions such as time, distance, volume, curvature, angle, and separating the future from the past.

Metric tensor: The fundamental mathematical object in the study of general relativity that describes the deviation of Pythagoras's theorem in a curved space.
Microwave: An electromagnetic wave with wavelength in the micrometer range.

Microwave background radiation: Thermal radiation with a temperature about 3K that is apparently uniformly distributed in the Universe; the radiation, discovered by A. A. Penzias and R. W. Wilson in 1964. It is believed to be a redshifted remnant of the hot radiation that was in thermal equilibrium with matter during the first hundred thousand years after the Big Bang.

Michael Faraday's rotation: An experiment performed by Faraday to demonstrate electromagnetic wave nature of light by detecting changes in the polarization of light waves in response to passage of light through a controlled magnetic field.

Minkowski space-time: Space and time considered together, with special importance attached to the progress of a light flash, and to the light-cone and the 'interval'.

Missing Mass Problem: Observed excess abundance of dark matter in the universe and galaxies over the visible matter (95% vs. 5%) is characterized as missing mass problem. At present, the composition of dark matter is unknown (composed of weakly interacting massive particles WIMPs) but it's prescience is detected by gravity effects.

Monochromatic radiation: A radiation is monochromatic if it is of a single wavelength. It is achromatic if it is composed from signals of different wavelengths.

Muon [MEW-on] (μ): The second flavor of charged lepton (in order of increasing mass),with electric charge -1.

Muon chamber: The outer layers of a particle detector capable of registering tracks of charged particles. Except for the charge-less neutrinos, only muons reach this layer from the collision point.

Neutral: Having a net charge equal to zero. Unless specified otherwise, it usually refers to electric charge.

Neutrino [new-TREE-no] (υ): A lepton with no electric charge. Neutrinos participate only in weak and gravitational interactions and, therefore, are very difficult to detect. Three known types of neutrino exist, all of which are very light and could possibly even have zero mass.

Neutron [new-TRON] (n): A baryon with electric charge zero; it is a fermion with a basic structure of two down quarks and one up quark (held together by gluons). The neutral component of an atomic nucleus is made from neutrons. Different isotopes of the same element are distinguished by having different numbers of neutrons in their nucleus.

Neutron Star: A compact star in which the internal pressure support is provided by neutron degeneracy pressure. Their masses can not exceed roughly the mass of the Sun because of the Chandrasekhar limit. Their radii is about 10 km and the densities are about 10^{18} kg m^{-3}.

Newtonian geometry: A geometry in spacetime is called Newtonian if the spacetime interval for the geometry is described by two distances, spatial dl and temporal dt, here $dl^2 = dx^2 + dy^2 + dz^2$.

Newton's universal theory of gravity: Theory of gravity declaring that the force of attraction between two bodies is proportional to the product of their masses and inversely proportional to the square of the distance between them.

NP incomplete: A problem whose solution requires infinite computational resource for real time computation of results. NP complete problems may be solved with finite resource in real time.

Nuclear fusion: Nuclear fusion is a nuclear reaction in which two or more atomic nuclei collide at very high speed and fuse together to form a heavier nucleus and release energy. The temperature required to produce fusion is on the order of 10 million degrees K.

Nucleon: A proton or a neutron; that is, one of the particles that makes up a nucleus.

Nucleosynthesis: Primordial Nucleosynthesis is the process that creates new atomic nuclei from pre-existing nucleons, primarily protons and neutrons. The first nuclei were formed about three minutes after the Big Bang. Nucleosynthesis requires a high speed collision, which can only be achieved in nature at very high temperature.

Nucleus: A collection of neutrons and protons that forms the core of an atom (plural: nuclei).

Observable universe: That portion of the universe inside the cosmic particle horizon.

Orbital magnetic quantum number m and l: Quantum mechanics is applied to the hydrogen atom by using potential energy function $U(r) = -k_e e^2/r$ in the Schrödinger equation. The solution of this equation yields wave functions for allowable states and allowed energies. The allowed function depend on two additional quantum numbers orbital magnetic quantum number m and orbital quantum number l. The value for l are integers in range from 0 to n-1 and the value for m are integers in range –l to +l. (Also see principal quantum number)

Open Universe: A universe with negative curvature, so that its geometry is analogous to that of a saddle-shaped hyperbolic surface.

Parity: The operation of studying a system of quarks and related sequence of events reflected in a mirror according to QCD rules.

Parsec: It is the largest unit of distance for measuring distances of celestial objects outside the solar systems. Parsec is defined as the perpendicular distance at which an observer's line of sight located at 1 AU subtends a parallax angle of 1 arc s. 1 pc = 3.2616 light years.

Particle accelerator (collider): Machine for boosting particles speed to nearly at light speed and smashing them together to probe the structure of matter within the particles.

Pauli exclusion principle: A principle of quantum mechanics stating that no two electrons have the same position and the momentum.

