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Classical physics

Notes

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conservation of energy principle: - during an interaction, energy can change from one form to another but the total amount of energy remains constant. energy cannot be created or destroyed.

First law of thermodynamics

(energy in – energy out=ΔE) this law represents the first fundamental idea of thermodynamics that since energy cannot be created or destroyed we can always calculate input +or output or Δ by the first law in all modules relative and quantum.

Second law of thermodynamics

When energy is transferred from a quality to another at least 2 different products emerge this is called wasted energy. This wasted quality is always a degraded form compared to original so we can say that "energy has quality as well as quantity, and actual processes occur in the direction of decreasing quality of energy"

Weight is considered a force since newton's second law W = mg

Where on earth the gravity is equal 9.8m/s.

Joule is equal to one newton meter. Which is basically force times distance. When one joule is measuring rate of energy we can call it watt or (J/s). this typically used in electricity.

$\rho = \frac{m}{v}$ is known to be the equation for density but it is important to note that the reciprocal of density is the specific volume v so we can say that volume per unit of mass is $v = \frac{v}{m} = \frac{1}{p}$ **v** here is a **specific volume** in which it is described as *volume per unit of mass*. There are many factors affecting the density of gases like temperature and pressure.

Note: - although temperature and pressure affect density they can be neglected because in most analysis that change does not exceed 15%.

Since there is a lot of factors to produce an equation that is easy to understand. Physicists now use **relative density** which is defined as the ratio of the density of a substance to the density of some standard substance at a specified temperature (usually water at

4°C, for which ρH_2O =1000kg/m^3) so we can compare all densities of substance at 4°C at specific gravity using this equation to give us a percentage. $\frac{\rho}{\rho H_2O}$. This also is called **specific gravity** sometimes.

TABLE 1–3

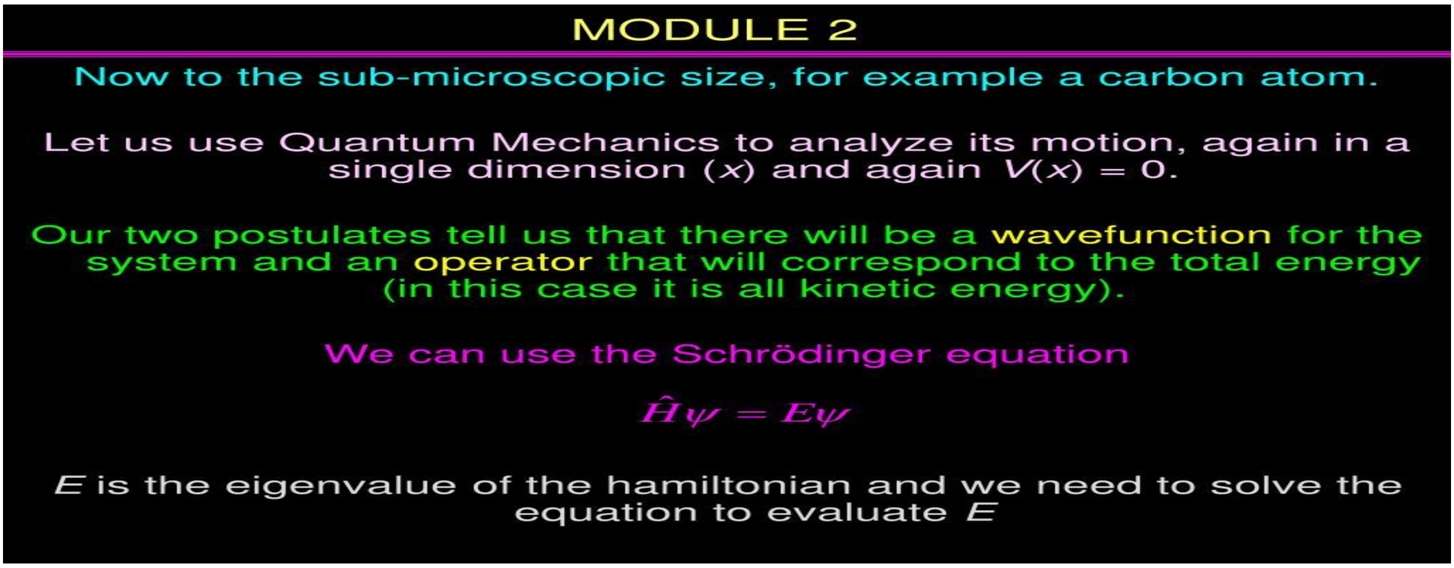
Specific gravities of some substances at 0°C

Substance	SG
Water	1.0
Blood	1.05
Seawater	1.025
Gasoline	0.7
Ethyl alcohol	0.79
Mercury	13.6
Wood	0.3–0.9
Gold	19.2
Bones	1.7–2.0
Ice	0.92
Air (at 1 atm)	0.0013

this table for instance compares substances to the density of water at 0 Celsius.

Kinetic energy is the energy that an object has because of its motion **not velocity alone**. (The energy that a system possesses as a result of its motion relative to some reference frame is called kinetic energy (KE).) if all parts of a system move with the same motion we can say that $KE = m\frac{v^2}{2}$. or on a unit mass basis we can say that $KE = \frac{v^2}{2}$.

In quantum mechanics the equation changes due to probability being introduced and potential energy being neglected. Note: -this will be explained in detail in the quantum notes.



