PHY118-2080 (New))

Tribhuvan University
Institute of Science and Technology
2080

Bachelor Level / First Year/ First Semester/ Science
Computer Science and Information Technology (PHY118)
(Physics)
(NEW COURSE)

Full Marks: 60
Pass Marks: 24
Time: 3 hours.

Candidates are required to give their answers in their own words as far as practicable.
The questions are of equal value.

Section A

Long Answer Questions:
Attempt any TWO questions [2×10=20]

1. Distinguish rigid and non-rigid body. Derive an expression for rotational kinetic energy and discuss the conditions for conservation of energy. A wheel of radius 0.4 m and moment of inertia 1.2 kg-m^2, pivoted at the center, is free to rotate without friction. A rope is wound around it and a 2-kg weight is attached to the rope. When the weight has descended 1.5 m from its starting position, find the rotational velocity of the wheel. [10]

2. Setup Schrodinger equation for Hydrogen atom using spherical polar coordinates. Separate radial and angular part of this equation using appropriate separation constant. Discuss the separation constant and hence the quantum numbers associated with these two equations. What information can be drawn from the angular part of the Schrodinger equation? Explain. [10]

3. What are RTL and TTL gates? How memory and clock circuits can be made by using these gates? Show it. Explain their working scheme. Is it true that TTL logic gates are typically fabricated onto a single integrated circuit (IC)? [10]

Section B

Short Answer Questions: [8×5=40]
Attempt any EIGHT questions:

4. Describe classical free electron model. [5]

5. How electric and magnetic fields are incorporated in electromagnetic wave? Explain. [5]

6. Describe the following process of IC production: (a) Oxidation and (c) Doping. Explain Photolithography in brief. [5]

7. An oscillating block of mass 250 g takes 0.2 sec to move between the endpoints of the motion, which are 50 cm apart. Find the frequency and amplitude of the motion. What is the force constant of the spring? [5]

8. A potential difference of 100 V is applied between the two plates one being at the high potential. An alpha particle of charge $q = 3.2 \times 10^{-19}$ C is released from one plate to another plate. What will be the velocity of the alpha-particle when it reaches the plate? The mass of the alpha particle is 6.70×10^{-19} kg. [5]

9. Calculate the uncertainty in the momentum of an electron if uncertainty in its position is 1 Å (10^{-10} m). [5]

10. A current of 50 A is supplied in a slab of copper 0.5 cm thick and 2 cm wide which is placed in a magnetic field B of 1.5 T. The magnetic field is perpendicular to the plane of the slab and to the current. If the free electron concentration in copper is 8.4×10^{28} electrons/m^3, what will be the magnitude of the Hall voltage across the width of the slab? [5]

11. Sodium has a body-centered cubic structure with a one-atom basis. The density and the atomic weight of sodium are 0.971 g/cm^3 and 23 g/mole, respectively. What is the length of the unit cube of the structure? [5]

12. The output of a digital circuit (y) is given by this expression:

$$y = (C + \bar{B}A)(\overline{A + B + D})$$

where A, B, C and D represent inputs. Draw a circuit of above equation using OR, AND and NOT gate and hence find its truth table. [5]

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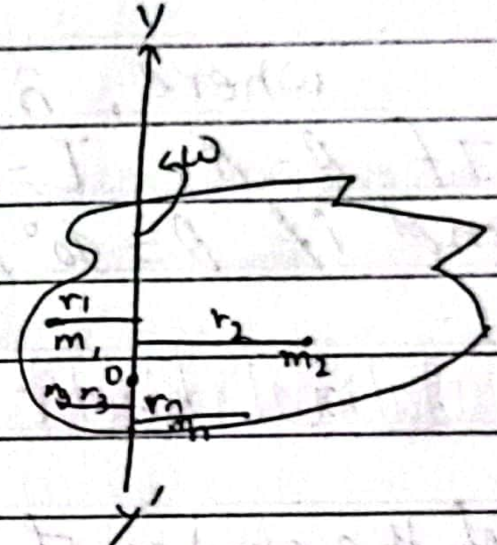
Explain moment of Inertia of the rigid body and Torque. Also find the Rotational kinetic energy of rigid body and condition of conservation.

Q.N;1

⇒

Moment of Inertia of the rigid body:-

Let M be the Total mass of rigid body, it has minimum number of particle having masses $m_1, m_2 \ldots m_n$ and distance from axis of rotation are $r_1, r_2 \ldots r_n$. The moment of inertia of particle becomes



$$I_1 = m_1 r_1^2$$
$$I_2 = m_2 r_2^2$$
$$\vdots \qquad \vdots$$
$$I_n = m_n r_n^2$$

The moment of Inertia of the rigid body becomes sum of the moment of individual particle.

$$I = I_1 + I_2 + I_3 + \cdots + I_n$$

$$I = m_1 r_1^2 + m_2 r_2^2 + \cdots + m_n r_n^2$$

$$\boxed{I = \sum_{i=1}^{n} m_i r_i^2}$$

Torque

Moment of the force is called Torque. It is denoted by τ. It is vector quantity. Mathematically It is the product of force and perpendicular from the axis of rotation.

$$\tau = \vec{r} \times \vec{f} \quad --- (1)$$

It's unit is Nm and Dimension is $[ML^2T^{-2}]$

eqn (1) can be written as

$$\tau = rf\sin\theta\,\hat{n}$$

where, $\hat{n}$ is the unit vector

If $\theta = 0°$, $\tau = 0$ which is minimum value

and if $\theta = 90°$, $\tau = Fr$ which is maximum value.

