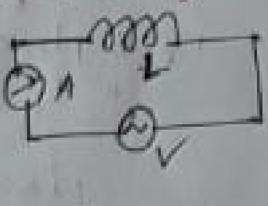
- **problem**: What is the inductive reactance of a coil if the current through it is 20 mA and voltage across it is 100V.

Sol^n: $E_L = I X_L \quad \therefore X_L = \frac{E_L}{I} = \frac{100}{20\times10^{-3}} = 5\,k\Omega$

- **problem**: A capacitor of 50 pF is connected to an ac source of frequency 1 kHz. Calculate it resistance.

Sol^n: $X_C = 1/\omega C = \frac{1}{2\pi f C} = \frac{1}{2\pi\times10^{3}\times50\times10^{-12}} = \frac{10^7}{\pi}\,\Omega$

- **problem**: In given ckt. applied voltage $V = 50\sqrt{2}\sin(100\pi t)$ volt and ammeter reading is 2A then calculate value of L.

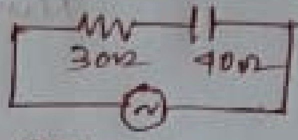


Sol^n: $E_{r.m.s} = I_{r.m.s} X_L$ Reading of ammeter $= I_{r.m.s}$

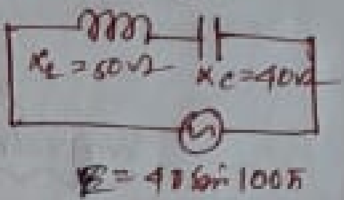
$X_L = \frac{E_{r.m.s}}{I_{r.m.s}} = \frac{E_0}{\sqrt{2} I_{r.m.s}} = \frac{50\sqrt{2}}{\sqrt{2}\cdot 2}$

$= 25\,\Omega \Rightarrow L = \frac{X_L}{\omega} = \frac{25}{100\pi} = \frac{1}{4\pi}$ H.

- **problem**: Calculate the impedence of the ckt.



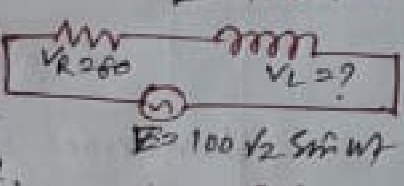
Sol^n: $Z = \sqrt{R^2+(X_C)^2} = \sqrt{(30)^2+(40)^2} = \sqrt{2500} = 50\,\Omega$



Sol^n: $Z = X_L - X_C = (50 - 40)\,\Omega = 10\,\Omega$

$I_0 = \frac{E_0}{Z} = \frac{40}{10} = 4A$

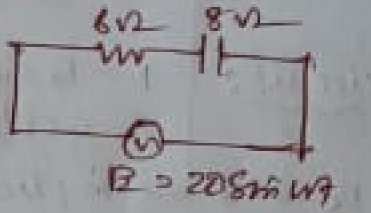
$I_{r.m.s} = \frac{4}{\sqrt{2}} = 2\sqrt{2}\,A$



Sol^n: $E^2 = E_R^2 + E_L^2 \Rightarrow E_L^2 = E^2 - E_R^2$

$E_L = \sqrt{E^2 - E_R^2} = \sqrt{100^2 - 60^2} = \sqrt{6400}$

$= 80$ volt.



Sol^n: $Z = \sqrt{R^2 + X_C^2} = \sqrt{6^2+8^2} = 10\,\Omega$

$E = IZ \Rightarrow I = \frac{E_0}{Z} = \frac{20}{10} = 2A$

$I_{r.m.s} = \frac{2}{\sqrt{2}} = \sqrt{2}\,A$.

- **problem**: When 10V DC is applied across a coil current through it is 2.5 A, if 10V, 50 Hz AC is applied current reduces to 2A. Calculate reactance of the coil.

Sol^n: For 10V DC $\therefore E = IR \Rightarrow R = \frac{E}{I} = \frac{10}{2.5} = 4\,\Omega$

For 10V AC $\therefore E = IZ \Rightarrow Z = \frac{E}{I} = \frac{20}{10} = 5\,\Omega$

$Z = \sqrt{R^2+X_L^2} = 5 \Rightarrow R^2 + X_L^2 = 25 \Rightarrow X_L^2 = 5^2 - 4^2 \Rightarrow X_L = 3\,\Omega$.

- **problem**:

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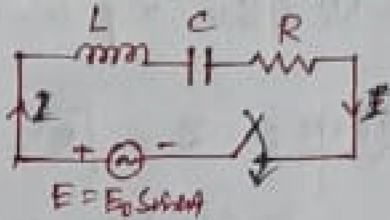
L-C-R circuit:

Series L-C-R ckt:

$E = E_0 \sin \omega t$

$E_R = IR$, $E_L = L\frac{dI}{dt}$, $E_C = \frac{q}{C}$



By Kirchhoff's law:

$$E_R + E_L + E_C = E$$

$$\therefore IR + L\frac{dI}{dt} + \frac{q}{C} = E_0 \sin \omega t.$$

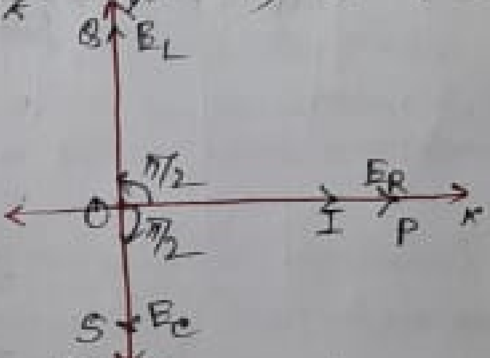
Differentiate & rearranging we get ⇒

$$L\frac{d^2I}{dt^2} + R\frac{dI}{dt} + \frac{1}{C}\frac{dq}{dt} = \omega E_0 \cos \omega t$$

$$\text{or, } L\frac{d^2I}{dt^2} + R\frac{dI}{dt} + \frac{I}{C} = \omega E_0 \cos \omega t \quad \left(\because I = \frac{dq}{dt}\right)$$

After solving this differential equation we get ⇒

$$I = \frac{E_0}{\sqrt{R^2 + (\omega L - 1/\omega C)^2}} \sin(\omega t - \phi) = \frac{E_0}{Z} \sin(\omega t - \phi) = I_0 \sin(\omega t - \phi)$$



Phase: E_R is in phase with I $\quad \vec{OP} = E_R$

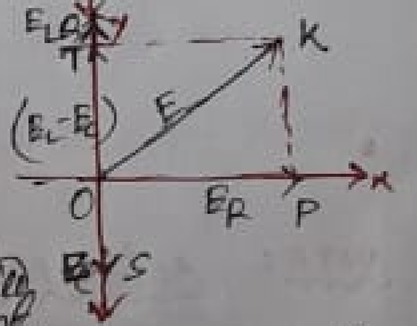
E_L leads I by $90°$ $\quad \vec{OQ} = E_L$

E_C lags behind I by $90°$. $\quad \vec{OS} = E_C$

So E_L & E_C are opposite to each other.

- If $E_L > E_C$ ie $\omega L > \frac{1}{\omega C}$ ie $I_0 \omega L > I_0/\omega C$ then

$$\vec{OT} = E_L - E_C = \omega L - 1/\omega C$$
$$\text{or } I_0(\omega L - 1/\omega C)$$



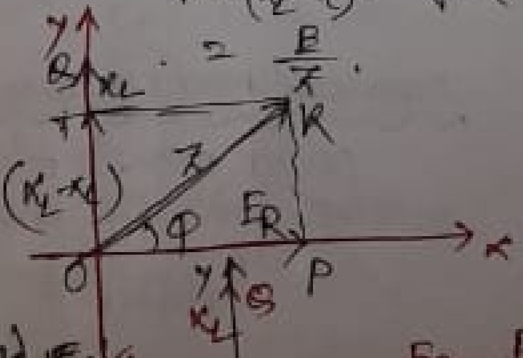
$\vec{OK} = \vec{E}$ = Resultant of E_R & $(E_L - E_C)$ = applied emf.

$$\therefore E = \sqrt{E_R^2 + (E_L - E_C)^2} = I\sqrt{R^2 + (X_L - X_C)^2} \Rightarrow I = \frac{E}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{E}{\sqrt{R^2 + (\omega L - 1/\omega C)^2}} = \frac{E}{Z}.$$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$

