2024-2025

TN CLASS 12

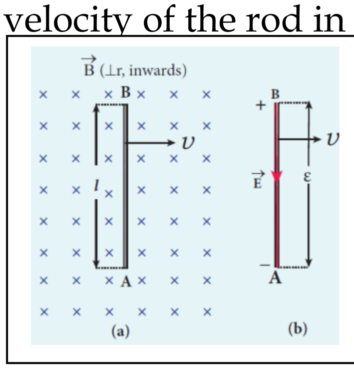
PHYSICS

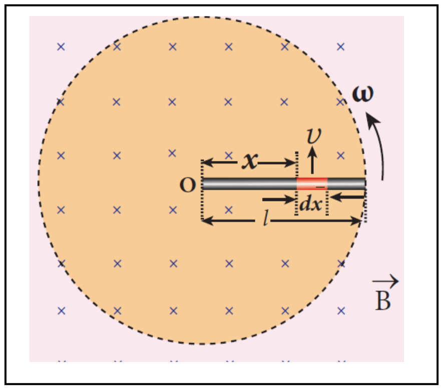
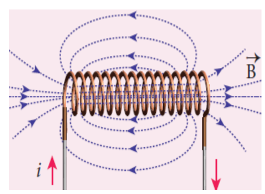
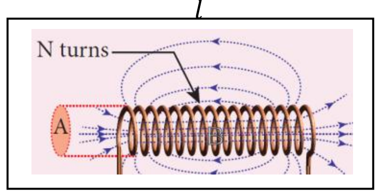
Formulae Sheet...!!

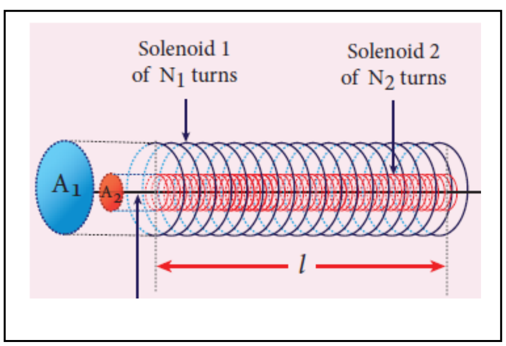
Electromagnetic Induction & Alternating Current

SS PRITHVI

PRIT-EDUCATION

FORMULAE	EXPLANATION OF THE TERMS INVOLVED	SI UNIT
<u>MAGNETIC FLUX</u> $\Phi_B = \int_A \vec{B}.\,d\vec{A}$ $\Phi_B = \int_A \vec{B}.\,d\vec{A} = BA\cos\theta$	Magnetic Flux = (ϕ) A = area where the integral is taken over θ= angle b/w the direction of the magnetic field and the outward normal to the area B = magnetic field	**SI unit: Tm^2.** **other unit: weber or *Wb*** **1 Wb = 1 T m^2**
<u>FARADAY'S II-ND LAW OF ELECTROMAGNETIC INDUCTION</u> $\varepsilon = \frac{d(N\emptyset)}{dt}$	**ε**=induced emf ϕ = magnetic flux N = no of turns in the coil Nϕ = flux linkage	**VOLT**
<u>LENZ'S LAW</u> $\varepsilon = -\frac{d(N\emptyset)}{dt}$	**ε** = induced emf ϕ = magnetic flux N = no of turns in the coil Nϕ = flux linkage **Negative sign denotes that direction of induced emf opposes the change in magnetic flux.**	**VOLT**
<u>MOTIONAL EMF FROM LORENTZ FORCE</u> $\varepsilon = Blv$ If the ends A and B are connected by an external circuit of total resistance *R*, then current i= $\frac{\varepsilon}{R} = \frac{Blv}{R}$	**ε** = emf B = uniform magnetic field l = length of the rod v = uniform velocity of the rod in magnetic field 	**VOLT**

ROD ROTATING about one of its ends with angular velocity in a uniform magnetic field where the plane of rotation of rod s perpendicular to the field $\varepsilon = \frac{1}{2}B\omega l^2$ B = uniform magnetic field l = length of the rod ω = angular velocity	 	VOLT
SELF-INDUCTION $L = \frac{N\Phi_B}{i}$ cases: • If $i = 1\,A$, then $L = N\Phi_B$	L = self-inductance or coefficient of self-induction of the coil Nϕ = flux linkage i = current in the coil • If current *i* changes with time, an emf is induced in it. $\varepsilon = -L\frac{di}{dt}$ => $L = \frac{-\varepsilon}{di/dt}$  	• Wb A^{-1} • Vs A^{-1} • henry (H) $1\,H = 1\,Wb\,A^{-1} = 1\,VsA^{-1}$
SELF-INDUCTANCE OF A LONG SOLENOID $L = \mu n^2 Al$ ➔ $L = \mu_o \mu_r n^2 Al$	A = cross sectional area of the coil μ_o = permeability of free space μ_r = dielectric medium's relative permeability n = turn density => n= $\frac{N}{l}$  	Henry (H)

