is oscillation can be compared to that of a block connected to a spring-

$$\frac{d^2x}{dt^2}+\omega_0^2 x=0 \qquad \varepsilon=-L\frac{d^2q}{dt^2} \qquad F=m\frac{d^2x}{dt^2}$$

Here $\omega_0 = \sqrt{k/m}$ where k is the spring constant. Comparing the two equations, we see that L is analogous to mass 'm'. L is a measure of resistance to change in current in the circuit.

For an LC circuit-

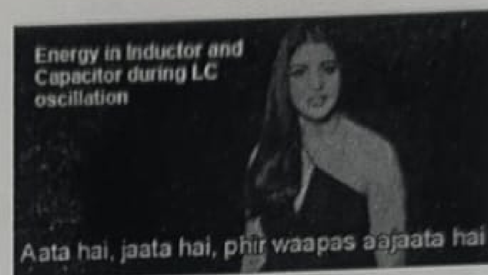
$$\omega=\frac{1}{\sqrt{LC}}$$

And for a spring-

$$\omega_0=\sqrt{\frac{k}{m}}$$

So, 1/C is analogous to k. the constant k= F/x tells us the force required to produce unit displacement similarly, 1/C= v/q tells us the potential difference required to store unit charge

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



The above discussion is not realistic because-

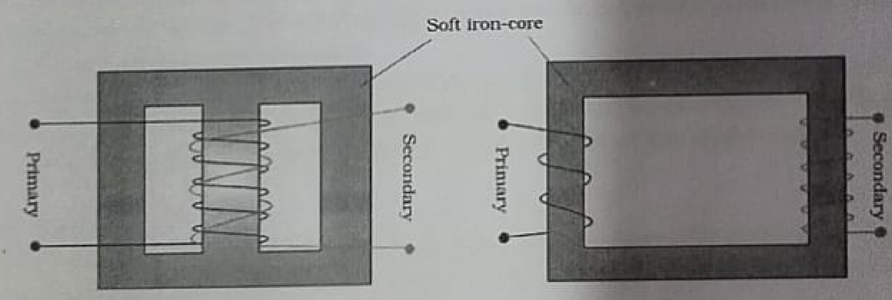
1. Every inductor has some resistance. The resistance causes damping of charge and current which causes the oscillations to die away
2. Even if the total resistance is 0, the total energy will not remain constant, it is radiated away in the form of electromagnetic waves.

Transformer (PYQ 2020, 2019, 2018, 2017, 2015, 2011)

It is a device used to step up or step-down alternating voltage

Principle- mutual induction

Construction- A transformer consists of two sets of coils insulated from each other. They are wound over a soft iron core either on top of each other or on separate limbs of the core. One of the coils, known as the primary coil has N_1 turns and the other coil, called secondary coil has N_2 turns. Usually, primary coil is for input and secondary coil is for output.



Working- When an alternating current is passed through the primary coil, an alternating magnetic flux is induced in the coil. Through mutual induction, the alternating emf in the primary coil sets up an alternating emf and hence alternating current in the secondary coil. We assume that the coils have no resistance and entire flux of the primary coil is linked with the secondary coil i.e. there is no flux leakage. According to Faraday's laws, the emf induced in N_1 turns of the primary coil-

$$\varepsilon_1=-N_1\frac{d\phi}{dt}$$

Similarly, the emf induced in N_2 turns of the secondary coil- $\varepsilon_2 = -N_2 \frac{d\phi}{dt}$

Assuming $\varepsilon_1 = V_1$ and $\varepsilon_2 = V_2$ where V_1 and V_2 are the potential across primary and secondary coil respectively

$$V_1 = -N_1 \frac{d\phi}{dt}$$

$$V_2 = -N_2 \frac{d\phi}{dt}$$

Dividing both we get-

$$\boxed{\frac{V_1}{V_2} = \frac{N_1}{N_2}}$$

Now assuming that there is no power loss-
Power at primary = power at secondary

$$V_1 I_1 = V_2 I_2$$

$$\frac{I_1}{I_2} = \frac{V_2}{V_1}$$

Where I_1 and I_2 are currents in primary and secondary coils respectively. Therefore,

$$\boxed{\frac{I_1}{I_2} = \frac{N_2}{N_1}}$$

Assumptions made-
1. The primary resistance the current is small
2. Entire flux of primary coil is linked with the secondary coil i.e. there is no flux leakage
3. The secondary current is small

