SEMESTER – II/IV/VI

19MMU504/19CHU503 **PHYSICS – II** **4H - 4C**

Instruction Hours / week: L: 4 T: 0 P: 0 **Marks:** Internal: **40** External: **60** Total: **100**

End Semester Exam: 3 Hours

Course Objectives:

- To give the basic knowledge on material properties.
- To acquire knowledge on magnetism and digital electronics.
- To educate and motivate the students in the field of science.

Course Outcomes:

Students can able to

- Explain how physics applies to phenomena in the world around them.
- Recognize how and when physics methods and principles can help address problems in their major and then apply those methods and principles to solve problems.

UNIT – I

Electrostatics: Coulombs law – electric field – Gauss's law and its applications – potential – potential due to various charge distribution. Parallel plate capacitors – dielectrics- current – galvanometer – voltmeter – ammeter- potentiometric measurements.

UNIT - II

Magnetism: Magnetic field – Biot Savart's law – B due to a solenoid – Amperes law – Faradays law of induction – Lenz's law. Magnetic properties of matter –Dia, para and ferro - Cycle of magnetization – Hysteresis – B-H curve – Applications of B-H curve.

UNIT - III

Modern Physics: Einstein's Photoelectric effect-characteristics of photoelectron –laws of photoelectric emission-Einstein's photo electric equations- Compton effect-matter waves-De-Broglie Hypothesis. Heisenberg's uncertainty principle-Schrödinger's equation- particle in a box.

UNIT-IV

Atomic and Nuclear Physics: Atom Models : Sommerfield's and Vector atom Models – Pauli's exclusion Principle – Various quantum numbers and quantization of orbits. X-rays : Continuous and Characteristic X-rays – Mosley's Law and importance – Bragg's Law.

Nuclear forces –characteristics - nuclear structure by liquid drop model – Binding energy – mass defect – particle accelerators – cyclotron and betatron – nuclear Fission and nuclear Fusion.

UNIT - V

Digital Electronics: Decimal – binary – octal and hexadecimal numbers– their representation, inter-conversion, addition and subtraction, negative numbers. Sum of products – product of sums – their conversion – Simplification of Boolean expressions - K-Map – min terms – max terms - (2, 3 and 4 variables). Basic logic gates – AND, OR, NOT, NAND, NOR and EXOR gates – NAND and NOR as universal building gates – Boolean Algebra – Laws of Boolean Algebra – De Morgan's Theorems – Their verifications using truth tables.

SUGGESTED READINGS

1. Narayanamurthi, Electricity and Magnetism, The National Publishing Co, First edition,1988.

2. J. B. Rajam, Atomic Physics., S. Chand & Company Limited, New Delhi, First edition, 1990.

3. B. N. Srivastava, Basic Nuclear Physic, Pragati Prakashan, Meerut, 2005.

4. Albert Paul Malvino, Digital principles and Applications, McGraw-Hill International Editions, New York, 2002.

5. Digital fundamentals – by Floyd 8th edition Pearson education 2006

6. R. S. Sedha, A text book of Digital Electronics, S. Chand & Co, New Delhi, First edition ,2004.

UNIT – I

Electrostatics: Coulombs law – electric field – Gauss's law and its applications – potential – potential due to various charge distribution. Parallel plate capacitors – dielectrics- current – galvanometer – voltmeter – ammeter- potentiometric measurements.

Electrostatics:

Coulomb's law

The force between two charged bodies was studied by Coulomb in 1785.Coulomb's law states that the force of attraction or repulsion between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. The direction of forces is alongthe line joining the two point charges.
One Coulomb is defined as the quantity of charge, which when placed at a distance of 1 metre in air or vacuum from an equal and similar charge, experiences a repulsive force of 9×10^9 N. The forces exerted by charges on each other are equal in magnitude and opposite in direction.

Electric Field

Electric field due to a charge is the space around the test charge in which it experiences a force. The presence of an electric field around a charge cannot be detected unless another charge is brought towards it.
When a test charge $q_o$is placed near a charge q, which is the source of electric field, an electrostatic force F will act on the test charge.

Gauss's law

The law relates the flux through any closed surface and the netcharge enclosed within the surface. The law states that the total flux

1

of the electric field E over any closed surface is equal to $\frac{1}{\varepsilon_o}$ times the net charge enclosed by the surface.

q —

$\varphi = _{\varepsilon o}$

This closed imaginary surface is called Gaussian surface. Gauss's law tells us that the flux of E through a closed surface S depends only on the value of net charge inside the surface and not on the location of the charges. Charges outside the surface will not contribute to flux.

Applications of Gauss's Law

i) **Field due to an infinite long straight charged wire**

Consider an uniformly charged wire of infinite length having a constant linear charge density λ (charge per unit ^{E} length). Let P be a point at a distance r from the wire (Fig. 1.17) and E be the electric field at the point P. A cylinder of length *l*, radius r, closed at each end by plane caps normal to the axis is chosen as Gaussian surface. Consider a very small area *ds* on the Gaussian surface. By symmetry, the magnitude of the electric field will be the same at all points on the curved surface of the cylinder and directed radially outward. $_{E}$ and *ds* are along the same direction.

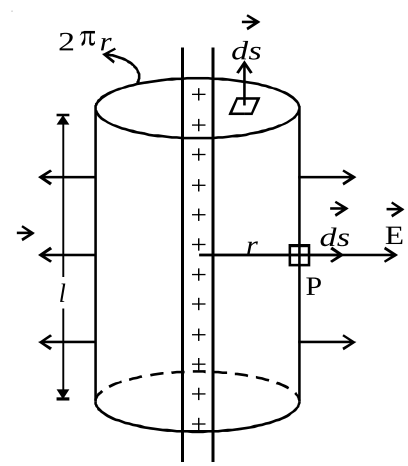


Fig 1.17 Infinitely long straight charged wire

The electric flux (φ) through curved surface = $\int$ E ds cos θ

φ = $\int$ E ds [∵θ= 0;cosθ=1]

= E (2π*rl*)

(∵ The surface area of the curved part is 2π rl)

Since $_{E}$ and *ds* are right angles to each other, the electric flux through the plane caps = 0

∴ Total flux through the Gaussian surface, φ = E. (2πrl)

The net charge enclosed by Gaussian surface is, q = λl

∴ By Gauss's law,

$$E(2\pi rl) = \frac{\lambda l}{\varepsilon_o} \quad \text{or} \quad E = \frac{\lambda}{2\pi\varepsilon_o r}$$

The direction of electric field E is radially outward, if line charge is positive and inward, if the line charge is negative.

Electric field due to an infinite charged plane sheet

Consider an infinite plane sheet of charge with surface charge density σ. Let P be a point at a distance *r* from the sheet (Fig. 1.18) and E be the electric field at P. Consider a Gaussian surface in the form of cylinder of cross− sectional area A and length *2r* perpendicular to the sheet of charge. *Fig 1.18 Infinite plane sheet* By symmetry, the electric field is at right angles to the end caps and away from the plane. Its magnitude is the same at P and at the other cap at P′.
Therefore, the total flux through the closed surface is given by

$$\varphi = \iint_P E\, ds + \iint_{P'} E\, ds \qquad (\because \theta = 0, \cos\theta = 1)$$

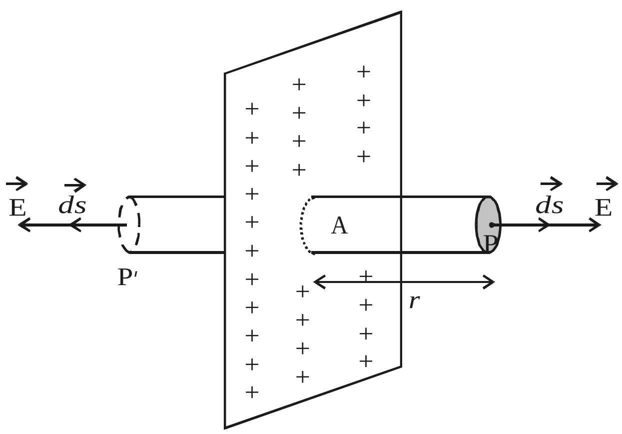
$$= E A + E A = 2 E A$$

If σ is the charge per unit area in the plane sheet, then the net positive charge *q* within the Gaussian surface is, $q = \sigma A$

Using Gauss's law,

$$2 E A = \frac{\sigma A}{\varepsilon_o}$$

$$\therefore E = \frac{\sigma}{2\varepsilon_o}$$



Capacitance of a conductor

When a charge *q* is given to an isolated conductor, its potential will change. The change in potential depends on the size and shape of the conductor. The potential of a conductor changes by V, due to the charge *q* given to the conductor.

$q \alpha$ V or $q = CV$

i.e. $C = q/V$

Here C is called as capacitance of the conductor.

The capacitance of a conductor is defined as the ratio of the charge given to the conductor to the potential developed in the conductor.

The unit of capacitance is farad. A conductor has a capacitance of one farad, if a charge of 1 coulomb given to it, rises its potential by 1 volt.

The practical units of capacitance are μF and pF.

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Principle of a capacitor

Consider an insulated conductor (Plate A) with a positive charge '*q*' having potential V (Fig 1.22a). The capacitance of A is C = q/V. When another insulated metal plate B is brought near A, negative charges are induced on the side of B near A. An equal amount of positive charge is induced on the other side of B (Fig 1.22b). The negative charge in B decreases the potential of A. The positive charge in B increases the potential of A. But the negative charge on B is nearer to A than the positive charge on B. So the net effect is that, the potential of A decreases. Thus the capacitance of A is increased.

If the plate B is earthed, positive charges get neutralized (Fig 1.22c). Then the potential of A decreases further. Thus the capacitance of A is considerably increased.

The capacitance depends on the geometry of the conductors and nature of the medium. A capacitor is a device for storing electriccharges.

A A B A

B

++ -++ -
++ -++ -
++ -++ -
++ -++ -
++ -++ -
++ -++ -
++ -++ -
++ -++ -
++ -++ -

Fig 1.22 Principle of capacitor

Capacitance of a parallel plate capacitor

The parallel plate capacitor consists of two parallel metal plates X and Y each of area A, separated by a distance *d*, having a surface charge density σ (fig. 1.23). The medium

-q

+*q* is given to the plate X. It induces

a charge –*q* on the upper surface of *Fig 1.23 Parallel plate capacitor* earthed plate Y. When the plates are very close to each other, the field is confined to the region between them. The electric lines of force starting from plate X and ending at the plate Y are parallel to each other and perpendicular to the plates.

By the application of Gauss's law, electric field at a point between the two plates is,

$$E = \frac{\sigma}{\varepsilon_o}$$

Potential difference between the plates X and Y is

$$V = \int_d^0 -E\, dr = -\int_d^0 \frac{\sigma}{\varepsilon_o} dr = \frac{\sigma d}{\varepsilon_o}$$

The capacitance (C) of the parallel plate capacitor

$$C = \frac{q}{V} = \frac{\sigma A}{\sigma d/\varepsilon_o} \quad \left[\text{since}, \sigma = \frac{q}{A}\right]$$

$$\therefore \quad C = \frac{\varepsilon_o A}{d}$$

The capacitance is directly proportional to the area (A) of the plates and inversely proportional to their distance of separation (d).

Dielectrics and polarization

Dielectrics

A dielectric is an insulating material in which all the electrons are tightly bound to the nucleus of the atom. There are no free electrons to carry current. Ebonite, mica and oil are few examples of dielectrics. The electrons are not free to move under the influence of an external field.

UNIT – II

Magnetism: Magnetic field – Biot Savart's law – B due to a solenoid – Amperes law – Faradays law of induction – Lenz's law. Magnetic properties of matter –Dia, para and ferro - Cycle of magnetization – Hysteresis – B-H curve – Applications of B-H curve.

MAGNETISM

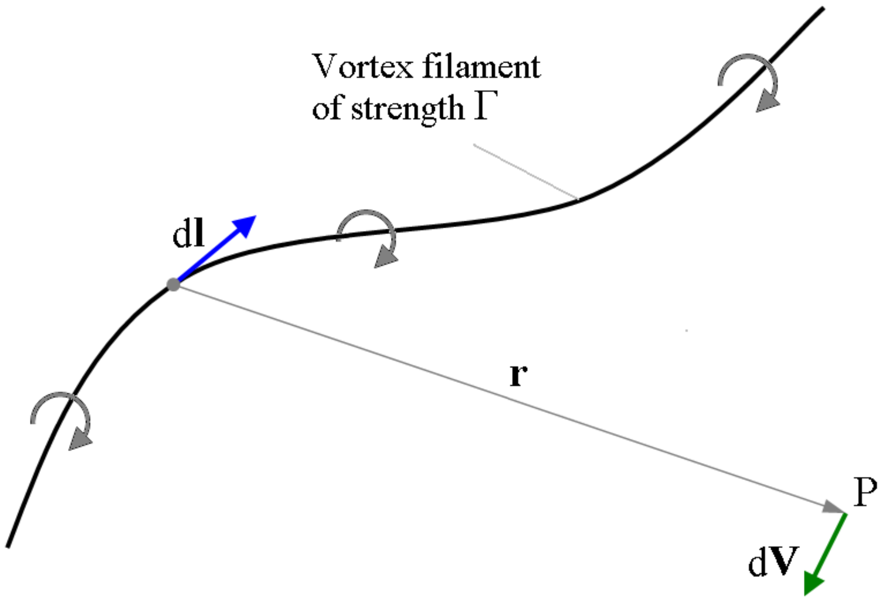
Magnetic field

A vector field in the neighbourhood of a magnet, electric current, or changing electric field, in which magnetic forces are observable. Magnetic fields such as that of Earth cause magnetic compass needles and other permanent magnets to line up in the direction of the field. Magnetic fields force moving electrically charged particles in a circular or helical path. This force—exerted on electric currents in wires in a magnetic field—underlies the operation of electric motors.

The Biot Savart Law states that it is a mathematical expression which illustrates the magnetic field produced by a stable electric current in the particular electromagnetism of physics. It tells the magnetic field toward the magnitude, length, direction, as well as closeness of the electric current. This law is basic to magnetostatics and plays an essential role related to the Coulomb's law in electrostatics. Whenever magneto statics do not apply, then this law must be changed by the equation of Jefimenko's. This law is applicable in the magnetostatic estimate, & is reliable by both Gauss's (magnetism) and Ampere's (circuital) law. The two physicists from French namely "Jean Baptiste Biot" & "Felix Savart" implemented an exact expression intended for magnetic flux density at a position close to a current carrying conductor in the year 1820. Screening a magnetic compass needle deflection, the two scientists completed that every current component estimates a magnetic field in the space (S).

What is Biot Savart Law?

A conductor which carries current (I) with the length (dl), is a basic magnetic field source. The power on one more related conductor can be expressed easily in terms of the magnetic field (dB) due to the primary. The magnetic field dB dependence on the 'I' current, dimension as well as direction of the length dl & on distance 'r' was primarily estimated by Biot & Savart.



Biot Savart Law

Once from end to end observations as well as calculations they derived an expression, that includes the density of magnetic flux (dB), is directly proportional to the element length (dl), the flow of current (I), the sine of the angle θ among the flow of current direction and the vector combining a given position of the field, with the current component is inversely proportional to the square of the distance (r) of the specified point from the current element. This is the Biot Savart law statement.

Magnetic Field Element

Thus, dB is proportional to I dl $\sin\theta / r^2$ or, it can be written as $dB = k\, Idl \sin\theta / r^2$

$dH = \mu0\ \mu r/4\pi \times Idl \sin\theta / r^2$
$dH = k \times Idl \sin\theta / r^2$ (Where $k = \mu0\ \mu r/4\pi$)
dH is proportional to $Idl \sin\theta / r^2$
Here, k is a constant, thus the final Biot-Savart law expression is
$dB = \mu0\ \mu r/4\pi \times Idl \sin\theta / r^2$

Solenoids and Magnetic Fields

A solenoid is a long coil of wire wrapped in many turns. When a current passes through it, it creates a nearly uniform magnetic field inside.

Solenoids can convert electric current to mechanical action, and so are very commonly used as switches.

The magnetic field within a solenoid depends upon the current and density of turns.

In order to estimate roughly the force with which a solenoid pulls on ferromagnetic rods placed near it, one can use the change in magnetic field energy as the rod is inserted into the solenoid. The force is roughly

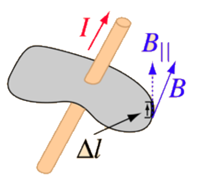
$$\text{force on rod} = \frac{\text{change in magnetic field energy}}{\text{distance rod moves into solenoid}}$$

The energy density of the magnetic field depends on the strength of the field, squared, and also upon the magnetic permeability of the material it fills. Iron has a much, much larger permeability than a vacuum.

Even small solenoids can exert forces of a few newtons.

Ampere's Law

The magnetic field in space around an electric current is proportional to the electric current which serves as its source, just as the electric field in space is proportional to the charge which serves as its source. Ampere's Law states that for any closed loop path, the sum of the length elements times the magnetic field in the direction of the length element is equal to the permeability times the electric current enclosed in the loop.



$$\sum B_{||} \Delta l = \mu_0 I$$

Faraday's law of induction

In physics, a quantitative relationship between a changing magnetic field and the electric field created by the change, developed on the basis of experimental observations made in 1831 by the English scientist Michael Faraday.

The phenomenon called electromagnetic induction was first noticed and investigated by Faraday; the law of induction is its quantitative expression. Faraday discovered that, whenever the magnetic field about an electromagnet was made to grow and collapse by closing and opening the electric circuit of which it was a part, an electric current could be detected in a separate conductor nearby. Moving a permanent magnet into and out of a coil of wire also induced a current in the wire while the magnet was in motion. Moving a conductor near a stationary permanent magnet caused a current to flow in the wire, too, as long as it was moving. Faraday visualized a magnetic field as composed of many lines of induction, along which a small magnetic compass would point. The aggregate of the lines intersecting a given area is called the magnetic flux. The electrical effects were thus attributed by Faraday to a changing magnetic flux. Some years later the Scottish physicist James Clerk Maxwell proposed that the fundamental effect of changing magnetic flux was the production of an electric field, not only in a conductor (where it could drive an electric charge) but also in space even in the absence of electric charges. Maxwell formulated the mathematical expression relating the change in magnetic flux to the induced electromotive force (E, or emf). This relationship, known as Faraday's law of induction (to distinguish it from his laws of electrolysis), states that the magnitude of the emf induced in a circuit is proportional to the rate of change of the magnetic flux that cuts across the circuit. If the rate of change of magnetic flux is expressed in units of webers per second, the induced emf has units of volts. Faraday's law is one of the four Maxwell equations that define electromagnetic theory.

Lenz's law states that when an EMF is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced EMF is such, that it produces an induced current whose magnetic field opposes the initial changing magnetic field which produced it
The negative sign used in Faraday's law of electromagnetic induction, indicates that the induced EMF (ε) and the change in magnetic flux ($\delta\Phi_B$) have opposite signs. The formula for Lenz's law is shown below:

$$\epsilon = -N\frac{\partial \Phi_B}{\partial t}$$

Where:
ε = Induced emf
$\delta\Phi_B$ = change in magnetic flux
N = No of turns in coil

Magnetic Properties Of Matter

All matter exhibits magnetic properties when placed in an external magnetic field. Even substances like copper and aluminum that are not normally thought of as having magnetic properties are affected by the presence of a magnetic field such as that produced by either pole of a bar magnet. Depending on whether there is an attraction or repulsion by the pole of a magnet, matter is classified as being **either paramagnetic or diamagnetic**, respectively. A few materials, notably iron, show a very large attraction toward the pole of a permanent bar magnet; materials of this kind are called **ferromagnetic.**

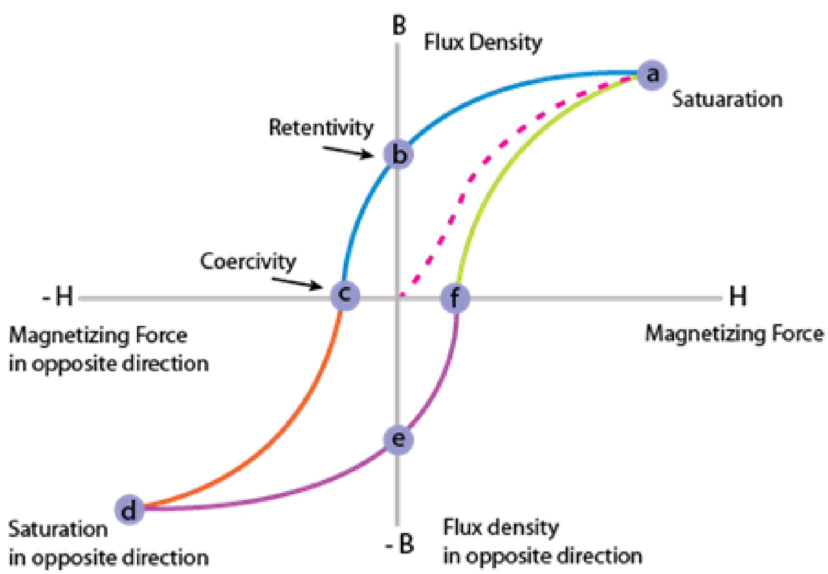
In 1845 Faraday became the first to classify substances as either diamagnetic or paramagnetic. He based this classification on his observation of the force exerted on substances in an inhomogeneous magnetic field. At moderate field strengths, the magnetization $\boldsymbol{M}$ of a substance is linearly proportional to the strength of the applied field $\boldsymbol{H}$. The magnetization is specified by the magnetic susceptibility χ (previously labeled χm), defined by the relation $\boldsymbol{M} = \chi\boldsymbol{H}$. A sample of volume V placed in a field $\boldsymbol{H}$ directed in the x-direction and increasing in that direction at a rate $d\mathbf{H}/dx$ will experience a force in the x-direction of $\boldsymbol{F} = \chi\mu_0 VH\,(d\mathbf{H}/dx)$. If the magnetic susceptibility χ is positive, the force is in the direction of increasing field strength, whereas if χ is negative, it is in the direction of decreasing field strength. Measurement of the force $\boldsymbol{F}$ in a known field $\boldsymbol{H}$ with a known gradient $d\mathbf{H}/dx$ is the basis of a number of accurate methods of determining χ.