Pair production: The creation of a particle and its antiparticle from energy.

Particle: A subatomic object with a definite mass, volume, and charge that manifests force of gravity on other particles, and does not permit other particles to occupy its position without resistance (inertia).

Path integral formalism (PIF): It is a procedure (rules) to determine the probable number of light quanta that will be reflected from mirror and refracted through a glass surface, given the probability amplitude of light incident to the surfaces of a glass plate.

Perturbation theory: Framework for simplifying a difficult problem by finding an approximate solution that is subsequently refined as more details initially ignored are systematically included.

Perihelion: The point in its orbit where a planet or comet is nearest the Sun.

Period (T): It is defined as the time interval between two successive peak events of a travelling wave front in the time domain.

Periodic table: A listing of the chemical elements according to their properties, invented by Dmitri Mendeleev.

Photon [FOE-than] (γ): The carrier particle of electromagnetic interaction.

Phase: When used in reference to matter, describes its possible states, solid phase, liquid phase, gas phase. More generally refers to the possible descriptions of a physical system as features on which it depends (temperature, string coupling constant values, form of spacetime, etc.) are varied.

Phase speed of wave (v_{ph} m/s): It is defined as the speed at which the crest or the trough of the wave, which is a fixed point on the wave, moves in relation to the space.

Phase transition: A change in the physical nature of the system that results in discrete transition of the system to another state.

Photoelectric effect: Phenomenon in which electron are ejected from a metallic surface when the surface is exposed to light.

Photosynthesis: A biochemical process in which solar energy is converted into chemical energy, carbon dioxide and water are absorbed, and oxygen is released.

Pion [PIE-on] (π): The least massive type of meson, pion can have electric charges +/- 1or 0

Planck energy: About 1,000 Kilowatt hours, the energy necessary for probing to distances as small as the Planck length. This is the amount of typical energy of a vibrating string in string theory.

Planck length: About 10^{-33} centimeters, the scale below which quantum fluctuations in the fabric of spacetime would become enormous. This is the size of a typical string in string theory.

Planck mass: About 10^{18} times the mass of a proton; about 10^{-5} times the mass of a gram; about the mass of a small grain of dust. This is the typical mass equivalent of a vibrating string in string theory.

Planck constant: Denoted by the symbol h', Planck's constant is a fundamental parameter in quantum mechanics. It determines the size of the discrete units of energy, mass, spin, etc. into which the microscopic world is partitioned. Its value is 1.05×10^{-27} grams-cm/s s or 6.626×10^{-34} J.s. This constant characterizes a basic particle into integral multiples of parameters mass, energy etc.

Planck tension: About 10^{39} tons. This is the tension on a typical string in string theory.

Planck time: It is the time required for light to travel, in a vacuum, a distance of 1 Planck length. The unit is named after Max Planck, who was the first to propose it. Also, it is known as the time at which the size of the Universe was roughly the Planck length. Expression for Planck time:

$$t_P = \sqrt{\frac{\hbar G}{c^5}} \approx 5.39124(27) \times 10^{-44}\ \mathrm{s}$$

where:

$\hbar = h/2\pi$ is the reduced Planck constant (sometimes h is used instead of $\hbar$ in the definition)

G = gravitational constant, *c* = speed of light in a vacuum, s is the SI unit of time, the second.

The two digits between parentheses denote the standard error of the estimated value.

For processes that occur in a time *t* less than one Planck time, dimensional analysis suggests that the effects of both quantum mechanics and gravity will be important under these circumstances, requiring a theory of quantum gravity.

Planck waves: The energy radiation waves such as the visible light, the infrared radiation and, waves at and above the corresponding frequency range are categorized in this book as Planck waves. Max Planck established that energy carried by these waves is computed by formulae $E = h \times \nu$ J. Further according to the principles of Skylativity® theory, these waves are non electromagnetic in nature as opposed to Radio Frequency waves which are electromagnetic.

Plasma: A gas of charged particles.

Polarization: It is related to a radiation quantum and is defined as its phase angle in space-time compared to some reference in time and space.

Polarized light: Light that is transmitted or reflected such that vibration plane of the energy wave is at a fixed angle to a reference plane that contains the line of propagation. The radiation is unpolarized if the angle of vibrating plane changes with respect to the reference plane.

Positron [PAUSE-i-tron] (e^+): The antiparticle of the electron. In 1931, Paul Dirac realizes that the positively charged particles required by his equation are new objects (he calls them “positrons”). They are exactly like electrons; in particular, they have the identical mass, but positively charged. The positrons are first example of antiparticles.

Poynting Theorem: In electromagnetism a vector, equal to the cross product of the electric-field strength and the magnetic-field strength (mks units) whose outward normal component, when integrated over a closed surface, gives the outward flow of electromagnetic energy through that surface.