Rotational Kinetic energy

Let M be the mass of rigid body. It consists of the number of particle of masses $m_1, m_2, m_3 \ldots m_n$ and distance from axis of rotation are $r_1, r_2, r_3 \ldots r_n$. which is shown in figure. The particle having same angular velocity ω but different linear velocity

$v_1 = r_1\omega$, $v_2 = r_2\omega$, $v_3 = r_3\omega$ ---- $v_n = r_n\omega$

Rotational kinetic energy of individual particles are

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$$E_1 = \frac{1}{2} m v_1^2 = \frac{1}{2} m_1 r_1^2 \omega^2$$

Similarly,

$$E_2 = \frac{1}{2} m_2 r_2^2 \omega^2$$

$$E_3 = \frac{1}{2} m_3 r_3^2 \omega^2$$

$$\vdots$$

$$E_n = \frac{1}{2} m_n r_n^2 \omega^2$$

Total Rotational Kinetic energy of rigid body is equal to the sum of rotational kinetic energy of individual particle.

$$E = E_1 + E_2 + E_3 + \cdots + E_n$$

$$E = \frac{1}{2} m_1 r_1^2 \omega^2 + \frac{1}{2} m_2 r_2^2 \omega^2 + \frac{1}{3} m_3 r_3^2 \omega^2 + \cdots + \frac{1}{2} m_n r_n^2 \omega^2$$

$$E = \frac{1}{2} \left[\sum_{i=1}^{n} m_i r_i^2 \right] \omega^2$$

There are two conservation. They are conservation of momentum and Energy. The momentum is conserved if there are no application of Force or Torque. Energy is conserved if energy becomes constant in any point after certain interval of time.

A large wheel of radius 0.4m and moment of inertia $1.2 kgm^2$, pivoted at the centre is free to rotate without friction. A rope is wound it and a 2kg weight is attached to the rope. When the weight has descended 1.5m from its starting position

(a) What is its downward velocity?

(B) What is the rotational velocity of wheel?

Numerical Part

Given,

radius $(r) = 0.4m$

Moment of inertia $(I) = 1.2 kgm^2$

mass $(m) = 2kg$

height $(h) = 1.5m$

velocity $(v) = ?$

(a) From conservation of energy,

P.E of weight = K.E of weight + Rotational K.E of wheel

or, $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

or, $2mgh = mv^2 + I\omega^2$

or, $2mgh = mv^2 + I\frac{v^2}{r^2}$ $\quad (\omega = \frac{v}{r})$

or, $2mgh = v^2\left(m + \frac{I}{r^2}\right)$

or, $v^2 = \frac{2mgh}{m + I/r^2}$

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or, $v = \sqrt{\dfrac{2mgh}{m + I/r^2}} = \sqrt{\dfrac{2\times2\times9.8\times1.5}{2 + \frac{(1.2)}{(0.4)^2}}}$

$\therefore\ v = 2.5\,m/sec$

(b) we have,

velocity of wheel $(v) = 2.5\,m/sec$

since,

$v = r\omega$

$\omega = \dfrac{v}{r} = \dfrac{2.5}{0.4} = 6.2\,rad/sec.$

Solution of Schrodinger wave equation in Spherial Polar Co-ordinates

Q.N;2

(Q.N) Set of schrodinger equation for hydrogen atom using spherical polar co-ordinates out separat ~~radial~~ radial and angular part of this equation without solving angular and radial-equation. Discuss the Quantum number associated with these.

=> The schrodinger wave equation in three dimension

$$\nabla^2\psi + \frac{2\mu}{\hbar^2}[E - V_{(r)}]\psi = 0 \quad \text{---- (I)}$$

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where,

$$\nabla^2 = \left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right]$$

so eqn (I) becomes

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{2\mu}{\hbar^2}[E - V(r)]\psi = 0 \quad \text{---- (II)}$$

where,

$$V(r) = \frac{-e^2}{4\pi\varepsilon_0 r} \quad [V_{(r)} \text{ for hydrogen atom}] \text{ spherically symmetric potential}$$

we can express the cartessian co-ordinates into spherical polar co-ordinate

Here,

$$\left.\begin{aligned} x &= \cancel{r\sin\phi}\ r\sin\theta\cos\phi \\ y &= r\sin\theta\sin\phi \\ z &= r\cos\theta \end{aligned}\right\} \text{---- (III)}$$

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For sphere,

$$r^2 = x^2 + y^2 + z^2$$

we have,

$$\frac{\delta r}{\delta x} = \sin\theta\cos\phi \;, \quad \frac{\delta r}{\delta y} = \sin\theta\cos\phi$$

$$\frac{\delta r}{\delta z} = \cos\theta \quad \text{------} \quad (iv)$$

Again,

$$\left.\begin{aligned} \frac{\delta\theta}{\delta x} &= \frac{\cos\theta\cos\phi}{r} \\ \frac{\delta\theta}{\delta y} &= \frac{\cos\theta\sin\phi}{r} \\ \frac{\delta\theta}{\delta z} &= -\frac{\sin\theta}{r} \end{aligned}\right\} \text{———} (V)$$

and

$$\left.\begin{aligned} \frac{\delta\phi}{\delta x} &= \frac{-\sin\phi}{r\sin\theta} \\ \frac{\delta\phi}{\delta y} &= \frac{\cos\phi}{r\sin\theta} \\ \frac{\delta\phi}{\delta z} &= 0 \end{aligned}\right\} \text{———} (VI)$$

By solving we get,

$$\left.\begin{aligned} \frac{\delta\psi}{\delta x} &= \frac{\delta\psi}{\delta r}\cdot\frac{\delta r}{\delta x} + \frac{\delta\psi}{\delta\theta}\cdot\frac{\delta\theta}{\delta x} + \frac{\delta\psi}{\delta\phi}\cdot\frac{\delta\phi}{\delta x} \\ \frac{\delta\psi}{\delta y} &= \frac{\delta\psi}{\delta r}\cdot\frac{\delta r}{\delta y} + \frac{\delta\psi}{\delta\theta}\cdot\frac{\delta\theta}{\delta y} + \frac{\delta\psi}{\delta\phi}\cdot\frac{\delta\phi}{\delta y} \end{aligned}\right\}$$