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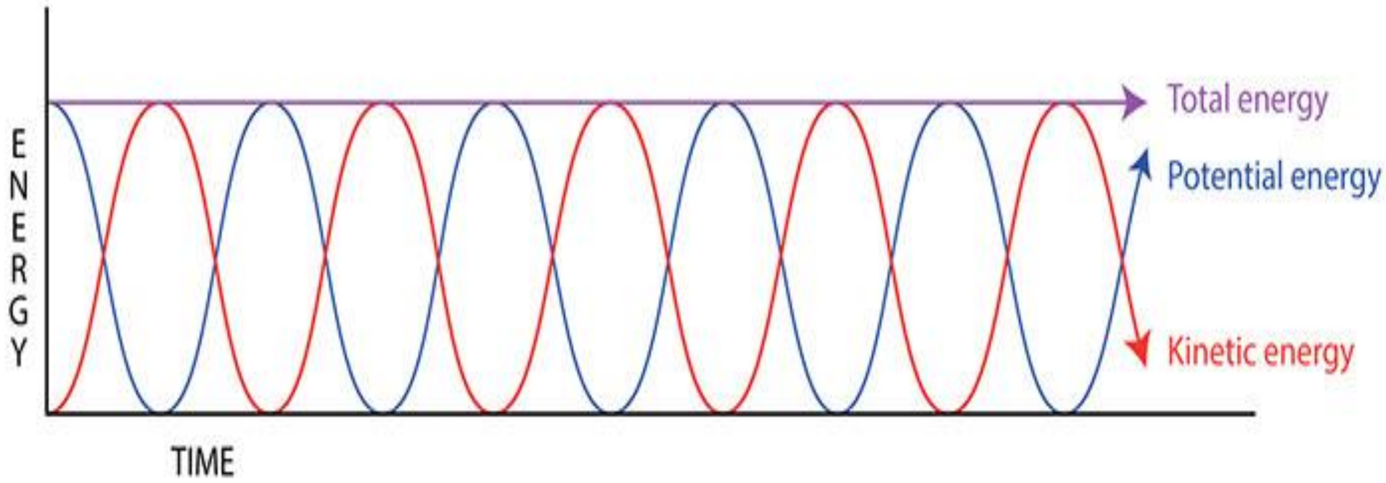
If we plot a KE line against a PE line on a graph we would clearly notice that when KE is at maximum PE is at a minimum meaning that energy oscillates in a system between PE and KE.



notice how this graph indicates that the energy put into a system stays the same according to the first law of thermodynamics.

Speed

Speed should really have its own book but here we only will cover “classical” speed. **Velocity** is speed with direction. A common misconception about velocity is that its equation $\frac{d}{t} = v$ this is wrong as it should be *displacement of distance/time*.

There are many forums of speed

: - Uniform speed.

: - Variable speed.

: - Average speed.

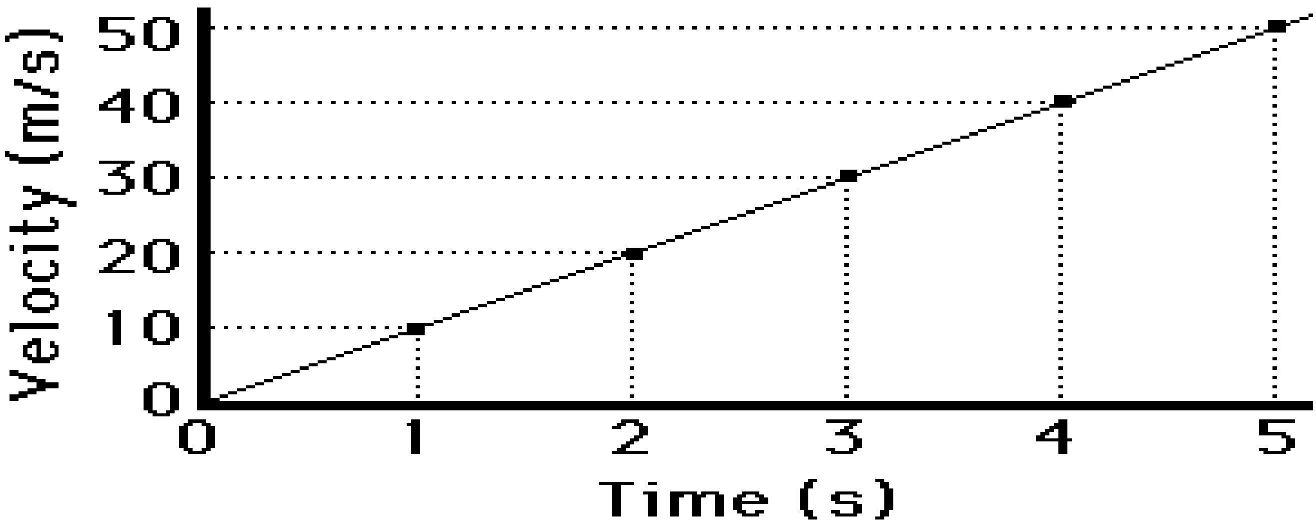
: - Instantaneous speed.

: -relative speed.

Uniform speed

Uniform speed is when speed is constant with 0 acceleration or declaration this means that to know if an object is in motion we have to compare it to a stationary object. This works if an object moves in straight line only is centripetal forces in a circle mean that to remain in constant speed you have to accelerate. This doesn't negate the fact that objects can't accelerate and decelerate uniformly as acceleration is a unit of its own like velocity is.

Uniform speed graph looks like this=



Notice how 1x=10y consistently thought graph.