= Impedence of the ckt.

$$\tan\phi = \frac{(X_L - X_C)}{R} = \frac{(\omega L - 1/\omega C)}{R}$$

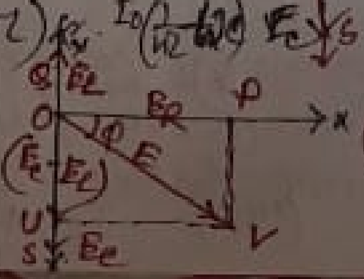


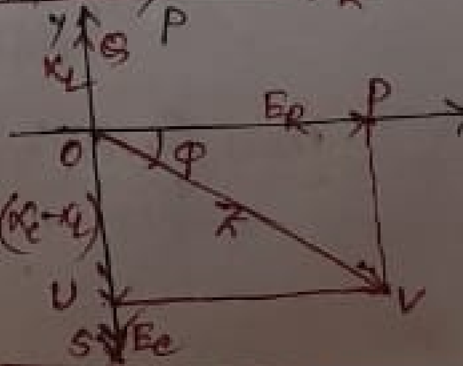
- If $E_L < E_C$ ie $\omega L < \frac{1}{\omega C}$ ie $I_0 \omega L < \frac{I_0}{\omega C}$ then

$OU = (X_C - X_L) = \left(\frac{1}{\omega C} - \omega L\right)$ or $I_0\left(\frac{1}{\omega C} - \omega L\right)$

$\vec{OV} = \vec{E} = \sqrt{E_R^2 + (E_C - E_L)^2}$

$= I\sqrt{R^2 + (X_C - X_L)^2}$

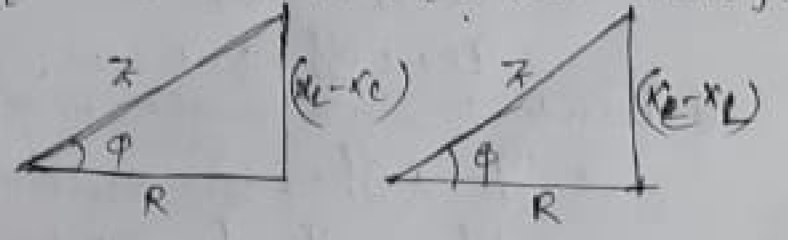




NOTE: $\omega L > \frac{1}{\omega C}$ then ϕ is +ve i.e. I lags behind by phase or $X_L > X_C$
& $\omega L < 1/\omega C$ " ϕ is −ve i.e. I leads by phase, or $X_L < X_C$

Impedence: $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$ = Impedence of the L−C−R Cnt.

In complex quantity: $Z = R + j\,(\omega L - 1/\omega C)$ where $j = \sqrt{-1}$.



Dissipative power: $P = EI = E_0 \sin\omega t \cdot I_0 \sin(\omega t - \phi)$

$$= E_0 I_0 \left(\sin^2\omega t \cos\phi - \sin\omega t \cos\omega t \sin\phi\right)$$

$$P_{av} = \bar{P} = \langle P \rangle_{\text{full cycle}} = \frac{1}{T}\int_0^T E_0 I_0 \left(\sin^2\omega t \cos\phi - \sin\omega t \cos\omega t \sin\phi\right) dt$$

$$= \frac{E_0 I_0}{T}\left[\cos\phi \int_0^T \sin^2\omega t\, dt - \frac{1}{2}\sin\phi \int_0^T \sin 2\omega t\, dt\right]$$

$$= \frac{E_0 I_0}{T}\left(\cos\phi \cdot T/2 - \frac{1}{2}\cdot \sin\phi \cdot 0\right) = \frac{E_0 I_0}{2}\cos\phi$$

$$= \frac{E_0}{\sqrt{2}}\frac{I_0}{\sqrt{2}}\cos\phi$$

$$= E_{rms} I_{rms} \cos\phi$$

$$= P_{rms} \cos\phi.$$

$\because \int_0^T \sin^2\omega t\, dt = -\frac{1}{2}\int_0^T (\cos 2\omega t - 1)\, dt = T/2$

$\because \int_0^T \sin 2\omega t\, dt = 0$

$P_{rms} = E_{rms} I_{rms} = \frac{E_0}{\sqrt{2}}\frac{I_0}{\sqrt{2}}$

NOTE: Active power or True power (প্রকৃত/সক্রিয় ক্ষমতা): কোনো পরিবর্তী বর্তনীতে প্রকৃতপক্ষে যে ক্ষমতা ক্ষয় হয় তাকে ঐ বর্তনীর True or active power বলে।

$$P_{true} = \frac{E_0 I_0}{2}\cos\phi = \langle P \rangle = \bar{P}.$$

Apparent power or Reactive power (আপাত ক্ষমতা/প্রতিক্রিয়াশীল ক্ষমতা): কোনো পরিবর্তী বর্তনীতে rms প্রবাহমাত্রা এবং rms বিভবপ্রভেদের গুণফলকে আপাত বা প্রতিক্রিয়াশীল ক্ষমতা বলা হয়।

$$P_{apparent} = P_{rms} = I_{rms} E_{rms} = I_0/\sqrt{2} \cdot E_0/\sqrt{2}$$

Power factor (ক্ষমতা গুণাঙ্ক): কোনো পরিবর্তী বর্তনীর প্রকৃত ক্ষমতা ও আপাত ক্ষমতার অনুপাতকে power factor বলে।

$\therefore$ Power factor $(\cos\phi)$ $= \dfrac{\text{প্রকৃত/True power}}{\text{আপাত/Apparent power}} = \dfrac{\bar{P}}{P_{rms}} = \cos\phi = \dfrac{R}{Z}$

$= \dfrac{\text{Average power}}{\text{rms power}}$

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- **Wattless current (শক্তিহীন প্রবাহমাত্রা):** যে সমস্ত বর্তনীর ক্ষেত্রে তড়িচ্চালক বল ও প্রবাহমাত্রার মধ্যে দশা পার্থক্য $\pi/2$ বা 90° হয় অর্থাৎ $\phi = \pi/2$, সেই বর্তনী দ্বারা ব্যয়িত ক্ষমতা শূন্য হয়, সেই বর্তনীর প্রবাহমাত্রাকে শক্তিহীন প্রবাহমাত্রা বলে।
  ie $I_{rms}\sin\phi$. $\langle P \rangle = E_{rms} I_{rms} \cos 90^\circ = 0$

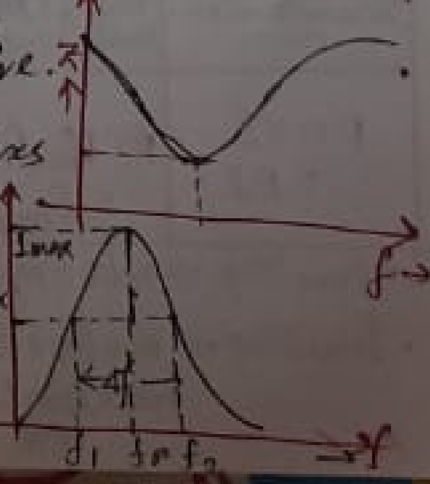
- **Resonance (অনুনাদ):**
  A circuit is said to be resonant when the natural frequency of circuit is equal to frequency of the applied voltage.
  For resonance both L and C must present in circuit.
  → Series Resonance (শ্রেণি অনুনাদ)
  → parallel Resonance (সমান্তরাল অনুনাদ)

- **Series Resonance:** In L-C-R series cnt, $X_L = X_C$ then $\phi = 0$.
  So Impedence Z is minimum which equal to the resistance R. So that the current in the cnt. is maximum means power is maximum. This is called series resonance.

- **Series ie At Resonance:** $\boxed{X_L = X_C}$, $\boxed{E_L = E_C}$, $\boxed{\phi = 0}$ (ie E_R & I are in phase)
  Then $\boxed{Z_{min} = R}$ (Impedence minimum)
  & $\boxed{I_{max} = \frac{E_R}{R}}$ (Current maximum)
  Power = maximum.