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$$\frac{\delta\psi}{\delta z} = \frac{\delta\psi}{\delta r}\cdot\frac{\delta r}{\delta y} + \frac{\delta\psi}{\delta\theta}\cdot\frac{\delta\theta}{\delta y} + \frac{\delta\psi}{\delta\phi}\cdot\frac{\delta\phi}{\delta z} \quad \text{--- (VII)}$$

$$\left.\begin{aligned}\frac{\delta^2\psi}{\delta x^2} &= \frac{\delta}{\delta x}\left(\frac{\delta\psi}{\delta x}\right)\\ \frac{\delta^2\psi}{\delta y^2} &= \frac{\delta}{\delta y}\cdot\left(\frac{\delta\psi}{\delta y}\right)\\ \frac{\delta^2\psi}{\delta z^2} &= \frac{\delta}{\delta y}\cdot\left(\frac{\delta\psi}{\delta z}\right)\end{aligned}\right\} \text{--- (VIII)}$$

Using all values of above equations in eq^n (ii) and solving we get.

$$\frac{1}{r^2}\frac{\delta}{\delta r}\left(r^2\frac{\delta\psi}{\delta r}\right) + \frac{1}{r^2\sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\cdot\frac{\delta\psi}{\delta\theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\delta^2\psi}{\delta\phi^2} +$$

$$\frac{2\mu}{\hbar^2}\left[E - V(x)\right]\psi = 0 \text{ --- (ix)}$$

where, $\mu = \frac{m_1 m_2}{m_1+m_2}$ is called reduced mass of hydrogen atom.

Separation of variable

We can separate radial and angular part

$$\psi(r,\theta,\phi) = R(r)\,Y(\theta,\phi) \text{ --- (10)}$$

$$\psi = (R, Y)$$

Using relation (10) in eq^n (ix)

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$$\frac{Y}{r^2}\frac{\delta}{\delta r}\left(r^2\frac{\delta R}{\delta r}\right)+\frac{R}{r^2\sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\cdot\frac{\delta Y}{\delta\theta}\right)+\frac{R}{r^2\sin^2\theta}\frac{\delta^2 Y}{\delta\phi^2}+$$

$$\frac{2\mu}{\hbar^2}[E-V(r)]RY=0 \quad ----(11)$$

Dividing eq^n (11) by R.Y and multiplying by r^2 we get

$$\frac{1}{R}\frac{\delta}{\delta r}\left(r^2\frac{\delta R}{\delta r}\right)+\left[\frac{1}{\sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\frac{\delta Y}{\delta\theta}\right)+\frac{1}{\sin^2\theta}\frac{\delta^2 Y}{\delta\phi^2}\right]\frac{1}{Y}+$$

$$\frac{2\mu r^2[E-V(r)]}{\hbar^2}=0$$

or, $$\frac{1}{R}\frac{\delta}{\delta r}\left(r^2\frac{\delta R}{\delta r}\right)+\frac{2\mu r^2[E-V(r)]}{\hbar^2}=-\frac{1}{Y}\left[\frac{1}{\sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\frac{\delta Y}{\delta\theta}\right)+\frac{1}{\sin^2\theta}\frac{\delta^2 Y}{\delta\phi^2}\right]=\lambda \quad ----(12)$$

where, ~~wher~~ λ is constant.

By separation,

$$\frac{1}{R}\frac{\delta}{\delta r}\left(r^2\frac{\delta R}{\delta r}\right)+\frac{2\mu r^2[E-V(r)]}{\hbar^2}=\lambda \cancel{=-\frac{1}{\lambda}\left[\frac{1}{\sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\frac{\delta Y}{\delta\theta}\right)\right.}$$

is called Radial eq^n and is

$$-\frac{1}{\lambda}\left[\frac{1}{\sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\frac{\delta Y}{\delta\theta}\right)+\frac{1}{\sin^2\theta}\frac{\delta^2 Y}{\delta\phi^2}\right]=\lambda$$

called angular equation.

Angular part consists of polar equation θ and azimuthal equation ϕ

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For quantum numbers:

(i) The solution of polar equation gives the ~~Ori~~ orbital quantum number $l = 0, 1, 2, 3 \ldots$

(ii) The solution of Radial equation gives principal quantum number n for which $= 1, 2, 3 \ldots$

(iii) The solution of azimuthal equation gives the magnetic quantum number $m_l = 0, \pm 1, \pm 2, \pm 3 \ldots$

The energy of radial equation is similar to energy of hydrogen atom. Thus these quantum numbers for the model of hydrogen atom are related as magnetic quantum number m_l, orbital quantum number l and Principal quantum number n

Logic Family, RTL and TTL Gates

In digital designs, a circuit configuration or arrangement of the circuit elements in a special manner will result in a particular logic family. Electrical characteristics of the IC will be indentical. In other words, different parameter like Noise margin, Fan In, Fan out etc. will be identical.

Different IC's belonging to the same logic families will be compatible with each other.

Digital IC gates are classified not only by their logic operation, but also by the specific logic circuit family to which it belongs. Each logic family has its own basic electronic circuit upon which more complex digital circuits and function are developed.

Q.N;3

Different Types of Logic Gate Families

RTL : Resistor transistor logic gate family

DCTL : Direct coupled transistor logic gate family

RCTL : Resistor capacitor transistor logic gate family

DTL : Diode transistor logic gate family

TTL : Transistor transistor logic gate family

IIL : Integrated injection gate family

Resistor transistor logic (RTL) gate family is often found in an IC. In which all the logic are implemented using resistor and transistors.

An example of RTL gate is shown in figure, which implements the NOR function.

The circuit consists of two inverters wired in parallel with V_{out} and the collector R_C common to both. V_A and V_B are two inputs and each affects the output of their respective transistor.

Suppose $V_A = 5V$ and $V_B = 0V$, transistor A will conduct, that is, I_{B_1} will be high and therefore I_C will be high. Consequently, the collector of A will be at approximately 0V with respect to ground ($V_{CE} \approx 0V$) and V_{out} will be 0V.