Substances for which the magnetic susceptibility is negative (e.g., copper and silver) are classified as diamagnetic. The susceptibility is small, on the order of -10^{-5} for solids and liquids and -10^{-8} for gases. A characteristic feature of diamagnetism is that the magnetic moment per unit mass in a given field is virtually constant for a given substance over a very wide range of temperatures. It changes little between solid, liquid, and gas; the variation in the susceptibility between solid or liquid and gas is almost entirely due to the change in the number of molecules per unit volume. This indicates that the magnetic moment induced in each molecule by a given field is primarily a property characteristic of the molecule.

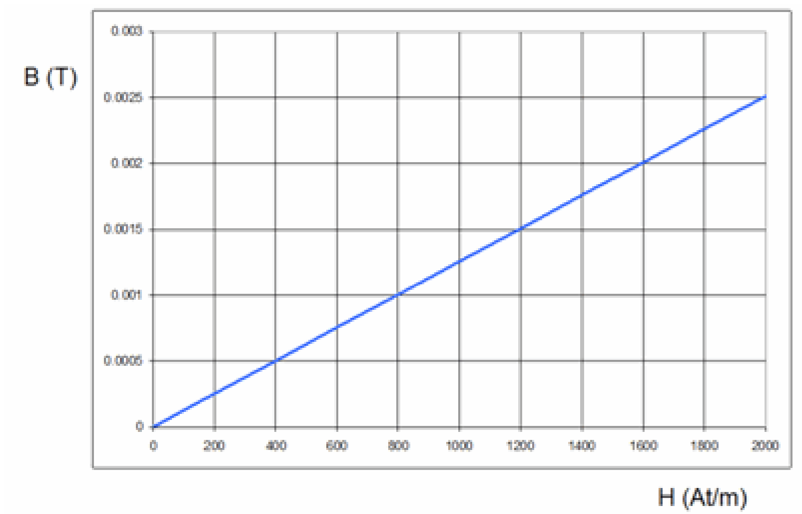
Substances for which the magnetic susceptibility is positive are classed as paramagnetic. In a few cases (including most metals), the susceptibility is independent of temperature, but in most compounds it is strongly temperature dependent, increasing as the temperature is lowered. Measurements by the French physicist Pierre Curie in 1895 showed that for many substances the susceptibility is inversely proportional to the absolute temperature T; that is, $\chi = C/T$. This approximate relationship is known as Curie's law and the constant C as the Curie constant. A more accurate equation is obtained in many cases by modifying the above equation to $\chi = C/(T - \theta)$, where θ is a constant. This equation is called the Curie–Weiss law (after Curie and Pierre-Ernest Weiss, another French physicist). From the form of this last equation, it is clear that at the temperature $T = \theta$, the value of the susceptibility becomes infinite. Below this temperature, the material exhibits spontaneous magnetization—i.e., it becomes ferromagnetic. Its magnetic properties are then very different from those in the paramagnetic or high-temperature phase. In particular, although its magnetic moment can be changed by the application of a magnetic field, the value of the moment attained in a given field is not always the same; it depends on the previous magnetic, thermal, and mechanical treatment of the sample.

Hysteresis

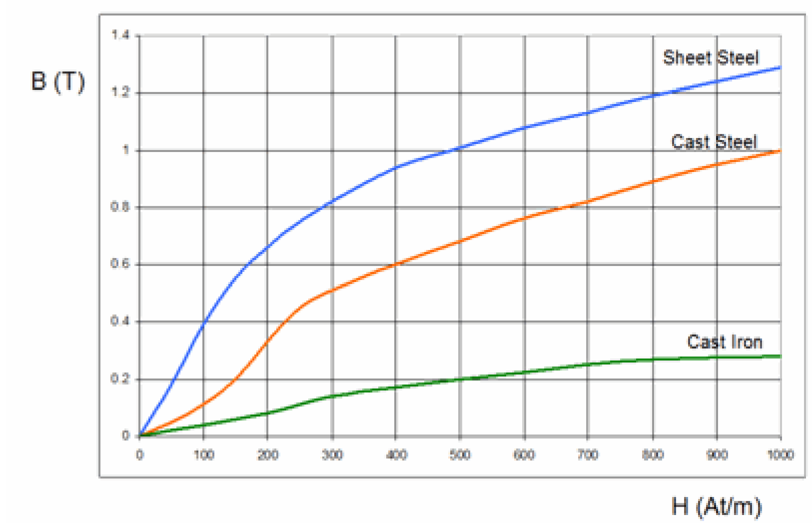
The phenomenon in which the value of a physical property lags behind changes in the effect causing it, as for instance when magnetic induction lags behind the magnetizing force.



The B-H curve is the curve characteristic of the magnetic properties of a material or element or alloy. It tells you how the material responds to an external magnetic field, and is a critical piece of information when designing magnetic circuits. In the plots below, for a vacuum an H of 800 At/m creates a B of 1 mT. With a sheet steel core, an H of 800 At/m creates a B of 1.2 T. A huge increase in B for the same H! The hysteresis comes into play when the material has been magnetized. The B within the material does not go back to what it was before, but is dependent on the history of its magnetization.



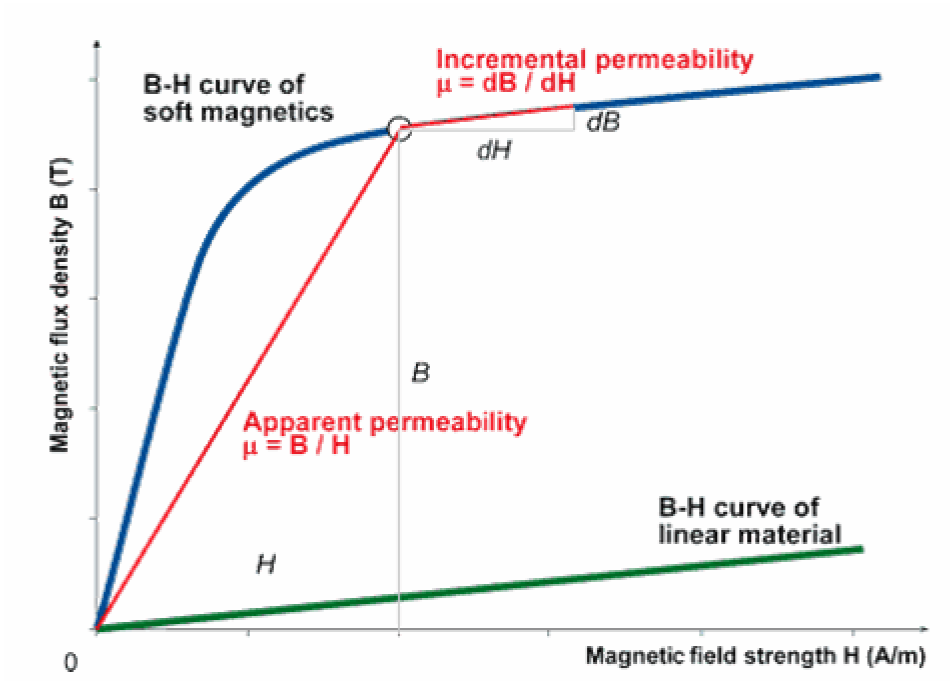
B-H for Vacuum



B-H for various materials

c. The slope of the curve - **Permeability**

The slope of the B-H curve at some location on its curve is its incremental permeability at that location. However, sometimes the permeability is measured from the origin to the location of interest, and that slope is called its apparent permeability, μ.



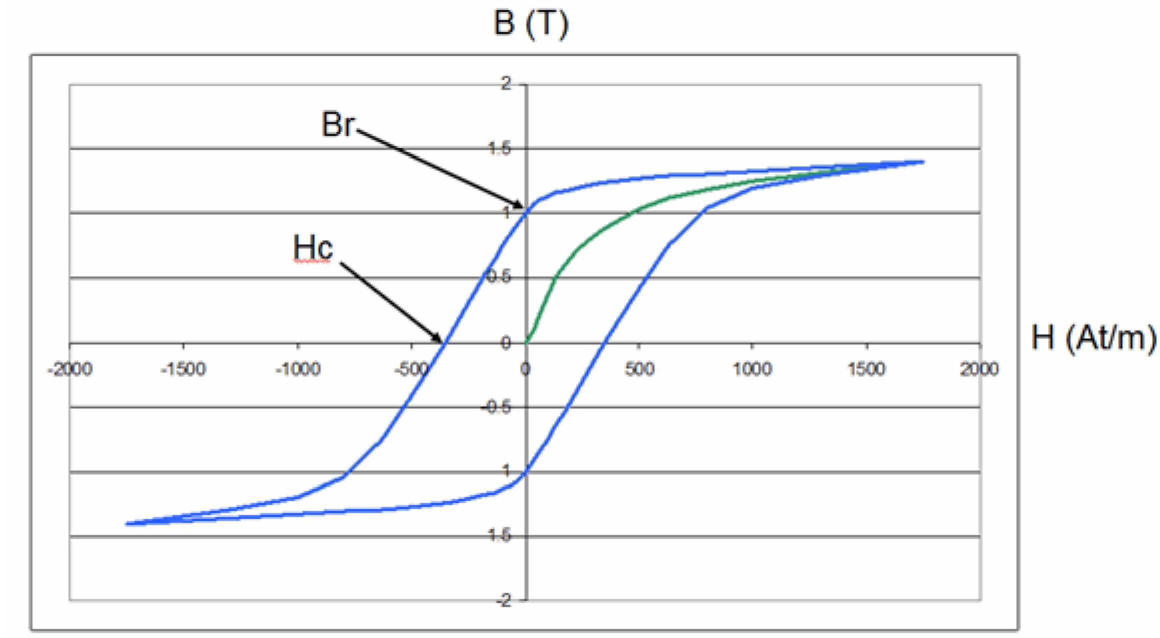
For non-magnetic materials that do not saturate, the curve has a fixed slope approximately equal to μ_0

i. Diamagnetic materials have a slightly smaller slope

ii. Paramagnetic materials have a slightly greater slope

d. Critical points on the curve

For ferromagnetic materials that are non-linear, they have a μ_r that is much greater than 1, but when they saturate their μ_r approaches 1.



i. The residual magnetism, Br, or remanence (or retentivity), is the flux density that is left within the material after it has been magnetized.

ii. A material with a high Br is desired for permanent magnets.

http://en.wikipedia.org/wiki/Remanence

iii. The coercivity, Hc, is the magnetic field intensity that is required to demagnetize the material after it has been magnetized.

iv. A material with a high Hc is desired for permanent magnets to prevent them from being easily demagnetized.

v. Rare earth magnets have a much higher Hc than Alnico magnets.

http://en.wikipedia.org/wiki/Coercivity

vi. The saturation effect of the material occurs when all of the magnetic domains within the material have become aligned with the external magnetic field that surrounds it.

e. Characteristics of soft magnetic material

i. A material with a very low Br and Hc

ii. It does not retain a strong magnetic field (does not make a good permanent magnet), and is easy to demagnetize

iii. The area enclosed by the B-H curve is small, so it has low hysteresis losses or core losses

iv. This material is desired for use in transformers, motors and electromagnets where the magnetic field is always changing.

v. Electrical steels, which contain about 1-2% Si, is a soft magnetic material.
e. Characteristics of hard magnetic material
i. A material with a very high Br and Hc

ii. It retains a strong magnetic field (makes a good permanent magnet), and is difficult to demagnetize

iii. The area enclosed by the B-H curve is large, so it has high hysteresis losses or core losses

iv. This material is desired for use in permanent magnets.

v. Alloys such as AlNiCo and NdFeB are hard magnetic materials.

UNIT – III

Modern Physics: Einstein's Photoelectric effect-characteristics of photoelectron –laws of photoelectric emission-Einstein's photo electric equations- Compton effect-matter waves-De-Broglie Hypothesis. Heisenberg's uncertainty principle-Schrödinger's equation- particle in a box.

Modern Physics

Einstein's Photoelectric effect

The photoelectric effect is a phenomenon where electrons are emitted from the metal surface when the light of sufficient frequency is incident upon. The concept of photoelectric effect was first documented in 1887 by Heinrich Hertz and later by Lenard in 1902. But both the observations of the photoelectric effect could not be explained by Maxwell's electromagnetic wave theory of light. Hertz (who had proved the wave theory) himself did not pursue the matter as he felt sure that it could be explained by the wave theory. It, however, failed on the following accounts:

According to the wave theory, energy is uniformly distributed across the wavefront and is dependent only on the intensity of the beam. This implies that the kinetic energy of electrons increases with light intensity. However, the kinetic energy was independent of light intensity.
Wave theory says that light of any frequency should be capable of ejecting electrons. But electron emission occurred only for frequencies larger than a threshold frequency (ν0).
Since energy is dependent on intensity according to wave theory, the low-intensity light should emit electrons after some time so that the electrons can acquire sufficient energy to get emitted. However, electron emission was spontaneous no matter how small the intensity of light.
Following is the table with link of other experiment related to photoelectric effect:

Einstein's explanation of Photoelectric effect

Einstein resolved this problem using Planck's revolutionary idea that light was a particle. The energy carried by each particle of light (called quanta or photon) is dependent on the light's frequency (ν) as shown:
E = hν
Where *h = Planck's constant = 6.6261 × 10-34 Js.*
Since light is bundled up into photons, Einstein theorized that when a photon falls on the surface of a metal, the entire photon's energy is transferred to the electron.

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A part of this energy is used to remove the electron from the metal atom's grasp and the rest is given to the ejected electron as kinetic energy. Electrons emitted from underneath the metal surface lose some of the kinetic energy during the collision. But the surface electrons carry all the kinetic energy imparted by the photon and have the maximum kinetic energy.
We can write this mathematically as:

Energy of photon
= energy required to eject electron (work function) + Maximum kinetic energy of the electron
E = W + KE
hv = W + KE
KE = hv – w

At the threshold frequency ν0 electrons are just ejected and do not have any kinetic energy. Below this frequency there is no electron emission. Thus, the energy of a photon with this frequency must be the work function of the metal.

w = hv_0
Thus, Maximum kinetic energy equation becomes:
KE = 12mv2max=hv–hv_0
12mv2max=h(v−v_0)

Vmax is the maximum kinetic energy of the electron. It is calculated experimentally using the stopping potential. Please read our article on Lenard's observations to understand this part.

Stopping potential = ev_0 = 12mv2max
Thus, Einstein explained the Photoelectric effect by using the particle nature of light.
Stay tuned with BYJU'S to learn more about the photoelectric effect along with engaging video lectures.

Compton effect, increase in wavelength of X-rays and other energetic electromagnetic radiations that have been elastically scattered by electrons; it is a principal way in which radiant energy is absorbed in matter. The effect has proved to be one of the cornerstones of quantum mechanics, which accounts for both wave and particle properties of radiation as well as of matter.

Matter waves

It is **the wave** formed by **matter**, or in another word, particles. Precisely speaking, every **matter** formed by particles, or just particles like electrons, have **wave**-like **property**, which means they can behave both like particles and **waves**. It is only when particles move that they have **wave**-like **property**

De Broglie's Thesis

In his 1923 (or 1924, depending on the source) doctoral dissertation, the French physicist Louis de Broglie made a bold assertion. Considering Einstein's relationship of wavelength *lambda* to momentum *p*, de Broglie proposed that this relationship would determine the wavelength of any matter, in the relationship:

lambda = *h* / *p*

recall that *h* is Planck's constant

This wavelength is called the *de Broglie wavelength*. The reason he chose the momentum equation over the energy equation is that it was unclear, with matter, whether *E* should be total energy, kinetic energy, or total relativistic energy. For photons, they are all the same, but not so for matter.

Assuming the momentum relationship, however, allowed the derivation of a similar de Broglie relationship for frequency *f* using the kinetic energy E_k:

$f = E_k / h$

Alternate Formulations

De Broglie's relationships are sometimes expressed in terms of Dirac's constant, *h-bar* = *h* / (2*pi*), and the angular frequency *w* and wavenumber *k*:

p = *h-bar* * kE_k

= *h-bar* * *w*

Experimental Confirmation

In 1927, physicists Clinton Davisson and Lester Germer, of Bell Labs, performed an experiment where they fired electrons at a crystalline nickel target. The resulting diffraction pattern matched the predictions of the de Broglie wavelength. De Broglie received the 1929 Nobel Prize for his theory (the first time it was ever awarded for a Ph.D. thesis) and Davisson/Germer jointly won it in 1937 for the experimental discovery of electron diffraction (and thus the proving of de Broglie's hypothesis).

Further experiments have held de Broglie's hypothesis to be true, including the quantum variants of the double slit experiment. Diffraction experiments in 1999 confirmed the de Broglie wavelength for the behavior of molecules as large as buckyballs, which are complex molecules made up of 60 or more carbon atoms.

Significance of the de Broglie Hypothesis

The de Broglie hypothesis showed that wave-particle duality was not merely an aberrant behavior of light, but rather was a fundamental principle exhibited by both radiation and matter. As such, it becomes possible to use wave equations to describe material behavior, so long as one properly applies the de Broglie wavelength. This would prove crucial to the development of quantum mechanics. It is now an integral part of the theory of atomic structure and particle physics.

Macroscopic Objects and Wavelength

Though de Broglie's hypothesis predicts wavelengths for matter of any size, there are realistic limits on when it's useful. A baseball thrown at a pitcher has a de Broglie wavelength that is smaller than the diameter of a proton by about 20 orders of magnitude.

The Heisenberg uncertainty principle states that it is impossible to know simultaneously the exact position and momentum of a particle. That is, the more exactly the position is determined, the less known the momentum, and vice versa. This principle is not a statement about the limits of technology, but a fundamental limit on what can be known about a particle at any given moment. This uncertainty arises because the act of measuring affects the object being measured. The only way to measure the position of something is using light, but, on the sub-atomic scale, the interaction of the light with the object inevitably changes the object's position and its direction of travel.

The Schrödinger Equation and a Particle in a Box

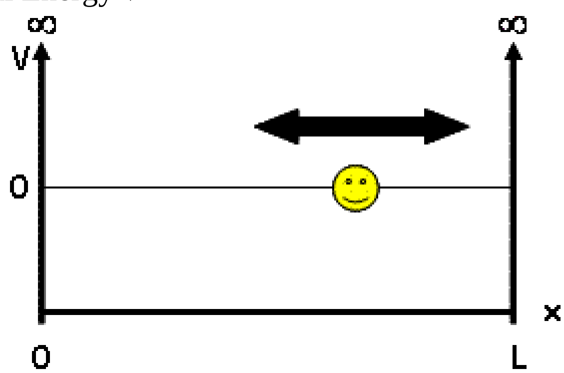
The particle in a box model (also known as the infinite potential well or the infinite square well) describes a particle free to move in a small space surrounded by impenetrable barriers. The model is mainly used as a hypothetical example to illustrate the differences between classical and quantum systems. In classical systems, for example a ball trapped inside a large box, the particle can move at any speed within the box and it is no more likely to be found at one position than another. However, when the well becomes very narrow (on the scale of a few nanometers), quantum effects become important. The particle may only occupy certain positive energy levels. The particle in a box model provides one of the very few problems in quantum mechanics which can be solved analytically, without approximations. This means that the observable properties of the particle (such as its energy and position) are related to the mass of the particle and the width of the well by simple mathematical expressions. Due to its simplicity, the model allows insight into quantum effects without the need for complicated mathematics. It is one of the first quantum mechanics problems taught in undergraduate physics courses, and it is commonly used as an approximation for more complicated quantum systems.

A particle in a 1-dimensional box is a fundamental quantum mechanical approximation describing the translational motion of a single particle confined inside an infinitely deep well from which it *cannot* escape.

The particle in a box problem is a common application of a quantum mechanical model to a simplified system consisting of a particle moving horizontally within an infinitely deep well from which it cannot escape. The solutions to the problem give possible values of E and ψψ that the particle can possess. E represents allowed energy values and ψ(x)ψ(x) is a wavefunction, which when squared gives us the probability of locating the particle at a certain position within the box at a given energy level.

To solve the problem for a particle in a 1-dimensional box, we must follow our **Big, Big recipe for Quantum Mechanics:**

Define the Potential Energy, *V*
Solve the Schrödinger Equation
Define the wavefunction
Define the allowed energies
Step 1: Define the Potential Energy *V*



***A particle in a 1D infinite potential well of dimension* LL.**

The potential energy is *0 inside the box* (V=0 for 0<x<L) and *goes to infinity at the walls of the box* (V=∞ for x<0 or x>L). We assume the walls have infinite potential energy to ensure that the particle has zero probability of being at the walls or outside the box. Doing so significantly simplifies our later mathematical calculations as we employ these **boundary conditions** when solving the Schrödinger Equation.

Step 2: Solve the Schrödinger Equation
The time-independent Schrödinger equation for a particle of mass *m* moving in one direction with energy *E* is

−ℏ22md2ψ(x)dx2+V(x)ψ(x)=Eψ(x)(1)(1)−ℏ22md2ψ(x)dx2+V(x)ψ(x)=Eψ(x)

with
ℏℏ is the reduced Planck Constant where ℏ=h2πℏ=h2π
m is the mass of the particle
ψ(x)ψ(x) is the stationary time-independent wavefunction
V(x) is the potential energy as a function of position
EE is the energy, a real number

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This equation can be modified for a particle of mass *m* free to move parallel to the x-axis with zero potential energy (V = 0 everywhere) resulting in the quantum mechanical description of free motion in one dimension:

−ℏ22md2ψ(x)dx2=Eψ(x)(2)(2)−ℏ22md2ψ(x)dx2=Eψ(x)

This equation has been well studied and gives a general solution of:

ψ(x)=Asin(kx)+Bcos(kx)(3)(3)ψ(x)=Asin(kx)+Bcos(kx)

where A, B, and k are constants.