Types of transformers-
1. **Step-up transformer**
   if the number of turns of secondary coil is more than that of the primary coil i.e. $N_1 < N_2$, we can see that $V_2 > V_1$.
   Such a transformer is called a step-up transformer

2. **Step-down transformer**
   If number of turns of primary coil is more than that of the secondary coil i.e. $N_1 > N_2$, we can see that $V_2 < V_1$.
   Such a transformer is called step down transformer

Energy losses in transformers/ factors affecting efficiency of a transformer (PYQ 2020, 2019, 2018, 2017, 2011)
1. **Flux leakage-** The complete flux of primary and secondary coil cannot be linked. There are always some leakages. It can be reduced by winding the coils over one another.
2. **Resistance of the windings-** The windings have some resistance which causes loss of energy in the form of heat. They are minimized by using thick wires
3. **Eddy currents-** The alternating emf induces eddy currents and causes loss of energy as heat
4. **Hysteresis-** The magnetization of core is continuously reversed by alternating magnetic field which causes loss of energy due to hysteresis. It can be reduced by using materials of low hysteresis loss.

Use of transformers-
The large-scale transmission of electrical energy is done with the help of transformers. The source voltage is stepped up to reduce current and hence minimize I^2R losses. At the point of consumption, the voltage is stepped down to about 240 V which reaches our home.

Efficiency of a transformer (η) (PYQ 2018)
It is defined as the ratio of useful output power to the input power

Apni Kaksha

Transformer

→ It can step up or step down Poten. diff.

① Working Principal
↳ Mutual Inductance.

② Transformer has basic 2 sectn —

① Shell —
It consist of prim. & Secondary coil of Copper. The effective resistance b/w prim & sec coil is ∞ because elec. current b/w two is open. ($R_{PS} = \infty$)

② Core —
∴ Both Cu coil are tightly wound over a bulk metal piece of high magnetic permeability (eg. soft iron) called core. Both coil are electrically insulated to core but core part magnetically coupled to both the coil.

③ Work →
It regulates AC Voltage & transfers the electrical power with change in freq of input supply. (The AC changes itself).

• Ideal Transformer ($\eta = 100\%$) → $I \propto \frac{1}{V} \propto \frac{1}{\text{no of turns}}$
↳ no loss of energy

ⓐ No Flux leakage —

$$\phi_S = \phi_P \Rightarrow \frac{-d\phi_S}{dt} = \frac{-d\phi_P}{dt}$$

• Power input = Power output

$e_S = e_P = e$ induced emf per turn of each coil is also same.

Total induced emf for Secondary $E_S = N_S e$
— " — Primary $E_P = N_P e$

$$\boxed{\frac{E_S}{E_P} = \frac{N_S}{N_P} = n \text{ or } P}$$

where
n: turn ratio
P: transformatn ratio

ⓑ No load conditn —
$V_P = E_P$ & $E_S = V_S$

$$\boxed{\frac{V_S}{V_P} = \frac{N_S}{N_P} = n \text{ or } P}$$

$$\boxed{\underset{\text{output voltage}}{V_S} = \frac{N_S}{N_P} \times \underset{\text{input voltage}}{V_P}}$$

Voltage ∝ no. of turns

ⓒ No power loss —
$P_{out} = P_{in}$
$V_S I_S = V_P I_P$

Note - Generally transformer deals in ideal conditn i.e $P_{in} = P_{out}$. If other info are not given

$$\boxed{\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} = n \text{ or } P}$$

$$\boxed{I_{out} = \frac{N_P}{N_S} I_{input}}$$

Practical
...al transformer ($n \neq 100\%$)

...me power is always lost ...ue to flux leakage, hysterisis, eddy current and heating of coil. Hence,

$P_{out} < P_{in}$ always

Efficiency of transformer,

$$\boxed{n = \frac{P_{out}}{P_{in}} = \frac{V_S I_S}{V_P I_P} \times 100}$$

* **losses in transformer** —

① Copper or joule heating loss

Where — Occurs in both coil of shell part

Reason — Due to heating effect of current ($H = I^2 RT$)

Remedy — To minimise these losses, high current coil always made up with thick wire and for removal of produced heat, circulatn of mineral oil should be used.