- **Resonance frequency:** $X_L = X_C \Rightarrow \omega_r L = \frac{1}{\omega_r C} \Rightarrow \omega_r^2 = \frac{1}{LC} \Rightarrow 2\pi f_r = \frac{1}{\sqrt{LC}}$
  $$\therefore \boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$$

- **Variation of Z with f:**
  If $f < f_r$ then $X_L < X_C$: ϕ = -ve the cnt. nature is capacitive.
  At $f = f_r$ then $X_L = X_C$: ϕ = zero (0), the cnt. nature is Resistive
  If $f > f_r$ then $X_L > X_C$; ϕ = +ve, the cnt. nature is Inductive.



- **Variation of I with f:** As f increases Z first decreases then increases.
  As f increases I 1st increases then decreases.

- At resonance Z = minimum so it is called acceptor circuit. It most readily accepts that current out of many currents whose frequency is equal to its natural frequency.

- In radio or TV tuning we receive the desired station by making the frequency of the circuit equal to that of the desired station.
- Half power frequency:
  The frequency at which power becomes half of its maximum value is called half power frequencies.
- Band width: $\Delta f = f_2 - f_1$
- Quality factor (Q): Q-factor of AC cnt. basically gives an idea about stored energy and lost energy.

$$Q = 2\pi \frac{\text{maximum energy stored per cycle}}{\text{maximum energy loss per cycle}}$$

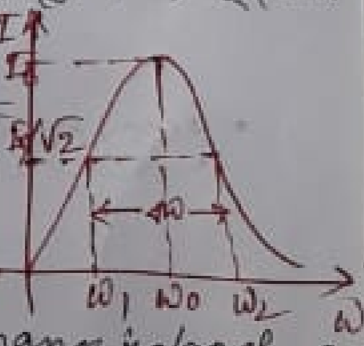
It represents the sharpness of resonance.
It is unit less and dimension less quantity.

$$Q = \frac{(X_L)_r}{R} = \frac{(X_C)_r}{R} = \frac{2\pi f_r L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{f_r}{\Delta f} = \frac{f_r}{\text{band width}}$$

$\left(\text{as } \omega_r = 2\pi f_r = \frac{1}{\sqrt{LC}}\right)$

- Band width $= \Delta\omega = \omega_2 - \omega_1 = R/L$
  = যে কোনো দুটি কৌণিক কম্পাঙ্কে বর্তনীর প্রবাহ সর্বোচ্চ প্রবাহমাত্রার অর্ধেক হয়, সেই কম্পাঙ্কে তড়িৎ প্রবাহমাত্রার সর্বোচ্চ প্রবাহমাত্রার $1/\sqrt{2}$ গুণ হয়, ঐ কম্পাঙ্ক দুটি অর্থাৎ ω_1 ও ω_2 এর অন্তর হল ঐ ব্যান্ড প্রস্থ (band width) হয়,

$$Q = \frac{\omega_0}{\omega_1 - \omega_2} = \frac{\omega_0}{R/L} = \frac{\omega_0 L}{R} = \frac{L}{R}\cdot\frac{1}{\sqrt{LC}} = \frac{1}{R}\sqrt{\frac{L}{C}}$$



- If Q is high then resonance is also sharp.

- Magnification:
  At resonance
  $E_L = E_C = QE$ (E = Supplied voltage)
  So at resonance
  Magnification factor = Q factor

- Sharpness (তীক্ষ্ণতা):

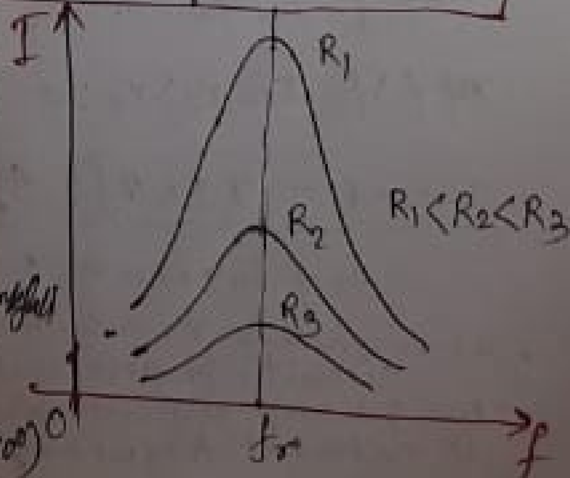
$\boxed{\text{Sharpness} \propto \text{Quality factor (Q-factor)} \propto \text{Magnification factor.}}$

$\boxed{R \text{ decreases} \Rightarrow Q \text{ increases} \Rightarrow \text{Sharpness increases}}$

- NOTE

Instantaneous power	Average/Actual/dissipative power/Power loss	Virtual/Apparent/rms power	Peak power
$P = VI$ $= EI$	$P = V_{rms} I_{rms} \cos\varphi$ $= E_{rms} I_{rms} \cos\varphi$	$P = V_{rms} I_{rms}$ $= E_{rms} I_{rms}$	$P = V_0 I_0$ $= E_0 I_0$

- $I_{rms}\cos\varphi \Rightarrow$ active part of current or wattfull current or workfull current. It is in phase with voltage.
- $I_{rms}\sin\varphi \Rightarrow$ Inactive part of current, wattless current, workless current. It is in quadrature (90°) with voltage.



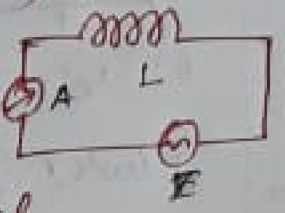
Problem: What is the inductive reactance of a coil if the current through it is 20 mA and voltage across it is 100 volt.

Sol^n: $E_L = I X_L$ $\therefore X_L = \frac{E_L}{I} = \frac{100}{20\times10^{-3}} = 5k\Omega$

Problem: A capacitor of 50 pF is connected to an ac source of frequency 1 kHz. Calculate its reactance?

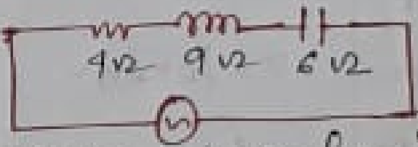
Sol^n: $X_C = 1/\omega C = \frac{1}{2\pi f C} = \frac{1}{2\pi\times10^3\times50\times10^{-12}} = \frac{10^7}{\pi}\Omega$

Problem: In the ckt. applied voltage $E = 50\sqrt{2}\sin(100\pi)t$ Volt and ammeter reading is 2A then calculate value of L?



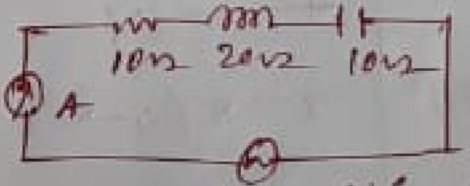
Sol^n: $E_{r.m.s} = I_{rms} X_L$
Done before.

Problem: Find the impedence of given circuit.



Sol^n: $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{4^2 + (9-6)^2}$
$= \sqrt{4^2+3^2} = \sqrt{25} = 5\Omega$ $(\because X_L > X_C \therefore$ Inductive$)$

Problem: Find out the reading of the ammeter and also calculate the potential difference of given L-C-R ckt.



Sol^n: $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{10^2 + (20-10)^2}$
$= 10\sqrt{2}\,\Omega$

$I_0 = \frac{E_0}{Z} = \frac{100}{10\sqrt{2}} = \frac{10}{\sqrt{2}}$ A

$I_{rms} = \frac{10}{\sqrt{2}\cdot\sqrt{2}} = 5A$ (Ammeter reads RMS value).

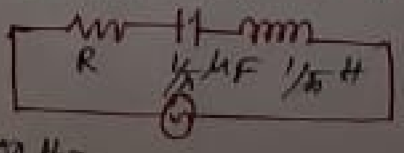
$E_R = 5\times10 = 50V$
$E_C = 5\times10 = 50V$

Problem: For LCR ckt. with an AC source $R = 300\Omega$, $C = 20\mu F$, $L = 1.0H$, $E_{rms} = 50V$ and $f = 50/\pi$ Hz. Find rms value of ac?

Sol^n: $I_{rms} = \frac{E_{rms}}{Z} = \frac{E_{rms}}{\sqrt{R^2 + (\omega L - 1/\omega C)^2}} = \frac{50}{\sqrt{300^2 + \left[2\pi\times\frac{50}{\pi}\times1 - \frac{1}{20\times10^{-6}\times2\pi\times\frac{50}{\pi}}\right]^2}}$

$= \frac{50}{\sqrt{(300)^2 + \left[100 - \frac{10^3}{2}\right]^2}} = \frac{50}{100\sqrt{9+16}} = \frac{1}{10} = 0.1A$

Problem: For what frequency the voltage across the resistance R will be maximum?