Step 3: Define the wavefunction

The solution to the Schrödinger equation we found above is the general solution for a 1-dimensional system. We now need to apply our **boundary conditions** to find the solution to our particular system. According to our boundary conditions, the probability of finding the particle at x=0 or x=L is zero. When x=0x=0, sin(0)=0sin(0)=0, and cos(0)=1cos(0)=1; therefore, *B must equal 0* to fulfill this boundary condition giving:
ψ(x)=Asin(kx)(4)(4)ψ(x)=Asin(kx)

We can now solve for our constants (A and k) systematically to define the wavefunction.

Solving for k

Differentiate the wavefunction with respect to x:

dψdx=kAcos(kx)(5)(5)dψdx=kAcos(kx)
d2ψdx2=−k2Asin(kx)(6)(6)d2ψdx2=−k2Asin(kx)
Since ψ(x)=Asin(kx)ψ(x)=Asin(kx), then

d2ψdx2=−k2ψ(7)(7)d2ψdx2=−k2ψ

If we then solve for k by comparing with the Schrödinger equation above, we find:

k=(8π2mEh2)1/2(8)(8)k=(8π2mEh2)1/2

Now we plug k into our wavefunction:

ψ=Asin(8π2mEh2)1/2x(9)(9)ψ=Asin(8π2mEh2)1/2x

Solving for A

To determine A, we have to apply the boundary conditions again. Recall that the *probability of finding a particle at x = 0 or x = L is zero.*

When x=Lx=L:

0=Asin(8π2mEh2)1/2L(10)(10)0=Asin(8π2mEh2)1/2L
This is only true when
(8π2mEh2)1/2L=nπ(11)(11)(8π2mEh2)1/2L=nπ
where n = 1,2,3…

Plugging this back in gives us:

ψ=AsinnπLx(12)(12)ψ=AsinnπLx
To determine AA, recall that the total probability of finding the particle inside the box is 1, meaning there is no probability of it being outside the box. When we find the probability and set it equal to 1, we are *normalizing* the wavefunction.
∫L0ψ2dx=1(13)(13)∫0Lψ2dx=1

For our system, the normalization looks like:

A2∫L0sin2(nπxL)dx=1(14)(14)A2∫0Lsin2(nπxL)dx=1
Using the solution for this integral from an integral table, we find our normalization constant, AA:
A=2L−−√(15)(15)A=2L

Which results in the normalized wavefunction for a particle in a 1-dimensional box:

ψ=2L−−√sinnπLx(16)(16)ψ=2LsinnπLx
Step 4: Determine the Allowed Energies

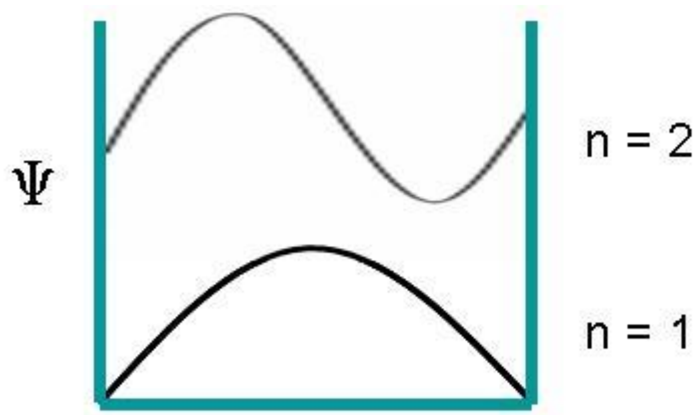
Solving for E results in the allowed energies for a particle in a box:

En=n2h28mL2(17)(17)En=n2h28mL2
This is an important result that tells us:

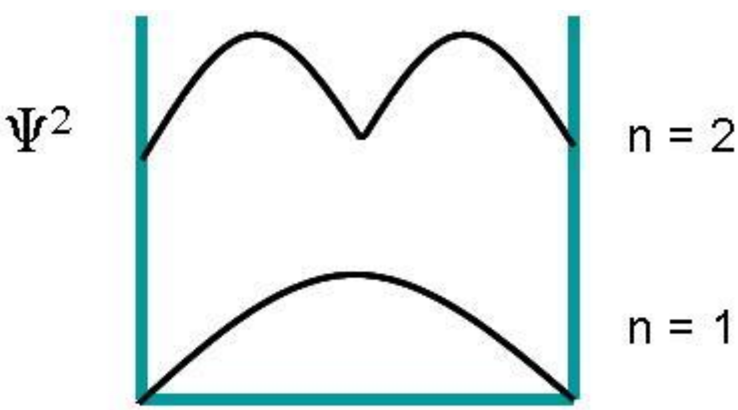
The energy of a particle is quantized and
The lowest possible energy of a particle is **NOT** zero. This is called the **zero-point energy** and means the particle can **never be at rest** because it always has some kinetic energy.

This is also consistent with the Heisenberg Uncertainty Principle: if the particle had zero energy, we would know where it was in both space and time.

The wavefunction for a particle in a box at the n=1n=1 and n=2n=2 energy levels look like this:



The probability of finding a particle a certain spot in the box is determined by squaring ψψ. The probability distribution for a particle in a box at the n=1n=1 and n=2n=2 energy levels looks like this:



Notice that the number of **nodes** (places where the particle has zero probability of being located) increases with increasing energy n. Also note that as the energy of the particle becomes greater, the quantum mechanical model breaks down as the energy levels get closer together and overlap, forming a continuum. This continuum means the particle is free and can have any energy value. At such high energies, the classical mechanical model is applied as the particle behaves more like a continuous wave. Therefore, the particle in a box problem is an example of Wave-Particle Duality.

IMPORTANT FACTS TO LEARN FROM THE PARTICLE IN THE BOX

- The energy of a particle is quantized. This means it can only take on discrete energy values.
- The lowest possible energy for a particle is **NOT** zero (even at 0 K). This means the particle *always* has some kinetic energy.
- The square of the wavefunction is related to the probability of finding the particle in a specific position for a given energy level.
- The probability changes with increasing energy of the particle and depends on the position in the box you are attempting to define the energy for.
- In classical physics, the probability of finding the particle is independent of the energy and the same at all points in the box.

UNIT – IV

Atomic & Nuclear physics: Atom models: Sommerfeld and vector atom model – Pauli's exclusion principle – Various quantum numbers and quantization of orbitals – X-rays: continuous and characteristic x-rays- Moseley's law – Braggs law.
Nuclear forces – characteristics – nuclear structure by liquid drop model – binding energy – mass defect – particle accelerator – cyclotron and betatron – nuclear fission and fusion.

Atomic & Nuclear physics

Sommerfeld atom model and its Drawbacks

In order to explain the observed fine structure of spectral lines, Sommerfeld introduced two main modifications in Bohr's theory.

Sommerfeld atom model

In order to explain the observed fine structure of spectral lines, Sommerfeld introduced two main modifications in Bohr's theory.

(i) According to Sommerfeld, the path of an electron around the nucleus, in general, is an ellipse with the nucleus at one of its foci.

(ii) The velocity of the electron moving in an elliptical orbit varies at different parts of the orbit. This causes the relativistic variation in the mass of the moving electron.

Now, when elliptical orbits are permitted, one has to deal with two variable quantities.

(i) The varying distance of the electron from the nucleus (r).

(ii) The varying angular position of the electron with respect to the nucleus i.e the azimuthal angle φ (Fig).

To deal with these two variables, two quantum numbers are introduced

(i) The principal quantum number n of Bohr's theory, which determines the energy of the electrons, and

(ii) a new quantum number called orbital (or azimuthal) quantum number (l) which has been introduced to characterize the angular momentum in an orbit i.e., it determines the orbital angular momentum of the electron. Its values vary from zero to (n-1) in steps of unity.

This orbital quantum number (l) is useful in finding the possible elliptical orbits. The possible elliptical orbits are such that

$b/a = l+1/n$

where a and b are semi-major and semi-minor axes respectively of the ellipse.

According to Sommerfeld's model, for any principal quantum number n, there are n possible orbits of varying eccentricities called sub-orbits or sub-shells. Out of n subshells, one is circular and the remaining (i.e., n-1) are elliptical in shape.

These possible sub-orbits possess slightly different energies because of the relativistic variation of the electron mass.

Consider the first energy level (n=1). When n = 1, l = 0 i.e., in this energy level, there is only one orbit or sub-shell for the electron. Also, when a = b, the two axes of the ellipse are equal. As a result of this, the orbit corresponding to n=1 is circular. This subshell is designated as s sub-shell. Since, this sub-shell belongs to n=1, it is designated as 1s (Fig a).

Similarly, for the second energy level n=2, there are two permissible sub-shells for the electrons. For n=2, l can take two values, 0 and 1.

When n = 2, l = 0.

b/a= 0+1/2 =1/2

or

b=a/2

This subshell corresponding to l = 0 is elliptical in shape and is designated as 2s.

when n = 2, l = 1.

b/a= 1+1/2 =2/2 =1

or

b=a

This sub-shell corresponding to l = 1 is circular in shape and is designated as 2p (Fig b).

For n = 3, l has three values 0, 1 and 2, i.e. there are three permissible sub-shells for the electrons.

when n = 3, l = 0.

b/a= (0+1)/3 =1/3 =1 or b=a/3

when n = 3, l = 1.

b/a= (1+1)/3 =2/3 =1 or b=2a/3

and when n = 3, l = 2.

b/a= (2+1)/3 =3/3 =1 or b=a

The sub-shells corresponding to l = 0, 1 and 2 are designated as 3s, 3p and 3d respectively. The circular shell is designated as 3d and the other two are elliptical in shape (Fig c).

It is common practice to assign letters to l-values as given below:

Orbital quantum number l	:	0	1	2	3	4
electron state :		s	p	d	f	g

Hence, electrons in the l = 0, 1, 2, 3 states are said to be in the s, p, d, f states.

Fine structure of spectral line

Based on Sommerfeld atom model, the total energy of an electron in the elliptical orbit can be shown as,

En = (-me4Z2) / (8ε02h2n2)

This expression is the same as that obtained by Bohr. Thus the introduction of elliptical orbits gives no new energy levels and hence no new transition. In this way, the attempt of Sommerfeld to explain the fine structure of spectral lines failed. But soon, on the basis of variation of mass of electron with velocity, Sommerfeld could find the solution for the problem of the fine structure of the spectral lines.

According to Sommerfeld, the velocity of the electron is maximum when the electron is nearest to the nucleus and minimum when it is farthest from the nucleus, since the orbit of the electron is elliptical. This implies that the effective mass of the electron will be different at different parts of its orbit. Taking into account the relativistic variation of the mass of the electron, Sommerfeld modified his theory and showed that the path of electron is not a simple ellipse but a precessing ellipse called a rosette (Fig).

Based on this idea, Sommerfeld successfully explained the fine structure of spectral lines of hydrogen atom.

Drawbacks

(i) Though Sommerfeld's modification gave a theoretical background of the fine structure of spectral lines of hydrogen, it could not predict the correct number of observed fine structure of these lines.

(ii) It could not explain the distribution and arrangement of electrons in atoms.

(iii) Sommerfeld's model was unable to explain the spectra of alkali metals such as sodium, potassium etc.

(iv) It could not explain Zeeman and Stark effect.

(v) This model does not give any explanation for the intensities of the spectral lines.

Vector model of the atom

This model is fully about orbital angular momentum in quantum mechanics in the context of the atom. In physics, in particular quantum mechanics, the vector model of the atom is a model of the atom in terms of angular momentum.[1] It can be considered as the extension of the Rutherford-Bohr-Sommerfeld atom model to multi-electron atoms.

The model is a convenient representation of the angular momenta of the electrons in the atom. Angular momentum is always split into orbital L, spin S and total J:

Given that in quantum mechanics, angular momentum is quantized and there is an uncertainty relation for the components of each vector, the representation turns out to be quite simple (although the background mathematics is quite complex). Geometrically it is a discrete set of right-circular cones, without the circular base, in which the axes of all the cones are lined up onto a common axis, conventionally the z-axis for three-dimensional Cartesian coordinates.[2] Following is the background to this construction.

Mathematical background of angular momenta

Cones of spin angular momentum, here shown for a spin-1/2 particle

The commutator implies that for each of L, S, and J, only one component of any angular momentum vector can be measured at any instant of time; at the same the other two are indeterminate. The commutator of any two angular momentum operators (corresponding to component directions) is non-zero. Following is a summary of the relevant mathematics in constructing the vector model.

The commutation relations are (using the Einstein summation convention):

In multi-electron atoms, the vector sum of two angular momenta is:

$$\mathbf{J} = \mathbf{J}_1 + \mathbf{J}_2$$

for the z-component, the projected values are:

$$J_z = J_{1z} + J_{2z}$$

where

$$\mathbf{J}_z = m_j \hbar$$
$$\mathbf{J}_{1z} = m_{j_1} \hbar$$
$$\mathbf{J}_{2z} = m_{j_2} \hbar$$

and the magnitudes are:

$$|\mathbf{J}| = \hbar\sqrt{j(j+1)}$$
$$|\mathbf{J}_1| = \hbar\sqrt{j_1(j_1+1)}$$
$$|\mathbf{J}_2| = \hbar\sqrt{j_2(j_2+1)}$$

in which

$$j \in \{|j_1 - j_2|, |j_1 - j_2| - 1 \cdots j_1 + j_2 - 1, j_1 + j_2\}$$

Where

- L = (L1, L2, L3), S = (S1, S2, S3) and J = (J1, J2, J3) (these correspond to L = (Lx, Ly, Lz), S = (Sx, Sy, Sz) and J = (Jx, Jy, Jz) in Cartesian coordinates),

- a, b, c ∈ {1,2,3} are indices labelling the components of angular momenta
- εabc is the 3-index permutation tensor in 3-d.

The magnitudes of L, S and J however can be measured at the same time, since the commutation of the square of an angular momentum operator (full resultant, not components) with any one component is zero.

These mathematical facts suggest the continuum of all possible angular momenta for a corresponding specified quantum number:

One direction is constant, the other two are variable.

The magnitude of the vectors must be constant (for a specified state corresponding to the quantum number), so the two indeterminate components of each of the vectors must be confined to a circle, in such a way that the measurable and un-measurable components (at an instant of time) allow the magnitudes to be constructed correctly, for all possible indeterminate components.

The geometrical result is a cone of vectors, the vector starts at the apex of the cone and its tip reaches the circumference of the cone. It is convention to use the z-component for the measurable component of angular momentum, so the axis of the cone must be the z-axis, directed from the apex to the plane defined by the circular base of the cone, perpendicular to the plane. For different quantum numbers, the cones are different. So there are a discrete number of states the angular momenta can be, ruled by the above possible values for , s, and j. Using the previous set-up of the vector as part of a cone, each state must correspond to a cone. This is for increasing , s, and j, and decreasing , s, and j> Negative quantum numbers correspond to cones reflected in the x-y plane. One of these states, for a quantum number equal to zero, clearly doesn't correspond to a cone, only a circle in the x-y plane.

The number of cones (including the degenerate planar circle) equals the multiplicity of states, .

Bohr model

It can be considered the extension of the Bohr model because Niels Bohr also proposed angular momentum was quantized according to:

where m is an integer, produced correct results for the Hydrogen atom. Although the Bohr model doesn't apply to multi-electron atoms, it was the first successful quantization of angular momentum applied to the atom, preceding the vector model of the atom.

Addition of angular momenta

For one-electron atoms (i.e. hydrogen), there is only one set of cones for the orbiting electron. For multi-electron atoms, there are many states, due to the increasing number of electrons.

The angular momenta of all electrons in the atom add vectorially. Most atomic processes, both nuclear and chemical (electronic) – except in the absolutely stochastic process of radioactive decay - are determined by spin-pairing and coupling of angular momenta due to neighbouring nucleons and electrons. The term "coupling" in this context means the vector superposition of angular momenta, that is, magnitudes and directions are added.

This process may be repeated for a third electron, then the fourth etc. until the total angular momentum has been found.

LS coupling

The process of adding all angular momenta together is a laborious task, since the resultant momenta is not definite, the entire cones of precising momenta about the z-axis must be incorporated into the calculation. This can be simplified by some developed approximations -

such as the Russell-Saunders coupling scheme in L-S coupling, named after H. N. Russell and F. A. Saunders (1925).

Pauli Exclusion Principle

The Pauli Exclusion Principle states that, in an atom or molecule, no two electrons can have the same four electronic quantum numbers. As an orbital can contain a maximum of only two electrons, the two electrons must have opposing spins. This means if one is assigned an up-spin (+1/2), the other must be down-spin (-1/2).

Electrons in the same orbital have the same first three quantum numbers, e.g., n=1n=1, l=0l=0, ml=0ml=0 for the 1s subshell. Only two electrons can have these numbers, so that their spin moments must be either ms=−1/2ms=−1/2 or ms=+1/2ms=+1/2. If the 1s orbital contains only one electron, we have one ms value and the electron configuration is written as 1s1 (corresponding to hydrogen). If it is fully occupied, we have two ms values, and the electron configuration is 1s2 (corresponding to helium). Visually these two cases can be represented as

As you can see, the 1s and 2s subshells for beryllium atoms can hold only two electrons and when filled, the electrons must have opposite spins. Otherwise they will have the same four quantum numbers, in violation of the Pauli Exclusion Principle.

Various quantum numbers

The four quantum numbers are the principle quantum number, n, the angular momentum quantum number, l, the magnetic quantum number, ml, and the electron spin quantum number, ms.

The principle quantum number , n, describes the energy and distance from the nucleus, and represents the shell. For example, the 3d subshell is in the n=3 shell, the 2s subshell is in the n=2 shell, etc.

The angular momentum quantum number , l, describes the shape of the subshell and its orbitals, where l=0,1,2,3... corresponds to s,p,d, and f subshells (containing s,p,d,f orbitals), respectively. For example, the n=3 shell has subshells of l=0,1,2, which means the n=3 shell contains s, p, and d subshells (each containing their respective orbitals). The n=2 shell has l=0,1, so it contains only s and p subshells. It is worth noting that each shell has up to n−1 types of subshells/orbitals.

The magnetic quantum number , ml, describes the orientation of the orbitals (within the subshells) in space. The possible values for ml of any type of orbital (s,p,d,f...) is given by any integer value from −l to l. So, for a 2p orbital with n=2 and l=1, we can have m1=−1,0,1. This tells us that the p orbital has 3 possible orientations in space.

If you've learned anything about group theory and symmetry in chemistry, for example, you might remember having to deal with various orientations of orbitals. For the p orbitals, those are px, py, and pz. So, we would say that the 2p subshell contains three 2p orbitals (shown below).

Finally, the electron spin quantum number, ms, has only two possible values, +12and−12. As the name implies, these values describe the spin of each electron in the orbital. Remember that there are only two electrons to every orbital, and that they should have opposite spins (think Pauli exclusion principle). This tells us that there are two electrons per orbital, or per ml value, one with an ms value of +12 and one with an ms value of −12. Therefore, n describes the shell, both n and l describe a subshell, n, l, and ml describe an orbital, and all four quantum numbers (n, l, ml, ms) describe an electron.

Quantization of Orbitals:

1. Orbitals are not quantized. An atomic orbital is a mathematical function that describes the wave-like behavior of electrons in an atom. This function can be used to calculate the probability of finding any electron of an atom in any specific region around the atom's nucleus. The term may also refer to the physical region or space where the electron can be calculated to be present, as defined by the particular mathematical form of the orbital. It is the energy, angular momentum, velocity, etc., of the electron that are quantized.

2. Electromagnetic radiation is quantized in the sense that it can be thought of travelling in the form of particles called photons. There are numerous evidences in the support of this fact such as photoelectric effect, compton effect, etc.

X-Ray Spectrum – Characteristic and Continuous

X-rays, also known as X-radiation, refers to electromagnetic radiation (no rest mass, no charge) of high energies. X-rays are high-energy photons with short wavelengths and thus very high frequency. The radiation frequency is key parameter of all photons, because it determines the energy of a photon. Photons are categorized according to the energies from low-energy radio waves and infrared radiation, through visible light, to high-energy X-rays and gamma rays.

Most X-rays have a wavelength ranging from 0.01 to 10 nanometers (3×1016 Hz to 3×1019 Hz), corresponding to energies in the range 100 eV to 100 keV. X-ray wavelengths are shorter than those of UV rays and typically longer than those of gamma rays.

X-Ray Spectrum – Characteristic and Continuous

For X-rays generated by X-ray tube, the part of energy that is transformed into radiation varies from zero up to the maximum energy of the electron when it hits the anode. The maximum energy of the produced X-ray photon is limited by the energy of the incident electron, which is equal to the voltage on the tube times the electron charge, so an 100 kV tube cannot create X-rays with an energy greater than 100 keV. When the electrons hit the target, X-rays are created by two different atomic processes:

- Bremsstrahlung. The bremsstrahlung is electromagnetic radiation produced by the acceleration or deceleration of an electron when deflected by strong electromagnetic fields of target high-Z (proton number) nuclei. The name bremsstrahlung comes from the German. The literal translation is ‘braking radiation’. From classical theory, when a charged particle is accelerated or decelerated, it must radiate energy. The bremsstrahlung is one of possible interactions of light charged particles with matter (especially with high atomic numbers). These X-rays have a continuous spectrum. The intensity of the X-rays increases linearly with decreasing frequency, from zero at the energy of the incident electrons, the voltage on the X-ray tube. Changing the material from which the target in the tube is made has no effect on the spectrum of this continuous radiation. If we were to switch from a molybdenum target to a copper target, for example, all features of the x-ray spectrum would change except the cutoff wavelength.