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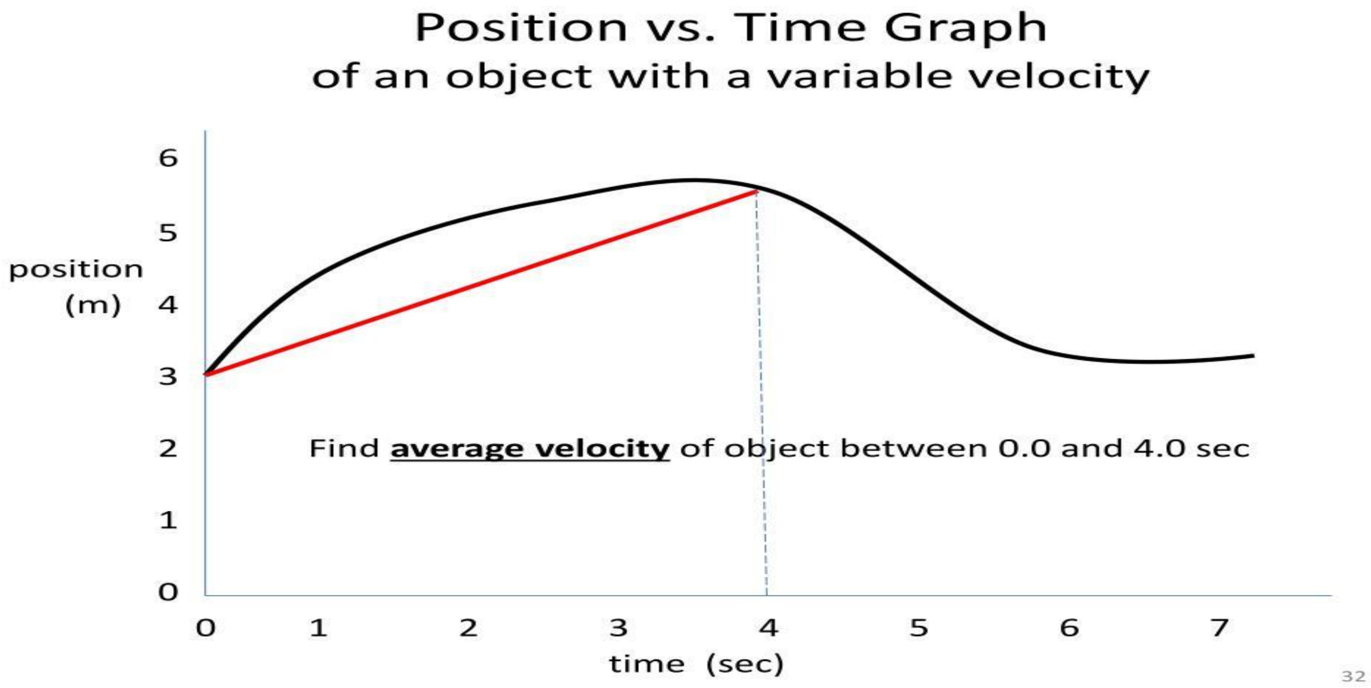
Variable speed

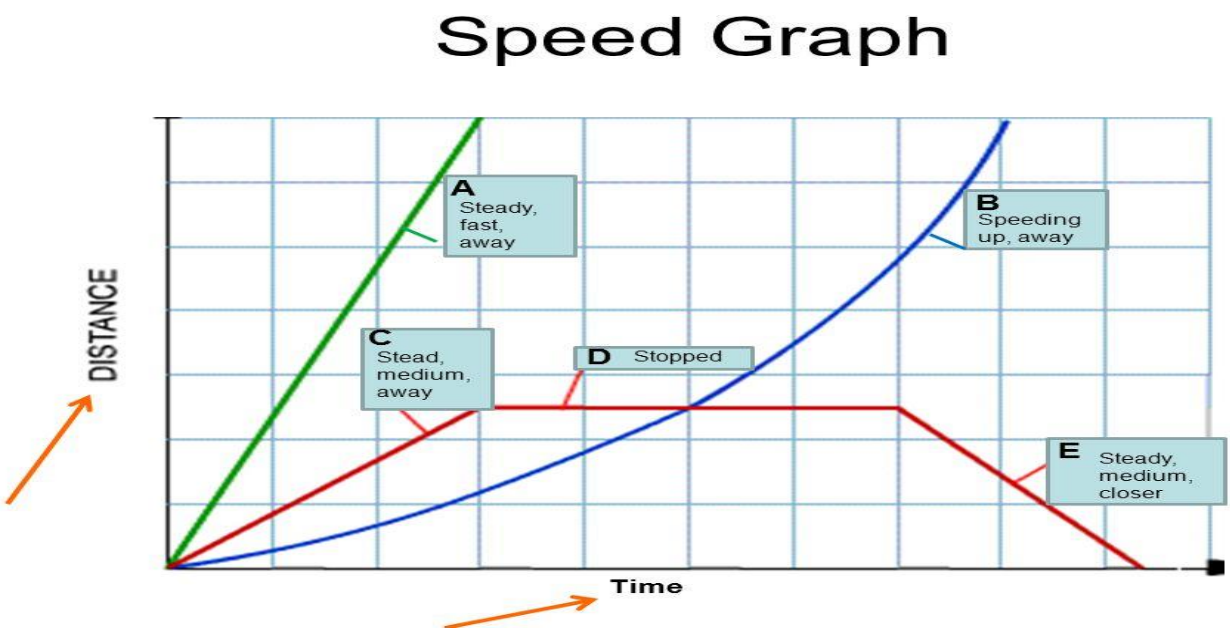
In uniform speed a body covers the same displacement of distance in the same time, constantly giving it a constant speed throughout its path. But in variable speed a body covers unequal displacements of distance in equal intervals of time.so in the first 5 seconds a body might cover 60m the next five a body cover 8 then the body cover 6 and so on like on this graph=



Notice how distance is different between every time interval.

Averege speed

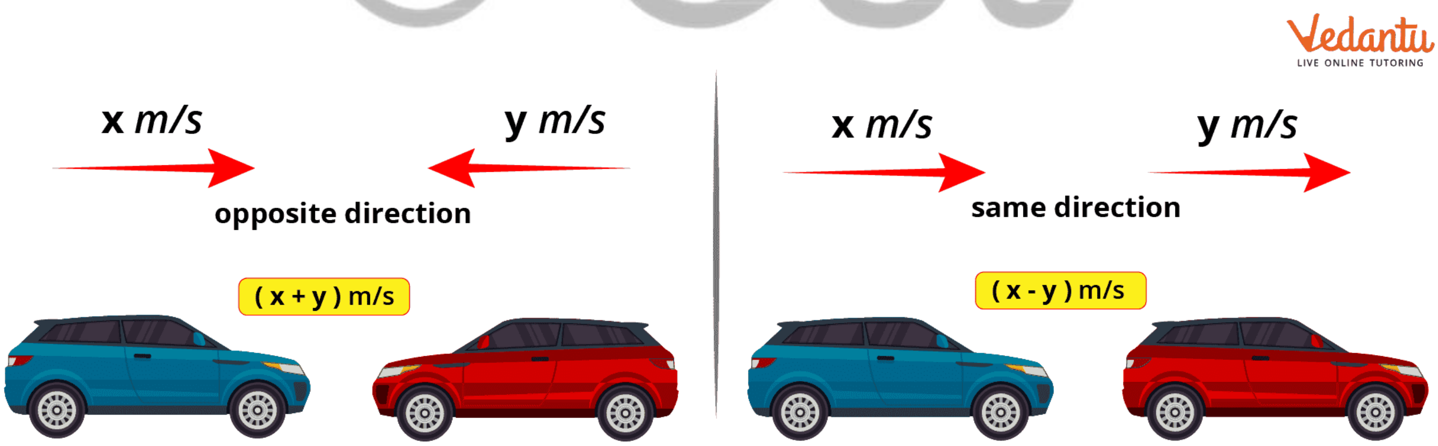
Averege speed is when calculating the averege speed of body in motion in large displacment of distance.what makes averege speed special is that we conclude the motion of a body using such graphs.for instance the formula for testing v is distance/time=speed but this equation only meausures speed at one interval of time while averege speed calculate speed over a wide range of time.