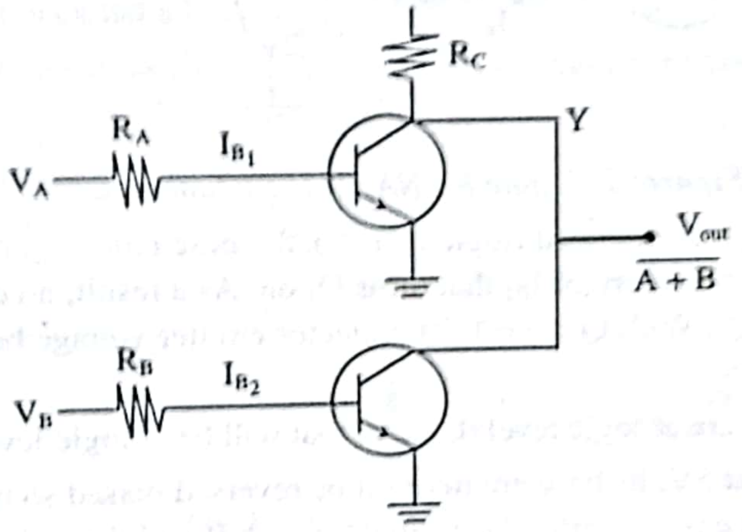


Figure: RTL circuit for NOR logic function.

A similar output will be obtained if $V_A = 0V$ and $V_B = 5V$ or if both $V_A = V_B = 5V$.

Thus, if either or both inputs are logic level 1, the output will be at logic level 0.

If $V_A = V_B = 0V$, then neither of the two transistor will conduct ($I_C = 0$) and both collectors will be at 5V with respect to their emitters, which are grounded; $V_{out} = 5V$.

Thus the circuit implements the NOR logic function.

The primary advantage of RTL technology was that it used a minimum number of transistors. The disadvantage of RTL is its high power dissipation, limited fan in, and has a low noise immunity.

TTL gates have many advantages over RTL and DTL gates with some simple modifications the fan out of the TTL gate can be as great as 15 (For RTL gates it is typically 5 and for DTL gates it is 8). The propagation delay for a TTL gate is about 10 nsec as compared with 25 nsec for the DTL and RTL gates. The noise immunity is also better for the TTL gates.

An example of TTL gate is shown in figure, which implements a NAND function.

The input transistor Q_1 is an npn transistor with several emitters. Transistor with 8 or more input emitters are not unusual nor difficult to manufacture in IC form.

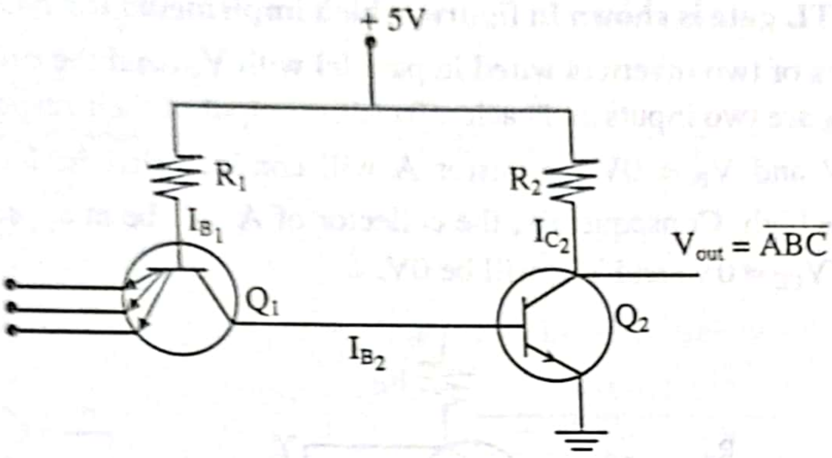


Figure: TTL gate for NAND logic function.

If any one the inputs of Q_1 is grounded (logic level 0), the base emitter junction of Q_1 will be forward based, so a large base current I_{B1} that turns Q_1 on. As a result, no current flows in the emitter base junction of Q_2. With Q_2 cutoff, its collector emitter voltage becomes 5V, that is, $V_{out} = 5V$.

Thus, if any of the inputs are at logic level 0, the output will be at logic level 1.

If all the input of Q_1 are at 5V, its base emitter will be reversed biased so no current can flow from the base of Q_1 to its emitter, current can flow through R and through the forward biased base collector of Q_1. This will turn Q_2 on and make its collector emitter voltage 0V therefore $V_{out} = 0V$.

Thus, when all inputs are at logic level 1, the output will be a logic level 0.

This is logically a NAND gate.

Fanout: It is the maximum number of inputs that can be driven by a logic gate. A fanout 10 means 10 unit loads can be driven by the gate still maintaining the output logic level.

Propagation delay: The time required for the output of a digital circuit to change states after a change at one or more of its inputs.

Noise immunity: It is the ability of a gate to stay in a given logic state in the presence of fluctuations (noise) in the input signal. A large noise immunity means output logic level will not change in the presence of large fluctuations in the input logic level.

4. Fabrication of a Simple IC (Fabrication of DTL NOR gate)

In the fabrication of an IC, parts of several circuit components are often formed simultaneously. This is illustrated with the example of fabrication of a DTL NOR gate as discussed step by step below.