- Characteristic X-ray emission. If the electron has enough energy it can knock an orbital electron out of the inner electron shell of a metal atom. Since the process leaves a vacancy in the electron energy level from which the electron came, the outer electrons of the atom cascade down to fill the lower atomic levels, and one or more characteristic X-rays are usually emitted. As a result, sharp intensity peaks appear in the spectrum at wavelengths that are a characteristic of the material from which the anode target is made. The frequencies of the characteristic X-rays can be predicted from the Bohr model.

Internal conversion is an electromagnetic process, by which a nuclear excited state decays by the direct emission of one of its atomic electrons.

Since the process leaves a vacancy in the electron energy level from which the electron came, the outer electrons of the atom cascade down to fill the lower atomic levels, and one or more characteristic X-rays are usually emitted. Sometimes X-ray may interact with another orbital electron, which may be ejected from the atom. This second ejected electron is called an Auger electron. This is very similar to electron capture, but in case of electron capture, a nucleus changes its atomic number. As a result, the atom thus emits primary high energy electron, characteristic X-rays or secondary Auger electron, none of which originate in that nucleus.

Moseley's Law

Introduction to Moseley's Law

Soon after Rutherford's scattering theory had been confirmed by experiment (about 1913), the one-to-one association of an atomic number Z with each element was solidified by the work of Henry Moseley (1887- 1915). He used Bohr's model of atomic structure to determine the energy emitted when low-level electrons change orbitals. This energy has a strong dependence on an atomic number so that by measuring the energy of the x-rays characteristic of an element, its atomic number Z can be unambiguously determined. In today's lab, you will measure the x-ray spectra of a number of elements and also identify several unknown elements by looking at their characteristic x-ray spectra.

Moseley's law is an empirical law concerning the characteristic x-rays that are emitted by atoms. The law was discovered and published by the English physicist Henry Moseley in 1913.

A widespread simplification is an idea that the effective charge of the nucleus decreases by 1 when it is being screened by an unpaired electron that remains behind in the K-shell. In any case, Bohr's formula for Moseley's K-alpha X-ray transitions became:

Apparatus:

- The setup is quite simple. First, a 57Co γ-ray source decays in such a way as to produce (among other things) several photons mainly consisting of 136 keV, 122 keV and 14 keV γ-rays. [Later in the course we will learn that the 57Co undergoes electron capture, the product of which is an 57Fe nucleus in an excited state. Upon relaxation the 57Fe nucleus emits the γ−rays.] The γ-rays strike the shielded target and knock electrons out from the target atoms. Other electrons drop down to fill the hole created by the ejected electron and in the process emit characteristic x-rays.
- A proportional tube is used to detect the x-rays. It consists of a chamber filled with a noble gas (typically xenon). A thin positively charged wire runs along the axis. When an x-ray interacts inside the tube, it ejects electrons from the gas atoms. These are attracted to the wire, speed up enough to eject other electrons, and eventually cause a cascade of electrons to accelerate toward the wire. This charge pulse is amplified and recorded. The strength of the signal is proportional to the x-ray energy deposited in the tube; hence the name "proportional tube." Please be very careful with the tube because the Be window is very thin and fragile.
- You will use a multi-channel analyzer to determine x-ray energies. The multi-channel analyzer is mounted on a card inside the PC. A multi-channel analyzer measures all of the voltage pulses from the proportional tube and sorts them into bins according to their strength. Each bin records pulses that fall within a set energy range and the bins form a sequential array so that the bin number N is proportional to the strength of the voltage pulse (which, if we use a proportional tube, is proportional to the x-ray energy.)

Experiment:

- The detector will see more than just the x-rays of interest to you. In addition, γ-rays directly from the Co source will strike the detector. More importantly, source γ's will also interact in the shielding, producing a lead x-ray spectrum. Since there is so much more the lead shielding than there is a sample, this may mask the signal. To eliminate this background, the data are accumulated in two steps. First, with the multi-channel analyzer on add, data are accumulated for some predetermined time. Then the sample is removed and the analyzer is set to subtract. Data are accumulated for the same amount of time. This eliminates the background counts at the same rate they were accumulated, resulting in data which represent only the contribution from the sample.

- First measure the x-ray spectra of six known samples: Al, Ti, Cu, Zr, Ag, and Te. Save your data to files that you can read later.
- Measure the spectra from a two of unknown elements. Again, save your data to files that you can read later.

Analysis:

- First, you should confirm Moseley's law with six known samples. Since the energy of the characteristic x-ray should (according to Moseley) be proportional to (Z-δ) 2 and channel number N is proportional to E, then N is proportional to (Z-δ) 2 . Thus, N kZ = − b g δ . Make a plot of N vs. Z for the six known samples. Obtain the best value of k and δ from this graph. Look at your spectra carefully and think about what the uncertainties in your data are. Devise a reasonable method for determining the uncertainties in δ and k.
- Determine Z for the unknowns by comparing the peak position for each with your results from the six known samples. Don't forget about the uncertainty associated with this determination.

What is Bragg's Law and Why is it Important?

Bragg's Law refers to the simple equation:

(eq 1) n = 2d sin

derived by the English physicists Sir W.H. Bragg and his son Sir W.L. Bragg in 1913 to explain why the cleavage faces of crystals appear to reflect X-ray beams at certain angles of incidence (theta,). The variable d is the distance between atomic layers in a crystal, and the variable lambda is the wavelength of the incident X-ray beam (see applet); n is an integer

This observation is an example of X-ray wave interference (Roentgenstrahlinterferenzen), commonly known as X-ray diffraction (XRD), and was direct evidence for the periodic atomic structure of crystals postulated for several centuries. The Braggs were awarded the Nobel Prize in physics in 1915 for their work in determining crystal structures beginning with NaCl, ZnS and diamond. Although Bragg's law was used to explain the interference pattern of X-rays scattered by crystals, diffraction has been developed to study the structure of all states of matter with any beam, e.g., ions, electrons, neutrons, and protons, with a wavelength similar to the distance between the atomic or molecular structures of interest.

How to Use this Applet

The applet shows two rays incident on two atomic layers of a crystal, e.g., atoms, ions, and molecules, separated by the distance d. The layers look like rows because the layers are projected onto two dimensions and your view is parallel to the layers. The applet begins with the scattered rays in phase and interferring constructively. Bragg's Law is satisfied and diffraction is occurring. The meter indicates how well the phases of the two rays match. The small light on the meter is green when Bragg's equation is satisfied and red when it is not satisfied.

The meter can be observed while the three variables in Bragg's are changed by clicking on the scroll-bar arrows and by typing the values in the boxes. The d and variables can be changed by dragging on the arrows provided on the crystal layers and scattered beam, respectively.

Deriving Bragg's Law

Bragg's Law can easily be derived by considering the conditions necessary to make the phases of the beams coincide when the incident angle equals and reflecting angle. The rays of the incident beam are always in phase and parallel up to the point at which the top beam strikes the top layer at atom z (Fig. 1). The second beam continues to the next layer where it is scattered by atom B. The second beam must travel the extra distance AB + BC if the two beams are to continue traveling adjacent and parallel. This extra distance must be an integral (n) multiple of the wavelength ( ) for the phases of the two beams to be the same:

(eq 2) n = AB +BC .

Recognizing d as the hypotenuse of the right triangle Abz, we can use trigonometry to relate d and to the distance (AB + BC). The distance AB is opposite so,

(eq 3) AB = d sin .

Because AB = BC eq. (2) becomes,

(eq 4) n = 2AB

Substituting eq. (3) in eq. (4) we have,

(eq 1) n = 2 d sin

and Bragg's Law has been derived. The location of the surface does not change the derivation of Bragg's Law.

Players in the Discovery of X-ray Diffraction

Friedrich and Knipping first observed Roentgenstrahlinterferenzen in 1912 after a hint from their research advisor, Max von Laue, at the University of Munich. Bragg's Law greatly simplified von Laue's description of X-ray interference. The Braggs used crystals in the reflection geometry to analyze the intensity and wavelengths of X-rays (spectra) generated by different materials. Their apparatus for characterizing X-ray spectra was the Bragg spectrometer.

Laue knew that X-rays had wavelengths on the order of 1 Å. After learning that Paul Ewald's optical theories had approximated the distance between atoms in a crystal by the same length, Laue postulated that X-rays would diffract, by analogy to the diffraction of light from small periodic scratches drawn on a solid surface (an optical diffraction grating). In 1918 Ewald constructed a theory, in a form similar to his optical theory, quantitatively explaining the

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fundamental physical interactions associated with XRD. Elements of Ewald's eloquent theory continue to be useful for many applications in physics.

If we use X-rays with a wavelength ( ) of 1.54Å, and we have diamonds in the material we are testing, we will find peaks on our X-ray pattern at values that correspond to each of the d-spacings that characterize diamond. These d-spacings are 1.075Å, 1.261Å, and 2.06Å. To discover where to expect peaks if diamond is present, you can set to 1.54Å in the applet, and set distance to one of the d-spacings. Then start with at 6 degrees, and vary it until you find a Bragg's condition. Do the same with each of the remaining d-spacings. Remember that in the applet, you are varying , while on the X-ray pattern printout, the angles are given as 2 . Consequently, when the applet indicates a Bragg's condition at a particular angle, you must multiply that angle by 2 to locate the angle on the X-ray pattern printout where you would expect a peak.

Nuclear forces

Nuclear forces (also known as nuclear interactions or strong forces) are the forces that act between two or more nucleons. They bind protons and neutrons (“nucleons”) into atomic nuclei. The nuclear force is about 10 millions times stronger than the chemical binding that holds atoms together in molecules. This is the reason why nuclear reactors produce about a million times more energy per kilogram fuel as compared to chemical fuel like oil or coal. However, the range of the nuclear force is short, only a few femtometer (1 fm =10−15 m), beyond which it decreases rapidly. That is why, in spite of its enormous strength, we do not feel anything of this force on the atomic scale or in everyday life. The development of a proper theory of nuclear forces has occupied the minds of some of the brightest physicists for seven decades and has been one of the main topics of physics research in the 20th century. The original idea was that the force is caused by the exchange of particles lighter than nucleons known as mesons, and this idea gave rise to the birth of a new sub-field of modern physics, namely, (elementary) particle physics. The modern perception of the nuclear force is that it is a residual interaction (similar to the van der Waals force between neutral atoms) of the even stronger force between quarks, which is mediated by the exchange of gluons and holds the quarks together inside a nucleon.

Characteristics of the nuclear force

Some properties of nuclear interactions can be deduced from the properties of nuclei. Nuclei exhibit a phenomenon known as saturation: the volume of nuclei increases proportionally to the number of nucleons. This property suggests that the nuclear (central) force is of short range (a few fm) and strongly attractive at that range, which explains nuclear binding. But the nuclear force has also a very complex spin-dependence. Evidence of this property first came from the observation that the deuteron (the proton-neutron bound state, the smallest atomic nucleus) deviates slightly from a spherical shape: it has a non-vanishing quadrupole moment. This suggests a force that depends on the orientation of the spins of the nucleons with regard to the vector joining the two nucleons (a tensor force). In heavier nuclei, a shell structure has been observed which, according to a proposal by M. G. Mayer and J. H. D. Jensen, can be explained by a strong force between the spin of the nucleon and its orbital motion (the spin-orbit force). More clear-cut evidence for the spin-dependence is extracted from scattering experiments where one nucleon is scattered off another nucleon, with distinct spin orientations. In such experiments, the existence of the nuclear spin-orbit and tensor forces has clearly been established. Scattering experiments at higher energies (more than 200 MeV) provide evidence that the nucleon-nucleon interaction turns repulsive at short inter-nucleon distances (smaller than 0.5 fm, the hard core).

Besides the force between two nucleons (2NF), there are also three-nucleon forces (3NFs), four-nucleon forces (4NFs), and so on. However, the 2NF is much stronger than the 3NF, which in turn is much stronger than the 4NF, and so on. In exact calculations of the properties of light nuclei based upon the “elementary” nuclear forces, it has been shown that 3NFs are important. Their contribution is small, but crucial. The need for 4NFs for explaining nuclear properties has not (yet) been established.

Nuclear forces are approximately charge-independent meaning that the force between two protons, two neutrons, and a proton and a neutron are nearly the same (in the same quantum mechanical state) when electromagnetic forces are ignored.

Liquid Drop Model of Nucleus

One of the first models which could describe very well the behavior of the nuclear binding energies and therefore of nuclear masses was the mass formula of von Weizsaecker (also called the semi-empirical mass formula – SEMF), that was published in 1935 by German physicist Carl Friedrich von Weizsäcker. This theory is based on the liquid drop model proposed by George Gamow.

According to this model, the atomic nucleus behaves like the molecules in a drop of liquid. But in this nuclear scale, the fluid is made of nucleons (protons and neutrons), which are held together by the strong nuclear force. The liquid drop model of the nucleus takes into account the fact that the nuclear forces on the nucleons on the surface are different from those on nucleons in the interior of the nucleus. The interior nucleons are completely surrounded by other attracting nucleons. Here is the analogy with the forces that form a drop of liquid.

In the ground state the nucleus is spherical. If the sufficient kinetic or binding energy is added, this spherical nucleus may be distorted into a dumbbell shape and then may be splitted into two fragments. Since these fragments are a more stable configuration, the splitting of such heavy nuclei must be accompanied by energy release. This model does not explain all the properties of the atomic nucleus, but does explain the predicted nuclear binding energies.

Volume term – aV.A. The first two terms describe a spherical liquid drop of an incompressible fluid with a contribution from the volume scaling with A and from the surface, scaling with A2/3. The first positive term aV.A is known as the volume term and it is caused by the attracting strong forces between the nucleons. The strong force has a very limited range and a

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given nucleon may only interact with its direct neighbours. Therefore this term is proportional to A, instead of A2. The coefficient aV is usually about ~ 16 MeV.

Surface term – asf.A2/3. The surface term is also based on the strong force, it is, in fact, a correction to the volume term. The point is that particles at the surface of the nucleus are not completely surrounded by other particles. In the volume term, it is suggested that each nucleon interacts with a constant number of nucleons, independent of A. This assumption is very nearly true for nucleons deep within the nucleus, but causes an overestimation of the binding energy on the surface. By analogy with a liquid drop this effect is indicated as the surface tension effect. If the volume of the nucleus is proportional to A, then the geometrical radius should be proportional to A1/3 and therefore the surface term must be proportional to the surface area i.e. proportional to A2/3.

Coulomb term – aC.Z2.A-⅓. This term describes the Coulomb repulsion between the uniformly distributed protons and is proportional to the number of proton pairs Z2/R, whereby R is proportional to A1/3. This effect lowers the binding energy because of the repulsion between charges of equal sign.

Asymmetry term – aA.(A-2Z)2/A. This term cannot be described as 'classically' as the first three. This effect is not based on any of the fundamental forces, this effect is based only on the Pauli exclusion principle (no two fermions can occupy exactly the same quantum state in an atom). The heavier nuclei contain more neutrons than protons. These extra neutrons are necessary for stability of the heavier nuclei. They provide (via the attractive forces between the neutrons and protons) some compensation for the repulsion between the protons. On the other hand, if there are significantly more neutrons than protons in a nucleus, some of the neutrons will be higher in energy level in the nucleus. This is the basis for a correction factor, the so-called symmetry term.

Pairing term – δ(A,Z). The last term is the pairing term δ(A,Z). This term captures the effect of spin-coupling. Nuclei with an even number of protons and an even number of neutrons are (due to Pauli exclusion principle) very stable thanks to the occurrence of 'paired spin'. On the other hand, nuclei with an odd number of protons and neutrons are mostly unstable.

With the aid of the Weizsaecker formula the binding energy can be calculated very well for nearly all isotopes. This formula provides a good fit for heavier nuclei. For light nuclei, especially for 4He, it provides a poor fit. The main reason is the formula does not consider the internal shell structure of the nucleus.

In order to calculate the binding energy, the coefficients aV, aS, aC, aA and aP must be known. The coefficients have units of megaelectronvolts (MeV) and are calculated by fitting to experimentally measured masses of nuclei. They usually vary depending on the fitting methodology. According to ROHLF, J. W., Modern Physics from α to Z0 , Wiley, 1994., the coefficients in the equation are following:

Using the Weizsaecker formula, also the mass of an atomic nucleus can be derived and is given by:

m = Z.mp +N.mn -Eb/c2

where mp and mn are the rest mass of a proton and a neutron, respectively, and Eb is the nuclear binding energy of the nucleus.From the nuclear binding energy curve and from the table it can be seen that, in the case of splitting a 235U nucleus into two parts, the binding energy of the fragments (A ≈ 120) together is larger than that of the original 235U nucleus.

According to the Weizsaecker formula, the total energy released for such reaction will be approximately 235 x (8.5 – 7.6) ≈ 200 MeV.

Mass Defect

In physics and chemistry, a mass defect refers to the difference in mass between an atom and the sum of the masses of the protons, neutrons, and electrons of the atom.

This mass is typically associated with the binding energy between nucleons. The "missing" mass is the energy released by the formation of the atomic nucleus. Einstein's formula, E = mc2, may be applied to calculate the binding energy of a nucleus. According to the formula, when energy increases, mass and inertia increase. Removing energy reduces mass.

- A mass defect is the difference between an atom's mass and the sum of the masses of its protons, neutrons, and electrons.
- The reason the actual mass is different from the masses of the components is because some of the mass is released as energy when protons and neutrons bind in the atomic nucleus. Thus, the mass defect results in a lower-than-expected mass.
- The mass defect follows the conservation laws, where the sum of mass and energy of a system is constant, but matter can be converted into energy.

Mass Defect Example

For example, a helium atom containing two protons and two neutrons (four nucleons) has a mass about 0.8 percent lower than the total mass of four hydrogen nuclei, which each contain one nucleon.

Particle accelerator

A particle accelerator is a machine that uses electromagnetic fields to propel charged particles to very high speeds and energies, and to contain them in well-defined beams.[1]

Large accelerators are used for basic research in particle physics. The largest accelerator currently operating is the Large Hadron Collider (LHC) near Geneva, Switzerland, operated by the CERN. It is a collider accelerator, which can accelerate two beams of protons to an energy of 6.5 TeV and cause them to collide head-on, creating center-of-mass energies of 13 TeV. Other powerful accelerators are KEKB at KEK in Japan, RHIC at Brookhaven National Laboratory in New York and, formerly, the Tevatron at Fermilab, Batavia, Illinois. Accelerators are also used as synchrotron light sources for the study of condensed matter physics. Smaller particle accelerators are used in a wide variety of applications, including particle therapy for oncological purposes, radioisotope production for medical diagnostics, ion implanters for manufacture of semiconductors, and accelerator mass spectrometers for measurements of rare isotopes such as radiocarbon. There are currently more than 30,000 accelerators in operation around the world.[2]
There are two basic classes of accelerators: electrostatic and electrodynamic (or electromagnetic) accelerators.[3] Electrostatic accelerators use static electric fields to accelerate particles. The most common types are the Cockcroft–Walton generator and the Van de Graaff generator. A small-scale example of this class is the cathode ray tube in an ordinary old television set. The achievable kinetic energy for particles in these devices is determined by the accelerating voltage, which is limited by electrical breakdown.

Electrodynamic or electromagnetic accelerators, on the other hand, use changing electromagnetic fields (either magnetic induction or oscillating radio frequency fields) to accelerate particles. Since in these types the particles can pass through the same accelerating field multiple times, the output energy is not limited by the strength of the accelerating field. This class, which was first developed in the 1920s, is the basis for most modern large-scale accelerators.
Rolf Widerøe, Gustav Ising, LeóSzilárd, Max Steenbeck, and Ernest Lawrence are considered pioneers of this field, conceiving and building the first operational linear particle accelerator,[4] the betatron, and the cyclotron.

Because the target of the particle beams of early accelerators was usually the atoms of a piece of matter, with the goal being to create collisions with their nuclei in order to investigate nuclear structure, accelerators were commonly referred to as atom smashers in the 20th century.[5] The term persists despite the fact that many modern accelerators create collisions between two subatomic particles, rather than a particle and an atomic nucleus

Cyclotron Accelerators

The cyclotron principle involves using an electric field to accelerate charged particles across a gap between two "D-shaped" magnetic field regions. The magnetic field accelerates the particles in a semicircle, during which time the electric field is reversed in polarity to accelerate the charge particle again as it moves across the gap in the opposite direction. In this way a moderate electric field can accelerate charges to a high energy. This overcame the difficulty of electric discharge caused by the high DC voltages in the Cockroft-Walton and van de Graaf accelerators.

In 1930, Earnest O. Lawrence operated the first successful cyclotron, accelerating protons with a radio frequency (RF) voltage applied across the gap between the two "Dee" magnetic field regions. The first model was only 10 cm in diameter. A larger unit built with the assistance of M. Stanley Livingston was about 25 cm in diameter and accelerated protons to about 1 MeV of energy.

The upper bound on energy obtainable from the cyclotron is set by relativistic effects. Since the cyclotron frequency of the RF accelerating voltage depends upon the particle mass, the effects of relativistic mass cause the particle to get progressively more out of step with the accelerating voltage as its speed increases. This problem is addressed in the synchrocyclotron by varying the frequency of the accelerating voltage to track the relativistic effects.

Betatron

Invented in 1940 by D. W. Kerst, the betatron is a circular accelerator for electrons. It differs from the cyclotron in that the acceleration of the electrons is achieved by increasing the magnetic flux through the orbit of the electrons. The electrons travel in an orbit of fixed radius, and are accelerated by the magnetic field which also keeps them in the orbit.

In the betatron, one must deal with the relativistic effects on the electron as well as the loss of energy from radiation. All accelerated charges radiate electromagnetic energy, and accelerated electrons radiate more energy in a given kinetic energy range than would protons. This radiative energy loss, called synchrotron radiation, limits the maximum energy from the betatron to a few hundred MeV. The acceleration program for the increasing of the magnetic flux to keep the electron accelerating in a fixed-radius orbit must account for the change in the relativistic particle energy γmc2.