Sol^n: It happens at resonance
$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{\frac{1}{\pi}\times10^{-6}\times\frac{1}{\pi}}} = 500$ Hz

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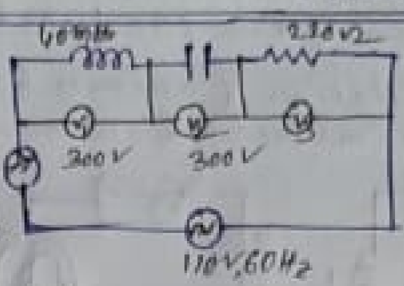
Problem: In series L-C-R cnt. find V_3 & I?



Soln: $\omega L = \frac{1}{\omega C}$ at resonance.

$C = \frac{1}{\omega^2 L} = \frac{1}{4\pi^2 \nu^2 L} = \frac{1}{4\pi^2 \times 60^2 \times 60 \times 10^{-3}}$
$= 176 \mu F$

$\therefore V_3 = V_R \Rightarrow V_3 = 110V$ and $I = \frac{V}{R} = \frac{110}{220} = 0.5A$

Problem: Radio receiver receives a message at 300m band, if the available inductance is 1 mH, then calculate required capacitance.

Soln: Radio receives EM waves ($V_{EM} = 3\times10^8$ m/sec $= C$)

$c = \nu\lambda \Rightarrow \nu = \frac{3\times10^8}{300} = 10^6 Hz.$

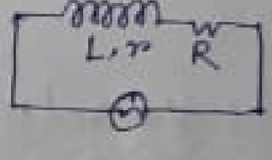
$f = \frac{1}{2\pi\sqrt{LC}} = 1\times10^6 \Rightarrow C = \frac{1}{4\pi^2 \times 10^{-3} \times 10^{12}} = 25 pF.$

Choke coil: In DC cnt. current is reduced with the help of a resistance. Loss of electrical energy I^2R loss in form of heat in the resistor. In AC cnt. it is done by choke coil.

Choke coil is a copper coil acts as an simple inductor is used to reduced current in a.c cnt without much loss of energy.

principle: The working of a choke is based on the working of an inductor. When ac flows through it then current lags behind the emf by phase $\pi/2$ radian.

Working: Cnt. of choke coil is a series L-R cnt.



If resistance of choke coil $= r$ (very small)

Then current $I = E/Z$; $Z = \sqrt{(R+r)^2 + (\omega L)^2}$

$R \to$ resistance of the electrical appliance.

$P_{av} = E_{eff} I_{eff} \cos\phi = E_{eff} I_{eff} \frac{R}{\sqrt{R^2 + \omega^2 L^2}}$ (neglecting r)

Power loss in the choke $P_{av} = E_{rms} I_{rms} \cos\phi \to 0.$

$\because \cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + \omega^2 L^2}} \simeq \frac{R}{\omega L} \to 0$ (as L is very large & $R \ll \omega L$)

Problem: If power factor of a R-L cnt. is $\frac{1}{2}$ when applied voltage is $V = 100 \sin 100\pi t$ volt and resistance of cnt is 200Ω then calculate the inductance of the cnt.

Soln: $\cos\phi = R/Z \Rightarrow \frac{1}{2} = R/Z \Rightarrow Z = 2R \Rightarrow \sqrt{R^2 + X_L^2} = 2R$

$X_L = \sqrt{3} R = \omega L \Rightarrow L = \frac{\sqrt{3}R}{\omega} = \frac{\sqrt{3}\times200}{100\pi} = \frac{2\sqrt{3}}{\pi} H$

Problem: A cnt. consisting of an inductance and a resistance joined to a 200 volt supply (AC). It draws a current of 10 A. If the power consumed in the cnt. is 1500 watt. Calculate the wattless current.

Soln: Apparent power $= 200\times10 = 2000 W$

power factor $\cos\phi = \frac{\text{True power}}{\text{Apparent p}} = \frac{1500}{2000} = 3/4$

Wattless current $= I_{rms}\sin\phi = 10\sqrt{1-(3/4)^2} = \frac{10\sqrt{7}}{4} A$

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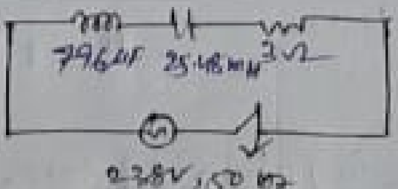
Problem: Find X_L, X_C, Z, φ, I_{rms}, P_{av} & power factor?



Sol^n: $E_0 = 283V$, $f = 50\,Hz$, $R = 3\Omega$,
$L = 25.48\,mH$, $C = 796\,\mu F = 796\times10^{-6}\,F$
$= 25.48\times10^{-3}\,H$.

$\therefore X_L = 2\pi f L = 2\times3.14\times50\times25.48\times10^{-3} = 8\Omega$

$X_C = \frac{1}{2\pi f C} = \frac{1}{2\times3.14\times50\times796\times10^{-6}} = 4\Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{3^2 + (8-4)^2} = 5\Omega$

$\tan\varphi = \frac{X_L - X_C}{R} = \frac{8-4}{3} = 4/3 \Rightarrow \varphi = \tan^{-1}(4/3) = 53.1°$.

$I_{rms} = I_0/\sqrt{2} = \frac{E_0}{\sqrt{2}Z} = \frac{1}{1.414}\times\frac{283}{5} = 40\,A$

$P_{av} = I_{rms}^2 R = 40^2\times3 = 4800\,W$

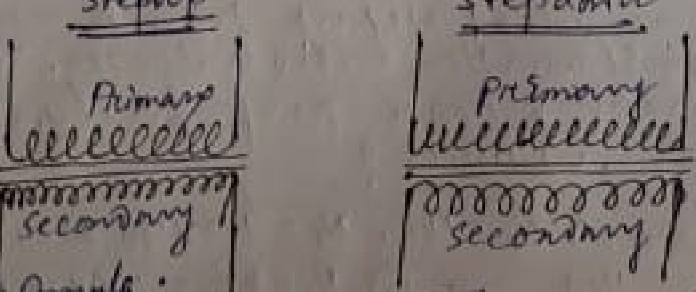
power factor $= \cos\varphi = \cos53.1° = 0.6 = R/Z = 3/5 = 0.6$.

Q-factor $= \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{3}\sqrt{\frac{25.48\times10^{-3}}{796\times10^{-6}}} = \frac{1}{3}\sqrt{32.01} = \frac{5.657}{3} = 1.8859$

Transformer:

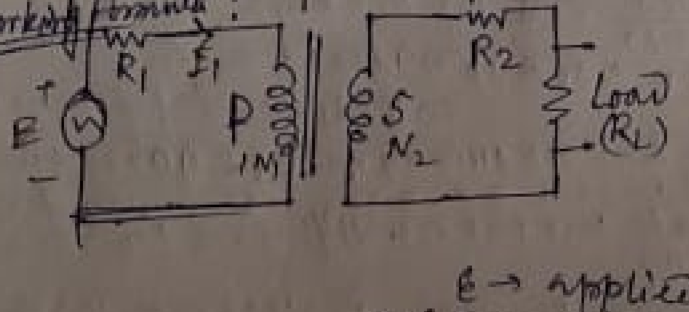
A transformer is a electrical device, based on the principle of mutual inductance, used for converting large alternating current at low voltage into small current at high voltage and vice versa.

Transformer two types
→ Stepup: The transformers which convert low voltages into higher ones called stepup transformer
→ Stepdown: The transformers which convert high voltages into lower ones called stepdown transformer.



(Coil type transformer
Shell " ")

Working formula:



$N_1 \to$ no. of turns in the primary coil
$N_2 \to$ " " " secondary.

Induced emf in the primary coil $E_1 = -N_1\frac{d\phi}{dt}$

" " " " secondary coil $E_2 = -N_2\frac{d\phi}{dt}$

$\therefore \frac{E_2}{E_1} = \frac{N_2}{N_1}$

$E \to$ applied emf in the primary. But by Lenz's law self induction emf E_1 opposes E in the primary coil.