$V_S = \varepsilon_S$, $V_P = \varepsilon_P$

• Flux leakge losses —

Where — These losses occur in b/w both the coil of shell part.

Cause — Due to air gap b/w both the coil

Remedy — To minimise these losses both coil are tightly wound over a common soft iron core (high mag. permeability) so a closed path of mag. feild line formed itself within the core and tries to make coupling factor $K \to 1$

(iii) Iron losses —

Where — Occurs in core part

Cause → (i) Hysterisis

(ii) Eddy Current losses

(a) Hysterisis loss —

Cause — Transformer core always prsnt in the effect of Alternating mag. feild ($B = B_0 \sin\omega t$) so it will magnatised & demagnatised with very high freq ($f = 50Hz$)

During diamagnetizatn a part of mag. energy left inside core part in form of residual mag. feild. Finally the residual energy waste as heat.

emedy - To minimise ese losses material of transformer core should be such that it can be asily magnitised & demagnetised. For this purpose mag. soft material is used.

Eddy Current losses:

* It is a group of induced current which are produced, when metal bodies placed in time varying f mag. feild or they move in ext mag. feild in so such a way that flux through them changes with respect to time.

- Applicatn → Inductn Furnace -

- Due to these induced current a strong eddy ~~current~~ force (or torque) acts on metal body which always opposes the translatory (or rotatory) motion of metal body, according to lenz law.

Applicatn of eddy Current -

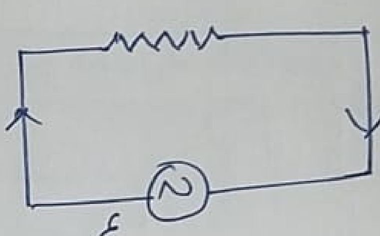
(i) Inductn Furnace
(ii) Dead beat galvanometer
(iii) Electric Brakes
(iv) Induction motor
(v) Car speedometer
(vi) Energy meter.

Different type of Circuit →

Simple Circuit Contain One basic element i.e L, r, C

Complicated Circuit Contain all of them.

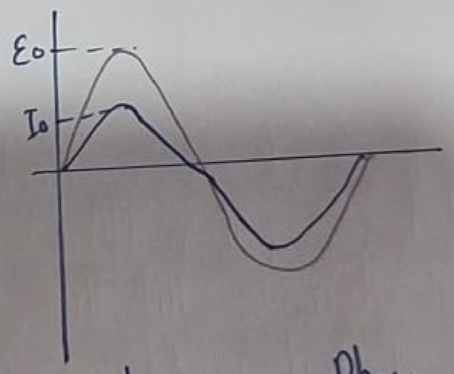
(i) AC Circuit Containg pure resistance -



$\mathcal{E} - IR = 0$

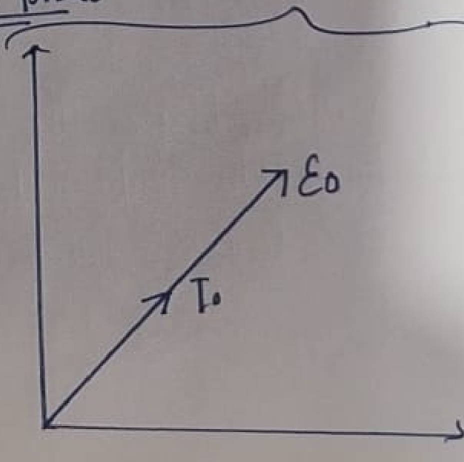
$\mathcal{E}_0 \sin\omega t = IR$

$I = \frac{\mathcal{E}_0}{R} \sin\omega t$



$\left\{ \begin{array}{l} E = \mathcal{E}_0 \sin\omega t \\ I = I_0 \sin\omega t \end{array} \right\}$ → Same phase

Phasor daig



$I_0 = \frac{\mathcal{E}_0}{R}$, hence,

$\frac{I_0}{\sqrt{2}} = \frac{E}{R\sqrt{2}}$

$I_{rms} = \frac{E_{rms}}{R}$

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③ Max eff:

→ same value bcs $x = 0.707$

$$\%\eta = \frac{\cancel{0.9}\ 0.707 \times 20 \times 0.8}{(0.707 \times 20 \times 0.8) + 2 \times 0.45} \times 100$$

$$= \underline{92.63\%}$$

Parts of DC Motor

① Frame or Yoke:

→ it provides mech. support to the poles

→ It provides protectn against Mechanical damage

→ it will not allow any ~~B~~ mag. feild to go outside.

