NAME -CHIRAG GARG
REG NO- 21BCE2769
DA 3

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Digital assignment - III

Class ID: VL2022230507148 Slots: Y11+Y12+Y21

1) Construct and explain the working principle of LED and PIN photo detector.

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Digital Assignment - 3

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Chirag Garg

(1) Construct and explain the working principle of LED and PIN photo detector

(A) LED
Light emitting diodes is a semiconductor p-n junction diode which emits light when it is forward biased

Construction

A n type layer is grown on a substrate and a p-type layer is deposited on it by diffusion. Since carrier recombination takes place in the p-layer, It is deposited upper most for maximum light emission, a metal film anode is deposited at the outer edge of the p-layer. The bottom of the substrate is coated with metal (gold) film for reflecting most of the light surface of the device and also provide connection with n-type layer.

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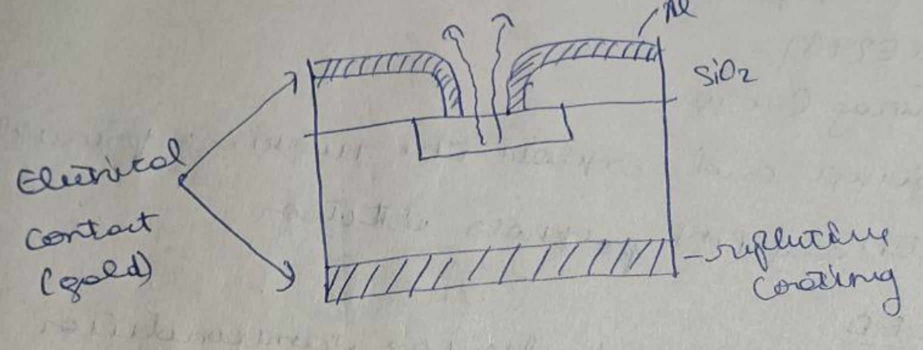

Working

When p-n junction diode is forward biased, the barrier width is reduced raising the potential energy on the n-side and lowering that on the p-side

The free electrons and holes have sufficient energy to move into the junction region. If a free electron meets a hole, it recombines with each other resulting in the release of a photon.

The light radiation of the LED is caused by the recombination of holes and electrons that are injected into the junction by forward bias voltage

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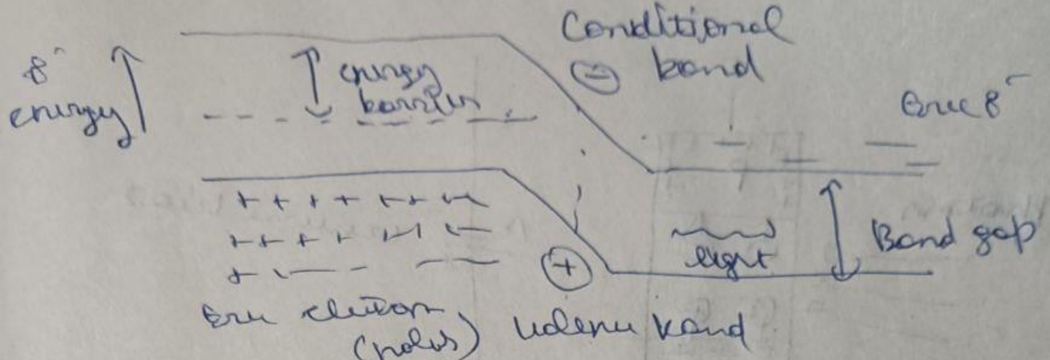

PIN photo detector

~~Construction~~
This is a device used to convert light energy into electrical energy

Construction
It consist of three layers such as P, n and intrinsic region with proper

Working
The P and N region are heavily doped
The intrinsic layer is slightly larger than both P-type and n-type for creating the light photon.

