Chapter: Rotational Dynamics

1. *Define: Moment of inertia⟹ The product of mass and square of distance from axis of rotation* $(\boldsymbol{I = mr^2})$,
2. *Define: Radius of Gyration ⟹ Perpendicular distance from axis of rotation to centre of mass.*

Questions related to comparison of linear and rotational motion

1. *What is the counterpart/rotational analogue of linear displacement: ⟹* ***angular displacement****, linear velocity: ⟹* ***Angular velocity****, linear acceleration: ⟹* ***Angular acceleration****, mass: ⟹****Moment of inertia****, force: ⟹****Torque,*** *linear momentum: ⟹****Angular Momentum.***

Questions where conservation of angular momentum applicable:

2. *Angular velocity of earth increases when it comes closer to the sun in its orbit:* ***As it come closer to sun, Its Moment of inertia decreases and to conserve angular momentum its angular velocity must Increase***

3. *If earth shrinks suddenly, what would happen to length of the day:* ***[If earth shrinks suddenly, its moment of inertial decreases(radius decreases) and from conservation of angular momentum*** $\{I \propto \frac{1}{\omega}\}$ ***its angular speed increase: length of the day decreases]***

4. *If the earth is struck by meteorites, the earth will slow down slightly:* ***[I increases, ω decreases*** $\{I \propto \frac{1}{\omega}\}$***, length of the day increases]***

5. *If the polar ice caps melts, what would happen to the length of the day:* ***[I increases, ω decreases*** $\{I \propto \frac{1}{\omega}\}$***, length of the day increases]***

6. *When tall building are constructed on earth, the duration of day night slightly increases:* ***[I increases, ω decreases*** $\{I \propto \frac{1}{\omega}\}$***, length of the day increases]***

7. *A Ballet dancer can increase or decrease her spinning rate by using the principle of conservation of angular momentum:* ***[From principle of conservation of angular momentum*** $\{I \propto \frac{1}{\omega}\}$***, she can change her spinning rate by changing moment of inertia, and moment of inertia can be changed by stretching or folding her hands]***

8. *A dancer girl/man is rotating over a turntable with her/his arms outstretched. If she lowers her arms how does this affect her motion?*

9. *In a flywheel, most of the mass is concentrated at the rim/ Spokes are fitted in the bicycle:* ***It increases moment of inertia, greater the moment of inertia, the more will be the opposition to any change in uniform rotational motion, as a result motion will be smooth and steady.***

10. *Can you distinguish between raw egg and boiled egg:* ***(boiled egg spins faster than raw egg, because raw egg has greater moment of inertia)?***

11. *A fan with blades takes longer time to come to rest than without blades:* ***Fan with blades has greater mass and greater moment of inertia, due to which it has greater opposition to any change in rotational motion***

Which is faster: (Which has greater acceleration)

Solid Sphere > Solid Cylinder > Hollow Sphere > Ring = Hollow Cylinder

Chapter: Electrical Circuits

1. State two Kirchhoff's laws in electricity

1st Law⟹ *The algebraic sum of current meeting at a point (junction) is always zero.*

$$\text{i.e. } \sum I = 0 \quad ;\ \text{at a point.}$$

This law is based on the principle of conservation of charge.

2nd Law ⇒ *The total sum of potential in a closed circuit (loop or mesh) is always zero.*

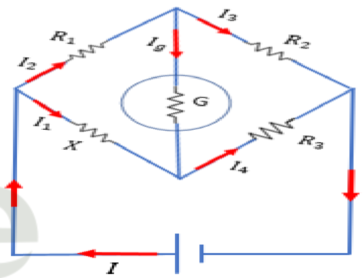
$$\text{i.e. } \sum V = 0 \quad ;\ \text{for a closed loop.}$$

This law is based on the principle of conservation of energy.

2. What is the principle of Wheatstone bridge? Draw circuit diagram and write the balance condition.

⇒ *Wheatstone bridge is an electrical arrangement which is used to measure an unknown resistance.*

At balanced condition, the product of resistance in opposite arms of the quadrilateral is equal.



i.e., at balanced condition, $R_1 \times R_3 = X \times R_2$

$$or,\ \frac{R_1}{R_2} = \frac{X}{R_3}$$

$$or,\ X = \frac{R_1}{R_2} \times R_3$$

The bridge is said to be ***balanced*** *if no current flows through the galvanometer.*