→ small machines are made with cast iron & large with rolled stell.

② Feild Poles or Pole shoe

→ They are connected with frame with the help of mag. feild

→ It provides mag. fild

→ ~~It s~~ It spreads the mag. fild lines uniformly due to its curved shape

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④ Pole shoes may be laminated to reduce eddy current loses Sometimes they are solid also.

③ Feild Coils or fild windings

→ these are wounded insulatd copper wires on one frame. which are wounded on pole shoe.

→ when current pases through the coil, poles get magnatised, and produce flux, so that an emf is produced.

→ fild windings are either connected in series or in parallel with armature winding.

④ Armature core:

(i) Cylindrical in shape

(ii) It is a rotatg part of machine

$(H = i^2Rt)$

(iii) On slots winding is made

(iv) Air duct dissipate the heat which is produced due to I^2Rt and due to air resistance & bearing resistance.

(v) Armature core is made with soft iron which is laminated to redue the eddy current losses.

(vi) Shaft is inserted in armmature core through hole with key way portion.

5. Armature winding or Armature conductor

→ Main funct^n is to produce emf in armature winding

They are placed in the slots of armature core

6. Commutator, brushes & brush holders

→ It converts AC induced emf in armature winding into DC

→ It is made with copper strips seperated by mica

→ Commutator simply collects the current & supplies it to carbon brushes and this brushes are placed in brush box with the help of brush holder.

7. Bearings.

→ Used to reduce frict^n

→ Used for smooth operat^n

→ Used to support the shaft.

Back EMF

$$E_b = \frac{\phi Z N P}{60 A}$$

$$\omega = \frac{2\pi N}{60}$$

Torque Eq^n of a DC Motor

→ It is the turning movement of force about an axis.

In case of motor, each armature conductor experience a force and these forces collectively produce a Torque (T_a)

$$P = T_a \times \omega$$

$$T_a = \frac{1}{2\pi} \cdot \phi Z I_a \cdot \left(\frac{P}{a}\right) \quad Nm$$

$$\boxed{T_a \propto \phi I_a}$$

• Power Eq^n of DC Motor

Max Power (P_m)

$$P_m = V I_a - I^2_a R_a$$

$E_b = \frac{V}{2}$ is a condit^n for max power.

Classificatⁿ of DC Motor

(i) Self excited → field and armature wind^g are connected with common dc source

(ii) DC Shunt motor → field and armature wind^g are connected in parallel with each other.

→ this motor is used when stable speed is req

(iii) DC series motor → field & armature wind^g are connected in series with each other.

Used when varities of speed & high torque is req

Eg → Air compressor, vacuum cleaner, etc.

(iv) DC Compound motor → field & armature wind^g are connected in series as well as parallel.

(i) Differential Compound Motor → Flux produces in series field winding & armature winding opposes each other. So, low torque is produced.

Eg → Pressure blower, circular saw, etc.

Differential Comp. motor

- long shunt
- Short shunt

• Cumulative compound motor: Flux produced in series field wind^g & armature wind^g are in same dirⁿ, so high torque is produced.

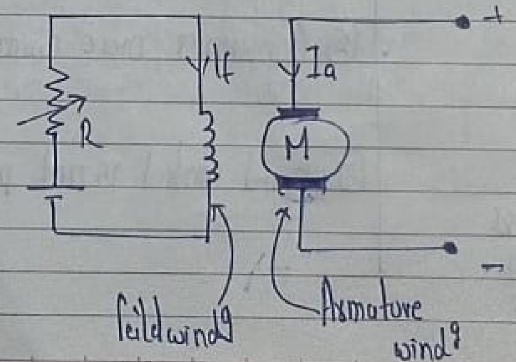
Eg → Electrical shaves, metal stamping, etc.