Fission and Fusion

The energy harnessed in nuclei is released in nuclear reactions. Fission is the splitting of a heavy nucleus into lighter nuclei and fusion is the combining of nuclei to form a bigger and heavier nucleus. The consequence of fission or fusion is the absorption or release of energy.

Introduction

Protons and neutrons make up a nucleus, which is the foundation of nuclear science. Fission and fusion involves the dispersal and combination of elemental nucleus and isotopes, and part of nuclear science is to understand the process behind this phenomenon. Adding up the individual masses of each of these subatomic particles of any given element will always give you a greater mass than the mass of the nucleus as a whole. The missing idea in this observation is the concept called nuclear binding energy. Nuclear binding energy is the energy required to keep the protons and neutrons of a nucleus intact, and the energy that is released during a nuclear fission or fusion is nuclear power. There are some things to consider however. The mass of an element's nucleus as a whole is less than the total mass of its individual protons and neutrons. The difference in mass can be attributed to the nuclear binding energy. Basically, nuclear binding energy is considered as mass, and that mass becomes "missing". This missing mass is called mass defect, which is the nuclear energy, also known as the mass released from the reaction as neutrons, photons, or any other trajectories. In short, mass defect and nuclear binding energy are interchangeable terms.

Nuclear Fission and Fusion

Nuclear fission is the splitting of a heavy nucleus into two lighter ones. Fission was discovered in 1938 by the German scientists Otto Hahn, Lise Meitner, and Fritz Strassmann, who bombarded a sample of uranium with neutrons in an attempt to produce new elements with Z > 92. They observed that lighter elements such as barium (Z = 56) were formed during the reaction, and they realized that such products had to originate from the neutron-induced fission of uranium-235:

23592U+10n→14156Ba+9236Kr+310n(21.6.11)(21.6.11)92235U+01n→56141Ba+3692Kr+301n

This hypothesis was confirmed by detecting the krypton-92 fission product. As discussed in Section 20.2, the nucleus usually divides asymmetrically rather than into two equal parts, and the fission of a given nuclide does not give the same products every time.

In a typical nuclear fission reaction, more than one neutron is released by each dividing nucleus. When these neutrons collide with and induce fission in other neighboring nuclei, a self-sustaining series of nuclear fission reactions known as a nuclear chain reaction can result (Figure 21.6.2). For example, the fission of 235U releases two to three neutrons per fission event. If absorbed by other 235U nuclei, those neutrons induce additional fission events, and the rate of the fission reaction increases geometrically. Each series of events is called a generation. Experimentally, it is found that some minimum mass of a fissile isotope is required to sustain a nuclear chain reaction; if the mass is too low, too many neutrons are able to escape without being captured and inducing a fission reaction. The minimum mass capable of supporting sustained fission is called the critical mass. This amount depends on the purity of the material and the shape of the mass, which corresponds to the amount of surface area available from which neutrons can escape, and on the identity of the isotope. If the mass of the fissile isotope is greater than the critical mass, then under the right conditions, the resulting supercritical mass can release energy explosively. The enormous energy released from nuclear chain reactions is responsible for the massive destruction caused by the detonation of nuclear weapons such as fission bombs, but it also forms the basis of the nuclear power industry.

Nuclear fusion, in which two light nuclei combine to produce a heavier, more stable nucleus, is the opposite of nuclear fission. As in the nuclear transmutation reactions discussed in Section 20.2, the positive charge on both nuclei results in a large electrostatic energy barrier to fusion. This barrier can be overcome if one or both particles have sufficient kinetic energy to overcome the electrostatic repulsions, allowing the two nuclei to approach close enough for a fusion reaction to occur. The principle is similar to adding heat to increase the rate of a chemical reaction. For example, in a typical fusion reaction, two deuterium atoms combine to produce helium-3, a process known as deuterium–deuterium fusion (D–D fusion):

221H→32He+10n(21.6.12)(21.6.12)212H→23He+01n

Because each neutron released can cause the fission of another 235U nucleus, the rate of a fission reaction accelerates geometrically. Each series of events is a generation.

In another reaction, a deuterium atom and a tritium atom fuse to produce helium-4, a process known as deuterium–tritium fusion (D–T fusion):

21H+31H→42He+10n(21.6.13)(21.6.13)12H+13H→24He+01n

Nuclear Fusion. In a nuclear fusion reaction, lighter nuclei combine to produce a heavier nucleus. As shown, fusion of 3H and 2H to give 4He and a neutron releases an enormous amount of energy. In principle, nuclear fusion can produce much more energy than fission, but very high kinetic energy is required to overcome electrostatic repulsions between the positively charged nuclei and initiate the fusion reaction.

Initiating these reactions, however, requires a temperature comparable to that in the interior of the sun (approximately 1.5 × 107 K). Currently, the only method available on Earth to achieve such a temperature is the detonation of a fission bomb. For example, the so-called hydrogen bomb (or H bomb) is actually a deuterium–tritium bomb (a D–T bomb), which uses a nuclear fission reaction to create the very high temperatures needed to initiate fusion of solid lithium deuteride (6LiD), which releases neutrons that then react with 6Li, producing tritium. The deuterium-tritium reaction releases energy explosively. Example 21.6.3 and its corresponding exercise demonstrate the enormous amounts of energy produced by nuclear fission and fusion reactions. In fact, fusion reactions are the power sources for all stars, including our sun.

To calculate the energy released during mass destruction in both nuclear fission and fusion, we use Einstein's equation that equates energy and mass:

$E=mc^2$

with

- m is mass (kilograms),
- c is speed of light (meters/sec) and
- E is energy (Joules).

UNIT – V

Digital Electronics

Digital Electronics: Decimal – binary – octal and hexadecimal numbers– their representation, inter-conversion, addition and subtraction, negative numbers. Sum of products – product of sums – their conversion – Simplification of Boolean expressions - K-Map – min terms – max terms - (2, 3 and 4 variables). Basic logic gates – AND, OR, NOT, NAND, NOR and EXOR gates – NAND and NOR as universal building gates – Boolean Algebra – Laws of Boolean Algebra – De Morgan's Theorems – Their verifications using truth tables.

Number Systems

There are infinite ways to represent a number. The four commonly associated with modern computers and digital electronics are: decimal, binary, octal, and hexadecimal.

Decimal (base 10) is the way most human beings represent numbers. Decimal is sometimes abbreviated as dec.

Decimal counting goes:
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, and so on.

Binary (base 2) is the natural way most digital circuits represent and manipulate numbers. (Common misspellings are "bianary", "bienary", or "binery".) Binary numbers are sometimes represented by preceding the value with '0b', as in 0b1011. Binary is sometimes abbreviated as bin.

Binary counting goes:

0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111, 10000, 10001, and so on.

Octal (base 8) was previously a popular choice for representing digital circuit numbers in a form that is more compact than binary. Octal is sometimes abbreviated as oct.

Octal counting goes:

0, 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, and so on.

Hexadecimal (base 16) is currently the most popular choice for representing digital circuit numbers in a form that is more compact than binary. (Common misspellings are “hexdecimal”, “hexidecimal”, “hexedecimal”, or “hexodecimal”.) Hexadecimal numbers are sometimes represented by preceding the value with '0x', as in 0x1B84. Hexadecimal is sometimes abbreviated as hex.

Hexadecimal counting goes:

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, 10, 11, and so on.

All four number systems are equally capable of representing any number. Furthermore, a number can be perfectly converted between the various number systems without any loss of numeric value.

At first blush, it seems like using any number system other than human-centric decimal is complicated and unnecessary. However, since the job of electrical and software engineers is to work with digital circuits, engineers require number systems that can best transfer information between the human world and the digital circuit world.

It turns out that the way in which a number is represented can make it easier for the engineer to perceive the meaning of the number as it applies to a digital circuit. In other words, the appropriate number system can actually make things less complicated.

Fundamental Information Element of Digital Circuits

Almost all modern digital circuits are based on two-state switches. The switches are either on or off. It doesn't matter if the switches are actually physical switches, vacuum tubes, relays, or transistors. And, it doesn't matter if the 'on' state is represented by 1.8 V on a cutting-edge CPU core, -12 V on a RS-232 interface chip, or 5 V on a classic TTL logic chip.

Because the fundamental information element of digital circuits has two states, it is most naturally represented by a number system where each individual digit has two states: binary.
For example, switches that are 'on' are represented by '1' and switches that are 'off' are represented by '0'. It is easy to instantly comprehend the values of 8 switches represented in binary as 10001101. It is also easy to build a circuit to display each switch state in binary, by having an LED (lit or unlit) for each binary digit.

Conversion of Numbers

Conversion of numbers from one system to another becomes necessary to understand the process and the logic of the operations of a computer system. It is not very difficult to convert numbers from one base to another. We will first discuss about the conversion of binary numbers to their decimal equivalents.

(i) Expansion Method:

In expansion method the conversion of binary numbers to their decimal equivalents are shown with the help of the examples.

1. Convert the decimal numbers to their binary equivalents:

(a) 256

Solution:

256

256	128	64	32	16	8	4	2	1
1	0	0	0	0	0	0	0	0

Since the given number 256 appears in the first row, we put 1 in the slot below 256 and fill all the other slots to the right of this slot with zeros.

Thus, $256_{10} = 100000000_2$

Addition and subtraction of octal numbers are explained using different examples.

Addition of octal numbers:

Addition of octal numbers is carried out by the same principle as that of decimal or binary numbers.

Evaluate:

(i) $(162)_8 + (537)_8$

Solution:

$$\begin{array}{r l} 1\,1 & \leftarrow\text{---- carry} \\ 1\,6\,2 & \\ \underline{5\,3\,7} & \\ 7\,2\,1 & \end{array}$$

Therefore, sum = 721_8

(ii) $(136)_8 + (636)_8$

Solution:

```
   1      <---- carry

  1 3 6
  6 3 6
  -----
  7 7 4
```

Therefore, sum = 774_8

(iii) $(25.27)_8 + (13.2)_8$

Solution:

```
  1          <---- carry

  2 5 . 2 7
  1 3 . 2
  ---------
  4 0 . 4 7
```

Therefore, sum = $(40.47)_8$

(iv) $(67.5)_8 + (45.6)_8$

Solution:

```
   1 1          <---- carry
   6 7 . 5
   4 5 . 6
 ---------
 1 3 5 . 3
```

Therefore, sum = $(135.3)_8$

(b) 77

Solution:

77

(b) 77

Solution:

77

The given number is less than 128 but greater than 64. We therefore put 1 in the slot corresponding to 64 in the first row. Next, we subtract 64 from 77 and get 13 as remainder.

This remainder is less than 16 and greater than 8. So we put 1 in the slot corresponding to 8 and subtract 8 from 13. This gives 13 - 8 = 5. This remainder is greater than 4 and less than 8.

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Hence we put 1 in the slot corresponding to 4 and subtracting 4 from 5 we get 1. Now, 1 is present in the right hand most slot of the first row. We, therefore, put 1 in the corresponding slot and fill all other slots with zeros.

Thus, 7710 = 10011012.

Conversion of decimal fractions to binary fractions may also be accomplished by using similar method. Let us observe the procedure with the help of the following example:

2. Convert 0.67510 to its binary equivalent.

Solution:

Convert Decial Number to Binary Number

Subtract .5 from the given number to get .675 - .5 = .175 and place 1 in the slot corresponding to .5 of the first row.

Now the number .175 is less than .25 and greater than .125. So, we put 1 in the slot corresponding to the number .125 of the first row and subtract .125 from .175 to get .175 - .125 = .05. The remainder .05 is less than .0625 but greater than .03125.

Hence we put 1 in the slot corresponding to 0.3125 and the subtraction given .05 - .03125 = .01875 and continue the process. The other slots are then filled with zeros.

64	32	16	8	4	2	1
1	0	0	1	1	0	1

Thus, .67510 = (.10101…)2

The given number is less than 128 but greater than 64. We therefore put 1 in the slot corresponding to 64 in the first row. Next, we subtract 64 from 77 and get 13 as remainder. This remainder is less than 16 and greater than 8. So we put 1 in the slot corresponding to 8 and subtract 8 from 13. This gives 13 - 8 = 5. This remainder is greater than 4 and less than 8.

(b) 77

Solution:

77

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Thus, .67510 = $(.10101\ldots)_2$

Subtraction of octal numbers:

Similarly, subtraction of octal numbers can be performed by following the rules of subtraction of decimal numbers.

Thus, for performing addition and subtraction of octal numbers we can follow the rules of addition and subtraction of decimal numbers.

Boolean functions may be practically implemented by using electronic gates. The following points are important to understand.

Electronic gates require a power supply.

Gate **INPUTS** are driven by voltages having two nominal values, e.g. 0V and 5V representing logic 0 and logic 1 respectively.

The **OUTPUT** of a gate provides two nominal values of voltage only, e.g. 0V and 5V representing logic 0 and logic 1 respectively. In general, there is only one output to a logic gate except in some special cases.

There is always a time delay between an input being applied and the output responding.

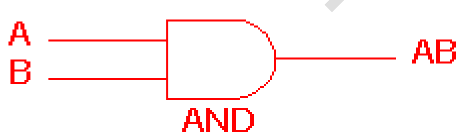
Truth Tables

Truth tables are used to help show the function of a logic gate. If you are unsure about truth tables and need guidence on how go about drawningthem for individual gates or logic circuits then use the truth table section link.

Logic gates

Digital systems are said to be constructed by using logic gates. These gates are the AND, OR, NOT, NAND, NOR, EXOR and EXNOR gates. The basic operations are described below with the aid of truth tables.

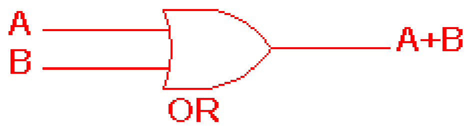
AND gate



2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

The AND gate is an electronic circuit that gives a **high** output (1) only if **all** its inputs are high. A dot (.) is used to show the AND operation i.e. A.B. Bear in mind that this dot is sometimes omitted i.e. AB

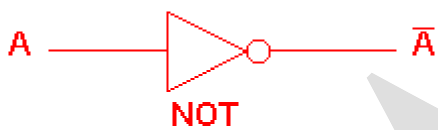
OR gate



2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

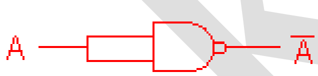
The OR gate is an electronic circuit that gives a high output (1) if **one or more** of its inputs are high. A plus (+) is used to show the OR operation.

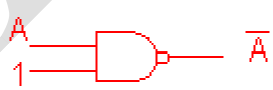
NOT gate



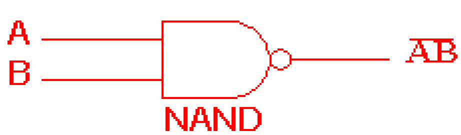
NOT gate	
A	$\overline{A}$
0	1
1	0

The NOT gate is an electronic circuit that produces an inverted version of the input at its output. It is also known as an *inverter*. If the input variable is A, the inverted output is known as NOT A. This is also shown as A', or A with a bar over the top, as shown at the outputs. The diagrams below show two ways that the NAND logic gate can be configured to produce a NOT gate. It can also be done using NOR logic gates in the same way.





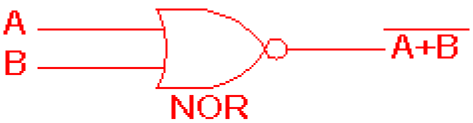
NAND gate



2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

This is a NOT-AND gate which is equal to an AND gate followed by a NOT gate. The outputs of all NAND gates are high if **any** of the inputs are low. The symbol is an AND gate with a small circle on the output. The small circle represents inversion.

NOR gate

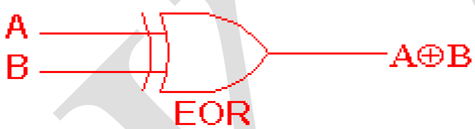


2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

This is a NOT-OR gate which is equal to an OR gate followed by a NOT gate. The outputs of all NOR gates are low if **any** of the inputs are high.

The symbol is an OR gate with a small circle on the output. The small circle represents inversion.

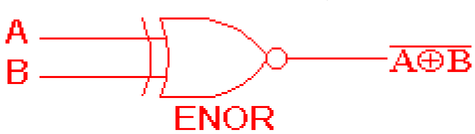
EXOR gate



2 Input EXOR gate		
A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

The '**Exclusive-OR**' gate is a circuit which will give a high output if **either, but not both**, of its two inputs are high. An encircled plus sign ($\oplus$) is used to show the EOR operation.

EXNOR gate



2 Input EXNOR gate		
A	B	$\overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

The '**Exclusive-NOR'** gate circuit does the opposite to the EOR gate. It will give a low output if **either, but not both**, of its two inputs are high. The symbol is an EXOR gate with a small circle on the output. The small circle represents inversion.

The NAND and NOR gates are called *universal functions* since with either one the AND and OR functions and NOT can be generated.

Note:

A function in *sum of products* form can be implemented using NAND gates by replacing all AND and OR gates by NAND gates.

A function in *product of sums* form can be implemented using NOR gates by replacing all AND and OR gates by NOR gates.

Table 1: Logic gate symbols

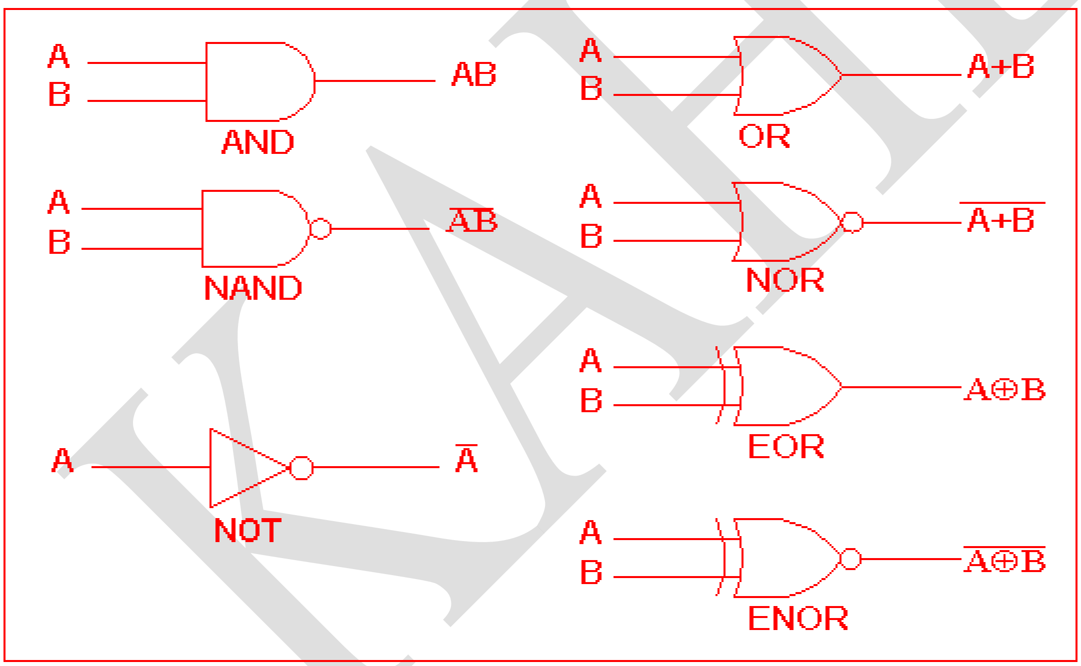


Table 2 is a summary truth table of the input/output combinations for the NOT gate together with all possible input/output combinations for the other gate functions. Also note that a truth table with 'n' inputs has 2^n rows. You can compare the outputs of different gates.

Table 2: Logic gates representation using the Truth table

NOT gate	
A	$\bar{A}$
0	1
1	0

INPUTS		OUTPUTS					
A	B	AND	NAND	OR	NOR	EXOR	EXNOR
0	0	0	1	0	1	0	1
0	1	0	1	1	0	1	0
1	0	0	1	1	0	1	0
1	1	1	0	1	0	0	1

Universal Gate | NAND and NOR Gate as Universal Gates

We have discussed different types of logic gates in previous articles. Now coming to the topic of this article we are going to discuss the **Universal Gate**. AND, NOT and OR gates are the basic gates; we can create any logic gate or any Boolean expression by combining a mixture of these gates.

But NOR gates and NAND gates have the particular property that any **one of them** can create any logical Boolean expression if appropriately designed. Meaning that you can create any logical Boolean expression using ONLY NOR gates or ONLY NAND gates. Other logical gates do not have this property. If you which to play around with these universal gates as part of an electronics project, many of the best Arduino starter kits contain these universal NOR and

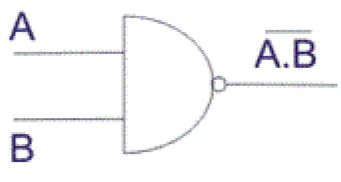
NAND gates.

Now we will look at the operation of NOR gates and NAND gates as **universal gates**.

NAND gate as Universal Gate

The below diagram is of a two input NAND gate. The first part is an AND gate and second part is a dot after it represents a NOT gate. So it is clear that during the operation of NAND gate, the inputs are first going through AND gate and after that, the output gets reversed, and we get the final output. Now we will look at the truth table of NAND gate.

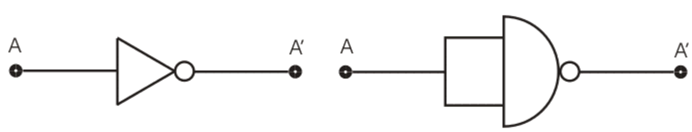
We will consider the truth table of the above NAND gate i.e. a two-input gate. The two inputs are A and B.