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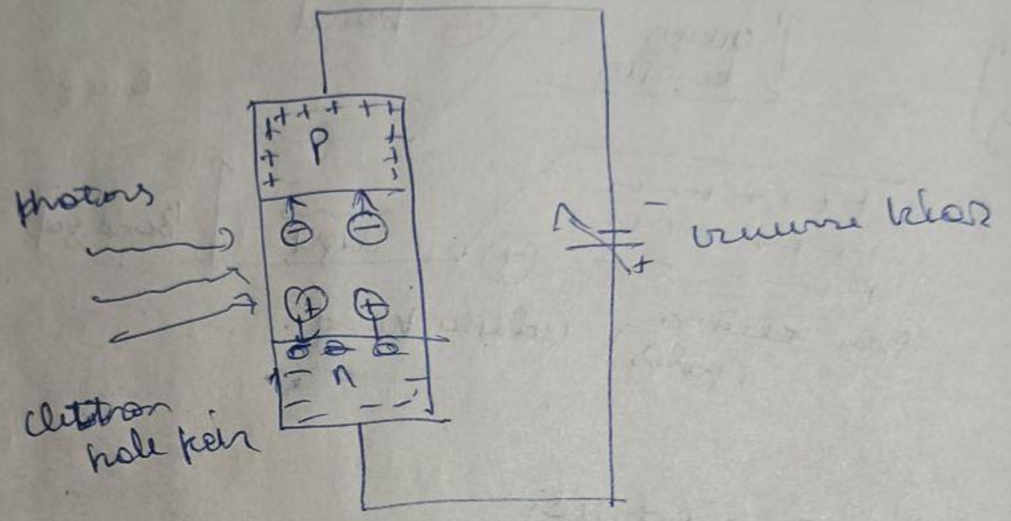

Working

The PIN diode is heavily reverse bias when a photon of higher energy is incident over the larger width intrinsic region layer, the the electron hole pair are created

The mobile charges are accelerated by applied voltage, which gives rise to photo current in the external circuit

It is linear device because of the photo current is directly proportional to the incident optical power on the PIN-photo diode

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Digital assignment - I

Class ID: VL2022230507148 Slots: Y11/Y12/Y21

1) Derive the wave equation of a string and write down the set of solutions of it.

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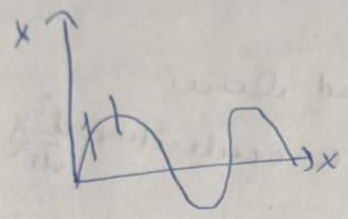
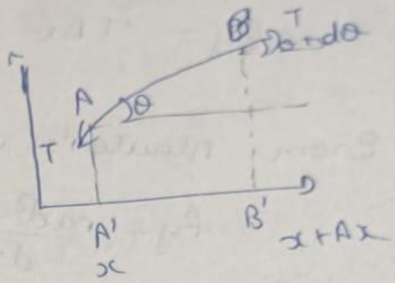
Engineering Physics
DA-I





Force in y direction

$F_y = T\sin(\theta + d\theta) - T\sin\theta$

x direction force is anyways $\approx 0 \approx T\cos(\theta+d\theta) - T\cos\theta$

As $\sin\theta \approx \tan\theta$ when θ is very small

$\tan\theta$ is also slope

$$F_y = T\frac{dy}{dx}\Big|_{x+\Delta x} - T\frac{dy}{dx}\Big|_{x}$$

we know that

$$\frac{dy}{dx} = \lim_{\Delta x \to 0} \frac{y(x+\Delta x, t) - y(x,t)}{\Delta x}$$

$$\frac{d^2y}{dx^2} = \lim_{x \to 0} \frac{\frac{dy}{dx}\Big|_{x+\Delta x, t} + -\frac{dy}{dx}\Big|_{x,t}}{\Delta x}$$

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$$F_y = T\Delta x \left[\frac{dy}{dx}\Big|_{(x+\Delta x)} - \frac{dy}{dx}\Big|_x \right]$$

$$F_y = T\Delta x \frac{d^2y}{dx^2}$$

From newton's second law

$$F_y = m\frac{d^2y}{dt^2} \qquad a = \text{acceleration} = \frac{d^2y}{dt^2}$$

$$m = \rho\, ds \qquad \rho = \text{mass density per unit length}$$

$$= \rho\sqrt{(\Delta x)^2 + (\Delta y)^2}\, ds \qquad ds = \text{very small length}$$

$$= \rho\,\Delta x\sqrt{1 + \left(\frac{\Delta y}{\Delta x}\right)^2}$$

$$m \approx \rho\Delta x \qquad v = \sqrt{\frac{T}{\rho}}$$

$$m\frac{d^2y}{dt^2} = T\Delta x\frac{d^2y}{dx^2}$$

$$\rho\Delta x\frac{d^2y}{dt^2} = T\Delta x\frac{d^2y}{dx^2}$$

$$\frac{d^2y}{dt^2} = \frac{T}{\rho}\frac{d^2y}{dx^2} \qquad v = \sqrt{\frac{T}{\rho}}$$

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2) Consider a wave travelling along +x-axis through a string which has impedances z_1 and z_2 such that $z_1 < z_2$, write down the wave equations of incident, reflected and transmitted waves with diagrams.