1. An n-type epilayer is grown on the p-type substrate

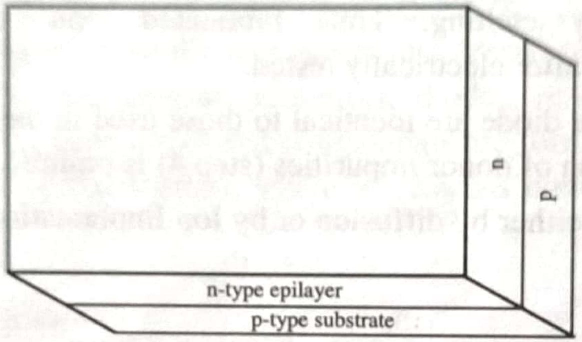


Figure 1

2. Coat with SiO_2 by oxidation and then with a photo-resist.

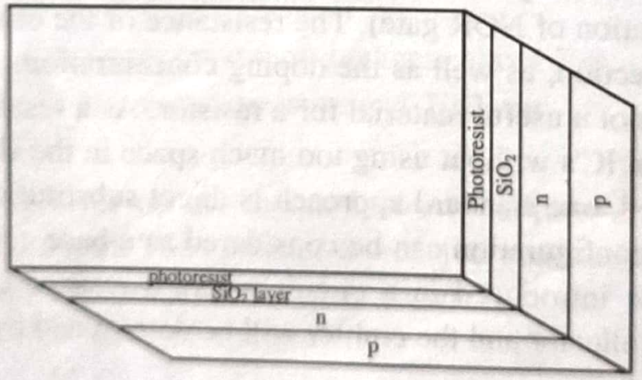


Figure 2

3. The wafer is exposed to uv radiation through the mask as shown in figure (3).

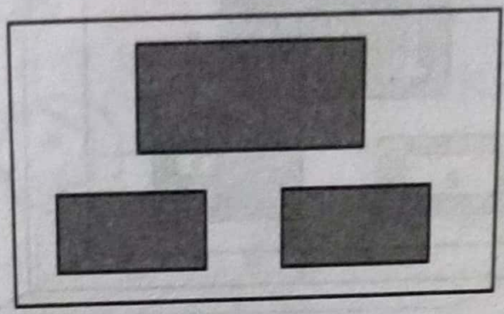


Figure 3

4. The photoresist in the region not covered by the mask is removed by uv radiation and the oxide is removed by etching. The islands of photo resist and oxide corresponding to mask region are-as shown in figure (4).

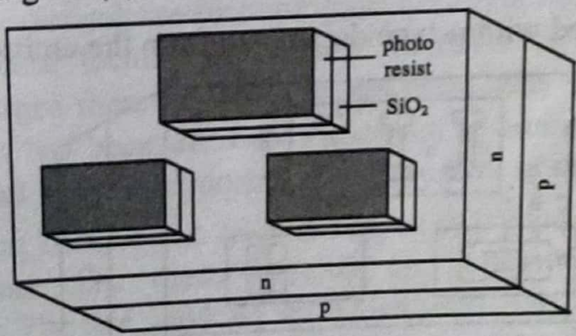


Figure 4

5. Dope the acceptors impurities on n-type epilayer so that the region except masked with SiO_2 and photo resist becomes P-type and the masked region remain n-type. Remove photo resist with photoresist remover and SiO_2 by etching.
Now the three n-type islands are formed on a p-type substate. The first island (i) serve to construct the transistor, another (ii) the diodes, and the third (iii) the three resistors.

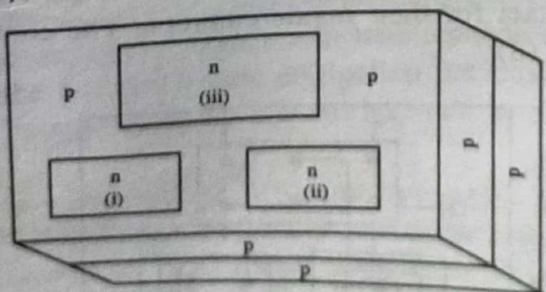


Figure 5

Classical Free Electron Model (CFE)

The first successful attempt to understand the electrical properties of metals was presented by P. Drude in 1900 and was extended by H.A. Lorentz in 1909. The results of these two investigators, as well as the work of others, is now called the classical free electron model (CFE). The CFE model was not totally adequate; subsequent models started with some of the basic assumptions of the Drude-Lorentz model but modified them with new concepts.

Assumptions of the Model; Q.N;4

1. The main assumption of the CFE model is that a metal is composed of an array of ions with valence electrons that are free to move through the ionic array with the only restriction that they remain confined with in the boundaries of the solid. Because these valence electrons are responsible for the electrical conduction of solid, they are called conduction electrons.
2. The mutual repulsion between the negatively charged electrons is neglected. In addition, the potential energy due to the ions is assumed to be everywhere constant. These free

electrons are basically treated as an ideal neutral gas that obeys Maxwell-Boltzmann statistics.

3. In the absence of an electric field, these electrons are moving with their random thermal velocities given by

$$\frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$$

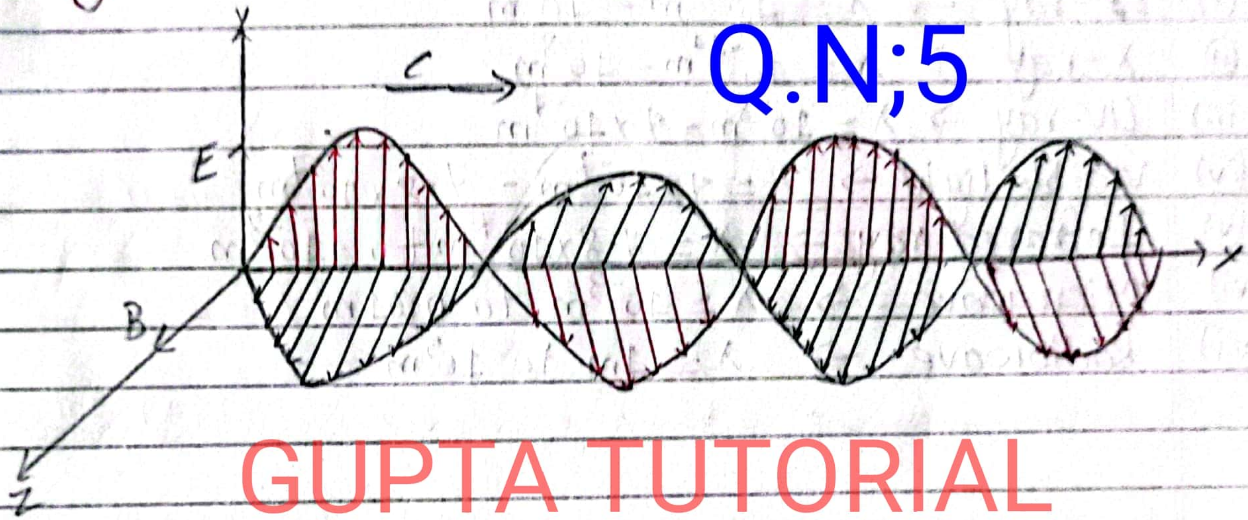
Here $\overline{v^2}$ is the average of the square of the thermal speeds.