Instantaneous speed is basically very rapid sudden displasment of distance in a small time inerval.

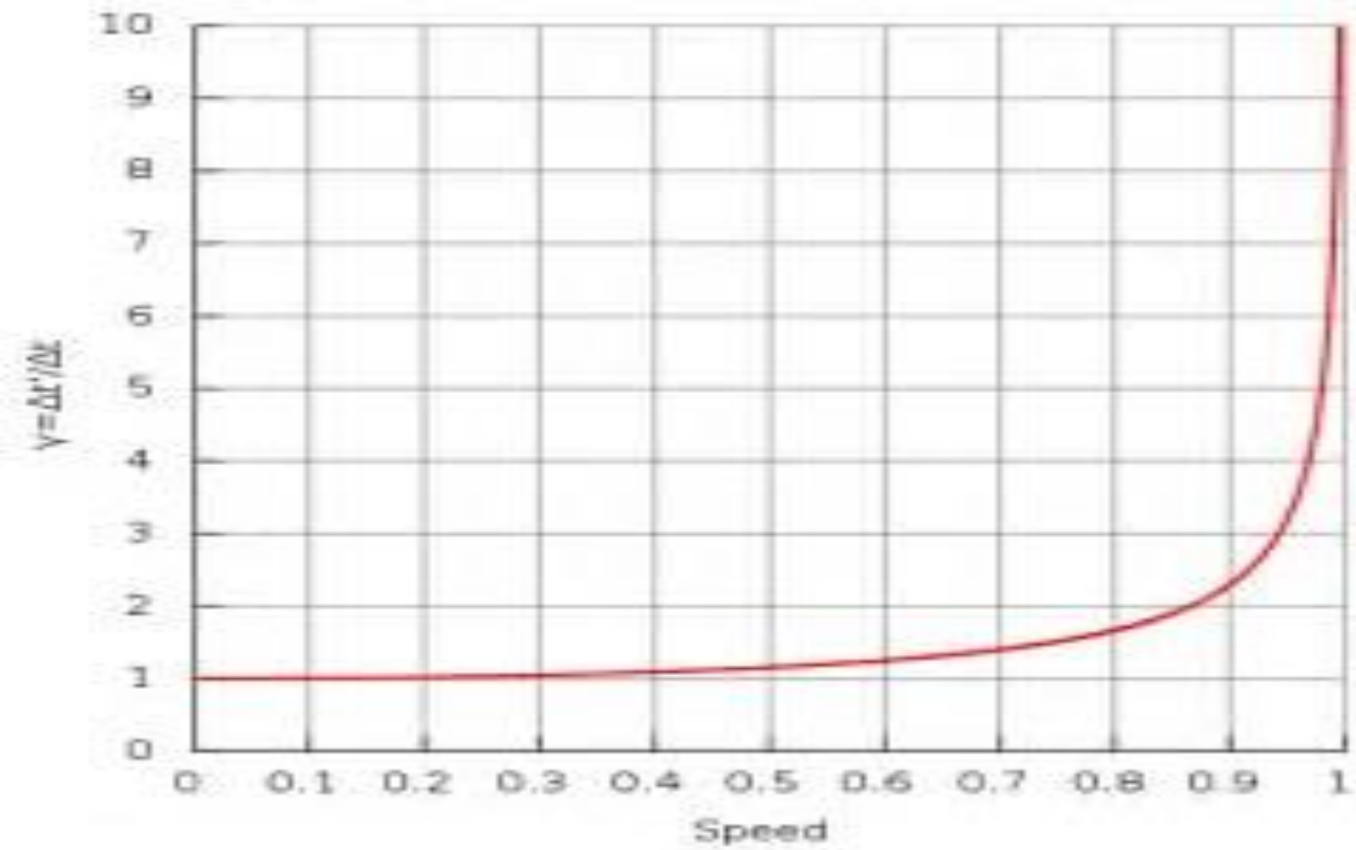
relative speed

is the velocity at which a body (with mass) is observed and calculated at a speed not stationary like previous examples where speed of observer was 0/ms.\



The previous graph explains simply the equations yet relative speed is far more complex as pyhsical phenomena's occur that don't follow this rule like;lorentz factor(lorentz factor is a ratio of meusrment correlating the speed of light to time),how *speed of light is always 299,792,458m/s* even when measured at relative speed,how time dilates $t = \frac{t^0}{\sqrt{1-\frac{v^2}{c^2}}}$.Since these notes are about thermodynamics relativity will not be covered yet it is important to know that the closer objects move relative to 299,792,458m/s the pyhsics change due to lorentz factor.

.like this graph suggests.



Newton’s laws

Newton is considered to be one of the most influential physicists and mathematicians to have changed the course of human history. His work in astronomy laid the foundation for our understanding of light, forces and geometry. It is important to know that measuring motion in three dimension is difficult due to the disturbances of gravity and friction etc.

Newton’s first law of motion: - “A uniformly moving body continues to move uniformly unless acted on by a force” Isolated bodies move uniformly in inertial systems by virtue of the definition of an inertial system. In contrast, the assertion that inertial systems exist is a statement about the physical world. Newton’s first law raises a number of questions such as what we really mean by an “isolated body,” but we defer these for the present.

What are *inertial* systems? In a coordinate system moving uniformly with respect to the track, the undisturbed rider again moves with constant speed, though a speed different from the one fixed to the track. Such coordinate systems are called inertial systems.it is important to note that uniform speed of an isolated body can exist in all coordinate systems.