Poynting Vector: The vector obtained in the direction of a right-hand screw from the cross product (vector product) of the electric field vector rotated into the magnetic field vector of an electromagnetic wave.

Primordial black hole: A type of black hole that may have formed in the Big Bang.

Precession of the Earth: A slow, canonical motion of the Earth’s axis of rotation caused by the gravitational pull of the Moon and the Sun on the Earth’s equatorial bulge.

Principal quantum number n: The Bohr model for atoms described the spectra of atomic hydrogen and hydrogen like ions without taking into consideration the effects of gravity. The model was based on a fact that electron in stable atom can exist in only discrete orbits such that angular momentum of the electron L_{pe} is integral multiples of $h/2\pi$. i.e. $L_{pe} = n \times h/2\pi$ Often n is referred as principal quantum number because the value of n are integers in range from 1 to ∞.

Principle of equivalence: Core principle of general relativity declaring the indistinguishability of accelerated motion immersion in a gravitational field (over small enough regions of observation) Generalizes the principle of relativity by showing that all observers, regardless of their state of motion, can claim to be at rest, so long as they acknowledge the presence of a suitable gravitational field.

Principle of relativity: Core principle of special relativity declaring that all constant velocity observers are subject to an identical set of physical laws, and that therefore, every constant velocity observer is justified in claiming that he or she is at rest. This principle is generalized by the principle of equivalence.

Proper time: A time interval measured with a clock at rest with respect to an observer.

Proton [PRO-than] (p): The most common hadron, a baryon with electric charge (+1) equal and opposite to that of electron (-1). Proton has a basic structure of two up quarks and one down quark (bound together by gluons). The nucleus of a hydrogen atom is a proton. A nucleus with electric charge Z contains Z protons; therefore, the number of proton is what distinguishes the different chemical elements.

Proton-proton chain: A sequence of thermonuclear reactions by which hydrogen nuclei are built-up into helium nuclei with a release of energy.

Quantum: The smallest discrete amount of any quantity (plural; quanta) into which something can be partitioned, according to the laws of quantum mechanics. For instance photons are the quanta of radiations. In physics it stands for energy of quantity h Planck’s constant.

Quantum Chromodynamics (QCD): QCD is a theory of strong interaction, a fundamental force describing interaction between quarks and gluons which make up hadrons such as the proton, neutron and pion. Also, QCD stipulates the laws of joining quarks and antiquarks to form baryons and mesons.

Quantum determinism: Property of quantum mechanics that knowledge of the quantum state of a system at one moment completely determines its quantum state at future and past moments. Knowledge of the quantum state, however, determines only the probability that one or another future will actually ensue.

Quantum Electrodynamics (QED): It is a relativistic quantum field theory of electromagnetic forces that is considered as strong interaction between electrons and protons ruled by special relativity.

Quantum entanglement: A termed used in quantum theory that describes the way in which particles/matter can become correlated such that they interact predictably with each other regardless of how far apart they are in spacetime.

Quantum geometry: Modification of Riemannian geometry required describing accurately the physics of space on ultramicroscopic scales, where quantum effects become important.

Quantum gravity: A theory that successfully mergers quantum mechanics and general relativity, possibly involving modifications of one or both. String theory is an example of a theory of quantum gravity.

Quantum Field Theory: The branch of quantum physics that is concerned with the theory of fields that is a theoretical framework for constructing quantum mechanical models of subatomic particles that accommodates discrete quantities associated with interacting particles.

Quantum Multiverse: The Multiverse is a theoretical framework in modern cosmology and high energy physics which presents the idea that there exist a vast array of potential universes which manifest their reality in some way. There are number of types of potential universes–the many world interpretation (MWI) of quantum physics, brane worlds predicted by string theory, and complex universe.

Quantum Loop Corrections (QLC): Quantum picture of a particle or an event is complicated by the uncertainty principle that allows virtual particles to appear and vanish for a brief time during interaction. Therefore, any rigorous computation involving Feynman diagrams for quantum process should account for various possibilities. For instance, a photon in transition can fragment into electron and positron pair that quickly annihilate to a photon. Electron and positron pair in transit forms a quantum loop in Feynman diagram. The way in which this loop effects the calculation of particle energies in the end is called quantum loop correction.

Quantum mechanics: Framework of laws governing the universe whose unfamiliar features such as quantum uncertainty, quantum fluctuations, and wave particle duality become most apparent on the nanoscopic scales of atoms and subnuclear particles. Alternately, The law of physics that apply on very small scales. The essential feature is that energy, momentum, and angular momentum, as well as charges comes in discrete amounts called quanta.

Quantum time standard (QTS): A calibrated instrument that measures standard time with an accuracy of 1 part in 10^{15} of a second by applying the principle of microwave absorption through the hyperfine transitions of electron orbits in Cesium-133 atoms, which are extremely stable.

