KUSAL ACADEMY

CHAPTER 20

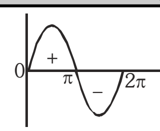
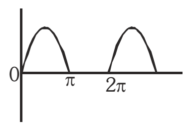
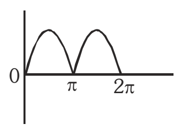
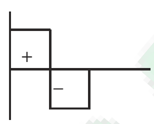
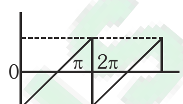
Alternating Current & EM Waves

Voltage or current is said to be alternating if periodically it changes its dir. and magnitude.

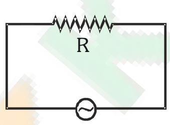
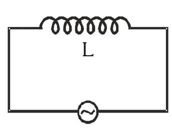
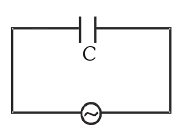
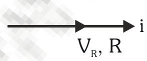
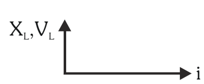
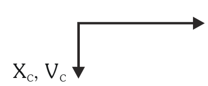
$i = I_0 \sin \omega t \qquad v = V_0 \sin(\omega t + \phi)$

$$\text{Average current} = \frac{\int_0^t i\,dt}{\int_0^t dt} \qquad i_{rms} = \sqrt{\frac{\int_0^t i^2\,dt}{\int_0^t dt}}$$

AC ammeter and voltmeter reads RMS value of current and voltages respectively $\Rightarrow i_0 > i_{rms} > i_{AV}$

Nature of wave form	Wave–form Value for half cycle	RMS Value	Average or mean
Sinusoidal		$\frac{I_0}{\sqrt{2}} = 0.707\ I_0$	$\frac{2I_0}{\pi} = 0.637\ I_0$ (half cycle)
Half wave rectifier		$\frac{I_0}{2} = 0.5\ I_0$	$\frac{I_0}{\pi} = 0.318\ I_0$ (full cycle)
Full wave rectifier		$\frac{I_0}{\sqrt{2}} = 0.707\ I_0$	$\frac{2I_0}{\pi} = 0.637\ I_0$
Square or Rectangular		I_0	I_0
Saw Tooth wave		$\frac{I_0}{\sqrt{3}}$	$\frac{I_0}{2}$

AC CIRCUITS

R	L	C
		
$V = V_0 \sin \omega t$	$V = V_0 \sin \omega t$	$V = V_0 \sin \omega t$
$i = \frac{V_0}{R} \sin \omega t$	$i = \frac{V_0}{\omega L}(-\cos \omega t)$	$i = \frac{V_0}{(1/\omega C)} \cos \omega t$
Resistance = R	Reactance $X_L = \omega L$	Reactance $X_C = \frac{1}{\omega C}$
		
$V_R = iR$	$V_L = iX_L$	$V_C = iX_C$

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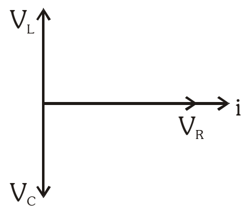
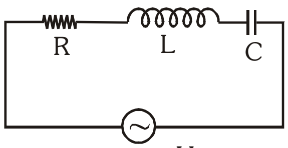
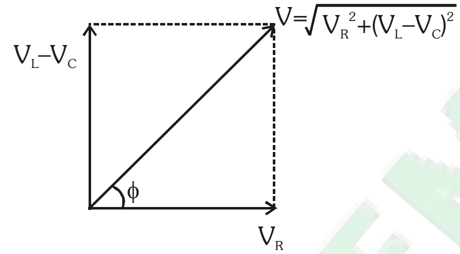
AC THROUGH LCR CIRCUIT

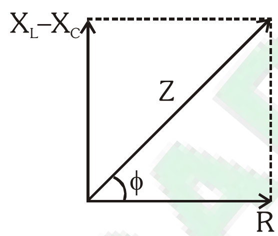




$v = V_0 \sin\omega t$

If $V_L > V_C \Rightarrow X_L > X_C$ then

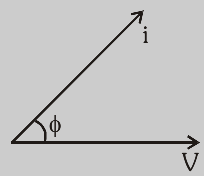




Impedence $= Z = \sqrt{R^2 + (X_L - X_C)^2}$ and **admittance** $= \frac{1}{Z}$ and $\left(i = \frac{V}{Z}\right)$ and $\left(\cos\phi = \frac{R}{Z}\right)$

Power in AC Circuit :

$V = V_0 \sin\omega t$
$i = I_0 \sin(\omega t + \phi)$
$\text{Power} = V_{rms}\, i_{rms} \cos\phi = i^2 R$
Wattfull current $= i_{rms} \cos\phi$
Wattless current $= i_{rms} \sin\phi$
Wattless power $= v_{rms}\, i_{rms} \sin\phi$
Where $\cos\phi$ = Power factor