Newton's second law of motion: - acceleration of a body doesn't only depend on the forces acting upon it but also on some property of the object this property is mass. To formulate an equation in this sense we can assume that.

m_1=is the mass of the first body

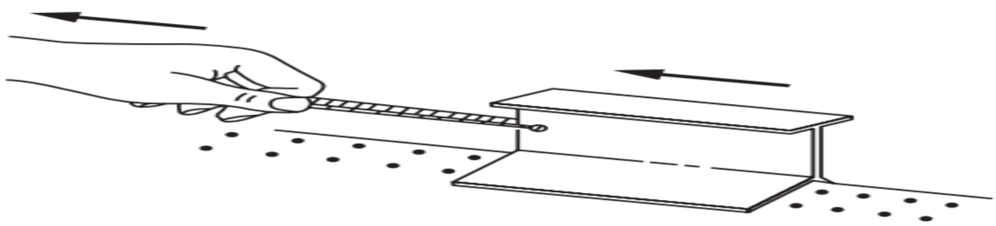
a_1=is the acceleration of the first body

a_2=is the acceleration of the second body

We can calculate m_2 by using this equation

$$m_2 \equiv m_1 \frac{a_1}{a_2}$$

This equation makes since when we introduce the rubber band experiment. We place a rider on a beam with tiny holes to shoot compressed air this ton eliminate friction and gravity. If we apply a force to the rider it will move with constant uniform speed. Now if we apply the same force to a body with more mass the acceleration would change.



Suppose that we pull the rider with a rubber band. When we start to stretch the rubber band, the rider starts to move. If we move our hand ahead of the rider so that the rubber band's stretch is constant, we find that the rider moves in a wonderfully simple way; its speed increases uniformly with time. The rider moves with constant acceleration. Now suppose that we repeat the experiment but with a different rider, perhaps one a good deal bigger than the first. If the same rubber band is stretched to the same length as before, it causes a constant acceleration, but the acceleration differs from the previous case. Here we define mass as inherit property of a body but in fact mass is $\frac{E}{c^2}$ where this equation measures the mass of the fundamental particles which are quarks and electrons this is explained thoroughly in the special relativity notes.

Forces: - we describe forces in the previous example as the operation of acting on something with regards to the rubber band which applied a force on the rider for example. We can establish a force scale by defining the unit force as the force that produces unit acceleration when applied to the unit mass.so a force is really a unit as a result of mass and acceleration so we can say that $f = ma$.force is far more complex than mass and acceleration and we can say that force describes the rubber band moving the rider and we can also say that force describes the attraction between two masses with gravity hence this equation $f = \frac{G_1 G_2}{d_2}$ forces always arise from real physical interactions between systems acceleration is merely a consequence of these interactions. we eliminate all interactions by isolating a body sufficiently from its surroundings—an inertial system—we expect it to move uniformly.

Newton's third law: - That force is necessarily the result of an interaction is made explicit by Newton's third law. The third law states that forces always appear in pairs that are equal in magnitude and opposite in direction if body b exerts force F_a on body a, then there must be a force $F_b$acting b, on due to body a, such that $F_{b=}-F_a$.there is never a lone force without a partner. If we notice newton's third law leads to the conservation of momentum law. We can also dive deeper into particle physics as when particles moving at high speeds where effects predicted by Einstein's special theory of relativity turns out that instead of the mass we defined, now called *rest mass* m_0 a more useful quantity is

$$m = m_0 / \sqrt{1 - \frac{v^2}{c^2}}$$

where

c=speed of light

v=speed of a particle

The reason our table top experiments did not us to a general expression for mass that even the largest everyday velocities and $m\ and\ \ m_0$ only differ by a few parts in 10^{10}

The following subjects require unit understanding so this table may help.

	SI	CGS	English
Length	1 meter (m)	1 centimeter (cm)	1 inch (in)
Mass	1 kilogram (kg)	1 gram (g)	1 slug
Time	1 second (s)	1 second (s)	1 second (s)
Acceleration	1 m/s^2	1 cm/s^2	1 ft/s^2
Force	1 newton (N) = 1 kg·m/s^2	1 dyne = 1 g·cm/s^2	1 pound (lb) = 1 slug·ft/s^2

Practical physics

So far we have viewed nature as if it were composed of ideal particles rather than real bodies. Sometimes such a simplification is justified—for instance in the study of planetary motion, where the size of the planets is of little consequence compared with the vast distances of our solar system, or in the case of elementary particles moving through an accelerator, where the size of the particles, about 10^{-15} m, is minute compared with the size of the machine. We must generalize newton's laws since they are not practical in use for instance $f = ma$ cannot work in rockets as they have a flow of mass where rocket fuel is ejected backwards while the tip accelerates forward. In this instance the equation doesn't work a more general form for the equation is

$$\mathbf{F} = \frac{d}{dt}(\mathbf{Mv})$$

Where *M represents constant mass of a particle*

$\mathbf{Mv}$ = momentum

This subject will be neglected since it requires a great knowledge in partial differential equations all you need to know is that these equations are very specific.

The ideal gas laws

What is the relationship between heat and energy? It is a pretty known that Heat is a common form of energy but how can we relate heat to energy in an equation? Gases are affected by temperature, pressure, moles and volume in a specific quantity. Turns out that physicist Benoît Paul Émile Clapeyron discovered an equation that relates all previous condition affecting gas into the *ideal gas law* where the following equation states.

$$\mathcal{P}\mathcal{V} = N_{\mathrm{mol}}RT$$

Temperature measured in kelvin where 0k is -273 Celsius

R is an empirical constant (universal constant) of 8.314 J/ (mole · K)

P is pressure variable

V is volume of gas variable

N represents number of moles of a gas

We can also say that matter which exists at 0 kelvin has its own "state of matter' known as the Bose-Einstein condensate at this temperature no mass can't exist since at 0 kelvin it has no motion but motion can be achieved through a quantum mechanics concept known as The uncertainty principle. The uncertainty principle requires every quantum mechanical system to have a fluctuating zero-point energy greater than the minimum of its classical potential well. This results in motion even at absolute zero.