$\therefore$ Resultant emf in the primary $= E - E_1$

$\therefore E - E_1 = R_1 I_1$ But R_1 is very small. So $E - E_1 = 0$ i.e $E = E_1$

$\therefore K = \frac{E_2}{E_1} = \frac{\text{output emf}}{\text{input emf}} = N_2/N_1 =$ transformer ratio.

For step up transformer : $\boxed{N_2 > N_1}$ i.e. $N_2/N_1 > 1$ i.e. $\boxed{E_2 > E_1}$ i.e. output voltage is greater than input voltage.

Step down " : $\boxed{N_2 < N_1}$ i.e. $N_2/N_1 < 1$ i.e. $\boxed{E_2 < E_1}$ i.e. output voltage is less than input voltage.

Currents in primary & secondary coil:

Let transformer to be ideal so that there are no energy loss.

Input power = output power i.e. $E_1 I_1 = E_2 I_2$

$\therefore I_1/I_2 = E_2/E_1$ i.e. $\boxed{I_1/I_2 = E_2/E_1 = N_2/N_1}$

Efficiency of a transformer:

$$\eta = \frac{\text{output power}}{\text{Input power}} \times 100\%$$

It be 90 to 99% for a transformer.

Use: i) In radio, telephones, loud speakers etc.

ii) TV, refrigerators, air conditioners, computers etc used voltage regulator.

iii) Stabilised power supplies.

iv) Step up & step ~~dow~~ transformer used in any electrical appliances.

v) In power station.

Energy losses in transformers: 1) Copper loss 2) Eddy current loss, 3) Hysteresis loss, 4) Flux leakage 5) Humming loss etc.

Problem: The primary coil of an ideal stepup transformer has 100 turns and the transformation ratio is also 100. The input voltage & the power are 220V & 1100 W respectively. Calculate. i) ~~N_2~~ ii) I_1, iii) E_2, iv) I_2, v) power ?

Soln: $N_1 = 100$, $E_1 = 220V$, $P_1 = 1100W$

i) $k = \frac{N_2}{N_1} = 100 \Rightarrow N_2 = 100$, $N_1 = 100 \times 100 = 10,000$

ii) $I_1 = P_1/E_1 = \frac{1100}{220} = 5A$ iii) $E_2 = kE_1 = 100 \times 200 = 22000V$

iv) $I_2 = I_1/k = 5/100 = 0.05A$, v) For ideal transformer output power = Input power = 1100W

Problem: A transformer efficiency 100%, has 200 primary turns & 40000 turns in secondary. It is connected to 220V ac mains & secondary feeds to a resistance 100kΩ. Calculate output pot. difference per turn and the power delivered to the load?

Soln: $\eta = 100\%$, $N_1 = 200$, $N_2 = 40,000$, $E_1 = 220V$, $R = 100k\Omega = 10^5\Omega$

$k = E_2/E_1 = N_2/N_1 \Rightarrow E_2 = N_2/N_1 \, E_1 = \frac{40000}{200} \times 220 = 44000V$

output Pd/turns $= \frac{E_2}{N_2} = \frac{44000}{40000} = 1.1V$ Power delivered to load $= E_2 I_2 = \frac{E_2^2}{R}$

$= \frac{(44000)^2}{10^5} = 19360W = 19.36kW$

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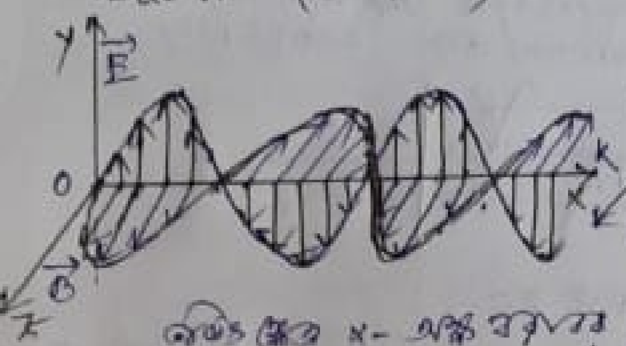
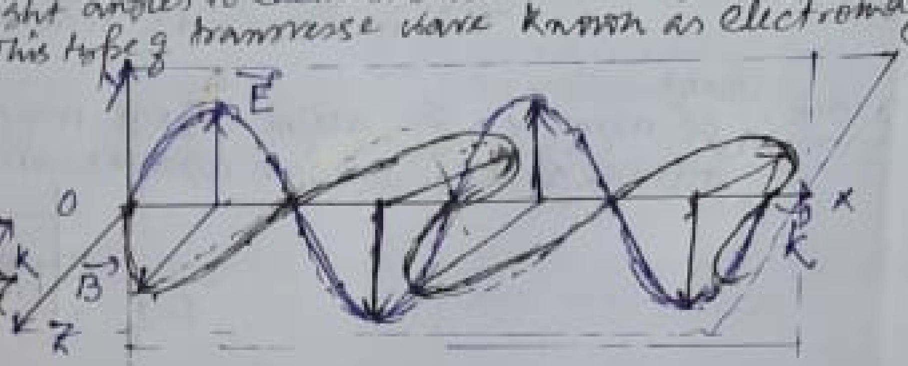
Electromagnetic wave (তড়িৎচুম্বকীয় তরঙ্গ):

পরিবর্তনশীল তড়িৎক্ষেত্র পরিবর্তনশীল চুম্বকক্ষেত্র সৃষ্টি করে এবং বিপরীতক্রমেও হয়, এই দুটি পরিবর্তনশীল ক্ষেত্র পরস্পর লম্ব এবং তরঙ্গ সঞ্চারণের অভিমুখের সাথেও লম্বভাবে থাকে, এই তরঙ্গকে তড়িৎচুম্বকীয় তরঙ্গ বলে।

A changing electric field produces a changing magnetic field and vice-versa which are acting at right angles to each other as well as at right angles to the direction of propagation. This type of transverse wave known as electromagnetic wave (e.m. wave).





তড়িৎ ক্ষেত্র x- অক্ষ বরাবর : $\vec{E} = \vec{E_0} \sin\omega\left(t - \frac{x}{c}\right) = \vec{E_0}\sin(\omega t - kx)$

চুম্বক ক্ষেত্র x- " " : $\vec{B} = \vec{B_0} \sin\omega\left(t - \frac{x}{c}\right) = \vec{B_0}\sin(\omega t - kx)$

$E_0, B_0 \rightarrow$ তড়িৎ ও চৌম্বক ক্ষেত্রের বিস্তার

$\omega, k \rightarrow$ কৌণিক কম্পাঙ্ক ও কৌণিক তরঙ্গ সংখ্যা।

Displacement Current (সরণ প্রবাহ):

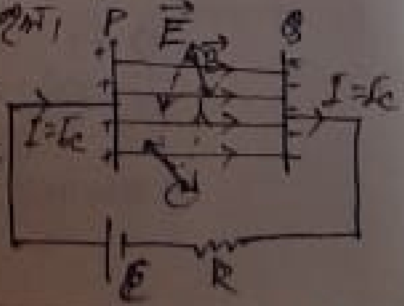
ধারকের দুই পাতের মধ্যবর্তী অঞ্চলে তড়িৎক্ষেত্র পরিবর্তিত হলে, ঐ অঞ্চলে যে তড়িৎপ্রবাহের সৃষ্টি হয় তাকেই সরণ প্রবাহ বা ম্যাক্সওয়েলের সরণ প্রবাহ বলে।

It is the current due to changing electric field between the plate of the capacitor and denoted as I_d.

The current due to the flow of charges in a conductor and is denoted as I_c known as the conduction current.