Q-2

→ Incident wave can be described by the equation

$$y_1(x,t) = A_1\cos(k_1x - \omega^* t)$$

A_1 = Amplitude of incident wave
k_1 = wave number
ω = angular velocity

→ The reflected wave can be described by equation

$$y_2(x,t) = A_2\cos(k_1x + \omega^* t)$$

A_2 = Amplitude of reflected wave

→ The transmitted wave can be described by equation.

$$y_3(x,t) = A_3\cos(k_2x - \omega^* t)$$

A_3 = Amplitude of transmitted wave
k_2 = wave number of transmitted wave

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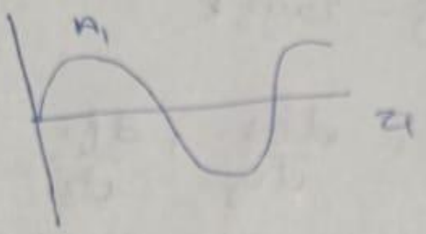
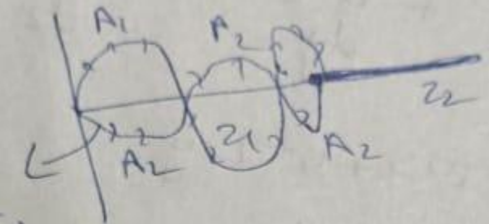
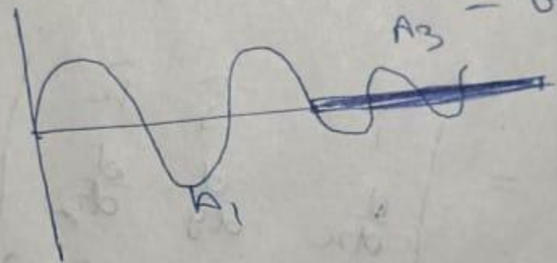


Incident wave



reflected waves

— Transmitted wave



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3) Standing waves are formed by a string with length l whose ends are fixed by rigid walls. Derive the wavelength of a standing waves.

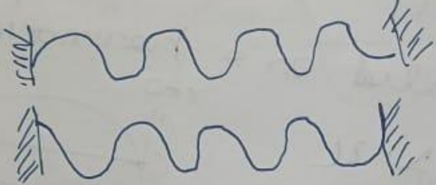
Superposition resultant

$$y_R = y_1 + y_2$$

$$= A\sin(kx-\omega t) + A\sin(kx+\omega t)$$

$$y_R = 2A\sin kx \cos\omega t$$

$x=0 \to L$ Stationary waves let derive expression for the eigen frequencies and allowed values of "k" in this system.



conditions $y_R(x=0,t) = 0$ and $y_R(x=L,t) = 0$.

$y_R(x=0,t) = 0$ is obviously satisfied
However for second boundary condition
$y_R(x=L,t) = 0$ to be satisfied,

we need
$$2A\sin kL\cos\omega t = 0$$
$$\sin kL = 0$$
$$kL = n\pi \qquad n = 1,2,3$$
$$k_n = \frac{n\pi}{L}$$

$$\lambda_n = \frac{2\pi}{k_n} = \frac{2\pi}{n\pi}L = \frac{2L}{n}$$

$$\lambda_n = \frac{2L}{n}$$

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4) Discuss the physical significance of gradient, divergence and curl. Calculate the divergence ($\nabla . \boldsymbol{f}$) and curl ($\nabla \times \boldsymbol{f}$) of a given vector field

$$\boldsymbol{f} = 5x^2\hat{\boldsymbol{i}} + 3xz^2\hat{\boldsymbol{j}} - 2xyz\hat{\boldsymbol{k}}$$

Q-4
Ans The gradient:

a) Take hight to be a function of x only. The gradient, then, would give you the direction (at a point) of greatest increase in height. In other words, it would point in the direction of steepest elevation

b) Mathematically, the gradient represents the slope of a line tangent to the graph, with magnitude equal to the slope.

The Divergence:

a) This tells you, in some sense, how 'spiky' your vector field at a point.

b) Mathematically and "more technically, the divergence represents the volume density of the outward flux of a vector field from an infinitesimal volume around given point.