Quarks [KWORK] (q): The particles that combine to form hadrons are called Quarks. Quarks have fractional electric charge and come in six flavors: up and down, top and bottom, charm and strange. Each meson contains two quarks, a pair of quark and antiquark, and each baryons contains three quarks. Quarks and antiquarks in mesons and baryons obey symmetry rules.

Quark star: A hypothetical celestial object whose density is between the density of a neutron star and a black hole or possibly the density of black holes. It is plausible that the compact exotic star is the remnant of a massive neutron star with all particles within it reduced to strange quarks. These are ultra-dense phase of degenerate matter to form inside a particularly massive neutron star.

QUASAR: A star like object with a very large redshift. This is an extreme form of active galactic nucleus in which the luminosity of the nucleus far exceeds the luminosity of the underlying galaxy. As a result, these objects have a stellar appearance on the photographic plates. The first members of this class were discovered through the optical identification of extragalactic radio sources and hence the origin of the name "quasi-stellar radio source' abbreviated to quasar. The quasars are the most luminous objects known in the Universe.

Radial Velocity of a Star: Radial velocity (proper motion) is the component of the motion of a **star** away from or toward the Earth along its line of sight, expressed in miles or kilometers per second and determined by the shift in the wavelength of light emitted by the **star.**

Radio Frequency: This is the frequency at which the atomic population is coherently transferred from one state to another by a resonant radiation field; it is named after its discoverer I. Rabi. It plays central role in atom-field interactions. These are oscillations of free mobile electrons and holes.

Radio astronomy: The astronomy associated with radio observations of celestial objects. The wavelength extends fro low radio frequencies (10 MHz, λ = 30 m) to centimeter and millimeter wavelength. At the low frequency of the range, the limit is imposed by the Earth's ionosphere and at the upper end by water vapor absorption in the atmosphere. Within this waveband, many sophisticated radio telescope systems have been constructed.

Radiation source: Light and all radiation sources are reverberation of electrostatic charge fields among protons and electrons which exists within the inner space of atoms. The reverberation of the field is created by vibrations of electrons.

Real particle: It is characterized by a definite rest mass M_o, occupies a definite volume of non-zero value, possesses an unique center of gravity, and exerts a force of gravity on another particle with rest mass M.

Real Universe: It is defined as the state of all objects within physical Universe that is tangible and occupy real space-time coordinates. Trajectory of all objects in real Universe follow Einstein's geodesics which are solutions to Einstein's field equation.
Red Giant: A large, cool star of high luminosity.

Red shift: The light from distant stars and more distant galaxies has distinct spectral feature, a characteristic of atoms of gaseous matter around the stars. When these spectra are examined, they are found to be shifted towards the red end of the spectrum. A redshift of light occurs whenever stars move away from the observer else blueshift is observed.

Relativistic geometry: A geometry in spacetime is called Relativistic if the spacetime interval for the geometry is described by a single distance metric, spacetime ds, where $ds^2 = c^2dt^2-dx^2-dy^2-dz^2$.

Receding systems: Two inertial systems are defined as receding systems if displacement between the two systems is increasing with time at a constant rate.

Residual interaction: Interaction between objects that do not carry a charge but do contain constituents that have charge. Except for those chemical substances involving electrically charged ions, much of chemistry is due to residual electromagnetic interactions between electrically neutral atoms. The residual strong interaction between protons and neutrons, due to the strong charges of their quark constituents, is responsible for the binding of the nucleus.

Resonance frequency f_r in QTS: It is the tuned frequency of microwave f_p at which the detector current I_D exhibits a peak, a resonance feature centered around f_r. Fine tuning of the oscillator and the clock is achieved by a phase sensitive detection of I_D and the subsequent integration to voltage U_R. The voltage tunes LO that is a voltage-controlled, temperature-stabilized quartz oscillator.

Retrograde motion: The apparent westward motion of planet with respect to background stars.

Retrograde orbit: An orbit of a satellite or planet around a planet or a star that is in the direction opposite to which the planet or the star rotates.

Retrograde rotation: A situation in which an object (such as a planet) rotates in a direction opposite to which it orbits around another object(such as the Sun).

Rest mass: See eternal mass.

Riemannian geometry: Mathematical framework for describing curved shape of any dimension. The geometry plays a central role in Einstein's theory of general relativity.

Right ascension: Right ascension (abbreviated RA; symbol α) is the angular distance (the arc) of the celestial equator measured eastward from the vernal equinox to the foot of the great circle passing through the celestial poles and a given point on the celestial sphere, expressed in time hr:min:sec.