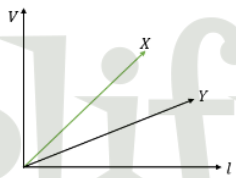
i.e. if $\boldsymbol{I_g = 0}$

3. *At which condition Wheatstone bridge work perfectly ⇒* ***The bridge is most sensitive when all four resistors are of the same order (equal).***
4. *Can we measure very low and very high resistance using Wheatstone Bridge?*
 ⇒ ***Wheatstone bridge method is not suitable for the measurement of very low and very high resistances because the galvanometer becomes insensitive***
5. **Meter Bridge (Slide wire bridge):** *It works on the principle of Wheatstone bridge. It is used to measure unknown resistance.*
6. **What is the principle of potentiometer:** ⇒ *"When a constant current is passed through a wire (conductor) of uniform cross-sectional area, the potential drop across any segment of the wire is directly proportional to the length of the segment."* *i.e.* $\boldsymbol{V \propto l}$
7. **Why do we prefer a potentiometer of longer wire?**
 ⇒ *we prefer a potentiometer of longer length* for sensitive measurement (for accurate measurement).
8. **Why do we prefer potentiometer to measure emf of a cell rather than a voltmeter?**
 ⇒ *The potentiometer is an ideal voltmeter as it measures the emf of a cell very accurately and does not draw any current from the cell. It is based on null deflection method.*
9. **How can we increase sensitivity of potentiometer?**
 ⇒ *The sensitivity of potentiometer can be increased by decreasing the potential gradient, this can be done by increasing the length of potentiometer wire.*
10. ***In potentiometer circuit to get balance point,***
    - *Emf of driver cell must be greater than emf of experimental cell.*
    - *Polarity of driver cell and experimental cell must be same.*

If these conditions do not meet, we cannot get balance point in the circuit.

11. ***The variation of potential difference V with length L in case of two potentiometers X and Y is as shown in diagram. Which one of these two will you prefer for comparing the emf of two cell? Justify your logic.***
 ⇒ *I will prefer potentiometer Y,*
 According to principle of potentiometer,

$$V \propto l$$
$$V = kl$$
$$k = \frac{V}{l}$$



We know, Lesser the potential gradient (k) *more sensitive will be potentiometer. In the figure, slope of the curve gives potential gradient, and potential gradient of potentiometer Y is smaller. Thus, potentiometer Y is more sensitive.*

12. *Why copper wire is not used in potentiometer (or in meter bridge):*
 ⇒The wire used in potentiometer (or in meter bridge) should have high resistivity and low temperature coefficient. Copper wire has low resistivity and high temperature coefficient, that's why it is not used in potentiometer.
 (Constantan or Manganin wire are used in meter bridge or potentiometer)

Notes:

- ***The material which shows Zero Electric Resistance or Infinite Conductivity below a certain temperature is called super conductor.***
- ***Ammeter is always connected in series in the circuit to avoid division of current.***
- ***Shunt is used to increase the range of ammeter and to protect the galvanometer from high currents.***
- ***when a current pass through a conductor of resistance for time then the heat developed in the conductor is equal to the product of the square of the current, the resistance and time. i.e.*** $\boldsymbol{H = I^2Rt}$

Formula:

- ***To compare EMF of two cells:*** $\frac{E_1}{E_2} = \frac{l_1}{l_2}$
- ***To find internal resistance:*** $\boldsymbol{r = \left(\frac{l_1}{l_2} - 1\right)R}$
- ***Conversion of galvanometer to ammeter (To find shunt):*** $\boldsymbol{S = \frac{I_g}{(I - I_g)}G}$
- ***Conversion of galvanometer to voltmeter:*** $V = I_g(G + R)$

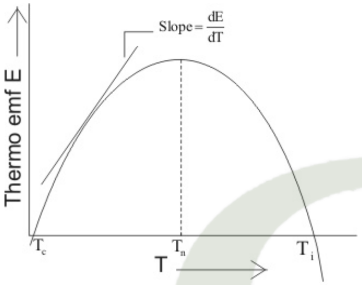
Chapter: Thermoelectric Effect

1. ***What is thermoelectric effect (Seebeck effect):*** *The phenomenon of production of electricity by keeping junctions (contact points) of two different metals at different temperatures is known as* ***Seebeck Effect or thermoelectric effect.***
2. ***On what factor does production of thermo emf depends: Nature of metals*** *used as pair in thermocouple and* ***Temperature difference*** *of two junctions of the thermocouple*
3. ***Cause of Seebeck effect:*** *Diffusion of electron from one metal to another.*

Note:

- ***Sb-Bi thermocouple is more preferred as compared to other thermocouples.*** *Because Sb-Bi thermocouple produces maximum thermo-emf for a given difference in temperature of the two junctions.*
- ***The thermoelectric effect obeys the law of conservation of energy****, In Seebeck Effect, Heat energy absorbed by the hot junction is converted into electric energy.*
- ***Variation of Thermo-Emf with temperature of Hot Junction:***

*Initially, when both ends are **at same temperature**, **no current** flows in the thermocouple and hence no thermo-emf is produced. On increasing the temperature of hot junction gradually, it is noticed that thermo emf also increases till it becomes maximum and then start to decrease, as shown in graph below. The thermo emf goes on decreasing and for certain value of temperature, it becomes zero and changes its polarity (direction).*



if the temperature of cold junction is kept at 0^0C, then mathematically, variation of thermo emf is given by, (parabolic nature)

$$E = \alpha\theta + \frac{1}{2}\beta\theta^2$$

Here, θ is the temperature of hot junction, α & β are thermoelectric constants.