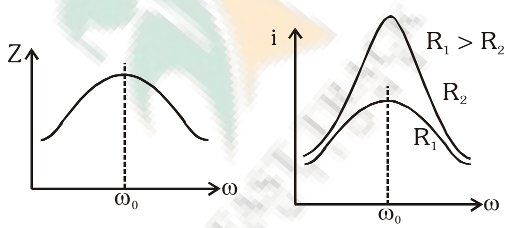


RESONANCE IN SERIES LCR CIRCUIT

At resonance

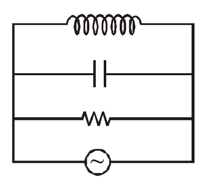
- $X_L = X_C$ or $V_L = V_C$
- $Z = R = \min \Rightarrow i = \frac{V}{R} = \max$
- Power factor $\left(\cos\phi = \frac{R}{Z} = 1\right)$
- Angle (or phase defference) Between v and i = 0°
- $V_R = V_{Source}$

Resonating frequency $\boxed{\omega_0 = \frac{1}{\sqrt{LC}}}$



Sharpness ∝ quality factor $= \frac{X_L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{f_0}{\text{Band width}}$

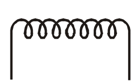
L-C-R PARALLEL COMBINATION



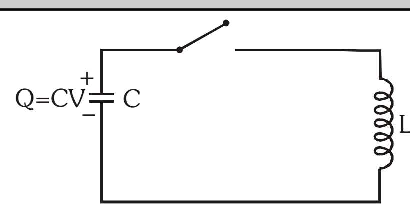
$$\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{x_L} - \frac{1}{x_C}\right)^2}$$

CHOKE COIL

It is used to control alternating current without any power loss. It is an inductor and low resistance.

high L, low R  $Z \approx X_L \Rightarrow \text{Power} = 0$

LC - OSCILLATION

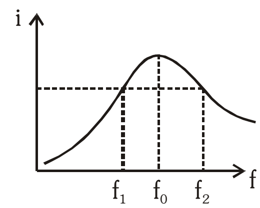


$V_C + V_L = 0 \quad \boxed{L\frac{d^2Q}{dt^2} + \frac{Q}{C} = 0}$

$Q = Q_0 \cos \omega t \Rightarrow i = -i_0 \sin \omega t \quad$ where $i_0 = Q_0\omega$

where $\boxed{\omega = \frac{1}{\sqrt{LC}}}$ frequency of oscillation

- $Q \text{ value} = \frac{\text{Resonance frequency}}{\text{Band width}}$



E.M.W

Maxwell's equations

1. $\oint \vec{E} \cdot \vec{dA} = \frac{Q}{\varepsilon_0}$ (Gauss's law of electricity)
2. $\oint \vec{B} \cdot \vec{dA} = 0$ (Gauss's law of magnetism)
3. $\oint \vec{E} \cdot \vec{d\ell} = -\frac{d\phi_E}{dt}$ (Faraday is law)
4. $\oint \vec{B} \cdot \vec{d\ell} = \mu_0\left[i_c + \varepsilon_0 \frac{d\phi_E}{dt}\right]$ (Empere – maxwell law)

DISPLACEMENT CURRENT

$\phi = EA = \frac{Q}{\varepsilon_0}$

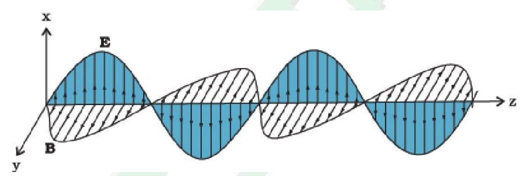
$\frac{d\phi}{dt} = \frac{1}{\varepsilon_0}\frac{dQ}{dt} \Rightarrow i_d = \varepsilon_0 \frac{d\phi_E}{dt}$

Electromagnetic wave :

$E_x = E_0 \sin(kz - wt)$

$B_y = B_0 \sin(kz - wt)$

$C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \frac{E_0}{B_0}$



Direction of propagation of light $\hat{E} \times \hat{B}$.

Poynting vector $\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B})$

Electric field energy density $= \frac{1}{2}\varepsilon_0 E^2$;

Magnetic field energy density $= \frac{B^2}{2\mu_0}$

Total energy density $= \frac{1}{2}\varepsilon_0 E^2 + \frac{B^2}{2\mu_0} = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0}$

If total energy transferred to a surface in time t is U, total momentum delivered to this surface is $p = U/c$.

Type	Wavelength range	Production	Detection
Radio	> 0.1 m	Rapid acceleration and decelerations of electrons in aerials	Receiver's aerials
Microwave	0.1m to 1 mm	Klystron valve or magnetron valve	Point contact diodes
Infra-red	1mm to 700 nm	Vibration of atoms and molecules	Thermopiles Bolometer, Infrared photographic film
Light	700 nm to 400 nm	Electrons in atoms emit light when they move from one energy level to a lower energy level	The eye Photocells Photographic film
Ultraviolet	400 nm to 1nm	Inner shell electrons in atoms moving from one energy level to a lower level	Photocells Photographic film
X-rays	1nm to 10^{-3} nm	X-ray tubes or inner shell electrons	Photographic film Geiger tubes Ionisation chamber
Gamma rays	$<10^{-3}$ nm	Radioactive decay of the nucleus	-do-

KEY POINTS

- An alternating current of frequency 50 Hz becomes zero, 100 times in one second because alternating current changes direction and becomes zero twice in a cycle.
- An alternating current cannot be used to conduct electrolysis because the ions due to their inertia, cannot follow the changing electric field.
- Average value of AC is always defined over half cycle because average value of AC over a complete cycle is always zero.
- AC current flows on the periphery of wire instead of flowing through total volume of wire. This known as skin effect.