Rydberg Constant: In 1885 physicists J. Balmer and J. Rydberg experimentally determined wave lengths for hydrogen atoms by applying an equation that closely matched an expression for frequency from Bohr's theoretical model for hydrogen atom. The empirical relationship between wavelengths and electron transition quantum numbers had a fitting parameter symbol R_∞ or R_H that is universally known as Rydberg constant whose value is $1.097373\times10^7 m^{-1}$

Scanning Tunneling Microscopy (STM): A high resolution microscope operating without using light or an electron beam instead the traversing of an ultra-sharpened metallic tip over a surface is monitored that reveals the sample's atomic and molecular detail. A contactless current flow is measured in a circuit between the scanning tip and the atoms of the sample surface. The current is found to be proportional to the density of electrons in the region.

Schrödinger equation: Equation governing the evolution of probability waves in quantum mechanics. In a more general context it describes the time evolution of the state of a quantum system. It is an equation that describes the propagation of the waves associated with subatomic particles.

Schwarzschild radius: It is a radius of a sphere of value such that when all the mass of an object is compressed within that sphere the escape speed from the surface of the sphere would be equal to the speed of light c.

Schwarzschild solution: Solution to equation of general relativity for a spherical distribution of matter: one implication of this solution is the possible existence of black holes.

Scintillation: A charged particle traversing matter leaves behind it a wake of excited molecules. Certain types of molecules will release a small fraction of this energy as light. This light can be detected by a phototube in a detector.

Second law of thermodynamics: Law stating that total entropy always increases.

Sidereal year: The orbital period of the Earth around the Sun with respect to the stars.

Sidereal period: The orbital period of the one object about another as measured with respect to the stars.

Singularity: Region of spacetime where physical variables become infinite, such as energy density, tidal forces, pressure, and world line of observer terminates and in which no life could exist in theory.

Skylativity® Theory: Revised theory of everything proposed by this author which describes characteristics and properties of all types of radiations and reveals facts about their origin. Also, it discloses the reasons for the forces of gravity and for the forces of dark matter. The theory combines the principles of QCD with classical QED with remarkable consistency. It facilitates unification of all forces of nature (strong color charge, strong EM, weak residual, and weak forces of gravity) at grand scale distance of Billions of light years in the outer-space of universe and at nanoscale distance of fractions of femtometer in inner-space of atoms.

SLAC: The Stanford Linear Accelerator Center in Stanford, California

Solar constant: The average amount of energy received from the Sun per square meter per second, measured just above the Earth's atmosphere.

Solar corona: Hot, faintly glowing gases seen around the Sun during a total solar eclipse; the uppermost regions of the solar atmosphere.

Solar eclipse: An eclipse of the Sun by the Moon, a passage of the Earth through the Moon's shadow.

Solar neutrino problem (SNP): It was discovered that the measured solar neutrino flux arriving from the Sun on the Earth was one third and one half the number predicted by Standard Solar Model. The discrepancy between the estimated neutrino flux and the observed flux was called Solar Neutrino Problem.

Space: A space is a physical entity that exist which is capable of storing and transporting other physical entities such as matter, energy and information without resistance.

Spacelike displacement: A displacement in relativistic spacetime interval is Spacelike if the spacetime interval of relativistic geometry has a negative value. In spacelike displacement events information exchange in real time is impossible.

Spacetime: A four-dimensional combination of time and the three dimensions of space.

Spin: Intrinsic angular momentum of a particle, given in units of h', the quantum unit of angular momentum, where $\hbar == h/2\pi == 6.58\times10^{-34}$ J s. Spin is a characteristic property for each type of particle.

Spontaneous emission: It is a electron orbit transition event in which an electron in orbit makes a transition to a lower energy state, emitting quanta of radiation.

Spontaneous symmetry breaking: It is a mode of realization of symmetry breaking in a physical system, where the underlying laws are invariant under a symmetry transformation the system as a whole changes under such transformation, in contrast to explicit symmetry breaking.

Spring tide: An ocean tide that occurs at new moon and full moon phases.

Stable: Does not decay. A particle is stable if no processes exist in which the particle disappears and in its place two or more different particles appear.

Standard Model: The electromagnetic and weak forces are now considered to be manifestations of a single force, the electromagnetic charge force. The combination quantum chromodynamics and quantum electrodynamics, the electroweak theory is called the Standard Model.

Stefan's Boltzmann law: A relationship between the temperature of a blackbody and the rate at which it radiates the energy.

STR: Einstein's special theory of relativity.

Stellar parallax: The apparent back and forth motion of stars in relation to background of further remote stars caused by Earth's orbital rotation surrounding the Sun is known as Stellar Parallax. The stellar parallax is measured as angular displacement, angle in units of arcsec.

Stimulated absorption: It is a electron orbit transition event in which an incoming quantum of light is absorbed raising the electron to a higher energy state.

Stimulated emission: It is an electron orbit transition event in which an incident quantum of radiation causes an excited atom to make a downward energy transition emitting a quantum that is identical to incident quantum.

Strange quark (s): The third flavor of quark (in order of increasing mass), carrying electric charge -1/3.