The Curl

a) This tells you, in some sense, how 'swirly' your vector field is at a point.

b) The curl tells you about the vector field's rotation (about a single point you're interested in)

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$F = 5x^2\hat{i} + 3xz^2\hat{j} - 2xyz\hat{k}$

Divergence: $\frac{df_x}{dx} + \frac{df_y}{dy} + \frac{df_z}{dz}$

$\frac{d}{dx}(5x^2) + \frac{d}{dy}(3xz^2) + \frac{d}{dz}(-2xyz)$

$= 10x + 0 - 2xy$

$= 10x - 2xy$

Curl:

$$\vec{\nabla}\times\vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{d}{dx} & \frac{d}{dy} & \frac{d}{dz} \\ 5x^2 & 3xz^2 & -2xyz \end{vmatrix}$$

$$\hat{i}\left(\frac{d}{dy}(-2xyz) - \frac{d}{dz}(3xz^2)\right) - \hat{j}\left(\frac{d}{dx}(-2xyz) - \frac{d}{dz}(5x^2)\right)$$

$$+ \hat{k}\left(\frac{d}{dx}(3xz^2) - \frac{d}{dy}(5x^2)\right)$$

$$- \hat{j}(-2xyz - 0) + \hat{k}(3z^2 - 0)$$

$$= \hat{i}(-2xz - 3x(2z)) - \hat{j}(-2xyz) + \hat{k}(3z^2)$$

$$\hat{i}(-2xz - 6xz) - \hat{j}(-2xyz)$$

$$= \boxed{-8xz\,\hat{i} + 2yz\,\hat{j} + 3z^2\,\hat{k}}$$

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5) Discuss the Maxwell's equations of electromagnetic wave. Derive the wave equation for electric and magnetic fields in vacuum.

The four Maxwell's eqn's are

1) Gauss's law

$$\nabla \cdot E = \rho / \varepsilon_0$$

Describes the relationship between electric fields and electric charges. It states that the divergence of electric field is proportional to the charge density at a given point in space

2) Gauss law for magnetic field

$$\nabla \cdot B = 0$$

Divergence of magnetic field is always zero meaning that magnetic field lines form closed loops. or no monopole exists

3) Faraday's law.

$$\vec{\nabla} \times \vec{B} = -dB/dt$$

It states that the curl of the electric field is proportional to the time rate of change of magnetic field.

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4) Ampere's law (with correction)

$$\vec{\nabla}\times\vec{B} = \mu_0(J+\varepsilon_0 dE/dt)$$

It states that curl of the magnetic fields ~~and electric currents, it~~ is proportional to the sum of electric current density and time rate of change of electric field, with const proportionality being the magnetic constant

Em max Eq's for free space in terms of $\vec{B}$

① $\vec{\nabla}\cdot\vec{D} = 0$
② $\vec{\nabla}\cdot\vec{B} = 0$
③ $\vec{\nabla}\times\vec{E} = -\frac{d\vec{B}}{dt}$
④ $\vec{\nabla}\times\vec{H} = \frac{d\vec{D}}{dt}$

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From Maxwell's 3rd Eqn

$$\vec{\nabla} \times \vec{E} = -\frac{d\vec{B}}{dt} \quad -(1)$$

taking curl of Eqn (1)

$$\vec{\nabla} \times (\vec{\nabla} \times \vec{E}) = -\frac{d}{dt}(\vec{\nabla} \times \vec{B}) \quad -(2)$$

From vector identity we know

$$\vec{\nabla} \times (\vec{\nabla} \times \vec{E}) = \vec{\nabla}(\vec{\nabla} \cdot \vec{E}) - \vec{\nabla}^2 \vec{E}$$

$$\vec{\nabla}(\vec{\nabla} \cdot \vec{E}) - \vec{\nabla}^2 \vec{E} = -\frac{d}{dt}(\vec{\nabla} \times \vec{B})$$

$\vec{\nabla} \cdot \vec{D} = 0$ or $\vec{\nabla} \cdot \vec{E} = 0$ for free space

& $\vec{B} = \mu_0 \vec{H}$

$$0 - \vec{\nabla}^2 \vec{E} = \mu_0 \frac{d}{dt}(\vec{\nabla} \times \vec{H})$$

Maxwell Eqn (4) $\vec{\nabla} \times \vec{H} = \frac{d\vec{D}}{dt}$

$$\vec{\nabla}^2 \vec{E} = \mu \frac{d}{dt}\left(\frac{d\vec{D}}{dt}\right) \qquad \boxed{\vec{D} = \varepsilon_0 \vec{E}}$$

$$\vec{\nabla}^2 \vec{E} = \mu_0 \varepsilon_0 \frac{d^2 \vec{E}}{dt^2}$$

Required Equation

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Digital assignment - III

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Digital Assignment - 3

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(1) Construct and explain the working principle of LED and PIN photo detector

(A) LED
Light emitting diodes is a semiconductor p-n junction diode which emits light when it is forward biased

Construction

A n type layer is grown on a substrate and a p-type layer is deposited on it by diffusion. Since carrier recombination takes place in the p-layer, It is deposited upper most for maximum light emission, a metal film anode is deposited at the outer edge of the p-layer. The bottom of the substrate is coated with metal (gold) film for reflecting most of the light surface of the device and also provide connection with n-type layer.