কোনো বর্তনীতে মোট প্রবাহ $\boxed{I = I_c + I_d}$

Concept of I_d: যদি একটি ধারক C একটি রোধ R, এর মাধ্যমে একটি তড়িৎকোষ E' এর সাথে যুক্ত, তবে সংযোগকারী তার এবং ধারকের দুই পাতের মধ্যে দিয়ে প্রবাহ চলে এবং ধারকের পাতে আধান জমা হয়। একটি তড়িৎ প্রবাহ আছে কি বলা যায়? ধারকের পাতে charge জমা হয়, ধারকের দুই পাতের মধ্যবর্তী অঞ্চলে একটি পরিবর্তনশীল তড়িৎক্ষেত্র উৎপন্ন হয়, আর একটি পরিবর্তনশীল চুম্বকক্ষেত্রের সৃষ্টি করে। বিজ্ঞানী Maxwell এই সময় [illegible] ধারকের দুই পাতের মধ্যবর্তী অঞ্চলে এমন একটি তড়িৎ প্রবাহ হয় যাকে সরণ প্রবাহ / displacement Current (I_d) বলে।



Electric field : $E = \frac{\sigma}{\epsilon_0} = \frac{q}{\epsilon_0 A}$; $A \rightarrow$ Area of the plates

In time dt charge on the plate of the capacitor increased by dq, then $I = \frac{dq}{dt}$

$\therefore$ Change in electric field ; $dE = \frac{dq}{\epsilon_0 A} = \frac{I\,dt}{\epsilon_0 A}$

$$\therefore \frac{dE}{dt} = \frac{I}{\epsilon_0 A} \Rightarrow I = \epsilon_0 A\frac{dE}{dt} = \epsilon_0 \frac{d}{dt}(AE) = \epsilon_0 \frac{d\phi_E}{dt} \quad (\because \phi_E = AE)$$

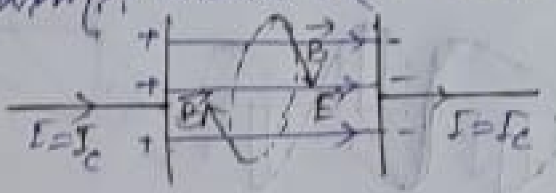
$$\therefore \boxed{I_d = \epsilon_0 \frac{d\phi_E}{dt}}$$

অ্যাম্পিয়ারের circuital law থেকে পাই যে,

$$\oint \vec{B}\cdot\vec{dl} = \mu_0(I_c + I_d) = \mu_0\left(I_c + \epsilon_0\frac{d\phi_E}{dt}\right)$$

This is known as Maxwell-Ampere's circuital law.

NOTE: ক্যাপাসিটরের দুই পাতের মধ্যবর্তী অঞ্চলে সময়ের সঙ্গে পরিবর্তনশীল তড়িৎক্ষেত্রের জন্য একটি চৌম্বকক্ষেত্রের সৃষ্টি হয় যা সরণ প্রবাহের দ্বারা উৎপন্ন হয়।



- শূন্য মাধ্যমে তড়িৎচুম্বকীয় তরঙ্গের গতিবেগ হল-

$c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$; $\mu_0 \to$ শূন্য মাধ্যমের চৌম্বকভেদ্যতা $= 4\pi\times10^{-7}\ N/C^2s^2$

$\epsilon_0 \to$ " " তড়িৎভেদ্যতা $= 8.854\times10^{-12}\ C^2/Nm^2$

$$\therefore c = \frac{1}{\sqrt{4\pi\times10^{-7}\times8.854\times10^{-12}}} = 3\times10^8\ m/sec.$$

যদি মাধ্যমের আপেক্ষিক তড়িৎভেদ্যতা ϵ_r ও চৌম্বকভেদ্যতা μ_r হয় তবে তড়িৎচুম্বকীয় তরঙ্গের গতিবেগ, $v = \frac{1}{\sqrt{\mu_0\mu_r\epsilon_0\epsilon_r}}$

- **Properties of e.m. wave:**

1) E.M. wave একটি তির্যক তরঙ্গ,
2) ত্বরান্বিত আধানগুলি (accelerated charges) e.m. wave উৎপন্ন করে,
3) e.m. wave তড়িৎক্ষেত্র বা চৌম্বকক্ষেত্র দ্বারা বিচ্যুত হয় না,
4) এই তরঙ্গ শূন্য মাধ্যমের মধ্য দিয়ে যেতে পারে,
5) এর গতিবেগ $c = \frac{1}{\sqrt{\mu_0\epsilon_0}} = 3\times10^8$ m/sec = শূন্য মাধ্যমে আলোর বেগের সমান,
6) শূন্য মাধ্যমে E এবং B এর মান সমদশায় পরিবর্তিত হয়,
7) তড়িৎচুম্বকীয় তরঙ্গের ক্ষেত্রে কোনো বিন্দুতে তড়িৎক্ষেত্র ও চৌম্বকক্ষেত্রের বিস্তারের অনুপাত ধ্রুবক হয় যা আলোর বেগের সমান হয় i.e. $E_0/B_0 = c$.
8) এই তরঙ্গের প্রতিফলন, প্রতিসরণ ও ব্যতিচারের মত আলোকীয় ধর্ম দেখা যায়,
9) এই তরঙ্গগুলি শক্তির সাথে সাথে রৈখিক ভরবেগ (p) ও বহন করে।
10) Maxwell এর 3য় ও 4র্থ e.m. wave equations হল: $\frac{\partial^2 E}{\partial x^2} = \mu_0\epsilon_0\frac{\partial^2 E}{\partial t^2}$, $\frac{\partial^2 B}{\partial x^2} = \mu_0\epsilon_0\frac{\partial^2 B}{\partial t^2}$

- $u_{av} = \frac{1}{2}\epsilon_0 E_0^2 + \frac{B_0^2}{4\mu_0} = \frac{1}{2}\epsilon_0 E_0^2 + \frac{B_0^2}{4\mu_0}\mu_0\epsilon_0 = \frac{1}{4}\epsilon_0 E_0^2 + \frac{1}{4}\epsilon_0 E_0^2$
$= \frac{1}{2}\epsilon_0 E_0^2 \quad \left(\because c = \frac{E_0}{B_0} \ \& \ c = \frac{1}{\sqrt{\mu_0\epsilon_0}}\right)$
- $u_{av} = \frac{1}{4}\epsilon_0 E_0^2 + \frac{B_0^2}{4\mu_0} = \frac{1}{4}\epsilon_0\left(\frac{B_0^2}{\mu_0\epsilon_0}\right) + \frac{B_0^2}{4\mu_0} = \frac{B_0^2}{2\mu_0}$.
- $\langle u_E \rangle = \langle u_B \rangle = \frac{1}{4}\epsilon_0 E_0^2 = \frac{1}{4}\epsilon_0 B_0^2 \cdot \frac{1}{\mu_0\epsilon_0} = \frac{B_0^2}{4\mu_0}$.
- **poynting vector ($\vec{P}$ or $\vec{S}$):**

একক ক্ষেত্রফলে একক সময়ে তড়িৎচুম্বকীয় তরঙ্গের শক্তি প্রবাহের হার যে ভেক্টর দ্বারা প্রকাশিত হয় তাকে পয়েন্টিং ভেক্টর বলে।
এই ভেক্টরের মান থেকে e.m. wave এর তীব্রতা (Intensity) পাওয়া যায়।

$\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B})$ • Unit : watt/m^2 in S.I.
Dimension : $[MT^{-3}]$

The energy crossing per unit area per unit time perpendicular to the direction of propagation is called the intensity of a wave. $U = u_{av}(c\Delta t)A \Rightarrow I = \frac{U}{A\Delta t} = u_{av}c$

∴ Intensity of e.m. wave is

$I = |\vec{S}| = \frac{1}{\mu_0}|\vec{E} \times \vec{B}| = \frac{EB}{\mu_0}$ (as $E \perp B$)
$= \frac{1}{\mu_0} \cdot \frac{E_0}{\sqrt{2}} \cdot \frac{B_0}{\sqrt{2}} = \frac{E_0 B_0}{2\mu_0}$

NOTE : $I = \frac{1}{2}\frac{E_0 B_0}{\mu_0} = \frac{1}{2}\epsilon_0 E_0^2 c = \frac{1}{2}\frac{B_0^2}{\mu_0}c$.

- **Momentum (p) and pressure (P) of e.m. wave:**

তড়িৎচুম্বকীয় তরঙ্গ শক্তি এবং ভরবেগ বহন করে, তাই কোনো তলের উপর একটি চাপ সৃষ্টি করে, এই চাপকে বিকিরণ চাপ (Radiation pressure) বলে।
তরঙ্গ সম্পূর্ণ শোষিত হলে তাহলে $p = \frac{U}{c}$, (p → ভরবেগ, U → e.m. wave এর শক্তি)
- সম্পূর্ণ প্রতিফলনের জন্য, $p = \frac{2U}{c}$.