String coupling constant: A (positive) number that governs how likely it is for a given string to split apart into two strings or for two strings to join together into one—the basic processes in string theory. Each string theory has its own string coupling constant, the value of which should be determined by an equation; currently such equations are not understood well enough to yield any useful information. Coupling constant less than 1 imply that perturbative methods are valid.

String theory: Unified theory of the Universe postulating that fundamental ingredients of nature are not zero-dimensional point particles but tiny one-dimensional filaments called strings. String theory harmoniously unites quantum mechanics and general relativity, the previously known laws of the small and the large, which are otherwise incompatible. It is often used a short form for superstring theory.

Strong interaction: The interaction responsible for binding quarks, antiquarks, and gluons to make hadrons. Residual strong interactions provides the nuclear binding force.

Subatomic particle: Any particle that is small compared to the size of the atom.

Summer Solstice: It is the time at which the Sun is at its northern most point in the sky (southernmost point in the S hemisphere), appearing at noon at its highest altitude above the horizon. It occurs about June 21 in Northern hemisphere, the longest day.

Superluminous speed: Motion that appears to involve speeds greater than the speed of light.

Superconductivity: A phenomenon occurring in some metals at very low temperatures, in which the electrical resistance drops to zero and the metal shows many other anomalous properties.

Supernova: An old star that has burnt most of its hydrogen collapses due to gravitational attraction, but then explodes from the onset of nuclear burning of more massive elements.

Synodic month: The period of revolution of the Moon with respect to the Sun; the length of one cycle of lunar phases.

Synodic period: The interval between successive occurrences of the same configuration of a planet.

Synchrotron: A type of circular accelerator in which the particles travel in synchronized bunches at fixed radius.

Symmetry: Any situation in which certain properties of particles or forces are equivalent.

Tachyon: Particle whose mass (squared) is negative; its presence in a theory generally yields inconsistencies. For instance tachyons are believed to have the speed above the speed of light.

Tangential Velocity of a Star: It is the component of the linear motion of a **star** with respect to the Sun, measured along a line perpendicular to its line of sight and expressed in miles or kilometers/sec.

Tau [TAOW] lepton: The third flavor of charged lepton (in order of increasing mass), with electric charge -1.

Terrestrial Planets: A **terrestrial planet** (telluric or Earth like **planet)** or rocky **planet** is a **planet** that is composed primarily of silicate rocks or metals. Within the Solar System, the **terrestrial planets** are the inner **planets** closest to the Sun, i.e. Mercury, Venus, Earth, and Mars.

Tevatron Collider: An accelerator at Fermilab that collides protons and antiprotons with center-of-mass energy of 2 TeV (2000 GeV).

Theorem: Particle wave separation: Theorem citing difference between real particles with rest mass and center of gravity vs. virtual particles with zero rest mass and without center of gravity.

Theory of Everything: A quantum mechanical theory (Unified field theory) that encompasses all forces and all matter within a single all encompassing framework.

Thermonuclear fusion: The combining of nuclei under conditions of high temperature in a process that releases substantial energy.

Tidal forces: A gravitational force whose strength and direction varies over a body and thus tends to deform the body. The force that arises due to gravitational field on a pair of massive objects which are inhomogeneous. The tidal force name is derived from the tides generated in the seas of the Earth as a result of the gravitational pull of the Moon and the Sun.

Time dilation: It is related to time measured by clocks of the same length within different inertial frames. Measured time by a clock in the first inertial frame appears to be faster than that measured in the second inertial frame by an identical clock and vice versa. This effect is known as Time dilation.

Timelike displacement: A displacement in relativistic spacetime internal is Timelike if the spacetime interval of relativistic geometry has a positive value. Communication in real time is feasible for events displaced by timelike intervals.

Top quark: The sixth flavor of quark (in order of increasing mass), with electric charge 2/3. Its mass is much greater than any other quark or lepton.

Total solar eclipse: A solar eclipse during which the Sun is completely hidden by the Moon.

Track: The record of the path of a particle traversing a detector.

Tracking: The reconstruction of a “track” left in a detector by the passage of a particle through the detector.

Transverse wave: When the vibration plane of an energy carrier wave is normal to the direction of propagation of the wave, it is called a transverse wave.

True speed of light (TSL) c: It is defined as the distance travelled by light in one second time measured by a standard clock from a point source located in ASF where the distance between the point source and the observer remain constant with respect to time.

Tuning fork diagram: A diagram that summarizes Edwin Hubble's classification scheme for spiral, barrel spiral, and elliptical galaxies.

UBV Photometry: UBV photometric system, also called the Johnson-Morgan system, is a wide band **photometric** system for classifying stars according to their colors. It is the first known standardized photoelectric system in which the photometric measurement of the color index of a star, is taken by using ultraviolet, blue, and visual yellow) filters.