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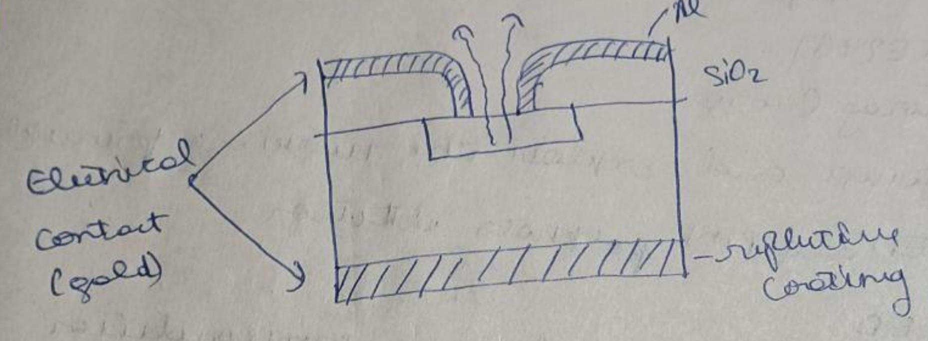

Working

When p-n junction diode is forward biased, the barrier width is reduced raising the potential energy on the n-side and lowering that on the p-side.

The free electrons and holes have sufficient energy to move into the junction region. If a free electron meets ~~a~~ a hole, it recombines with each other resulting in the release of a photon.

The light radiation of the LED is caused by the recombination of holes and electrons that are injected into the junction by forward bias voltage.

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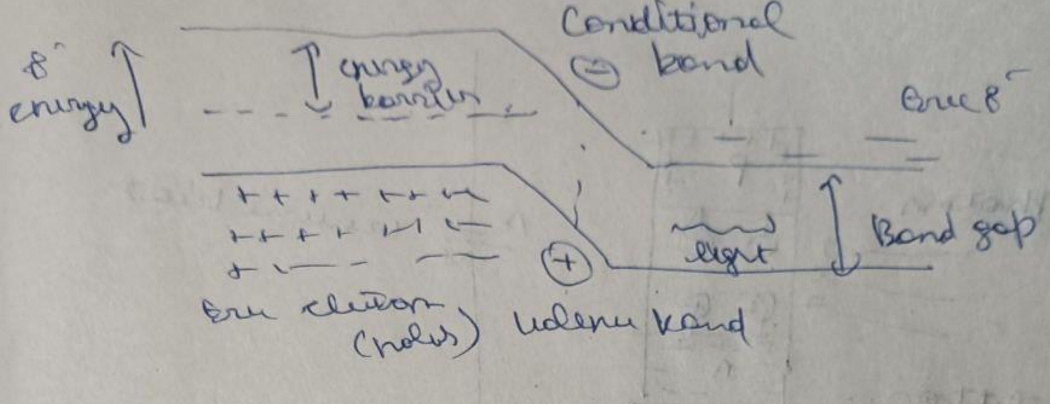

PIN photo detector

~~Constructio~~

This is a device used to convert light energy to electrical energy

Construction

It consist of three layers such as P, n and intrinsic region with proper

Working

The P and N region are heavily doped
The instrinsic layer is slightly larger than both P-type and n-type for creating the light photon.

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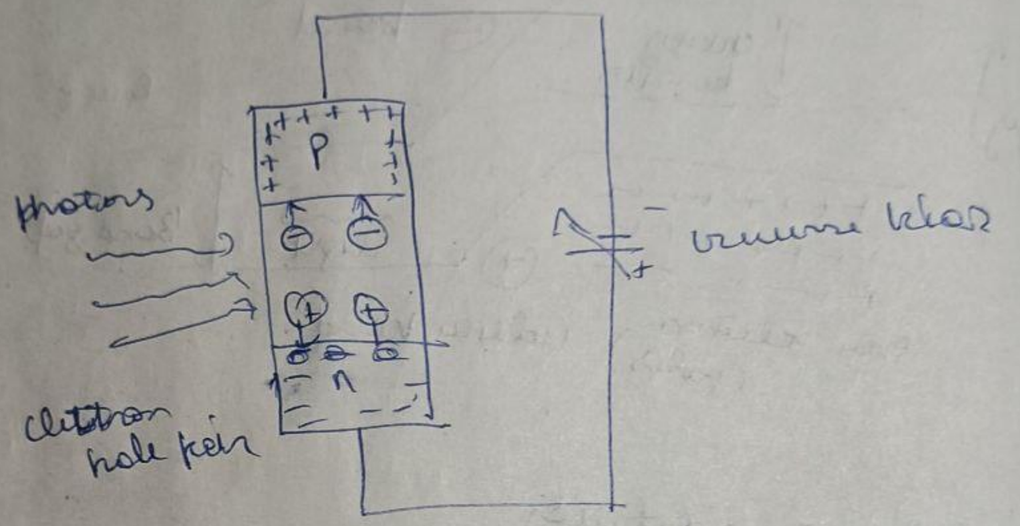