Viscosity

Viscosity refers to how easily liquid particles can slide over each other with then following equation.

$$F = \mu A \frac{u}{y}$$

Where $f = force$

Where μ viscosity of the fluid

Where $\frac{u}{y}$ equals rate of shear deformation

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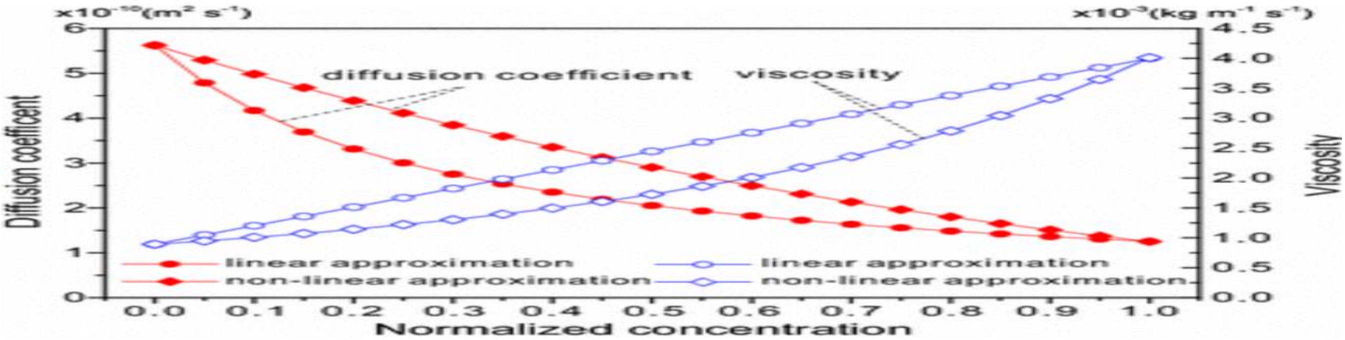
Viscosity also relates with gas in terms of diffusion as particles of a liquid have stronger attractive forces between them the less volatile they are hence the diffuse at a slower rate as shown by the following graph.



Special relativity

This chapter should be named flaws of Newtonian mechanics since in the centuries following publication of the Principia, Newtonian dynamics was accepted whole-heartedly not only because of its enormous success in explaining planetary motion but also in accounting for all motions commonly encountered on the Earth. Physicists and mathematicians (often the same people) created elegant reformulations of Newtonian physics and introduced more powerful analytical and calculation techniques, but the foundations of Newtonian physics were assumed to be unassailable. Then, on June 30 1905, Albert Einstein presented his special theory of relativity in his publication The Electrodynamics of Moving Bodies. The English translation, available on the web, is reprinted from Relativity: The Special and General Theory, Albert Einstein, Methuen, London (1920). The original publication is Zur Elektrodynamik bewegter K¨orper, Annalen der Physik 17 (1905). Einstein’s paper transformed our fundamental view of space, time, and measurement. Newtonian laws were unchallenged due to the generalization of speed most importantly light, light wasn’t well understood all throughout history up until the 1930’s when Einstein described light as a particle a photon and its flow as a wave resulting in the infamous interference pattern in the double slit experiment. It is an indication of Einstein’s genius that the troublesome problem of the ether pointed the way not to complexity and elaboration but to a simplification that unified the fundamental concepts of physics. Einstein regarded the difficulty with the ether not as a fault in electromagnetic theory but as an error in basic dynamical principles. He presented his ideas in the form of *two postulates*, prefacing them with a note on simultaneity and how to synchronize clocks.

1=The laws of physics take the same form in all inertial frames of reference.

2=As measured in any inertial frame of reference, light is always propagated in empty space with a definite velocity *c* that is independent of the state of motion of the emitting body. Or: the speed of light in free space has the same value *c* in all inertial frames of reference.

This means that light =c in all frames of reference is constant.

We have visited the effect of time dilation while explaining the Lorentz factor this notes is about classical physics interactions so only light will be covered to set a fundamental idea about its matrix.

Light

Light can be explained in four essential models.

1=Newton's Corpuscular Theory

2=Huygens' Wave Theory

3=Maxwell's Electromagnetic Theory

4=Quantum Model

Newton's Corpuscular Theory

Newton described light in his book the trinity as the following 'the reality of light, he argued, consists of motion transmitted through a material medium. Newton fully accepted the mechanical nature of light, although he chose the atomistic alternative and held that light consists of material corpuscles in motion.' Newton first described the medium as the ether an invisible medium which only reacts with light in his book optiks in 1675 this puzzled chemists. Newton regarded the idea that light was a wave since it didn't show diffraction properties a common phenomenon of waves. Newton came up with his particle model 'he explained different colors of light by proposing each color is encoded by a light corpuscle of a particular size'

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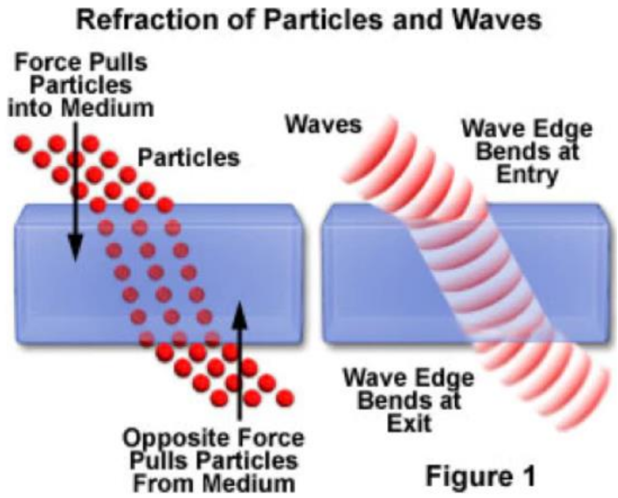


Figure 1

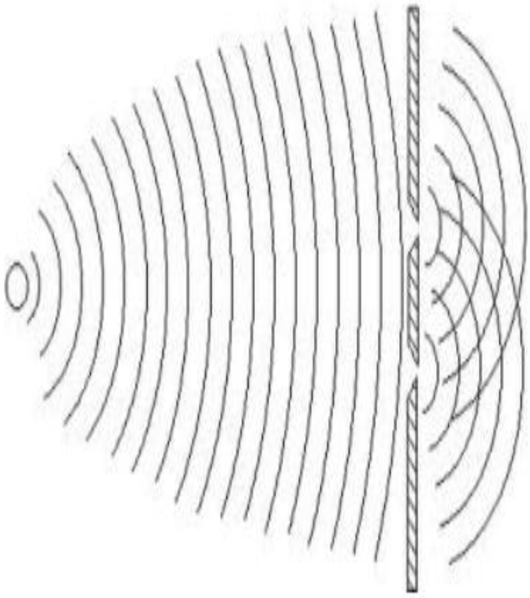
Without experimental evidence, Newton acknowledged that his theory is insufficient in explaining the partial reflection and partial refraction phenomenon of light.