Uncertainty Principle: The quantum principle, first formulated by Heisenberg, that states that it is not possible to know exactly both the position x and its momentum p of an object at the same time, $\Delta x \Delta p \geq \frac{1}{2} \hbar$. It can be written as $\Delta E\ \Delta t \geq \frac{1}{2} \hbar$ where ΔE means the uncertainty in energy and Δt means the uncertainty in life time of a state (see virtual particle).

Such uncertain aspects of the microscopic world become even more severe as the distance and time scales on which they are considered become ever smaller. Particles and fields undulate and jump between all possible values consistent with the quantum uncertainty.

Uniform Circular Motion (UCM): Motion of an object travelling at constant speed tracing a circular path is classified as UCM. A centripetal force is required to retain the object in circular orbit.

Unit time: It is defined as the duration of 9,192,631,770 cycles of microwave light absorbed by the hyperfine transition of Cesium-133 atoms in their ground state undisturbed by external fields.

Up quark: The least massive flavor of quark with electric charge 2/3.

Vernal Equinox: One of two points at which the ecliptic intersects the celestial equator and it is the time occurring about March 21 when the Sun crosses the plane of the Earth's equator, making night and day of approximately equal length all over the Earth.

Vertex detector: A detector placed very closed to the collision point in a colliding-beam experiment so that tracks coming from the decay of a short-lived particle produced in the collision can be accurately reconstructed and seen to emerge from a "vertex" point that is different from the collision point.

Virtual pair: A particle and antiparticle that exist for such a brief interval that they cannot be observed.

Virtual particle: It is an entity which possesses energy, lacks rest mass, occupies indefinite volume in space, and does not project the force of gravity, but may or may not project other types of force such as the magnetic force. We stipulate that light energy is composed of virtual particles, quanta of radiation.

VLBI: Very-long-baseline interferometry (VLBI) is a type of astronomical interferometry that is used in radio astronomy in which a signal from astronomical radio source is collected from several sparsely located telescopes on Earth and information of the signal is combined to form image of the source. In this arrangement effective signal gathering area and power is amplified by antenna disks of several telescopes.

VSL: Varying the speed of light theory proposed by Portuguese physicist and Cambridge University Professor, João Magueijo, in 1995

$W^{+/-}$ boson: A carrier particle of the weak interactions. It is involved in all electric-charge-changing weak processes.

Wave Entity: Wave entities such as the radiation waves are characterized by their self mobility and possess zero rest mass. Contradictory to waves, particle entities have non-zero value of rest mass and a unique center of gravity.

Wavefunction ψ(x): The mathematical object in quantum theory which determines probabilities of different results of experiments. It is a complex quantity, so it has an amplitude (whose square gives the probability) and a phase-angle. The phase angle has no direct physical interpretation, but is important in interference effects, where two wave-functions are added together.

Wavelength (λ): Wavelength defined as the minimum distance between two successive crests or troughs of a sinusoidal energy signal in space or time domain.

Weak interaction: The interaction responsible for all processes in which flavor changes, hence for the instability of heavy quarks and leptons, and particles that contain them. Weak interactions that do not change flavor (or charge) have also been observed.

White dwarf: A low-mass star that has exhausted all its nuclear fuel and contracted to a size roughly equal to the size of the Earth. Mass < 1.4 M_{Θ} Radius 1000 km, supported against gravity by quantum-mechanical degeneracy pressure of electrons.

Winter Solstice: It is the time at which the Sun is at its southernmost point in the sky (northernmost point in the S hemisphere) appearing at noon at its lowest altitude above the horizon. It occurs about December 22 (June 21 in the S hemisphere), the shortest day.

Wien's displacement law: A relationship between the temperature of a blackbody and the wavelength at which it emits the greatest intensity of radiation.

Workfunction: it is defined as the minimum quantity of energy required to remove an electron (completely) to infinity from a metal surface.

Worldline: In space-time, the history of a particle is represented by a worldline. The position of the particle in space at any particular time t is found by slicing space-time t and seeing where the slice cuts the worldline. Alternately, the trajectory of a free particle in 4-dimensional spacetime is called the worldline.

Wormhole: A tube-like region of space connecting one region of the Universe to another. In view of the fact that our Universe has no boundaries (infinite) existence of wormhole does make sense. It is a fictional entity.

Zeeman effect: A splitting or broadening of spectral lines due to a magnetic field.

Z^0 boson: A carrier particle of weak interactions. It is involved in all weak processes that do not change flavor.

Zenith: The highest point on celestial sphere that is vertically above an observer at given location on the Earth and is directly opposite to nadir at that point.