ধরি কোনো ক্ষেত্রফল A তলে t সময় ধরে আপতিত তরঙ্গের শক্তি
$U = IAt$; $I \rightarrow$ Intensity of e.m. wave.
∴ তলের উপর প্রযুক্ত বল $F = \frac{p}{t} = \frac{U}{ct} = \frac{IAt}{ct} = \frac{IA}{c}$
∴ বিকিরণ চাপ (Radiation pressure) $P = \frac{F}{A} = \frac{IA}{cA} = I/c$.
- সম্পূর্ণ প্রতিফলনের ক্ষেত্রে $P = \frac{2I}{c}$

Ex- সূর্যালোকের Radiation pressure হল 7×10^{-6} N/m^2 ... তাহলে সূর্যালোকের তীব্রতা নির্ণয় করো।

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- **তড়িৎচুম্বকীয় বর্ণালী (Electromagnetic Spectrum):**

বিভিন্ন প্রকার তড়িৎচুম্বকীয় তরঙ্গ তাদের তরঙ্গদৈর্ঘ্য বা কম্পাঙ্ক অনুযায়ী সাজালে যে বর্ণালী তৈরি হয়, তাকে E.M. Spectrum বলে। [illegible]

নাম	কম্পাঙ্কের পাল্লা (f) (Hz)	তরঙ্গদৈর্ঘ্যের পাল্লা (λ) (m)	কোথায় তৈরি হয়
1) γ-রশ্মি	$3\times10^{19} \sim 5\times10^{22}$	$6\times10^{-15} \sim 10^{-11}$	তেজস্ক্রিয় নিউক্লিয়াস থেকে,
2) X-রশ্মি	$10^{16} \sim 3\times10^{19}$	$10^{-11} \sim 3\times10^{-8}$	উচ্চ শক্তিসম্পন্ন ইলেকট্রন [illegible]
3) অতিবেগুনি রশ্মি (Ultraviolet ray)	$7.5\times10^{14} \sim 8\times10^{16}$	$3.75\times10^{-7} \sim 4\times10^{-7}$	[illegible]
4) দৃশ্যমান আলো (Visible light)	$4\times10^{14} \sim 7.5\times10^{14}$	$4\times10^{-7} \sim 8\times10^{-7}$	[illegible]
5) অবলোহিত রশ্মি (Infrared ray)	$10^{11} \sim 4\times10^{14}$	$8\times10^{-7} \sim 3\times10^{-3}$	[illegible]
6) মাইক্রোওয়েভ (Microwave)	$3\times10^{9} \sim 10^{12}$	$3\times10^{-4} \sim 0.1$	[illegible]
7) রেডিও তরঙ্গ (Radio wave)	কয়েক হার্জ থেকে 3×10^{9}	0.1 থেকে কয়েক কিলোমিটার	[illegible]

- AM (Amplitude Modulation) ব্যান্ড [illegible] 530 kHz ~ 1710 kHz
- সর্ট ওয়েভ ব্যান্ড → 54 MHz ([illegible])
- TV ব্যান্ড → 54 MHz ~ 890 MHz
- FM (Frequency Modulation) ব্যান্ড → 88 MHz ~ 108 MHz.
- মানুষ → visible ray range. } অনুভব করে।
  Snake → Infrared ray "
  Insects → Ultraviolet ray "

- **Energy Density of EM wave:**

[illegible] তড়িৎক্ষেত্র ও চৌম্বক ক্ষেত্রের শক্তির পরিমাণ;

$$u_E = \frac{1}{2}\epsilon_0 E^2 \ \& \ u_B = \frac{B^2}{2\mu_0}$$

$$\therefore \text{মোট শক্তি ঘনত্ব } u = u_E + u_B = \frac{1}{2}\epsilon_0 E^2 + \frac{B^2}{2\mu_0}$$

$$= \frac{1}{2}\epsilon_0\{E_0^2 \sin^2(\omega t - kx)\} + \frac{1}{2\mu_0}\{B_0^2 \sin^2(\omega t - kx)\}$$

$$\therefore \text{গড় শক্তি ঘনত্ব } u_{av} = \langle u \rangle = \overline{u}$$

$$= \frac{1}{2}\epsilon_0 E_0^2 \langle \sin^2(\omega t - kx)\rangle + \frac{B_0^2}{2\mu_0}\langle \sin^2(\omega t - kx)\rangle$$

$$= \frac{1}{2}\epsilon_0 E_0^2 \cdot \frac{1}{2} + \frac{B_0^2}{2\mu_0}\cdot\frac{1}{2} = \frac{1}{4}\epsilon_0 E_0^2 + \frac{B_0^2}{4\mu_0}$$

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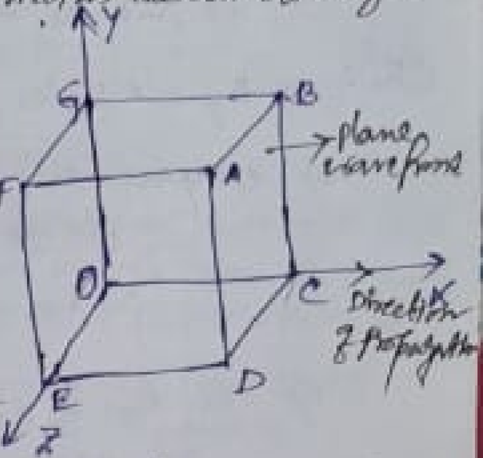
Transverse Nature of e.m. waves:

E.M. waves are transverse wave. The variating electric field($\vec{E}$) and magnetic field($\vec{B}$) are mutually perpendicular to each other as well as the direction of propagation of the wave.



proof: ধরি একটি e.m. wave x- অক্ষ বরাবর সঞ্চালিত, এর wavefront y-z plane এ অবস্থিত, যে কোনো সময় t তে ABCD হল একটি wavefront. এই ABCD wavefront এর কোথায় E ও B এর মান x এবং t এর উপর নির্ভরশীল।

Gauss's law অনুযায়ী ABCDEFGO [illegible] [illegible] কোনো আধান না থাকায়

$$\oint \vec{E}\cdot\vec{ds} = 0$$ any closed surface enclose by a charge.

or, $$\oint_{ABCD} \vec{E}\cdot\vec{ds} + \oint_{EFGO} \vec{E}\cdot\vec{ds} + \oint_{ADEF} \vec{E}\cdot\vec{ds} + \oint_{BCOG} \vec{E}\cdot\vec{ds} + \oint_{OCDE} \vec{E}\cdot\vec{ds} + \oint_{FABG} \vec{E}\cdot\vec{ds} = 0 \quad \text{--- (1)}$$

যেহেতু $\vec{E}$ টি y ও z [illegible] নির্ভর করে না তাই বিভিন্ন [illegible] y ও z অক্ষের লম্বতলে [illegible] [illegible] Cancel out হয়ে যায়,

i.e $$\oint_{OCDE} \vec{E}\cdot\vec{ds} + \oint_{FABG} \vec{E}\cdot\vec{ds} = 0 \quad \text{and} \quad \oint_{ADEF} \vec{E}\cdot\vec{ds} + \oint_{BCOG} \vec{E}\cdot\vec{ds} = 0$$

তাহলে 1) নং equn টি হবে

$$\oint_{ABCD} \vec{E}\cdot\vec{ds} + \oint_{EFGO} \vec{E}\cdot\vec{ds} = 0.$$

Again $\vec{E_x} \parallel \vec{ds}$: so $\oint_{ABCD} \vec{E}\cdot\vec{ds} = \oint_{ABCD} E_x ds \cos 0^\circ = E_x \int_{ABCD} ds = E_x S = E_x \times$ Area of the face ABCD

& $\vec{E_x'}$ anti $\parallel \vec{ds}$ (antiparallel) : so $\oint_{EFGO} \vec{E}\cdot\vec{ds} = \oint_{EFGO} E_x' ds \cos 180^\circ = E_x' \int_{EFGO} ds = E_x' S = E_x' \times$ Area of the face EFGO

$E_x \to$ x-components of electric field on surface ABCD &
$E_x' \to$ " " " " EFGO.