4. When an electric field is applied to the solid, the free electrons acquire an average drift velocity in the direction opposite to the electric field, thus producing an electric current.

Despite the many simplifying assumptions, this CFE model was able to explain many properties of metals in a quantitative and satisfactory way. It was able to predict Ohm's law, as well as the Wiedemann Franz law, an empirical formula relating the electrical and thermal conductivities in metals.

Q.N;5

Electromagnetic wave / Electromagnetic spectrum:-



When a charge is accelerated, then electric field is developed. Due to this electric field, magnetic field is induced perpendicular to the electric field. Due to this magnetic field, electric field again induced. Continuing this process, a wave is created and travell in the direction ~~E~~ perpendicular to both electric field and magnetic field known as direction of propagation of wave. Such wave is known as electromagnetic wave. Here, electric field and magnetic field are varies sinusiodally with time given by eq^n

$$\vec{E} = \vec{E}_0 \sin(kx - \omega t)$$

and $$\vec{B} = \vec{B}_0 \sin(kx - \omega t)$$

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where, $\vec{E}_0$ and $\vec{B}_0$ are maximum value of $\vec{E}$ and $\vec{B}$ respectively 'ω' is angular frequency which is same as that of accelerating charge. "K" is wave number.

Here, the $\vec{E} \times \vec{B}$ gives the direction of propagation of wave. The electromagnetic gives wave having different value of frequency is known as electromagnetic spectrume.

(i) γ-ray → $\lambda = 10^{-13} m - 10^{-10} m$

(ii) X-ray → $\lambda = 10^{-11} m - 10^{-8} m$

(iii) UV-ray → $\lambda = 10^{-8} m - 4 \times 10^{-7} m$

(iv) Visible light → $\lambda = 4 \times 10^{-7} m - 7.8 \times 10^{-7} m$

(v) Infrared ray → $\lambda = 7.8 \times 10^{-7} m$ to $10^{-3} m$

(vi) Microwave → $\lambda = 10^{-3} m$ to $0.01 m$

(vii) Radiowave → $\lambda = 1m$ to $10^{5} m$

The Process of IC Production

The first process involved in the fabrication of integrate circuit is photolithography which includes epitaxial growth, oxidation, oxide removal and pattern definition. The photolithography is followed by doping (introduction of selective impurities in Si) and metallization (Interconnection of components).

Q.N;6

1. Photolithography

It is the process which involves photographic transfer of a pattern to the surface of wafer to make diffusion window by etching. In this process a geometrical pattern is transferred from a mask to the surface of silicon wafer. Lithography literally means "Writing on stone". Photolithography involves following steps.

Step i: *Coat Si with oxide then with photoresist (Oxidation)*

At first the Silicon single crystal is oxidized in an oxidation furnace to form a thin layer of SiO_2, which is excellent barrier against diffusion. The oxide layer is grown by heating the silicon wafer to temperatures ranging between 1000°C and 1200°C in an atmosphere of either pure oxygen or steam. The thickness of the oxide layer depends on the oxidation time and the temperature and the composition of the atmosphere in which the oxidation is performed. By careful selection of these three parameters, the exact thickness of the layer can be controlled. A layer 0.1 μm thick can be grown in one hour at T = 1000°C, in pure oxygen. In the same time, a layer 0.5 μm thick grows in a steam environment.

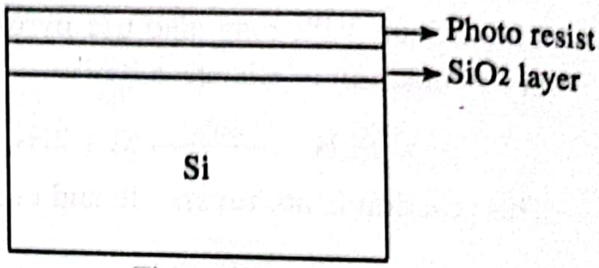


Figure (1)

Again coat the wafer with a radiation sensitive polymer film called the photo resist. Spin the silicon wafer very fast so that coating is uniform (figure 1).

Step ii: *Expose to radiation and develop the pattern (Pattern definition)*

Allow the UV radiation to fall on photo resist through mask. A mask is a glass plate with transparent and opaque regions made on it. Only those regions of the mask which are transparent allow the radiation to fall on the semiconductor. Only those portions which are exposed to radiation, their properties are going to change. The photo resists from the exposed regions are removed. Now the mask pattern is transferred to top of wafer. (Figure 2)

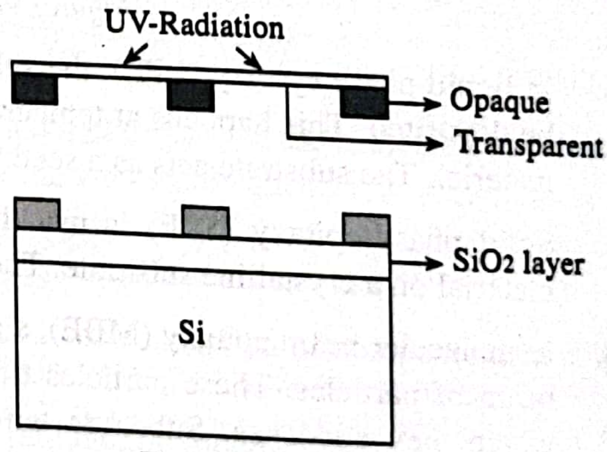


Figure (2)