When one varies the angle of incidence of a wave passing from one medium to another, part of the wave is reflected and part is refracted. The intensity of light refracted versus reflected depends on the angle of incidence and refractive index of the medium.

In the particular case where the wave passes from a slow medium to a fast medium, there is a critical angle where the entire wave is reflected. This phenomenon is called internal total reflection.

Newton’s explanation of refraction was later experimentally disapproved when the speed of light was found to be slower, rather than faster, in water. (water is a denser medium than air or vacuum)

Newton’s critical flaws: -the double slit experiment showed clear flaws in newton’s light model. When monochromatic light was shined at a double slit an interference pattern appeared clearly showing signs of diffraction.



This disapproves Newton's theory of light.

Huygens' Wave Theory

- Huygens' model of light assumes light behaves as a **longitudinal wave**. Huygens understood light's propagation as a wave's direction of travel. He proposed that the nature of light can be better understood by observing the motion of water surfaces. At the time of this proposal, Huygens was able to explain most of the properties of light including refraction, reflection & partial refraction and reflection, as well as diffraction. Huygens provided a new understanding of optics. Huygens' wave model supported observations of light’s diffraction.

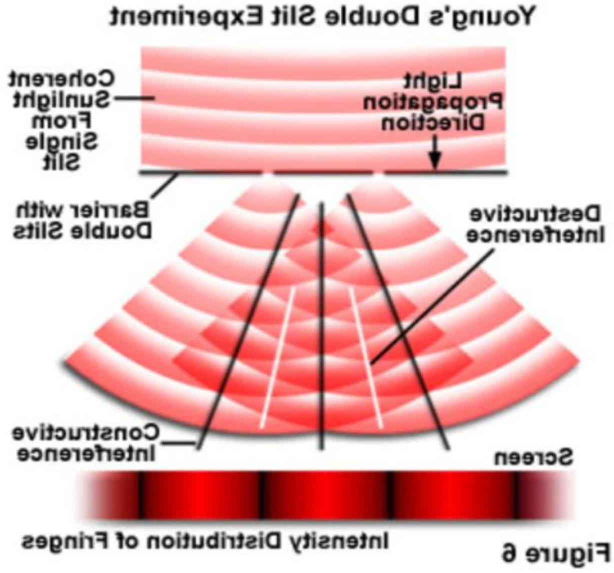


Figure 6

The electromagnetic wave model was able to account for polarization (Electromagnetic waves possess electric and magnetic fields which oscillate perpendicular to each other. However, these fields can be orientated in infinitely many axes – as long as the two fields remain perpendicular. The axis along which the electric field oscillates is referred to as the polarization axis.) as one of the many characteristics of light. However, Huygens' longitudinal wave model is unable to explain polarization as longitudinal waves cannot be polarized.

The wave model could not explain quantum mechanical phenomena of light including the photoelectric effect, Compton effect and Raman effect.

photoelectric effect: - A major breakdown of the wave theory occurred in the late 1880s when scientists first discovered that, under certain conditions, light could eject electrons from the atoms of several metals.

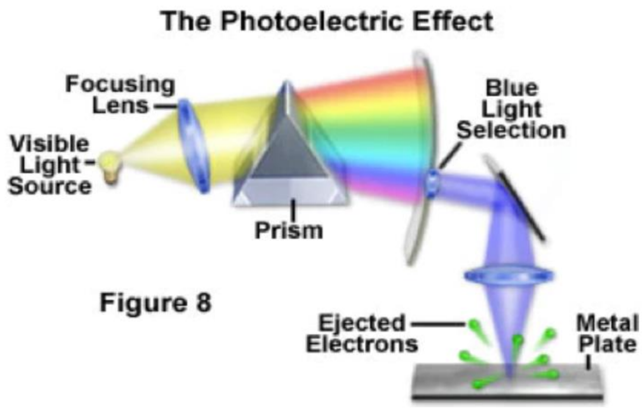


Figure 8

German physicist Philipp Lenard became interested in these observations, which he termed the photoelectric effect. Lenard used a prism to split white light into its component colors, and then selectively focused each color onto a metal plate to expel electrons. For a specific wavelength of light (blue, for example), the electrons produced a constant potential, or a fixed amount of energy. Decreasing or increasing the amount of light produced a corresponding increase or decrease in the number of electrons liberated, but each still maintained the same energy. In other words, emitted electrons' kinetic energy is dependent on the wavelength of light rather than its intensity. This idea challenged the wave model as supporters believed that energy of light was solely dependent on its intensity.

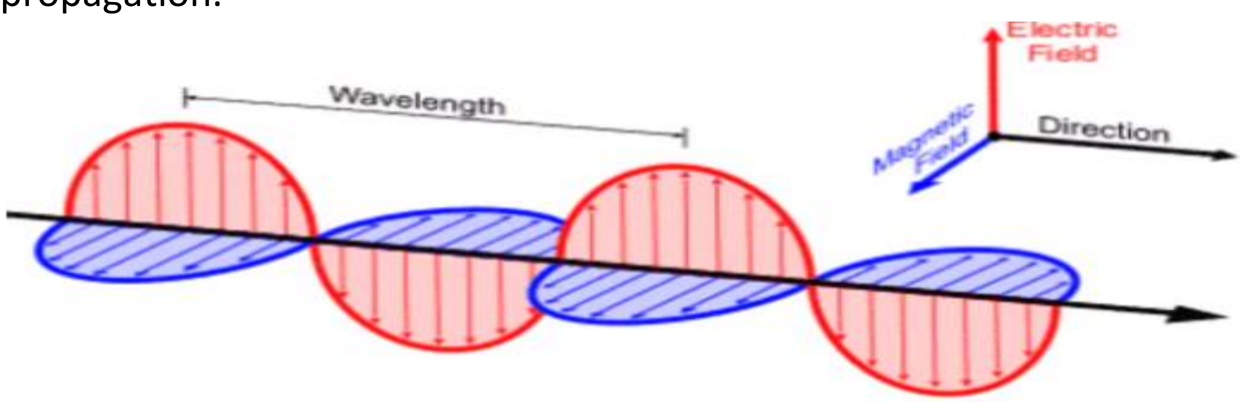
Critical flows disapproved Huygens' Wave Theory.