Cumulative compound motor

- long shunt
- Short shunt

Seperately excited DC Motor

In these motor, field wind^g are armature wind^g are connected seperatly



• Current carrying wire experiences force when it is placed inside the mag. feild

• Fleming's left hand rule

• Very accurate speed control can be obtained by these motor.

These motor are best suited for the applicatn where speed variatn is req from very low value to high value.

back Emf (E_b)

$E_b = V - I_a R_a +$ Brush losses

• Single phase Inductn motor

(i) It has a very much easy workg principle

(ii) There are no windg for the rotor. coz we have a squirrel cage ~~a~~ rotor.

(iii) 2 parts → stator, pole shoes.

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ulta.

Squirell Cage inductn Motor:

Adv	disadv
(i) Constructn is simple	(1) Startg torque is less
(ii) Weight is less	(2) Consumes more current during startg
(iii) Cost is less	(3) Speed control is not possible.
(iv) Maintainance is less	
(v) Efficiency is high	
Heatg effect is less	

Slip ring inductn motor

Adv

(1) High startg torque

(2) During ~~st~~ startg less current is used

(3) Speed control is possible

(4) More rotating contacts

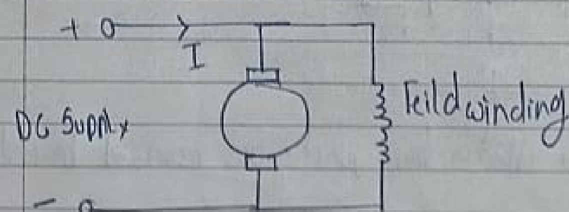
dis adv

(1) Constructn is complicated

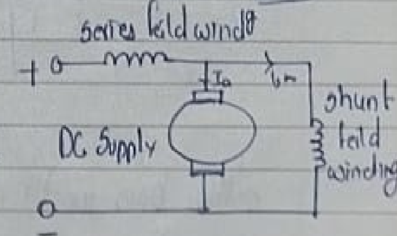
(2) Maintainance is high

(3) ~~Cost~~ Cost is high

• DC Shunt motor



• DC Compound motors.



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- Single phase induction motor.

It has 2 main parts: (i) stator (which stay still)
(ii) rotor (which rotates)

Stator: It receives electricity & creates a spinning magnetic feild.

Rotor: This is the part that spins. When the spinning mag. feild from the stator goes & near the rotor, it creates an elec. current in the rotor.

Working: the electric current in the rotor makes its own mag. feild. this new mag. feild tries to oppose the spinning mag. feild from the stator. So, the rotor tries to catch up with the spinning feild, and thats how it starts spining.

Once the rotor starts spining, the spining mag. feild from the stator keeps ~~the~~ making electric current in the rotor. which helps the motor to keep spinning and doing its job, like running fan or pump.

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3 phase inductⁿ Motor

A 3 phase inductor motor works on the principle of EMI. It consist of a stator and a rotor. the stator has 3 windings placed 120° apart, connected to a 3-Ø AC power supply. When AC power is applied to these winding, it creates a rotating mag. feild in the stator.

This rotating mag. feild generates current in the rotor bar due to principle of EMI. These induced current in the rotor create their own magnetic feild. As a result, the interactⁿ b/w the rotating mag. feild of the stator and induced mag. feild in the rotor causes the rotor ~~or~~ to start rotating.

The rotor tries to catch up with the rotatg mag. feild in the stator but never actually reaches the same speed. This diff b/w the rotating mag feild and the rotor speed is called slip. Greater the slip higher will be the torque.

As the rotor turns, it creats it own mag. feild, which interacts with the stator's mag. feild, causing countinous rotatⁿ. The motor runs at a speed slightly less than the speed of the rotating mag. feild generated by the stator. The speed diff allows the motor to generate torque and perform useful work.

Overall, 3 Ø inductⁿ motor operates on the creatⁿ of rotatg mag. feild in the stator, inducing current in rotor, and the resulting interactⁿ b/w these mag. feild.