Step iii: *Oxide removal*

Now the substance is kept in diluted etching solution (hydro fluoric acid, HF), the SiO_2 from the Si regions corresponding to transparency of mask is removed. (Figure 3)

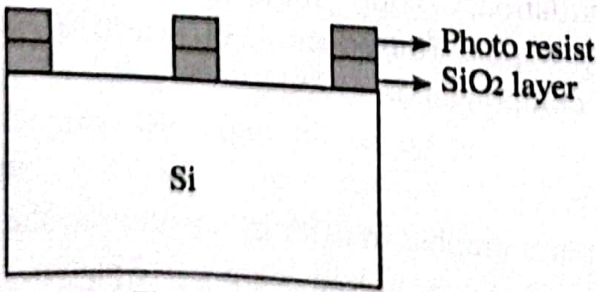


Figure (3)

Step iv: All the photoresist is removed by keeping it on photoresist remover solution (Figure 4).

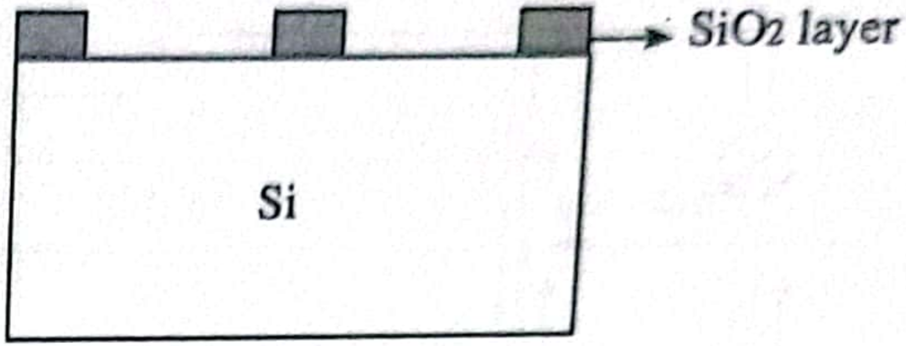


Figure (4)

Compare the pattern on mask with pattern of SiO_2 on the top of Si wafer, the opaque regions on the mask have corresponding pattern of SiO_2 on Si wafer. The regions corresponding to transparency of mask have no oxide. These are the regions where the dopant will be incorporated. This process in which UV light is used to produce the diffusion window pattern is called *Photolithography*.

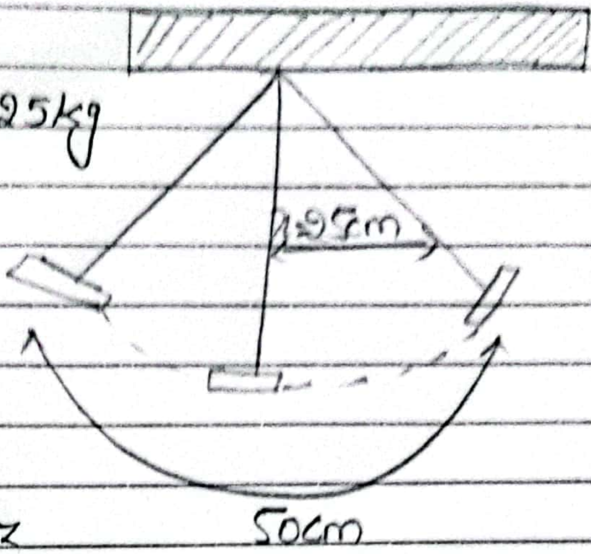
The pattern on the mask and wafer are identical. Those pattern obtained on wafer are said to be due to positive photoresist. A positive resist is one which gets soften when exposed to radiation. If the photoresist is hard, the complement pattern is obtained with semiconductor regions etched with UV radiation. It is called a negative photo resist.

(Note: SiO_2 is an excellent insulating material. It has good masking properties. The region which is not to be doped is masked with SiO_2. It does not allow dopant to pass through it.)

Doping

An integrated circuit has informal name chip. The formation of circuit components in a chip is achieved by the selective introduction of donor and acceptor impurities into the Si wafer to create localized n-type and p-type regions. The two most commonly used techniques for doping are diffusion and ion implantation.

7. Given,
Block of mass $(m) = 250g$
$= \frac{250}{1000} = 0.25kg$



Time taken $(T) = \cancel{0.2}\,0.2sec$

ⓐ frequency $(f) = ?$
ⓑ Amplitude of motion $(X_m) = ?$
ⓒ Force constant $(K) = ?$

we know,

ⓐ $F = \frac{1}{T} = \frac{1}{0.2} = 5Hz$

ⓑ $X_m =$ midpoint of Total amplitude (50cm)
$= \frac{50}{2} = 25cm$

ⓒ $T = 2\pi\sqrt{\frac{m}{K}}$

or, $\frac{T}{2\pi} = \sqrt{\frac{m}{K}}$

or, s.b.s

$\frac{T^2}{4\pi^2} = \frac{m}{K}$

$K = \frac{m4\pi^2}{T^2} = \frac{0.25 \times 4 \times \pi \times \pi}{(0.2)^2} = \frac{9.8696044}{0.04}$

$K = 246.74 \ N/m$

$\therefore$ frequency $(f) = 5Hz$
Amplitude of motion $(X_m) = 25cm$
Force Constant $(K) = 246.74 N/m$
Ans

8. Given,

Potential difference (V) = 100V

Charge of an alpha particle (q) = 3.2×10^{-19} C

Mass of an alpha particle (m) = 6.70×10^{-19} Kg

Velocity of an alpha particle (v) = ?