Maxwell's Electromagnetic Theory

Electromagnetism Faraday’s Law of Induction where an object experiencing change in magnetic flux experiences an induced emf. Faraday proposed that changing magnetic fields produced electric fields.

$$\varepsilon = -N\frac{\Delta\theta}{\Delta t}$$

Maxwell used his four equations to derive two new equations describing these oscillating magnetic and electric fields. The equation was characteristic of a wave, and also implied that the electric and magnetic fields were in phase and perpendicular to each other, oscillating in a direction perpendicular to the wave's propagation.



Maxwell's theory of electromagnetism also related electromagnetic waves to charges. He explained that an oscillating charge will produce a changing electric field, which in turn produces a changing magnetic field. These two changing fields will continue to mutually produce each other. When this oscillating charge is made to propagate, it results in a self-propagating electromagnetic wave.

Critical flaws of Maxwell's theories include The power of Maxwell's theory was limited because it was very much an ether theory, confined to the framework of the field approach, and lacked important elements provided by the conceptions of the Continental action-at-a- distance theorists also it didn't work in the quantum model.

Quantum Model

The quantum theory of light was proposed by Einstein, it states that light travels in bundles of energy, and each bundle is known as a photon. Each photon carries a quantity of energy equal to the product of the frequency of vibration of that photon and Planck's constant (6.6260701510^{-34} joule-hertz^{-1}). in the Photoelectric experiment, the electron is emitted by the metal with a particular kinetic energy. There exists a critical frequency for every metal, lower than which no electrons are emitted. This describes that the kinetic energy equals the light frequency times a constant, known as Planck's Constant. $E_{photon}=h\nu$

The quantum theory of light was given by Einstein, which describes matter, and light consists of minute particles that have properties of waves associated with them. Light consists of particles known as photons and matter are made up of particles called protons, electrons, and neutrons. When all the theories are put together, it can be concluded that light is a particle with wave behavior. So light is dual in nature.

Modern physics is wholly based on quantum theory as it explains the nature and behavior of matter and energy at the atomic and subatomic levels. Quantum physics and quantum mechanics are terms used to describe the nature and behavior of matter and energy at that level. Quantum computing, which employs quantum theory to dramatically boost computing capabilities beyond what is conceivable with today's classical computers, has attracted major funding from several countries.

The German Physical Society accepted physicist Max Planck's quantum theory in 1900. Planck wanted to know why, when a glowing body's temperature rises, the color of its radiation changes from red to orange to blue. He discovered the solution to his query by supposing that energy existed in discrete units, similar to how matter did, rather than just as a steady electromagnetic wave, as had previously been supposed, and was thus quantifiable. Quantum theory began with the existence of these units as its first premise.

To express these discrete units of energy, Planck devised a mathematical equation including a figure, which he dubbed quanta. Planck discovered that at certain discrete temperature levels (precise multiples of a basic minimum value), energy from a luminous body will occupy different sections of the color spectrum, as explained by the equation.

Planck anticipated that the discovery of quanta would lead to the development of a theory, but their very existence implied a fundamentally new and basic understanding of nature's principles. In 1918, Planck was awarded the Nobel Prize in Physics for his theory, but during the next thirty years, numerous scientists added to the contemporary knowledge of quantum theory.

While Albert Einstein's theory of relativity was essentially the result of his efforts, the quantum theory was produced over thirty years by a team of experts. Max Planck proposed that the energies of any harmonic oscillator (see the harmonic motion), such as the atoms in a blackbody radiator, are constrained to particular values, each of which is an integral (whole number) multiple of a basic, minimum value, in his explanation of blackbody radiation in 1900.

The energy E of this fundamental quantum is proportional to the oscillator's frequency v, or E=h, where h is a constant, now known as Planck's constant, with a value of 6.626071034 joule-second. Einstein argued in 1905 that radiation is quantized using the same formula, and he utilized this new theory to explain the photoelectric effect. Following Rutherford's discovery of the nuclear atom in 1911, Bohr utilized quantum theory to explain both atomic structure and atomic spectra in 1913, demonstrating the link between the energy levels of electrons and the frequencies of light emitted and absorbed.

The definitive mathematical formulation of quantum theory, quantum mechanics, was produced in the 1920s. In 1924, Louis de Broglie postulated that particles can show wavelike features as well as particle-like properties, as seen in the photoelectric phenomenon and atomic spectra. C. J. Davisson and L. H. Germer confirmed this hypothesis experimentally in 1927 when they observed diffraction of a beam of electrons analogous to diffraction of a beam of light.

Following de Broglie's idea, two distinct quantum mechanics formulations were provided. Erwin Schrödinger's (1926) wave mechanics make use of the wave function, a mathematical entity that is related to the chance of detecting a particle at a given position in space. Werner Heisenberg's matrix mechanics (1925) does not discuss wave functions or other related concepts, yet it has been proven to be mathematically equal to Schrödinger's theory.

This is all about the quantum theory of light and its explanation. It is considered to be the basis of modern physics and the world of theoretical physicists is focusing on it. Understand its concept and find out how it helps to unravel the various mysteries of the universe.

Energy of a photon

We can measure the energy of a photon using Einstein's equation:

$$E = hf = \frac{hc}{\lambda}$$

$h = 6.63 \times 10^{-34}$ Js → Planck constant

f = frequency of photon/electromagnetic radiation

$c = 3 \times 10^{8}$ m/s → speed of light in a vacuum

λ = wavelength of photon/electromagnetic radiation

Electricity