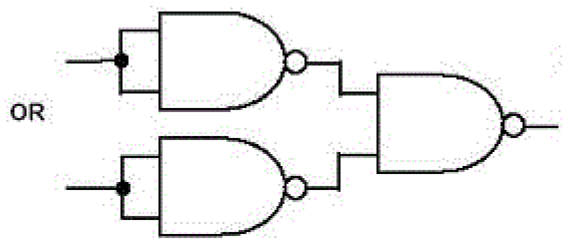
truth table of a nand gate

Inputs		Output
A	B	$X = \overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

Now we will see how this gate can be used to make other gates.



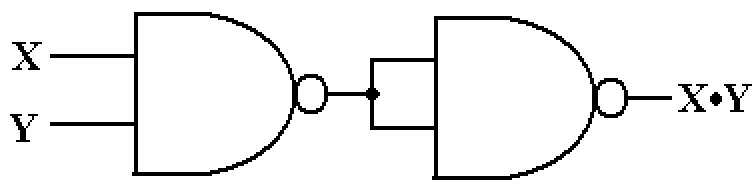
This is the circuit diagram of a NAND gate used to make work like a NOT gate, the original logic gate diagram of NOT gate is given besides.



A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

The above diagram is of an OR gate made from combinations of NAND gates, arranged in a proper manner. The truth table of an OR gate is also given beside the diagram.

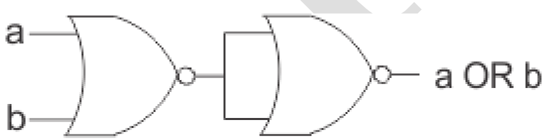
Now we will see the design of an AND gate from NAND gates.



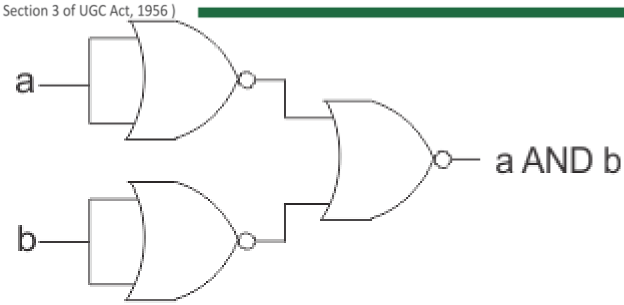
The above diagram is of an AND gate made from NAND gate. So we can see that all the three basic gates can be made by only using NAND gates, that's why this gate is called **Universal Gate**, and it is appropriate.

NOR gate as universal gate

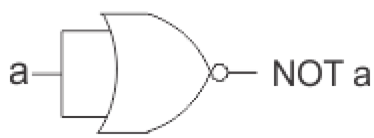
We have seen how NAND gate can be used to make all the three basic gates by using that alone. Now we will discuss the same in case of NOR gate.



The above diagram is of an OR gate made by only using NOR gates. The output of this gate is exactly similar to that of a single OR gate. We can see the circuit arrangement of OR gate using, NOR gate is similar to that of AND gate using NAND gates.



The above diagram as the name suggests is of AND gate using only NOR gate, again we can see that the circuit diagram of AND gate using only NOR gate is exactly similar to that of OR gate using only NAND gates. Now we will finally see how we can make a NOT gate by using only NOR gates.



The above diagram is of a NOT gate made by using a NOR gate. The circuit diagram is similar to that of NOT gate made by using only NAND gate.
So, from the above discussion, it is clear that all the three basic gates (AND, OR, NOT) can be made by only using NOR gate. And thus, it can be aptly termed as **Universal Gate**.

Laws of Boolean Algebra

As well as the logic symbols “0” and “1” being used to represent a digital input or output, we can also use them as constants for a permanently “Open” or “Closed” circuit or contact respectively.

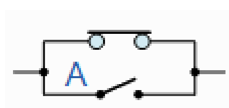
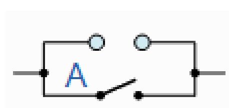
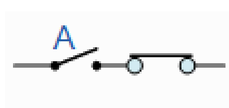
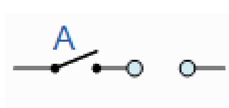
A set of rules or Laws of Boolean Algebra expressions have been invented to help reduce the number of logic gates needed to perform a particular logic operation resulting in a list of functions or theorems known commonly as the **Laws of Boolean Algebra**.

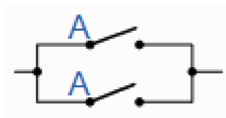
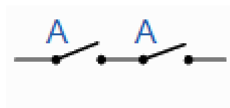
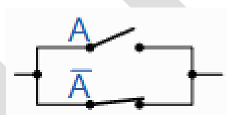
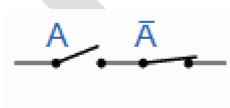
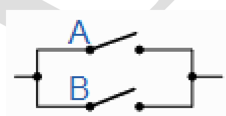
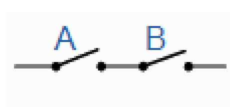
Boolean Algebra is the mathematics we use to analyse digital gates and circuits. We can use these “Laws of Boolean” to both reduce and simplify a complex Boolean expression in an attempt to reduce the number of logic gates required. *Boolean Algebra* is therefore a system of mathematics based on logic that has its own set of rules or laws which are used to define and reduce Boolean expressions.

The variables used in **Boolean Algebra** only have one of two possible values, a logic "0" and a logic "1" but an expression can have an infinite number of variables all labelled individually to represent inputs to the expression, For example, variables A, B, C etc, giving us a logical expression of A + B = C, but each variable can ONLY be a 0 or a 1.

Examples of these individual laws of Boolean, rules and theorems for Boolean Algebra are given in the following table.

Truth Tables for the Laws of Boolean

Boolean Expression	Description	Equivalent Switching Circuit	Boolean Algebra Law or Rule
A + 1 = 1	A in parallel with closed = "CLOSED"		Annulment
A + 0 = A	A in parallel with open = "A"		Identity
A . 1 = A	A in series with closed = "A"		Identity
A . 0 = 0	A in series with open = "OPEN"		Annulment

A + A = A	A in parallel with A = "A"		Idempotent
A . A = A	A in series with A = "A"		Idempotent
NOT A = A	NOT NOT A (double negative) = "A"		Double Negation
A + A = 1	A in parallel with NOT A = "CLOSED"		Complement
A . A = 0	A in series with NOT A = "OPEN"		Complement
A+B = B+A	A in parallel with B = B in parallel with A		Commutative
A.B = B.A	A in series with B = B in series with A		Commutative
A+B = A.B	invert and replace OR with AND		de Morgan’s Theorem
A.B = A+B	invert and replace AND with OR		de Morgan’s Theorem

Laws of Boolean Algebra

The basic **Laws of Boolean Algebra** that relate to the *Commutative Law* allowing a change in position for addition and multiplication, the *Associative Law* allowing the removal of brackets for addition and multiplication, as well as the *Distributive Law* allowing the factoring of an expression, are the same as in ordinary algebra.

Each of the *Boolean Laws* above are given with just a single or two variables, but the number of variables defined by a single law is not limited to this as there can be an infinite number of variables as inputs too the expression. These Boolean laws detailed above can be used to prove any given Boolean expression as well as for simplifying complicated digital circuits.

A brief description of the various **Laws of Boolean** are given below with A representing a variable input.

Description of the Laws of Boolean Algebra

A + (B + C) = (A + B) + C = A + B + C (OR Associate Law)

A(B.C) = (A.B)C = A . B . C (AND Associate Law)

(1) Two separate terms NOR´ed together is the same as the two terms inverted (Complement) and AND´ed for example: A+B = A . B

(2) Two separate terms NAND´ed together is the same as the two terms inverted (Complement) and OR´ed for example: A.B = A + B

Other algebraic Laws of Boolean not detailed above include:

Distributive Law – This law permits the multiplying or factoring out of an expression.

A(B + C) = A.B + A.C (OR Distributive Law)

A + (B.C) = (A + B).(A + C) (AND Distributive Law)

Absorptive Law – This law enables a reduction in a complicated expression to a simpler one by absorbing like terms.

A + (A.B) = A (OR Absorption Law)

A(A + B) = A (AND Absorption Law)

<u>Associative Law</u> – This law allows the removal of brackets from an expression and regrouping of the variables.

A + (B + C) = (A + B) + C = A + B + C (OR Associate Law)

A(B.C) = (A.B)C = A . B . C (AND Associate Law)

Boolean Algebra Functions

Using the information above, simple 2-input AND, OR and NOT Gates can be represented by 16 possible functions as shown in the following table.

Function	Description	Expression
1.	NULL	0
2.	IDENTITY	1
3.	Input A	A
4.	Input B	B
5.	NOT A	A
6.	NOT B	B
7.	A AND B (AND)	A . B
8.	A AND NOT B	A . B

9.	NOT A AND B	A . B
10.	NOT AND (NAND)	A . B
11.	A OR B (OR)	A + B
12.	A OR NOT B	A + B
13.	NOT A OR B	A + B
14.	NOT OR (NOR)	A + B
15.	Exclusive-OR	A . B + A . B
16.	Exclusive-NOR	A . B + A . B

Laws of Boolean Algebra Example No1

Using the above laws, simplify the following expression: (A + B)(A + C)

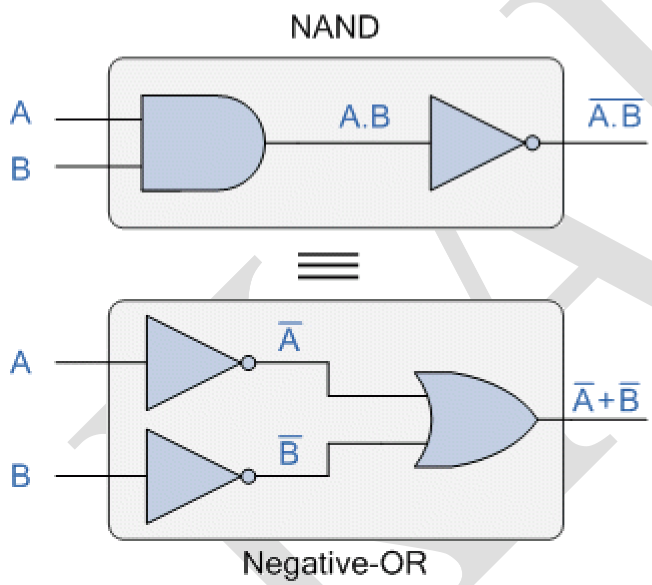
	Q =	(A + B).(A + C)
	A.A + A.C + A.B + B.C	– Distributive law
	A + A.C + A.B + B.C	– Idempotent AND law (A.A = A)
	A(1 + C) + A.B + B.C	– Distributive law
	A.1 + A.B + B.C	– Identity OR law (1 + C = 1)
	A(1 + B) + B.C	– Distributive law

	A.1 + B.C	– Identity OR law (1 + B = 1)
	A + (B.C)	– Identity AND law (A.1 = A)

Then the expression: (A + B)(A + C) can be simplified to A + (B.C) as in the Distributive law.

DeMorgan's Theorem

DeMorgan´s Theorem and Laws can be used to to find the equivalency of the NAND and NOR gates



As we have seen previously, Boolean Algebra uses a set of laws and rules to define the operation of a digital logic circuit with "0's" and "1's" being used to represent a digital input or output condition. Boolean Algebra uses these zeros and ones to create truth tables and mathematical expressions to define the digital operation of a logic AND, OR and NOT (or inversion) operations as well as ways of expressing other logical operations such as the XOR (Exclusive-OR) function.

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While George Boole's set of laws and rules allows us to analyise and simplify a digital circuit, there are two laws within his set that are attributed to **Augustus DeMorgan** (a nineteenth century English mathematician) which views the logical NAND and NOR operations as separate NOT AND and NOT OR functions respectively.

But before we look at **DeMorgan's Theory** in more detail, let's remind ourselves of the basic logical operations where A and B are logic (or Boolean) input binary variables, and whose values can only be either "0" or "1" producing four possible input combinations, 00, 01, 10, and 11.

Truth Table for Each Logical Operation

Input Variable		Output Conditions			
A	B	AND	NAND	OR	NOR
0	0	0	1	0	1
0	1	0	1	1	0
1	0	0	1	1	0
1	1	1	0	1	0

The following table gives a list of the common logic functions and their equivalent Boolean notation where a "." (a dot) means an AND operation, a "+" (plus sign) means an OR operation, and the complement or inverse of a variable is indicated by a bar over the variable.

Logic Function	Boolean Notation

AND	A.B
OR	A+B
NOT	A
NAND	A .B
NOR	A+B

DeMorgan's Theory

DeMorgan's Theorems are basically two sets of rules or laws developed from the Boolean expressions for AND, OR and NOT using two input variables, A and B. These two rules or theorems allow the input variables to be negated and converted from one form of a Boolean function into an opposite form.

DeMorgan's first theorem states that two (or more) variables NOR´ed together is the same as the two variables inverted (Complement) and AND´ed, while the second theorem states that two (or more) variables NAND´ed together is the same as the two terms inverted (Complement) and OR´ed. That is replace all the OR operators with AND operators, or all the AND operators with an OR operators.

DeMorgan's First Theorem

DeMorgan's First theorem proves that when two (or more) input variables are AND'ed and negated, they are equivalent to the OR of the complements of the individual variables. Thus the equivalent of the NAND function and is a negative-OR function proving that A.B = A+B and we can show this using the following table.

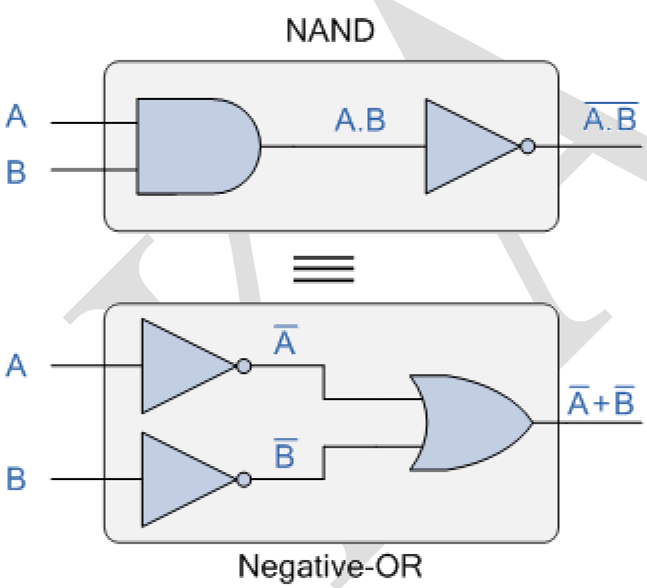
Verifying DeMorgan's First Theorem using Truth Table

Inputs	Truth Table Outputs For Each Term

B	A	A.B	A.B	A	B	A + B
0	0	0	**1**	1	1	**1**
0	1	0	**1**	0	1	**1**
1	0	0	**1**	1	0	**1**
1	1	1	**0**	0	0	**0**

We can also show that A.B = A+B using logic gates as shown.

DeMorgan's First Law Implementation using Logic Gates



The top logic gate arrangement of: A.B can be implemented using a NAND gate with inputs A and B. The lower logic gate arrangement first inverts the two inputs producing A and B which become the inputs to the OR gate. Therefore the output from the OR gate becomes: A+B

Thus an OR gate with inverters (NOT gates) on each of its inputs is equivalent to a NAND gate function, and an individual NAND gate can be represented in this way as the equivalency of a NAND gate is a negative-OR.

DeMorgan's Second Theorem

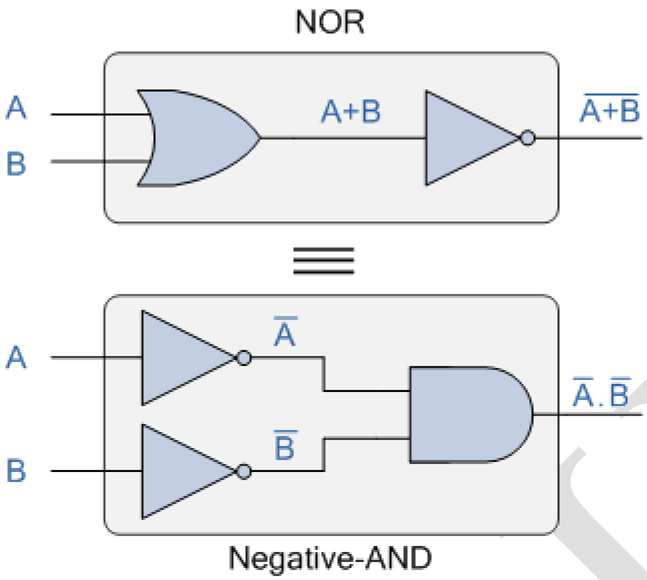
DeMorgan's Second theorem proves that when two (or more) input variables are OR'ed and negated, they are equivalent to the AND of the complements of the individual variables. Thus the equivalent of the NOR function and is a negative-AND function proving that A+B = A.B and again we can show this using the following truth table.

Verifying DeMorgan's Second Theorem using Truth Table

Inputs		Truth Table Outputs For Each Term				
B	A	A+B	A+B	A	B	A . B
0	0	0	**1**	1	1	**1**
0	1	1	**0**	0	1	**0**
1	0	1	**0**	1	0	**0**
1	1	1	**0**	0	0	**0**

We can also show that A+B = A.B using logic gates as shown.

DeMorgan's Second Law Implementation using Logic Gates



The top logic gate arrangement of: A+B can be implemented using a NOR gate with inputs A and B. The lower logic gate arrangement first inverts the two inputs producing A and B which become the inputs to the AND gate. Therefore the output from the AND gate becomes: A.B

Thus an AND gate with inverters (NOT gates) on each of its inputs is equivalent to a NOR gate function, and an individual NOR gate can be represented in this way as the equivalency of a NOR gate is a negative-AND.

Although we have used DeMorgan's theorems with only two input variables A and B, they are equally valid for use with three, four or more input variable expressions, for example:

For a 3-variable input

A.B.C = A+B+C

and also

A+B+C = A.B.C

For a 4-variable input

A.B.C.D = A+B+C+D

and also

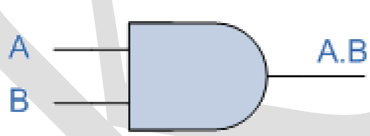
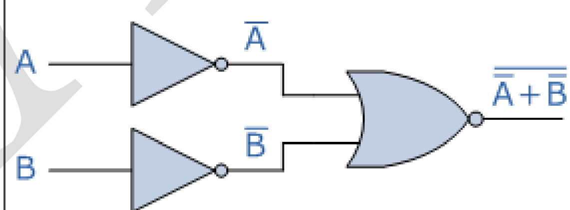
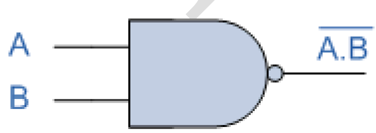
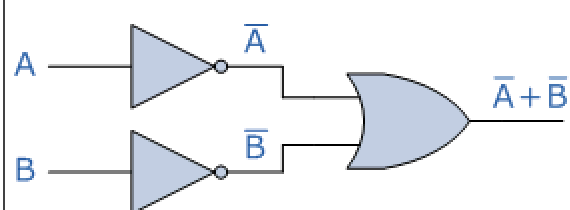
A+B+C+D = A.B.C.D

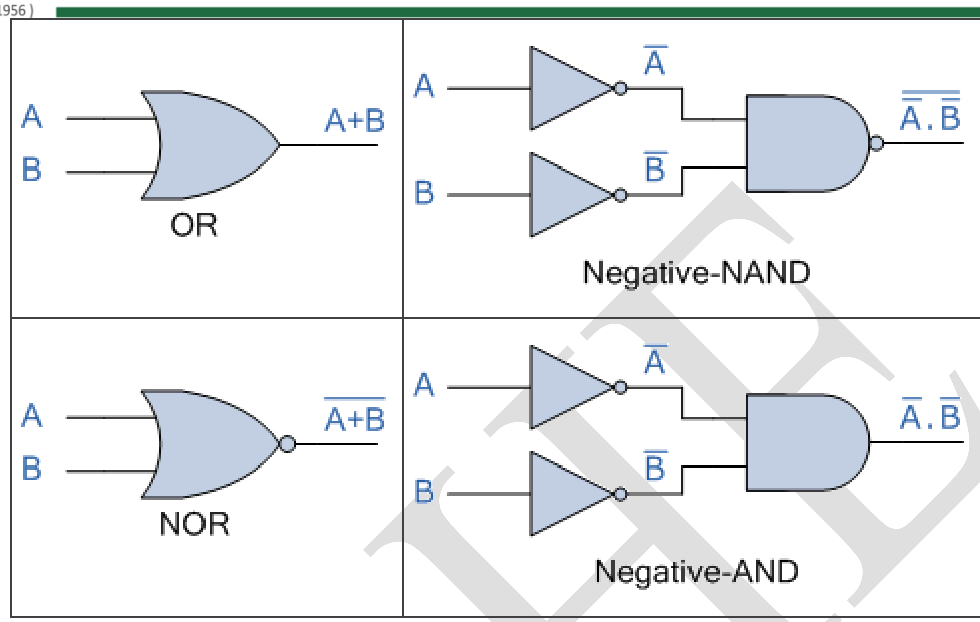
and so on.

DeMorgan's Equivalent Gates

We have seen here that DeMorgan's Theorems replace all of the AND (.) operators with OR (+) and vice versa and then complements each of the terms or variables in the expression by inverting it, that is 0's to 1's and 1's to 0's before inverting the entire function. Thus to obtain the DeMorgan equivalent for an AND, NAND, OR or NOR gate, we simply add inverters (NOT-gates) to all inputs and outputs and change an AND symbol to an OR symbol or change an OR symbol to an AND symbol as shown in the following table.

DeMorgan's Equivalent Gates

Standard Logic Gate	DeMorgan's Equivalent Gate
 AND	 Negative-NOR
 NAND	 Negative-OR



Then we have seen that the complement of two (or more) AND’ed input variables is equivalent to the OR of the complements of these variables, and that the complement of two(or more) OR’ed variables is equivalent to the AND of the complements of the variables as defined by *DeMorgan*.