Working

The PIN diode is heavily reverse bias when a photon of higher energy is incident over the larger width intrinsic region layer, the the electron hole pair are created

The mobile charges are accelerated by applied voltage, which gives rise to photo current in the external circuit

It is linear device because of the photo current is directly proportional to the incident optical power on the PIN-photo diode

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Digital assignment - I

Class ID: VL2022230507148 Slots: Y11/Y12/Y21

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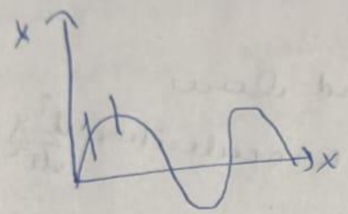
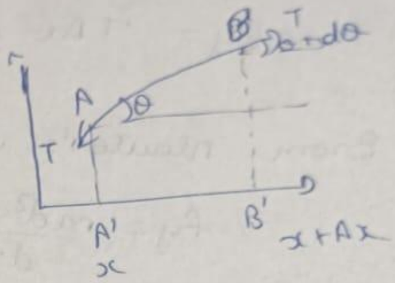
Engineering Physics
DA-I





Force in y direction

$F_y = T\sin(\theta + d\theta) - T\sin\theta$

x direction force is anyways $\approx 0 \approx T\cos(\theta+d\theta) - T\cos\theta$

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$$F_y = T\Delta x \frac{dy}{dx}(x+\Delta x) - \frac{dy}{dx}\Big|_x$$

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From newton's second law

$$F_y = m\frac{d^2y}{dt^2} \quad a = \text{acceleration} = \frac{d^2y}{dt^2}$$

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$$= \rho\sqrt{(\Delta x)^2 + (\Delta y)^2}\, ds = \text{very small length}$$

$$= \rho\,\Delta x\sqrt{1 + \left(\frac{\Delta y}{\Delta x}\right)^2}$$

$$m = \rho\,\Delta x \qquad v = \sqrt{\frac{T}{\rho}}$$

$$m\frac{d^2y}{dt^2} = T\Delta x\frac{d^2y}{dx^2}$$

$$\rho\,\Delta x\frac{d^2y}{dt^2} = T\Delta x\frac{d^2y}{dx^2}$$

$$\frac{d^2y}{dt^2} = \frac{T}{\rho}\frac{d^2y}{dx^2} \qquad v = \sqrt{\frac{T}{\rho}}$$

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2) Consider a wave travelling along +x-axis through a string which has impedances z_1 and z_2 such that $z_1 < z_2$, write down the wave equations of incident, reflected and transmitted waves with diagrams.