we know

$$\frac{1}{2} mv^2 = qV$$

or, $$v^2 = \frac{2qV}{m}$$

or, $$v = \sqrt{\frac{2qV}{m}}$$

or, $$v = \sqrt{\frac{2 \times 3.2 \times 10^{-19} \times 100}{6.7 \times 10^{-19}}}$$

or, $$v = \sqrt{95.5223881}$$

$$\therefore v = 9.77 \text{ m/s}$$

$\therefore$ The velocity of an alpha particle is 9.77m/s Ans

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9 Given,

Uncertainty in its position $(\lambda) = 1A\ (10^{-10} m)$

Uncertainty in the momentum of an electron $(p) = ?$

we know,

$$p = \frac{h}{\lambda}$$

$$= \frac{6.62 \times 10^{-34}\ J\,Sec}{10^{-10}\ m}$$

$$= 6.62 \times 10^{-24}\ J\,Sec/m$$

$\therefore$ Uncertainty in the momentum of an electron is 6.62×10^{-24} JSec/m

Sol Given,

Current $(I) = 50A$

Magnetic field $(B) = 1.5T$

Wide $(b) = 2\times10^{-2} m^2$

Concentration of copper $(N) = 8.4\times10^{28}$ electrons $/m^3$.

Hall voltage $(V_H) = ?$

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$$\text{Area}(A) = b \times \text{wide}$$
$$= 0.5 \times 10^{-2} \times 2 \times 10^{-2}$$
$$= 1 \times 10^{-4}\, m^2$$

we know,

$$\text{Hall voltage } (V_H) = \frac{IBb}{NqA}$$
$$= \frac{50 \times 1.5 \times 2 \times 10^{-2}}{8.4 \times 10^{28} \times 1.6 \times 10^{-19} \times 1 \times 10^{-4}}$$
$$= 1.12 \times 10^{-6}\, V_{//}$$

Body-centered cubic structure (N) = 2
Face - " " " (N) = 4
Simple - " " " (N) = 1

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11. Given,
Density of Sodium (ρ) = 0.971 g/cm^3
Atomic weight of Sodium (m) = 23 g/mole
No. of atoms per unit cell (N) = 2 ~~at~~ (in question there is body-centered)

length of the unit cube of the structure (a) = ?
we know,

$$\frac{N}{V} = \frac{\rho N_A}{m}$$

or, $$\frac{N}{a^3} = \frac{\rho N_A}{m}$$

or, $$a^3 = \frac{Nm}{\rho N_A} = \frac{2 \times 23}{0.971 \times 6.023 \times 10^{23}}$$

or, $$a^3 = \frac{46}{5.848333 \times 10^{23}}$$

or, $$a^3 = 7.8654 \times 10^{-23}$$

$$a = 4.284 \times 10^{-8}$$

$$\therefore a = 428.1 \, A^0$$

$\therefore$ length of the unit cube of the structure (a) = 428.1 A^0

12 Given, expression is

$$Y = (C + \overline{B}A)(\overline{A + B + D})$$

Input				Intermediated state					Output
A	B	C	D	$\overline{B}$	$\overline{B}A$	$C+\overline{B}A$	$A+B+D$	$\overline{A+B+D}$	$Y = (C+\overline{B}A)(\overline{A+B+D})$
0	0	0	0	1	0	0	0	1	0
0	0	0	1	1	0	0	1	0	0
0	0	1	0	1	0	1	0	1	1
0	0	1	1	1	0	1	1	0	0
0	1	0	0	0	0	0	1	0	0
0	1	0	1	0	0	0	1	0	0
0	1	1	0	0	0	1	1	0	0
0	1	1	1	0	0	1	1	0	0
1	0	0	0	1	1	1	1	0	0
1	0	0	1	1	1	1	1	0	0
1	0	1	0	1	1	1	1	0	0
1	0	1	1	1	1	1	1	0	0
1	1	0	0	0	0	0	1	0	0
1	1	0	1	0	0	0	1	0	0
1	1	1	0	0	0	1	1	0	0
1	1	1	1	0	0	1	1	0	0

fig:- Truth table

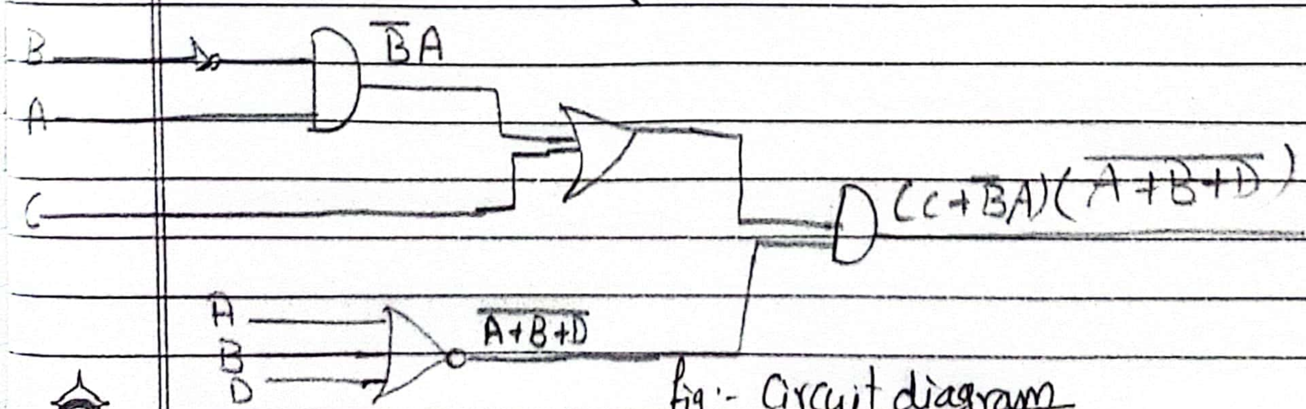

fig:- Circuit diagram