[19MMU203]
KARPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE - 641 021
(Under Section 3 of UGC Act 1956)
(For the candidates admitted from 2019 onwards)

B. Sc., DEGREE EXAMINATIONS, APRIL - 2020
Second Semester
DEPARTMENT OF MATHEMATICS
PHYSICS - II

QUESTIONS	OPTION 1	OPTION 2	OPTION 3	OPTION 4	ANSWER
UNIT-I					
If the distance between two charge is doubled the electrostatic force between the charge will be______	fourtime more	four time less	will increase into two times	will decrease into two times	four time less
The field due to a wire of uniform charge density at a perpendicular distance y from it	increases with increase in y	decrease with increaase in y	remains constant	depends upon the length of the wire	decrease with increaase in y
Field due to a uniformly charged ring at an axial point at distance very large as compared to the radius of the ring	independent of x	directly proportional to x	directly proportional to x^2	inversely proportional to x^2	inversely proportional to x^2
Electric charge enclosed by Gaussian surface is	0	1	min	max	0
For gauss's law point charges in closed surface must be distributed	arbitrarily	sequentially	rational	in line	arbitrarily
Electric field intensity outside two charged parallel plate is	$\sigma/2\varepsilon_0$	σ/ε_0	infinity	0	0
The total electric flux over any closed surface is	ε_0	σ/ε_0	ε_0/σ	q/ε_0	q/ε_0
Electric flux lines due to an infinite sheet of charge is	converging	radial	uniform and perpendicular to the sheet	uniform and parallel to the sheet	uniform and perpendicular to the sheet
One electron volt is __________.	1.6×10^{-19}joule	1.6 x 10-19volt	1.6 x 10-19joule	1.6 x 10 -21joule	1.6×10^{-19}joule
_________ law establishes a relationship between the electric flux and the electrostatic charge.	Lenz's	Keplers	Faraday	Gauss's	Gauss's
The ratio ϵ/ϵ0 is a dimensionless quantity known as ________	relative permeability	relative permittivity	absolute permittivity	permeability	relative permittivity
The electric field lines begin at the __________ charge and terminate at the _________ charge.	positive, negative	negative, positive	both positive	both negative	positive, negative

Total electric flux emanating from a charge q coulomb placed in air is ____________.	q/ϵ_0	$\epsilon_0 q$	q	$4\pi q$	q/ϵ_0
Gauss's law due to different charge distribution is used to calculate	electric field	electric charge	electric intensity	electric field lines.	electric intensity
The total flux across a closed surface enclosing charge is independent of	shape of the closed surface		volume of the enclosure	actual spatial argument of charges within the surface	all
The unit of Electric flux is __________.	Gauss's	Weber	$Nm^{-2}c^{-1}$	Nc^{-1}	$Nm^{-2}c^{-1}$
.Mechanical pressure on the surface of a charged conductor having surface charge density σ is __________.	$\epsilon_0 \sigma^2$	σ^2 / ϵ_0	$\sigma^2 / 2\epsilon_0$	$\sigma / 2\epsilon_0$	$\sigma^2 / 2\epsilon_0$
If the separation between two charges is increased the electric potential energy	always decreases	always increases	remains the same	may increase or decrease	may increase or decrease
Electric intensity due to an infinitely long plane sheet of a conductor at appoint close to its surface is	independent of r	proportional to $1/r^2$	proportional to r	inversely proportional to 1/r	independent of r
The total electric flux through a closed surface depends on	location of the charge only	the shape of the closed surface only	the value of the net charge only	both charge and shape	the value of the net charge only
Electric field intensity due to an infinite plane sheet of charge is	σ/ε_0	$q/2\varepsilon_0$	$\sigma/2\varepsilon_0$	q/ε_0	$\sigma/2\varepsilon_0$
Law stated as flux is $^1/_{E_0}$ times total charge is	ohms law	newton's law	gauss's law	coulombs law.	gauss's law
A Gaussian sphere closes an electric dipole within it. Then the total flux through the sphere is	half due to a single charge	double due to a single charge	zero	dependent on the position of the dipole	zero
The Flux of electric field is____	scalar	vector	zero	infinity	scalar
Flux density is measured in	Tesla	Weber	Ampere- turn	Maxwell	Tesla
Which of the following quantities are scalar?	dipole moment	electric force	electric field	electric potential	electric potential
A dipole is placed in a uniform electric field with its axis parallel to the field. It experiences	only a net force	only a torque	both a net force and torque	neither a net force nor a torque	neither a net force nor a torque
Electric potential energy U of two point charges is	$q_1q_2/4\varepsilon_0\pi r^2$	$q_1q_2/4\varepsilon_0\pi r$	$pE\sin\theta$	$pE\cos\theta$	$q_1q_2/4\varepsilon_0\pi r$
If a point lies at a distance x from the midpoint of the dipole, the electric potential at the point is proportional to	$1/x^2$	$1/x^3$	$1/x^4$	$1/x^{3/2}$	$1/x^2$
The law that governs the force between electric charge is called	Amperes	Coulomb law	Faraday	Ohms	Coulomb law

The minimum value of the charge in any object cannot be less than	1.6 x $10^{-19 coulomb}$	3.2 x $10^{-19\ Coulomb}$	4.8 x $10^{-19 Coulomb}$	1 coulomb	1.6 x $10^{-19 coulomb}$
An electric field can deflect	X rays	neutrons	alpha particle	gamma rays	alpha particle
Inside the hollow spherical conductor, the potential	is constant	varies directly as the distance from the centre	varies inversely as the distance from the centre	varies inversely as the square of the distance from the centre	is constant
The intensity at a point due to a charge is inversely proportional to	amount of the charge	size of the charge	distance of the point	square of the distance from the charge	square of the distance from the charge
The distance between two charge is douled then the force between them would become	half	one-fourth	doubled	four times	one-fourth
A surface enclosed an electric dipole, the flux through the surface is	infinite	positive	negative	zero	zero
Electric potential is a	vector quantity	scalar quantity	neither vector nor scalar	fictitious quantity	scalar quantity
The potential at any point inside a charged sphere is	zero	same as potential on the surface	smaller than the potential on the surface	greater than the potential on the surface	same as potential on the surface
Two smallspheres eaach carrying a charge q are placed r metre apart, one of the spheres is taken around the other one in a circular path, the work done will be equal to	force between them x r	force between them x 2r	force between them / 2nr	zero	zero
State which of the following is correct?	J=Coulomb x volt	J=Coulomb / volt	J= volt/ ampere	J= volt x ampere	J=Coulomb x volt
A positively charged glass rod attracts an object. The object must be	negatively charged	either negative charged or neutral	neutral	positively charged	either negative charged or neutral
A charge q islocated at the centre of a hypothetical cube. The electric flux through any face of the cube is	q/ϵ0	q/2ϵ0	q/4ϵ0	q/4ϵ0	q/4ϵ0
The force between two electrons seperated by a distance r varies as	r^2	relative permittivity	r^-1	r^-2	r^-2
The energy stored per unit volume of the medium of relative permittivity is _____________.	$\epsilon_r\epsilon_0E^2/2$	$\epsilon_0E^2/2$	$\epsilon_r\epsilon_0E/2$	$\epsilon_0E/2$	$\epsilon_r\epsilon_0E^2/2$
All magnetic moments within a domain will point in the __________ direction.	Different	Same	Positive	Negative	Same
The electrical energy consumed by a coil is stored in the form of:	magnetic field	force field	electrostatic field	electrical field	magnetic field
Electricity may be generated by a wire:	carrying current	wrapped as a coil	passing through a flux field	that has neutral domains	passing through a flux field
A magnetic field has:	lines of reluctance	polar fields	lines of force	magnetomotive force	lines of force

The polarity of induced voltage while a field is collapsing is	opposite to the force creating it	independent of the force creating it	identical to the force creating the field	present only if the force is stationary	opposite to the force creating it
What is magnetic flux?	the number of lines of force in webers	the number of lines of force in maxwells	the number of lines of force in flux density	the number of lines of force in teslas	the number of lines of force in webers
The energy stored in the charged capacitor is _________.	1/2 CV^2	1/2qV	v/q	qV	1/2 CV^2
The arrangement in which one conductor is charged and other is earthed is named as ____________.	capacitor	condenser	capacitor/ condneser	comparator	capacitor/ condneser
__________ device is useful to reduce voltage fluctuations in electric power supplies.	capacitor	condenser	converter	comparator	capacitor
The capacitance of a capacitor C is___________	q/v	qv	v/q	v/q	q/v
_______capacitors can bewidely used in the tuning circuits of radio receivers.	mica	electrolytic	paper	variable air	variable air
_______capacitors are used widely in a radia-set as a smoothing capacitors	electrolytic	mica	both mica and electrolytic	variable	both mica and electrolytic
________capacitor is used in a.c bridges	electrolytic	variable air capacitor	both mica and electrolytic	mica	variable air capacitor
___________ device is used to measure electrostatic potentials	electrometers	magnetometers	potentiometer	galvanometer	electrometers
A dielectric slab is introduced between the plates of an isolated charged parallel plate air capacitor.Which of the following quantities will remain unchanged?	charge on the capacitor	p.d across the capacitor	energy of the capacitor	electric field inside the capacitor	charge on the capacitor
The p.d across a capacitor is kept constant.If a dielectric slab of dielectric constant K is introduced between the plates,the stored energy will be __________.	decreases by a factor K	increases by a factor K	remains constant	increases or decreases depending on the nature of the	increases by a factor K
Capacitance has the dimension ____________.	$M^{-1}L^{-2}T^{4}I^{2}$	$ML^{2}T^{-4}I^{-2}$	$MLT^{-3}I^{-1}$	$M^{-1}L^{-1}T^{3}I$	$M^{-1}L^{-2}T^{4}I^{2}$
In gauss's law the electric flux E through a closed surface (s) depends on the value of net charge __________.	Inside the surface	outside the surface	on the surface	in the surface	Inside the surface
The unit of capacitance is ____________.	Farad	coulomb/volt	Farad and Coulomb/Volt	ohm	Farad and Coulomb/Volt
_________ device is used to generate and detect electromagnetic oscillation of high frequency.	capacitor	voltmeter	Resistor	galvanometer	capacitor
The normal component of D are ________________ across the boundary by the surface charge density	continuous	Discontinuous	Random	Discrete	Discontinuous
The tangential component of the electric field is __________ across the boundary.	continuous	Discontinuous	Random	Discrete	continuous

The potential difference between the conductors is proportional to the ________________ on the capacitor.	charge	voltage	current	time	charge
The coaxial cable used in communication system is a common example for which type of capacitor ___________.	spherical	cylindrical	Air capacitor	Parallel plate capacitor	Parallel plate capacitor
Variable air capacitor is used in ______________.	A.c bridges	D.c bridges	both a and b	tuning circuits	A.c bridges
_________ capacitors can be used only in unidirectional power supplies.	mica	Electrolytic	paper	variable	Electrolytic
An electron- volt (eV) is a unit of	Energy	Potential difference	Charge	Momentum	Energy
Farad is the unit of	capacitance	self inductance	mutual inductance	conductance of an electrolyte	capacitance
In a charged capacitor the energy is stored in	the field between the plates	positive chaarge	negative charge	neutral	the field between the plates
No current flows between two charged bodies connected together when they have the same	charge	potential	capacitance	resistance	potential
Dielectric materials are	insulating materials	semiconducting materials	magnetic materials	ferroelectric materials	insulating materials
Dielectric constant of vacuum is	infinity	100	one	zero	one
For making a capacitor it is better to select a dielectic having	low permittivity	high permitivitty	permitivity same as that of air	permitivity slightly more thanair	high permitivitty
A dielectric material must be a	resistor	insulator	good conductor	semi conductor	insulator
Which of the following material has highest value of dielectric constant	glass	vacuum	ceramics	oil	ceramics
When a dielectric slab is introduced in a parallel plate capacitor, the potential difference between the plates will	remain unchanged	decrease	increases	becomes zero	decrease
A capacitor consists of	two insulators seperated by a condenser	two conductors seperated by an insulator	2 insulator	2 conductor	two conductors seperated by an insulator

Unit-II

Which of the following material requires least magnetizing field to magnetize it?	Gold	Silver	Tungsten	Cobalt	Cobalt

Basic source of magnetism ______________	Charged particles alone	Movement of charged particles	Magnetic dipoles	Magnetic domains	Movement of charged particles
Units for magnetic flux density	Wb / m^2	Wb / A.m	A / m	Tesla / m	Wb / m^2
Magnetic permeability has units as	Wb / m^2	Wb / A.m	A / m	Tesla / m	Wb / A.m
Magnetic field strength's units are	Wb / m^2	Wb / A.m	A / m	Tesla / m	A / m
Example for dia-magnetic materials	super conductors	alkali metals	transition metals	Ferrites	super conductors
Example for ferro-magnetic materials	super conductors	alkali metals	transition metals	Ferrites	alkali metals
Example for anti-ferro-magnetic materials	salts of transition elements	rare earth elements	transition metals	Ferrites	rare earth elements
Example for ferri-magnetic materials	salts of transition elements	rare earth elements	transition metals	Ferrites	transition metals
Magnetic susceptibility para-magnetic materials is	0.00001	-10^-5	10^5	10^-5 to 10^-2	0.00001
Magnetic susceptibility dia--magnetic materials is	0.00001	-10^-5	10^5	10^-5 to 10^-2	10^-5 to 10^-2
Magnetic susceptibility ferro-magnetic materials is	0.00001	-10^-5	10^5	10^-5 to 10^-2	10^-5 to 10^-2
Typical size of magnetic domains ______ (mm)	1 to 10	0.1-1	0.05	0.001	0.001
Example for magnetic material used in data storage devices	45 Permalloy	CrO2	Cunife	Alnico	CrO2
Susceptibility of a magnetic material is defined as the ratio of _________ induced in material to magnetic field intensity (H)	Intensity of magnetization	magnetizing field	magntic induction	Conductivity	Intensity of magnetization
Those substances which are weakly magnetized in the direction opposite to that of the external magnetic field are called as ___________	ferromagnetic substances	diamagnetic	paramagnet	anti ferro	diamagnetic
The magnetic field that exists in vacuum and induces magnetism is called _____________	magnetic intensity	magnetizing field	magnetic field intensity	magnetization	magnetizing field
The temperature at which the domain structure gets destroyed and ferromagnetic substance is converted into paramagnetic substance is called as ___________	zeropoint temp.	high temperature	curie temperature	domain thoery	curie temperature
The ability of magnetizing field to magnetize a material medium is called ____________	magnetic intensity	magnetic field	magnetic field intensity	magnetization	magnetic field intensity

Relative Magnetic Permeability (μr) = ____________	1+χ	1/χ	1+χ	1+H	1+χ
Those substances which are strongly magnetized in the direction of the external magnetic field are called as ________	paramagnet	anti ferro	diamagnetic	ferromagnetic substances	ferromagnetic substances
Magnetic fields do no interact with ____________.	Moving permanent magnets	Stationary permanent magnets	Moving electric charges	Stationary electric charges	Stationary electric charges
The magnetic permeability of a material is defined as ratio of magnetic induction (B) to ______	susceptibility	magnetic intensity	magnetic field intensity	magnetic field	magnetic intensity
Above Curie temperature, Ferromagnetic substances become _________	magnet	anti ferro	diamagnetic	paramgnetic	paramgnetic
________ is defined as pole strength per unit area of cross section of material	susceptibility	magnetizing field	magnetic field intensity	intensity of magnetization	intensity of magnetization
The Curie Temperature (°K) for Nickel is _________ °K	136	316	613	631	631
The degree or extent to which magnetic field can penetrate or permeate a material is called ___________	magnetic permeability	susceptibility	magntic induction	intensity	magnetic permeability
Total number of magnetic lines of force crossing per unit area normally through a material is called ________	magnetic permeability	susceptibility	magntic induction	intensity	magntic induction
The magnetic energy stored in an inductor is ______ current	Directly proportional to	Inversely proportional to	Directly proportional to the square of	Inversely proportional to the square of	Directly proportional to the square of
The ratio of the permeability of material to the permiabiity of air or vacuum.	Relative permeability	Relative permittivity	Relative conductivity	Relative reluctivity	Relative permeability
The property of magnetic materials of retaining magnetism after withdrawal of the magnetizing force is known as	Retentivity	Reluctivity	Resistivity	Conductivity	Retentivity
The force between two magnetic poles varies with the distance between them. The variation is ______ to the square of that distance.	Equal	Greater than	Directly proportional	Inversely proportional	Inversely proportional
Permeability means	The conductivity of the material for magnetic lines of force	The magnetization test in the material after	the strength of an electromagnet	The strength of the permanent magnet	The conductivity of the material for magnetic lines of force
The magnetic field inside a solenoid	is constant	is uniform	increases with distance from the axis	decreases with distance from the axis	is uniform
Paramagnetic substance has a relative permeability of	Slightly less than one	Equal to one	Slightly greater than one	Very much greater than one	Slightly greater than one
For which of the following substance, the magnetic susceptibility is independent of temperature____	Dia	Para	Ferro	ferri	Dia
Electromagnets are made of soft iron because soft iron has___	high susceptibility and low retentivity	high susceptibility and high retentivity	low susceptibility and low retentivity	low susceptibility and high retentivity	high susceptibility and low retentivity

Magnetic field is always _____________.	solenoidal	Irrotational	harmonic in character	rotational	solenoidal
Magnetic flux has the dimension ___________.	$ML^{2}T^{-2}I^{-1}$	$MLT^{-2}I^{-1}$	$ML^{2}T^{-}I^{-1}$	$ML^{2}T^{-2}I$	$ML^{2}T^{-2}I^{-1}$
The permeability of free space is __________ WbA-1m-1.	$\mu_0=4\pi$	μ_0=4πx107	$\mu_0=4\pi x10^{-7}$	μ_0=4πx10 -8	$\mu_0=4\pi x10^{-7}$
The intrinsic magnetic moment of the atoms of a material is not zero.The material _______________.	must be paramagnetic	must be diamagnetic	must be ferromagnetic	may be paramagnetic or ferromagnetic	may be paramagnetic or ferromagnetic
The relative permeability of a material is 0.98.The material must be ________________.	paramagnetic	diamagnetic	ferromagnetic	ferrimagnetic	diamagnetic
Hysteresis refers to the ______ between flux density of the material and the magnetizing force applied.	Leading effect	Ratio	Equality	Lagging effect	Lagging effect
Hydrogen is an example of a _____ material.	Paramagnetic	Diamagnetic	Ferromagnetic	Non- magnetic	Paramagnetic
Cobalt is an example of a ______ material	Paramagnetic	Diamagnetic	Ferromagnetic	Non- magnetic	Ferromagnetic
Magnetic intensity is a	Phasor quantity	Physical quantity	Scalar quantity	Vector quantity	Vector quantity
The core of a magnetic equipment uses a magnetic material with	Least permeability	Low permeability	Moderate permeability	High permeability	High permeability
Which of the following is a paramagnetic material?	Carbon	Copper	Bismuth	Oxygen	Oxygen
._______ crystals are frequently used in computers memory cells.	Ferroelectric	Diamagnetic	Paramagnetic	Ferrielectric	Ferroelectric
Platinum exhibits the property of ___________.	diamagnet	ferromagnet	paramagnet	none	paramagnet
Diamagnetic substance are attracted by magnetic field.The attraction is __________.	very strong	weak	zero	negative	weak
A moving charge produces ___________.	electric field only	magnetic field only	both electric and magnetic fields	neither electric nor magnetic	both electric and magnetic fields
Differential form of Ampere's law for a steady current is __________.	ΔxH=J+∂D/∂t	$\Delta xB=\mu_0 J$	Δ.B=0	∫B.dl= μ0I	$\Delta xB=\mu_0 J$
The phenomenon by which a magnetic substance becomes a magnet when it is place near a magnet	Magnetic effect	Magnetic phenomenon	Magnetic induction	Electromagnetic induction	Electromagnetic induction
Which of the following materials has permeability slightly less than that of free space?	Paramagnetic	Non- magnetic	Ferromagnetic	Diamagnetic	Diamagnetic

The property of a material which opposes the creation of magnetic flux in it	Resistance	Reluctance	Permeance	Conductance	Reluctance
The susceptibility of a paramagnetic gas varies ________ as the absolute temperature.	directly	inversely	Similarily	opposite	inversely
If the relative permeability is less than 1,then the material will be_______________.	dia	para	ferro	ferri	dia
If the relative permeability is greater than 1,then the material will be_______________.	dia	para	ferro	ferri	para
If the relative permeability is very much greater than 1,then the material will be_______________.	dia	para	ferro	ferri	ferro
Lenz's law is a consequence of the law of conservation of	energy	momentum	mass	charge	energy
Lenz's law does not violate the principle of	conservation of charge	conservation of energy	conservation of mass conservation of momentum		conservation of energy
The direction of the induced emf during electromagnetic induction is determined by	Lenz's law	Amperes law	Maxwell law	Faaradays law	Lenz's law
Alternative current generator is basically based upon	amperes law	Lenz's law	faradays law	coulombs law	faradays law
Moving a coil in and out of magnetic field induces	force	potential difference	emf	voltage	emf
Which two values are plotted on a B-H curve graph?	reluctance and flux density	permeability and reluctance	magnetizing force and permeability	flux density and magnetizing force	flux density and magnetizing force
Faraday’s law states that the:	direction of the induced voltage produces an opposition	emf is related to the direction of the current	emf depends on the rate of cutting flux	direction of an induced current produces an aiding effect	emf depends on the rate of cutting flux
What does Faraday’s law concern?	a magnetic field in a coil	a magnetic field cutting a conductor	a magnetic field in a conductor	a magnetic field hystersis	a magnetic field cutting a conductor
What is hysteresis?	lead between voltage and current	lag between cause and effect	lag between voltage and current	lead between cause and effect	lag between cause and effect
What type of device consists of a coil with a moveable iron core?	solenoid	armature	read switch	relay	solenoid