Q-2

→ Incident wave can be described by the equation

$$y_1(x,t) = A_1 \cos(k_1 x - \omega^* t)$$

A_1 = Amplitude of incident wave

k_1 = wave number

ω = angular velocity

→ The reflected wave can be described by equation

$$y_2(x,t) = A_2 \cos(k_1 x + \omega^* t)$$

A_2 = Amplitude of reflected wave

→ The transmitted wave can be described by equation

$$y_3(x,t) = A_3 \cos(k_2 x - \omega^* t)$$

A_3 = Amplitude of transmitted wave

k_2 = wave number of transmitted wave

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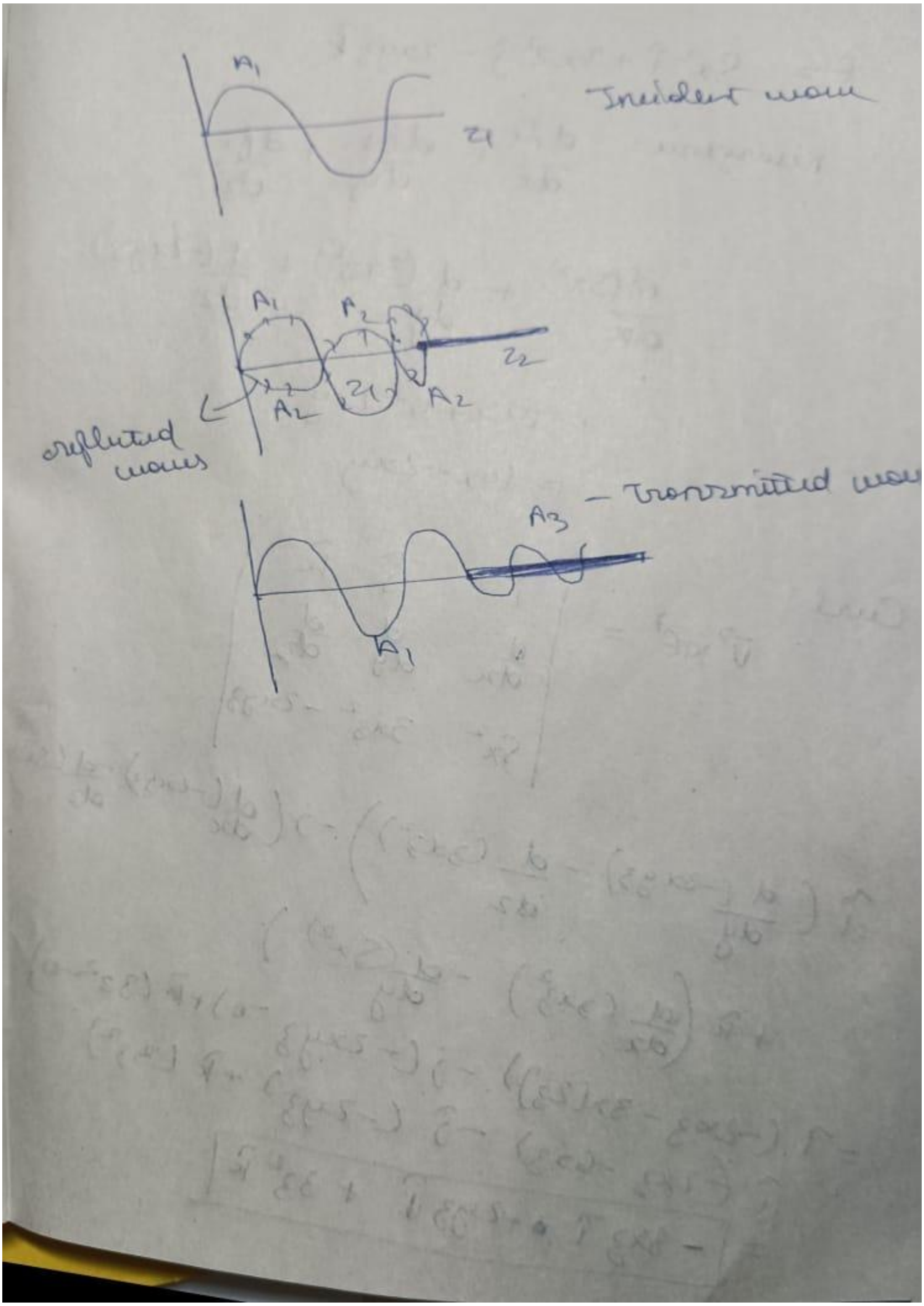

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3) Standing waves are formed by a string with length l whose ends are fixed by rigid walls. Derive the wavelength of a standing waves.

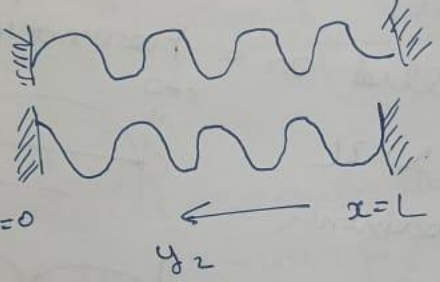
Superposition resultant

$$y_R = y_1 + y_2$$

$$= A\sin(kx - \omega t) + A\sin(kx + \omega t)$$

$$y_R = 2A\sin kx \cos \omega t$$

$x=0 \rightarrow L$ Stationary waves. Let derive expression for the eigen frequencies and allowed values of "k" in this system.



conditions $y_R(x=0,t) = 0$ and $y_R(x=L,t) = 0$.