ENERGY STORED IN AN INDUCTOR W = $U_B = \frac{1}{2}Li^2$	W = U_B = Energy stored in an inductor L = Self-inductance of a long solenoid i = alternating current	Joule (J)
ENERGY DENSITY $u_B = \frac{B^2}{2\mu}$	u_B = energy density B = magnetic field of long solenoid = $\mu_0 ni$	JOULE / m^3
MUTUAL INDUCTION $M_{21} = \frac{N_2\Phi_{21}}{i_1}$; $M_{21} = \frac{-\varepsilon_2}{di_1/dt}$ $M_{12} = \frac{N_1\Phi_{12}}{i_2}$; $M_{12} = \frac{-\varepsilon_1}{di_2/dt}$	i1 = current in coil 1 i2 = current in coil 2 M_{12} = mutual induction on coil 1 due to coil 2 M_{21} = mutual induction on coil 2 due to coil 1	Henry (H)
MUTUAL INDUCTANCE BETWEEN TWO LONG CO-AXIAL SOLENOIDS $M = \mu_\circ n_1 n_2 A_2 l$ If a dielectric medium of relative permeability μr is present inside the solenoids, $M = \mu n_1 n_2 A_2 l$ (or) $M = \mu_\circ \mu_r n_1 n_2 A_2 l$	l = length of the solenoid A2 = Cross sectional area of the solenoid 2 **A1>A2** n = turn density => n= $\frac{N}{l}$ μ_o = permeability of free space μ_r = dielectric medium's relative permeability  	Henry (H)

ENERGY CONSERVATION $$P=\frac{B^2l^2v^2}{R}$$	P = power V = uniform velocity of the rod in the B field B = magnetic field l = length of the rod R = Resistance	Watt or joule / s
ALTERNATING CURRENT $i = I_m \sin \omega t$	i = alternating current I_m = maximum value of induced current ωt = phase difference	
ALTERNATING EMF $$\varepsilon=\varepsilon_m \sin\omega t$$	ε_m = maximum value of induced emf ε = sinusoidal emf or alternating emf ωt = phase difference	VOLT
TRANSFORMER (voltage transformation ratio) $$\frac{V_s}{V_p}=\frac{N_s}{N_p}=\frac{I_p}{I_s}=K$$	*Np* and *Ns* = number of turns in the primary and secondary coil respectively *ip* and *is* = currents in the primary and secondary coil respectively *vs* and V_P = is the voltage across primary and secondary coil respectively	--------
STEP-UP TRANSFORMER $N_s > N_p\,(K>1)$, then $V_s > V_p$ $I_s < I_p$	voltage is increased and the current is decreased	--------
STEP-DOWN TRANSFORMER $N_s < N_p\,(K<1)$, then $V_s < V_p$ $I_s > I_p$	voltage is decreased and the current is increased	--------

EFFICIENCY OF A TRANSFORMER $\eta = \frac{\text{Output power}}{\text{Input power}} \times 100\%$	The efficiency η of a transformer is defined as the ratio of the useful output power to the input power	% (percentage)
MEAN OR AVERAGE VALUE OF AC (alternating current) $I_{av} = \frac{\text{Area of positive half-cycle (or negative half-cycle)}}{\text{Base length of half-cycle}}$ ➔ $I_{av} = 0.637\, I_m$	I_{av} = Mean or Average value of AC I_m = maximum value current Base length of half-cycle = π If there are n currents in a half-cycle of AC, namely *i*1, *i*2, ... *i*n, then average value is given by $I_{av} = \frac{\text{Sum of all currents over half-cycle}}{\text{Number of currents}}$ $I_{av} = \frac{i_1 + i_2 + \dots + i_n}{n}$	AMPERE
RMS VALUE OF AC $I_{RMS} = \sqrt{\frac{\text{Area of one cycle of squared wave}}{\text{Base length of one cycle}}}$ ⇨ $I_{RMS} = 0.707\, I_m$ Similarly for alternating voltage, $V_{RMS} = 0.707\, V_m$. NOTE: $V_m = \sqrt{2}\; V_{rms}$	I_{RMS} = RMS value of AC Base length of one cycle = 2 π For a symmetrical sinusoidal current rms value of current is 70.7 % of its peak value. For example, if we consider n currents in one cycle of AC, namely *i*1, *i*2, ... *i*n, then RMS value is given by $I_{RMS} = \sqrt{\frac{\text{Sum of squares of all currents over one cycle}}{\text{Number of currents}}}$ $I_{RMS} = \sqrt{\frac{i_1^2 + i_2^2 + \dots + i_n^2}{n}}$	I_{RMS} = AMPERE V_{RMS} = VOLTS