UNIT - III

Einstein's theory of photoelectric effect is based on	Newtons corpuscular theory of light	Huygen's wave theory of light	Maxwell's electromagnetic theory of light	Planck's quantum theory of light	Planck's quantum theory of light
The equation E= hv was deduced by:	Heisenberg	de Broglie	Einstein	Planck	Einstein
De Broglie wavelength (λ) associated with moving particles, mass, m, and velocity v is	h/mv	h/√2mEk	h/√2mqV	h/√2mkT	h/mv

Based on quantum theory of light, the bundles of energy =	hν	hλ	h/ν	h/λ	hν
De Broglie wavelength (λ) associated with moving particles of K.E is	h/mv	h/√2mEk	h/√2mqV	h/√2mkT	h/mv
Wave nature is not observed in daily life because we are using ___________.	Microscopic particles	macroscopic particles	molecules	atoms	macroscopic particles
_______ year de Broglie proposed that the idea of dual nature.	1921	1922	1923	1925	1923
de Broglie wavelength (λ) associated with charge q and potential difference of V volts is	h/mv	h/√2mEk	h/√2mqV	h/√2mkT	h/mv
The photoelectric effect was explained by Albert Einstein by assuming that:	light is a wave.	light is a particle.	an electron behaves as a wave.	an electron behaves as a particle.	light is a particle
The Compton Effect supports which of the following theories?	Special Theory of Relativity.	Light is a wave.	Thomson model of the atom.	Light is a particle.	Light is a particle.
Which one of the following objects, moving at the same speed, has the greatest de Broglie wavelength?	Neutron	Electron	Tennis ball	Bowling ball	electron
Which of the following formulas can be used to determine the de Broglie wavelength?	λ = hmv	λ = h/mv	λ = mv/h	λ = hm/c	λ = h/mv
The idea of dual nature of light was proposed by	Plank	De Broglie	Einstein	Maxwell	De Broglie
According to the de Broglie's hypothesis of matter waves, the concepts of energy, momentum and wavelength are applicable to	moving particles but not to radiation (photon)	moving particles as well as to radiation (photon)	radiation (photon) but not to moving particles	neither to moving particles nor to radiation (photon).	moving particles as well as to radiation (photon)
Experimental verification of de Broglie's matter waves was obtained in	Einstein"s Photoelectric experiment	Davisson and Germer Experiment	Compton"s Experiment	Plank	Davisson and Germer Experiment
The first experimental evidence for matter waves was given by _______	Einstein	de Broglie	Plancks	Davisson and Germer	Davisson and Germer
The de Broglie wavelength wave length of a moving electron subjected to a potential V is	1.26/V1/2	12.26/V1/2	12.26/V	2.26/V1/2	12.26/V1/2
Compute the de Broglie wavelength of an electron that has been accelerated through a potential difference of 9.0 kV. Ignore relativists effects.	1.3 x 10-11 m	1.7 x 10^{-22} m	1.2 x 10^{-26} m	1.7 x 10 3 m	1.7 x 10^{-22} m
Heisenberg's uncertainty principle states for the energy and time is	ΔEΔt = h	ΔEΔt = h/2π	ΔEΔt = 2πh	ΔEΔt = 2 π /h	ΔEΔt = h/2π
In which of the following is the radius of the first orbit minimum?	hydrogen atom	A tritium atom	Triply ionized beryllium	Doubly ionized helium	hydrogen atom
The Kinetic energy of electron of mass (m) is given by (T)	p/2m	p^2/2m	2mp	2mp^2	p^2/2m
Heisenberg's uncertainty principle states for the angular momentum and angle is	ΔJΔɵ = h	ΔJΔɵ = h/2π	ΔJΔɵ = 2πh	ΔJΔɵ = 2 π /h	ΔJΔɵ = h/2π
The radius of the nucleus of any atom is of the order of ____ m	10-8 m	10 -14 cm	10-14m	10-10 m	10-14m
Heisenberg's uncertainty principle states for the position and momentum is	ΔpΔq = h	ΔpΔq = h/2π	ΔpΔq = 2πh	ΔpΔq = 2 π /h	ΔpΔq = h/2π
The uncertainty in the total energy (ΔE) is	ΔT + ΔV	ΔT - ΔV	ΔT	ΔV	ΔT + ΔV
Based on the uncertainty principle, the minimum momentum (Pmin) =	h/I	ħ	ħl	l/ ħ	ħ
Who proposed the uncertainty principle?	Bohr	De Broglie	Heisenberg	Schroedinger	Heisenberg
The kinetic energy of electron in the atoms is	4 Mev	6 Mev	8 MeV	97 Mev	97 Mev
According to Heisenberg"s Uncertainty principle, Indeterminism in the measurement of canonically conjugate variables is due to	imperfection in measuring instruments	imperfection in measurement methods	the interminisim inherent in the auantum world itself		imperfection in measuring instruments
The value of ħ is	6.625 x 10^{-34} nm	5 x 10^{-34} nm	1.055 x 10^{34}nm	1.0555 x 10^{-34} nm	1.055 x 10^{34}nm
The mass of an electron is	9 x 10^{-34} nm	9x 10^{-31} m	6 x 10^{-34} nm	6.625 x 10^{-30} nm	9x 10^{-31} m
If we measure the position of a particle accurately then the uncertainty in measurement of momentum at the same instant becomes	0	Infinity	1	constant	Infinity
If we measure the energy of a particle accurately then the uncertainty in measurement of the time becomes	0	Infinity	1	constant	Infinity

Uncertainty principle is applicable to	macroscopic particles	microscopic particles	gases	liquids	microscopic particles
Uncertainty principle can be easily understandable with help of	Dalton's effect	Compton's effect	electron effect	photoelectric effect	Compton's effect
Heisenberg gave his concept in	1923	1927	1957	1933	1927
Heisenberg uncertainty principle is used for	data processing	information processing	data processinerosion	dilation	information processing
The Heisenberg uncertainty principle is concerned with what two properties?	mass and velocity	momentum and position	position and velocity	momentum and mass	momentum and position
Energy of photon is directly related to the	wavelength	wave number	frequency	amplitude	frequency
____ forms of Schroedinger's equation describe the motion of non-relativistic material particle.	$H\psi = E\psi$	$H\psi \neq E\psi$	$H\psi < E\psi$	$H\psi > E\psi$	$H\psi = E\psi$
If ψ_1 and ψ_2 are two different wave functions, both being satisfactory solution of wave equation for a given system, then these functions will be normalized, if	$\psi_j{}^*\psi_j d\tau = 1$	$\psi_j{}^*\psi_j d\tau \neq 1$	$\psi_j{}^*\psi_j d\tau > 1$	$\psi_j{}^*\psi_j d\tau < 1$	$\psi_j{}^*\psi_j d\tau = 1$
Schrodinger suggested seeking solutions of the waves equation which represents ___ waves.	non-progressive	progressive	non-standing	standing	standing
Momentum operator in Schroedinger equation (Pop) is	$\hbar/i$	$\hbar i$	$i/\hbar$	Ħ	$\hbar/i$
The minimum energy of a particle in a box (E) is	$\hbar^2/ml^2$	$\hbar^2/2ml^2$	$ml^2/\hbar^2$	$2ml^2/\hbar^2$	$\hbar^2/2ml^2$
The Schroedinger time-dependent wave equation is	$H\psi = E\psi$	$H\psi \neq E\psi$	$H\psi < E\psi$	$H\psi > E\psi$	$H\psi = E\psi$
The time-dependent Schroedinger equation is partial differential equation having ___ variables.	1	2	3	4	3
The Schroedinger equation for a free particle is	$\Delta^2\psi + (2m/\hbar^2)(E)\psi = 0$	$\Delta^2\psi + (2m/\hbar^2)(E)\psi \neq 0$	$\Delta^2\psi + (2m/\hbar^2)(E)\psi < 0$	$\Delta^2\psi + (2m/\hbar^2)(E)\psi > 0$	$\Delta^2\psi + (2m/\hbar^2)(E)\psi = 0$
The time independent form of Eop is	H	V	U	T	H
Wave function Ψ of a particle is	real quantity	a complex quantity	an imaginary quantity	any one of these	real quantity
Wave function is represented by ________	ψ	E	H	W	ψ
Schroedinger attempt the physical interpretation of ψ in terms of _______	volume density	current density	density	charge density	charge density
In wave function, energy per unit volume is equal to ___	A^2	E^2	H2	ψ^2	A^2
Photon density is ____	hν	A^2/h	A^2/ν	$A^2/h\nu$	$A^2/h\nu$
Photon density is proportional to ______	hν	A^2	h	ν	A^2
Particle density is proportional to ______	hν	ψ^2	h	ν	ψ^2
Schrodinger's equation described the	wave function	complement of the wave function	behavior of "matter" waves	motion of light	behavior of "matter" waves
Solutions to Schrodinger's equation are labeled with	psi	phi	mu	pi	psi
The hypothesis that nuclear forces possess an exchange character was put forward by	Pauli	Rutherford	Heisenberg	Max Plank	Heisenberg
Heisenberg force is due to	exchange of space	exchange of spin	exchange of space and spin	exchange of moments	exchange of space and spin
UNIT - IV					
The potential involved outside the nucleus is ____	gravitational	electromagnetic	nuclear	Coulombic	Coulombic
The atomic mass is almost equal to _____	the mass of the electron	the mass of the nucleus	the mass of the protons	the mass of the neutrons	the mass of the nucleus
The nuclear radius is proportional to	A^2/3	A	A^1/3	A^2	A^1/3
The nucleon density at the centre of any nucleus is	proportional to A	proportional A^2	proportional Z	almost the same	almost the same
The force which holds the nucleons together in a nucleus is	elelctromagnetic force	gravitational force	strong nuclear force	weak interaction	strong nuclear force
The non-central part of the nuclear force is called	elelctromagnetic force	tensor force	magnetic force	static force	tensor force
Nuclear exchange forces arise due to	exchange of mesons	exchange of charge	exchange moments	exxchange of strangeness	exchange of mesons
Nucleus is	positively charged	negatively charged	neutral	charge keeps on changing	positively charged
Proton has the charge	1637 times of an electron	1737 times of an electron	1837 times of an electron	1937 times of an electron	1837 times of an electron
Neutrons has the charge	1639 times of an electron	1739 times of an electron	1839 times of an electron	1939 times of an electron	1839 times of an electron
The difference between the total mass of the individual nucleons and the mass of the nucleus is known as	mass defect	binding energy	packing fraction	mass excess	mass defect

The mass of the nucleus is normally -------- the total mass of the nucleons	greater than	equal to	less than	can be anything	less than
Instrument used to measure nuclear masses and their other properties is called	Mass spectrograph	nuclear spectrometer	NMR spectrometer	magnetic spectrometer	Mass spectrograph
The constant nucleon density inside the nucleus supports	liquid drop model of the nucleus	shell model	collective model	unified model	liquid drop model of the nucleus
The constant binding energy per nucleon supports	shell model	collective model	liquid drop model	unified model	liquid drop model
In the liquid drop model, the restoring force after deformation is supplied by	internal force	gravitational attraction	surface tension	repulsion	surface tension
The surface energy is proportional to ---- where A is the mass number	A	A^1/3	A^2/3	A^2	A^2/3
The liquid drop model could not explain satisfactorily ----	surface vibration of the nuclei	surface energy of the nuclei	all the above	low lying discrete energy levels of nuclei	low lying discrete energy levels of nuclei
According to alpha particle model, a nucleus can be considered as	a sphere of individual nucleons	poly-atomic molecule of alpha particles	alpha and beta particles	poly-atomic molecule of beta particles	poly-atomic molecule of alpha particles
Alpha particle model could not describe the ground and excited states of	nuclei other than even-even nuclides	even-even nuclides	even-odd nuclides	odd-even nuclides	nuclei other than even-even nuclides
It is seen that nuclei with ----- nucleons are most stable, where n=1,2,3,….	2n-1	4n-2	4n	2n	4n
The nuclei with Z = ----- and ------ are found to be more than usually stable	50, 20	50,40	20, 40	30, 40	50, 20
The resemblance of the nucleus with a drop of liquid led to the suggestion of ----- model.	Fermi gas model	collective model	liquid drop model	Shell model	liquid drop model
The nuclear fission can be best explained using	shell model	liquid drop model	Fermi gas model	collective model	liquid drop model
As per liquid drop model, if the energy of the incident neutron is less than the critical energy, ----- takes place.	radiative capture	fusion	gamma ray emission	fission	radiative capture
Which model is the combination of liquid drop and shell model	Collective model	Unified model	optical model	Super-conductivity model	Collective model
Nuclei with N or Z near the end of a shell are found in …………. Distinct groups, known as islands of isomerism	three	two	seven	four	four
Alpha particle is emitted from	outside the nucleus	inside the nucleus	from the external orbits	inside a proton	inside the nucleus
The spin of an alpha particle is	1	1-Feb	3-Feb	0	0
Alpha particle is of ----- parity	no parity	odd	even	odd or even	even
The penetrating power of alpha particle is	large	small	medium	zero	small
There are ---- types of beta emission	2	1	3	4	3
The spin of the beta particle is	1-Feb	3-Feb	1	0	1-Feb
What is the most penetrating radiation?	gamma	alpha	beta	positron	gamma
Which types of radiation is the most dangerous?	gamma	alpha	beta	they are equally dangerous	gamma
A particle striking on the target nucleus, is absorbed by it and a new particle is ejected. This is an example of	photo disintegration	radiative capture	elastic scattering	disintegration	disintegration
Emission of alpha and beta rays is an example of	photo disintegration	radiative capture	spontaneous decay	spallation reaction	spontaneous decay
The strong nuclear force is	charge dependent	both charge and size dependent	charge indendent	size dependent	charge indendent

UNIT-V

Which number system is not a positional notation system?	ROMAN	Binary	decimal	Hexadecimal	ROMAN
The 10's complement of the octal number 715 is	63	539	285	395	539
The 9's complement of 381 is	372	508	618	390	618
The 1's complement of the binary number 1101101 is	10	100010	10011	1101110	100010

The 2's complement of the binary number 010111.1100 is	101001.11	101000.01	10111.0011	101000.0011	101000.01
Which system has a base or radix of 10:	Binary digit	Hexadecimal digit	Decimal digit	Octal digit	Decimal digit
In which counting, single digit are used for none and one:	Decimal counting	Octal counting	Hexadecimal counting	Binary counting	Binary counting
In which numeral every position has a value 2 times the value f the position to its right:	Decimal	Octal	Hexadecimal	Binary	Binary
In which digit the value increases in power of two starting with 0 to left of the binary point and decreases to the right of the binary point starting with power -1:	Hexadecimal	Decimal	Binary	Octal	Binary
Which system is used in digital computers because all electrical and electronic circuits can be made to respond to the states concept:	Hexadecimal number	Binary number	Octal number	Decimal number	Binary number
Which number is formed from a binary number by grouping bits in groups of 4-bit each starting at the binary point:	Binary	Octal	Decimal	Hexadecimal	Hexadecimal
Which number system has a base of 16 :	Binary number system	Octal number system	Decimal number system	Hexadecimal number system	Hexadecimal number system
. Counting in hex, each digit can be increment from__________:	0 to F	0 to G	0 to H	0 to J	0 to F
Which number can be converted into binary numbers by converted each hexadecimal digit to 4 bits binary equivalent using the code:	Binary number	Decimal number	Octal number	Hexadecimal number	Hexadecimal number
. How many system of arithmetic, which are often used in digital system:	5	6	3	4	4
Which are the system of arithmetic, which are often used in digital system:	Binary digit	Decimal digit	Hexadecimal digit	All of these	All of these
A number system that uses only two digits, 0 and 1 is called the___________:	Octal number system	Binary number system	Decimal number system	Hexadecimal number system	Decimal number system
Which of the following gates is known as coincidence detector?	AND	OR	NOT	NAND	AND
An inverter is also called as	NOT	OR	AND	NAND	NOT
Which gate has two or more input signals in which all input must be high to get a high output?	OR	NAND	AND	NOR	AND
A NOR gate has a high output only when the input bits are	low	high	some low some high	None of the above	low
A NOR gate is logically equivalent to an OR gate followed by an	AND	NAND	XOR	INVERTER	INVERTER
Boolean expression for NOR gate with two inputs x and y can be written as	(x+y)'	x . y	x+y	xy' + x'y	(x+y)'
Boolean expression for NAND gate with two inputs x and y can be written as	xy	x+y	x'+y'	None of the above	x+y
NAND gates can be used as which type gates?	NOT	OR	AND	All of the above	All of the above
An OR gate can be imagined as	switches connected in series	switches connected in parallel	MOS transistors connected in series	None of the above	switches connected in parallel
Which gate is known as Universal gate?	NOT	AND	NAND	OR	NAND
Any Boolean expression can be implemented using	only NOR gates	only NAND gates	only AND gates	only XOR gates	only NAND gates
Which digits are used to represent high & low level in digital circuits?	1 0	0 1	0 0	1 1	1 0
Complement of a Variable is represented by _________ over the Letter.	slash	bar	dot	hyphen	bar
What is the value for 1+1 in Boolean Addition?	2	10	1	0	1
Multiplication in Boolean algebra is the same as the __________ function	AND	OR	NOT	NOR	AND
The operation of an inverter is________	Complement Input variable	add +1 to input variable	add –1 to input variable	minus input variable	Complement Input variable
___________is same as Inversion.	complementation	exclusive	AND	OR	complementation
The output of an AND gate is 1(High) only when both inputs are __________	1 0	0 0	1 1	0 1	1 1
The output of an OR gate is 1(High) only when any one or more of the inputs are __________	high	low	medium	high	high
NAND is a complement of __________	NOT	AND	OR	NOR	AND

NOR is a complement of __________	NOT	AND	OR	NAND	OR
Commutative Law of Addition of 2 variables is written as	A+B=B+A	B+A=B+A	A+B=A + B	AB=AB	A+B=B+A
Commutative Law of Multiplication of 2 variables is written as	AB=BA	BA=BA	AB=AB	AB=A+B	AB=BA
Associative law of addition is stated as	A + (B + C) = (A+B)+C	(A + B)+ C = (A+B)+C	(A+B) C = A (B+C)	AB+C = A+BC	A + (B + C) = (A+B)+C
Associative law of multiplication is stated as	A (BC)=(AB) C	ABC=ACB	AB = BA	ABC=CAB	A (BC)=(AB) C
Distributive Law is stated as	A (B+C) = AB + AC	AB + AC = ABC	AB + C= AC + B	(AB) + C = AB + AC	A (B+C) = AB + AC
In Boolean algebra A + 0 =?	A	0	–A	1	A
In Boolean algebra A + 1 =?	A	0	–A	1	1
In Boolean algebra A .0 =?	A	0	–A	1	0
In Boolean algebra A .1 =?	A	0	–A	1	A
In Boolean algebra A +A =?	A	0	–A	1	A
In Boolean algebra A + Ā =?	A	0	–A	1	1
In Boolean algebra A .A =?	A	0	–A	1	A
In Boolean algebra A. Ā =?	A	0	–A	1	0
In Boolean algebra A + AB =?	A	0	–A	1	A
In Boolean algebra A + ĀB =?	A	0	B	A + B	A + B
In Boolean algebra (A +B)(A + C) =?	A	0	B	A +BC	A +BC
The Complement of a Sum =	Sum of the Complements	Product of the Complement	Complement of the sum	Sum	Sum of the Complements
Sum of Product expression is	two or more AND functions OR together	two or more OR functions AND together	two or more AND functions NOR together	two or more OR functions NOR together	two or more AND functions OR together
Product of Sum expression is	AND of two or more OR functions	OR of two or more AND functions	AND of two or more NAND functions	OR of two or more NAND functions	AND of two or more OR functions
Boolean expression can be simplified using	Associative law	rules and laws of Boolean algebra	Distributive law	None of the above	rules and laws of Boolean algebra
Sum of products expression is implemented with ________	AND-OR logic	OR-AND logic	NAND logic	NOR logic	AND-OR logic
The output of an exclusive – OR gate is HIGH when inputs have	Same state	Opposite State	Complement State	Alternate State	Opposite State
The output of an exclusive – NOR gate is HIGH when inputs have	Same state	Opposite State	Complement State	Alternate State	Same state
Any Logic Expression can be implemented using	NAND / NOR	AND / OR	X-OR / OR	NAND / AND	NAND / NOR
What are the common internal gate failures?	open input or output & shorted input or output	open input or output & Loaded input or output	open input or output & driving input or output	open input or output & bad input or output	open input or output & shorted input or output
The interconnecting paths represent a common electrical point is known as ____________.	Cell	Node	Point	Junction	Junction
The coincidence circuit is otherwise called as	Exclusive-NOR	Exclusive – OR	Exclusive – AND	Exclusive – NAND	Exclusive – OR
NAND & NOR gates are called as	Universal Gates	Functional gates	Logical Gates	Combinational gates	Universal Gates
Sum of products can be done using	demorgan's theorem	algebric theorem	demorgan's postulate	algebric postulate	demorgan's theorem
Two variables will be represented by	eight minterms	six minterms	five minterms	four minterms	four minterms
The output of AND gates in SOP is connected to	NOT gates	OR gates	AND gates	XOR gates	OR gates
The minterms in a karnaugh map are marked with a	y	x	0	1	1
Small circle in a NAND circuit represents	input	bits	output	complement	complement
Tabulation method is adopted for giving simplified function in	subtraction of sum	sum of products	product of sums	subtraction of product	product of sums
Each square in a karnaugh map represents a	points	values	minterm	maxterm	minterm
Sum of products can be done using	demorgan's theorem	algebric theorem	demorgan's postulate	algebric postulate	demorgan's theorem