$y_R(x=0,t) = 0$ is obviously satisfied. However for second boundary condition $y_R(x=L,t) = 0$ to be satisfied, we need

$$2A\sin kL \cos\omega t = 0$$

$$\sin kL = 0$$

$$kL = n\pi \qquad n = 1, 2, 3$$

$$k_n = \frac{n\pi}{L}$$

$$\lambda_n = \frac{2\pi}{k_n} = \frac{2\pi}{n\pi} L = \frac{2L}{n}$$

$$\lambda_n = \frac{2L}{n}$$

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4) Discuss the physical significance of gradient, divergence and curl. Calculate the divergence ($\nabla . \boldsymbol{f}$) and curl ($\nabla \times \boldsymbol{f}$) of a given vector field

$$\boldsymbol{f} = 5x^2\hat{\boldsymbol{i}} + 3xz^2\hat{\boldsymbol{j}} - 2xyz\hat{\boldsymbol{k}}$$

Q-4
Ans The gradient:

a) Take height to be a function of x only - The gradient, then, would give you the direction (at a point) of greatest increase in height. In other words, it would point in the direction of steepest ea elevation

b) Mathematically, the gradient represents the slope of a line tangent to the graph, with magnitude equal to the slope.

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b) The curl tells you about the vector field's rotation (about a single point you're interested in)

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$F = 5x^2\hat{i} + 3xz^2\hat{j} - 2xyz\hat{k}$

Divergence: $\frac{dF_x}{dx} + \frac{dF_y}{dy} + \frac{dF_z}{dz}$

$$\frac{d(5x^2)}{dx} + \frac{d}{dy}(3xz^2) + \frac{d}{dz}(-2xyz)$$

$$= 10x + 0 - 2xy$$

$$= 10x - 2xy$$

Curl:

$$\vec{\nabla} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{d}{dx} & \frac{d}{dy} & \frac{d}{dz} \\ 5x^2 & 3xz^2 & -2xyz \end{vmatrix}$$

$$\hat{i}\left(\frac{d}{dy}(-2xyz) - \frac{d}{dz}(3xz^2)\right) - \hat{j}\left(\frac{d}{dx}(-2xyz) - \frac{d}{dz}(5x^2)\right)$$

$$+ \hat{k}\left(\frac{d}{dx}(3xz^2) - \frac{d}{dy}(5x^2)\right)$$

$$-0) + \hat{k}(3z^2 - 0)$$

$$= \hat{i}(-2xz - 3x(2z)) - \hat{j}(-2xyz) + \hat{k}(3z^2)$$

$$\hat{i}(-2xz - 6xz) - \hat{j}(-2yz)$$

$$= \boxed{-8xz\,\hat{i} + 2yz\,\hat{j} + 3z^2\,\hat{k}}$$

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4) Ampere's law (with correction)

$$\vec{\nabla} \times \vec{B} = \mu_0 (J + \varepsilon_0 dE/dt)$$

It states that curl of the magnetic fields ~~and electric currents,~~ ~~it~~ is proportional to the sum of electric current density and time rate of change of electric field, being the magnetic with const proportionality constant

Em max Eq's for free space in terms of $\vec{B}$

① $\vec{\nabla} \cdot \vec{D} = 0$
② $\vec{\nabla} \cdot \vec{B} = 0$
③ $\vec{\nabla} \times \vec{E} = -\frac{d\vec{B}}{dt}$
④ $\vec{\nabla} \times \vec{H} = \frac{d\vec{D}}{dt}$

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From Maxwell's 3rd eqn

$$\vec{\nabla} \times \vec{E} = -\frac{d\vec{B}}{dt} \quad -① $$

taking curl of Eq ①

$$\vec{\nabla} \times (\vec{\nabla} \times \vec{E}) = -\frac{d(\vec{\nabla} \times \vec{B})}{dt} \quad -② $$

From vector identity we know

$$\vec{\nabla} \times (\vec{\nabla} \times \vec{E}) = \vec{\nabla}(\vec{\nabla} \cdot \vec{E}) - \nabla^2 \vec{E}$$

$$\vec{\nabla}(\vec{\nabla} \cdot \vec{E}) - \vec{\nabla}^2 \vec{E} = -\frac{d}{dt}(\vec{\nabla} \times \vec{B})$$

$\vec{\nabla} \cdot \vec{D} = 0$ or $\vec{\nabla} \cdot \vec{E} = 0$ for free space

& $\vec{B} = \mu_0 \vec{H}$

$$0 - \vec{\nabla}^2 \vec{E} = \mu_0 \frac{d}{dt}(\vec{\nabla} \times \vec{H})$$

Maxwell Eqn ④ $\vec{\nabla} \times \vec{H} = \frac{d\vec{D}}{dt}$

$$\vec{\nabla}^2 \vec{E} = \mu \frac{d}{dt}\left(\frac{d\vec{D}}{dt}\right) \qquad \boxed{\vec{D} = \varepsilon_0 \vec{E}}$$

$$\vec{\nabla}^2 \vec{E} = \mu_0 \varepsilon_0 \frac{d^2 \vec{E}}{dt^2}$$

Required Equation