AC CIRCUIT CONTAINING PURE RESISTOR $i = I_m \sin \omega t$	Applied voltage and the current are in phase with each other in a resistive circuit	I=AMPERE
AC CIRCUIT CONTAINING ONLY AN INDUCTOR $i = I_m \sin\left(\omega t - \pi/2\right)$	current lags behind the applied voltage by $\frac{\pi}{2}$ in an inductive circuit	I=AMPERE
INDUCTIVE REACTANCE $X_L = \omega L$	XL = inductive reactance ωL = resistance offered by the inductor The inductive reactance (XL) varies directly as the frequency. ➔ $X_L = 2\pi f L$	ohm
AC CIRCUIT CONTAINING ONLY A CAPACITOR $i = I_m \sin\left(\omega t + \pi/2\right)$	current leads the applied voltage by $\frac{\pi}{2}$ in a capacitive circuit	I = AMPERE
CAPACITIVE REACTANCE $X_c = \frac{1}{\omega C}$ ➔ $XC \propto \frac{1}{f}$	Capacitive reactance = XC $\frac{1}{\omega C}$ = resistance offered by the capacitor $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \frac{1}{0} = \infty$ capacitive circuit offers infinite resistance to the steady current.	ohm

SERIES RLC CIRCUIT $I_m = \frac{V_m}{Z}$ Where, $Z = \sqrt{R^2 + (X_L - X_C)^2}$ **SPECIAL CASES** 1) If $X_L > X_C$, $(X_L - X_C)$ is positive $\therefore i = I_m \sin \omega t; v = V_m \sin(\omega t + \phi)$	Capacitive reactance = XC XL = inductive reactance I_m = maximum value current Vm = maximum voltage Z = impedance of the circuit (effective opposition to the current by the series RLC circuit) 2) If $X_L < X_C$, $(X_L - X_C)$ is negative $\therefore i = I_m \sin \omega t; v = V_m \sin(\omega t - \phi)$ 3) If $X_L = X_C$, ϕ is zero $\therefore v = V_m \sin \omega t; \quad i = I_m \sin \omega t$	---------
RESONANCE IN SERIES RLC CIRCUIT $\omega_r = \frac{1}{\sqrt{LC}}$	ω_r = frequency of the applied alternating source $\frac{1}{\sqrt{LC}}$ = natural frequency of the RLC circuit	HERTZ
QUALITY FACTOR/Q-FACTOR $\text{Q-factor} = \frac{1}{R}\sqrt{\frac{L}{C}}$	$\text{Q-factor} = \frac{\text{Voltage across L or C at resonance}}{\text{Applied voltage}}$ R = Resistance connected in the circuit L = Inductance C = capacitance	

POWER IN AC CIRCUITS

$$P_{av} = V_{RMS}\ I_{RMS} \cos\phi$$

$V_{RMS} I_{RMS}$ = apparent power

cos ϕ = power factor

The average power of an AC circuit is also known as the true power of the circuit

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SPECIAL CASES

(i) For a purely resistive circuit, the phase angle between voltage and current is zero and cos φ = 1.

$$P_{av} = V_{RMS}\ I_{RMS}$$

(ii) For a purely inductive or capacitive circuit, the phase angle is $\pm \pi/2$ and $\cos(\pm \pi/2) = 0$.

$$\therefore P_{av} = 0$$

(iii) For series RLC circuit, the phase angle $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

$$\therefore P_{av} = V_{RMS}\ I_{RMS} \cos\phi$$

(iv) For series RLC circuit at resonance, the phase angle is zero and cos φ =1

$$P_{av} = V_{RMS}\ I_{RMS}$$

POWER FACTOR

(i) **Power factor = cos ϕ = cosine of the angle of lead or lag**

(ii) **Power factor** $= \frac{R}{Z} = \frac{\text{Resistance}}{\text{Impedance}}$

(iii) **Power factor** $= \frac{P_{av}}{V_{RMS} I_{RMS}} = \frac{\text{True power}}{\text{Apparent power}}$

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Table 4.3 Analogies between electrical and mechanical quantities

Electrical system	Mechanical system
Charge q	Displacement x
Current $i = \frac{dq}{dt}$	Velocity $v = \frac{dx}{dt}$
Inductance L	Mass m
Reciprocal of capacitance $\frac{1}{C}$	Force constant k
Electrical energy $= \frac{1}{2}\left(\frac{1}{C}\right)q^2$	Potential energy $= \frac{1}{2}kx^2$
Magnetic energy $= \frac{1}{2}Li^2$	Kinetic energy $= \frac{1}{2}mv^2$
Electromagnetic energy $U = \frac{1}{2}\left(\frac{1}{C}\right)q^2 + \frac{1}{2}Li^2$	Mechanical energy $E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$

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