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Conversions

Length

1 μm = 10^{-6} m = 10^{3} nm = 10^{4}A°
1 in = 2.54 cm = 1000 mil
1ft = 0.3048 m = 12 in
1m = 39.37 in = 3.281 ft
1 yd = 0.9144 m = 3 ft
1 km = 0.621 mi = 3278.9 ft
1 mi = 1.609 km = 5280 ft = 1760 yd= 8 fur.
1 AU = 149.6 Mkm = 92.96 Mmi
1 ly = 9.461×10^{12} km = 5.8785×10^{12} mi
1 ly = 63421.077 AU = 0.3066 pc
1 pc = 3.2616 ly = 19.174×10^{12} mi
1 pc = 206.7527 kAU = 30.851×10^{12} km

Area

1 m^2 = 10^4 cm^2 =10.76 ft^2
1 ft^2 = 0.0929 m^2 = 144 in^2
1 in^2 = 6.452 cm^2 and 1 mi^2 = 2.59 km^2
1 yd^2 = 0.8361 m^2 = 9 ft^2

Volume

1m^3 = 10^6 cm^3 = 6.102×10^4 in^3 = 1.3079 yd^3
1 ft^3 = 7.481 gal= 28.32 lit=2.832×10^{-2} m^3
1 gal = 3.786 lit = 231 in^3
1 lit = 10^3 cm^3 = 1.0576 qt = 0.0353 ft^3
1 yd^3 = 0.7646 m^3 and 1 mi^3 = 4.1682 km

Velocity

1 mi/h = 1.47ft/s = 0.447m/s = 1.61km/h
1 m/s = 100 cm/s = 3.281 ft/s
1 mi/min= 60 mph = 88 fps

Acceleration

1 m/s^2 = 3.28 ft/s^2 = 100 cm/s^2
1 ft/s^2 = 0.3048 m/s^2 = 30.48 cm/s^2
1 km/s^2 = 0.621 mi/s^2

Mass

1 carat = 0.2 gram
1 gram = 15.432 grain
1 lb = 16 ounces (oz.) = 0.4536 kg
1 kg = 2.2046 lb
1000kg = 1 t (metric ton)
2000 lb = 1 t (British ton)
1slug = 14.59 kg
1amu = 1.66×10^{-27} kg = 931.5 MeV/c^2

Time

1 s = 9,192,631,770 transitions of Cs 133
1 Yr= 365 days = 31557600 s = 8760 hr
1 day= 24 hr = 1.44×10^3 min =8.64×10^4 s
1 fortnight = 2 weeks = 14 days
1 millennium = 1000 Yr = 50 score Yr
1 eon = 1 Byr = 1 M millennia
Mag. Flux 1 gauss = 10-4 T (Tesla)
Charge 1 esu = $0.1(c/ms^{-1})^{-1}$ C

Force

1 dyne = 10^{-5} N
1 poundal = 0.138255 N
1 kgf = 9.8067 N
1N = 0.2248 lb
1lb (g) = 4.448 N
1 ton-f = 2204.62 lbf
1 Planck = 1.21027×10^{44} N

Pressure

1bar = 14.50 lb/in^2 = 10^5 Pa = 750.06 Torr
1 lb/in^2(psi)= 6894.8 Pa = 68.948 mbar
1atm = 14.7 lb/in2 = 1.013×10^5 N/m^2
1atm = 760 mm Hg = 14.696 lb/in^2 = 760 Torr
1 Torr = 1mmHg = 133.32 Pa
1 Pa = 1 N/m^2 = 1.45×10^{-4} psi
1 Pa = 10 μbar = 10 dynes/cm^2

Energy

1J (1 W.s)= 0.738 ft. lb , 1eV = 1.6022×10^{-19} J
1cal = 4.186 J, 1 GeV/c^2 = 1.783×10^{-27} kg
1 Btu = 252 cal = 1.054×10^3 J, 1 kwh = 3.6 MJ
1 erg = 10^{-7} J = 1 dyne cm = 624.15 GeV

Power

1 hp = 550 ft.lb/s = 0.746 kW
1 W = 1 J/s = 0.738 ft.lb/s
1 Btu/h = 0.293 W, dBW= 10 $\log_{10}$ P/1W
1 kw = 1000 J/s

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Reviewed By Francis Ben, PhD (The University of Adelaide, Australia) 01/09/2014

"Shailesh's book tackles the difficulty of understanding light as an entity in physical science. It presents arguments (both in words and mathematical forms) that highlight the limitations of Albert Einstein's theory of relativity. It attempts to address the misconceptions a lot of people have about the attributes of light. The book is a move forward from the physics that 'everyday' people have come to encounter during their schooling days (assuming that they chose to study physics at upper secondary levels).The contents of the book are almost too controversial, but in a good way as challenging existing theories and postulates is a way forward in the field of science. New ideas such as the notion of 'skylativity' and the integration of gravity at quantum scales are presented, and have been substantiated by a good number of backing information including mathematical expressions and equations. If the new ideas presented in this book become widely accepted in the physics community, its impact on educating our youth with physics will be dramatic – it will virtually change every single physics/physical science textbook used in schools.

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