$\therefore E_x S - E_x' S = 0$ i.e $(E_x - E_x')S = 0$

$\because S \neq 0$ so, $E_x - E_x' = 0$ i.e $\boxed{E_x' = E_x}$ অর্থাৎ তড়িৎক্ষেত্রের x-Component সময়ের সাথে পরিবর্তিত হয় না,

কিন্তু [illegible] [illegible] [illegible] হয় না, তাই [illegible] [illegible] [illegible] শূন্য হবে। i.e $E_x' = E_x = 0$.

[illegible] তড়িৎক্ষেত্র [illegible] [illegible] সাথে লম্বভাবে অবস্থিত, [illegible] [illegible] magnetic field ও wave propagation এর সাথে perpendicular অর্থাৎ E-field & M-field both of wave propagation vector এর সাথে লম্বভাবে [illegible] তাই বলা যায় e.m. waves are transverse wave.

Problem: একটি বিদ্যুৎচুম্বকীয় তরঙ্গের জন্য মাধ্যমে তড়িৎক্ষেত্রের সমীকরণ হল $E_x = 0$, $E_y = 0.5\cos[2\pi\times10^8 (t - x/c)]$ এবং $E_z = 0$.

a) E.M. wave কোন দিকে propagate করছে।
b) find λ of e.m. wave
c) find the eqn of B of this e.m. wave?

Soln:

a) $E_y = 0.5\cos[2\pi\times10^8 (t - x/c)]$ mean the wave propagate along +ve x-direction.

b) compare this wave with $E_y = E_0\cos\omega(t - x/c)$ then we get ⇒

$\omega = 2\pi\times10^8 = 2\pi n \Rightarrow n = 10^8$ Hz

$\therefore \lambda = \frac{c}{n} = \frac{3\times10^8 \text{ m/sec}}{10^8 \text{ Hz}} = 3\text{ m}.$

c) As E_x & $E_z = 0$ so B_x & $B_y = 0$.
As wave towards x-axis
& E-field along y-axis
so B " " z "

$$\therefore B_z = B_0\cos[2\pi\times10^8(t - x/c)] = \frac{E_0}{c}\cos[2\pi\times10^8(t - x/c)]$$
$$= \frac{0.5}{3\times10^8}\cos[2\pi\times10^8(t - x/c)]$$

Problem: একটি e.m. wave এর eqn হল $E = 20\sin\omega(t - x/c)$ V/m, Find intensity of the wave and r.m.s value of electric field?

Soln: $E = 20\sin\omega(t - x/c)$ V/m

$E_0 = 20$ V/m. $\quad I = \frac{1}{2}\epsilon_0 E_0^2 c = \frac{1}{2}\times8.85\times10^{-12}\times3\times10^8\times400$
$= 0.53$ W/m²

$E_{r.m.s} = \frac{E_0}{\sqrt{2}} = \frac{20}{\sqrt{2}} = 10\sqrt{2} = 14.14$ V/m

Problem: একটি সমতল e.m. wave চুম্বকক্ষেত্রটি হল $B_y = 2\times10^{-7}\sin(0.5\times10^3 x + 1.5\times10^{11} t)$ T

a) Find the ν & λ of the wave?
b) Find Electric field wave eqn?

Soln: $B_y = B_0\sin[2\pi(\frac{x}{\lambda} + t/T)]$ Comparing we get ⇒

$\frac{2\pi}{\lambda} = 0.5\times10^3 \Rightarrow \lambda = \frac{2\pi}{0.5\times10^3}$ m $= 1.26$ cm.

$\nu = \frac{1}{T} = \frac{1.5\times10^{11}}{2\pi} = 23.9$ GHz.

$B_0 = 2\times10^{-7}$ T $\Rightarrow E_0 = B_0 c = 2\times10^{-7}\times3\times10^8$ V/m $= 60$ V/m.

$E_z = 60\sin(0.5\times10^3 x + 1.5\times10^{11} t)$ V/m.

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Problem: একটি সমতল/Plane e.m. wave শূন্যে: যার তড়িৎক্ষেত্রের বিস্তার 2 V/m এবং যেটি z-অক্ষ বরাবর গতিশীল। চৌম্বকক্ষেত্রের গড় শক্তি ঘনত্ব কত?

Sol: $\langle u_B \rangle = \frac{1}{4}\frac{B_0^2}{\mu_0} = \frac{1}{4}\frac{E_0^2}{\mu_0 c^2} = \frac{1}{4}\epsilon_0 E_0^2 \quad \left(\because B_0 = \frac{E_0}{c}\right)\left(c = \frac{1}{\sqrt{\mu_0\epsilon_0}}\right)$

$= \frac{1}{4}\times 8.854\times 10^{-12}\times 2^2 = 8.854\times 10^{-12}\ J/m^3.$

Problem: একটি সমান্তরাল আলোর প্রাবল্য 10 W/m² এবং সেটি একটি 5 cm² ক্ষেত্রফলের উপর লম্বভাবে আপতিত হয়। 10 মিনিটে [illegible] ভরবেগ ও বল নির্ণয় কর। যদি পৃষ্ঠটি সম্পূর্ণ প্রতিফলক হয় তবে 10 মি. এ [illegible] বল নির্ণয় কর।

Sol: $\phi = 10\ W/m^2$

$A = 5\ cm^2 = 5\times 10^{-4}\ m^2$

$t = 10\ m = 600\ sec$

Total energy $\phi A t = U = 10\times 5\times 10^{-4}\times 600 = 3J$

$\therefore p = \frac{U}{c} = \frac{3J}{3\times 10^8\ m/sec} = 10^{-8}\ kg\,m/sec.$

$F = p/t = \frac{10^{-8}}{600} = 1.6\times 10^{-11} N$

পূর্ণ প্রতিফলনের ক্ষেত্রে ভরবেগের পরিবর্তন $= p - (-p) = 2p = 2\times 10^{8}\ kg\,m/sec$

$\therefore$ Force in 10 m is $F = \frac{2p}{t} = \frac{2\times 10^{8}}{600} = 3.3\times 10^{11} N.$

Problem: একটি e.m. wave এর frequency 2×10^{10} Hz, Amplitude 48 V/m. Find the λ, Amplitude of magnetic field and average energy density?

Sol: $\nu = 2\times 10^{10}\ Hz$ $\quad \lambda = c/\nu = \frac{3\times 10^8}{2\times 10^{10}} = 1.5\times 10^{-2}\ m.$

$E_0 = 48\ V/m$

$c = E_0/B_0 \Rightarrow B_0 = E_0/c = \frac{48}{3\times 10^8} = 16\times 10^{-8} T$ = Amplitude of B.

$u = \frac{1}{2}\epsilon_0 E_0^2 = \frac{1}{2}\times 8.85\times 10^{-12}\times (48)^2 = 10^{-8}\ J/m^3.$

Problem: 25 MHz কম্পাঙ্কের একটি plane e.m. wave শূন্য মাধ্যমে x-অক্ষ বরাবর গতিশীল। space এর কোনো একটি নির্দিষ্ট বিন্দুতে ও সময়ে $\vec{E} = 6.3\hat{j}$ V/m, ওই বিন্দুতে $\vec{B}$ কত?

Sol: $B = E/c = \frac{6.3}{3\times 10^8} T = 2.1\times 10^{-8} T.$

$\vec{E}$ along y-axis & e.m. wave along x-axis.

so, $\vec{B}$ " z-axis.

Problem: Find the amplitude of electric field in a parallel beam of light of intensity 2 W/m².

Sol: $I = u_{av}c = \frac{1}{2}\epsilon_0 E_0^2 c \Rightarrow E_0 = \sqrt{\frac{2I}{\epsilon_0 c}} = \sqrt{\frac{2\times 2.0\ W/m^2}{8.854\times 10^{-12}\frac{C^2}{N\cdot m^2}\times 3\times 10^8\ m/s}} = 38.8\ N/C$

Problem: 60 cm. দৈর্ঘ্যের laser beam এ কত শক্তি stored আছে যদি বিমটি 4 mW ক্ষমতা থেকে নির্গত হচ্ছে?

Sol: Time taken $t = \frac{60\ cm}{c} = 2\times 10^{-9}\ sec.$

$\therefore U = (4\ mW)t = 4\ mW\times 2\times 10^{-9}\ sec = 4\times 10^{-3}\ J/sec\times 2\times 10^{-9}\ sec = 8\times 10^{-12}\ J$