- ***Neutral Temperature:** The temperature of hot junction at which the Thermo-Emf becomes maximum is known as Neutral Temperature (θ_n). Its value depends on: **Nature of metal** used in thermocouple **but** does not depend on the temperature of cold junction.*
- ***Temperature of inversion:** The temperature of hot junction at which the thermo-emf becomes zero and changes its polarity is known as temperature of inversion (θ_i). Its value depends on: **Nature of metal** used in thermocouple and also depends upon the **temperature of cold junction.***
- ***Thermoelectric Power (P) or Seebeck Coefficient (S):** The rate of change of thermo emf with temperature (of hot junction) is called as Seebeck coefficient or thermoelectric power. **At neutral temperature, the thermoelectric power is zero.***
- ***Peltier Effect:** When an electric current is passed through a thermocouple, heat is either evolved or absorbed at the junction, depending upon the direction of flow of current. This effect is called Peltier effect.*
- ***Thermopile:** A thermopile is a device works on the principle of thermoelectric effect which is used to measure the intensity of radiation. It is made by connecting number of thermocouples in series. The thermocouples are made of Bismuth (Bi) and Antimony (Sb).*

***For Numerical:** 1. To find neutral temperature: $for\ \theta = \theta_n\ use, \frac{d\varepsilon}{d\theta} = 0$*

***2. To find neutral temperature:** $for\ \theta = \theta_i\ use, \varepsilon = 0$*

And: $\theta_n = \frac{\theta_i + \theta_c}{2}$

Chapter magnetic Field:

1. Force on a moving charge due to magnetic field***: { force on a charge particle depends on magnetic field intensity (B), charge (q) and $v\sin\theta$) i.e.***

$$F = Bqv\sin\theta$$

- ***Charged particle experience maximum force when it is moving in a direction perpendicular to magnetic field.***
- ***when** Charge particle moves parallel or **antiparallel to magnetic field the charge particle does not experience any force***

2. ***Vector Representation of Lorentz force:*** $\vec{F} = q[\vec{E} + (\vec{v}x\vec{B})]$

If Electric field is absent, then Lorentz force is simply due to magnetic field.

3. ***Magnetic Force on a Current Carrying Conductor:***

Total no. of electrons N = n Al

We know that when an electron moves in a magnetic field, it experiences a force, which is known as Magnetic force. The Magnetic force experienced by each electron is, $F = Bev_d \sin\theta$

The total magnetic force experienced by all the charges in the Conductor is,

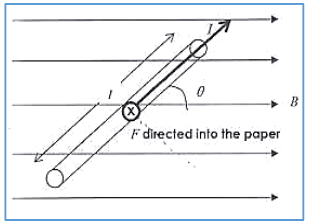
Or, $F = NBev_d \sin\theta$

Or, $F = nAlBev_d \sin\theta$

Or, $F = (v_d enA)lB \sin\theta$

Or, $\boldsymbol{F = BIl\sin\theta}$ $[I = v_d enA]$

$\therefore \vec{F} = I(\vec{l}x\vec{B})$



- ***For Numerical Problems:***
  - ∅ *If phrases like **self-supporting, Zero Tension or balancing itself comes in numerical problem, Use:** $\{mg = BIl\}$*
  - ∅ *If phrases like revolve in circular path comes: **Use:*** $(Bev = \frac{mv^2}{r} \Longrightarrow Be = \frac{mv}{r})$

Hall Effect:

∅ ***Hall Effect:** The phenomenon of production of transverse voltage in a current carrying metallic slab on applying a magnetic field along a direction perpendicular to the direction of current is called Hall Effect.*

∅ ***For derivation: Use⟹** $F_e = F_B$*

$$eE = Bev$$
$$E = Bv$$

Here, $E = \frac{V}{d}$ ***and*** $v = \frac{I}{neA}$

Then, $\frac{V}{d} = \frac{BI}{neA}$

$$V = \frac{BI}{net}$$

⇒Hall effect is more applicable in semiconductor as compared to conductor because** $V \propto \frac{1}{n}$**, As** $n_{sc} < n_c$**, the production of hall voltage will be more than that of conductor.

∅ ***For numerical:*** $V = \frac{BI}{net}$, *(mnemonic: we say **Bi** (bye) in inter**net**)*

***Where,** t =thickness, n =free electron density, e =electronic charge* 1.6×10^{-19} ***B** =Magnetic field intensity*

Biot Savart's law: (For Numerical)

- ∅ *Magnetic field at the centre of circular coil*: $\boldsymbol{B_c = \frac{\mu_0 NI}{2a}, a}$ $= radius$, **N**=*no of turns*
- ∅ *Magnetic field along the axis of circular coil*, $\boldsymbol{B_a} = \frac{\mu_0 NIa^2}{2[a^2+x^2]^{\frac{3}{2}}}$, *, Where x is distance from centre to the point on axis and* **N**=*no of turns*
- ∅ *Magnetic field due to straight conductor*: $\boldsymbol{B = \frac{\mu_0 I}{2\pi r}}$, ***(for infinitely long)***
- ∅ *Magnetic field along the axis of solenoid*: $\boldsymbol{B = \mu_0 nI, n}$ =*number of turns per unit length.*

Force Between two parallel Conductor:

- ∅ *If currents are in same direction*: ***Force is attractive***
- ∅ *If currents are in opposite direction*: ***Force will be repulsive***
- ∅ *Magnitude of force is same*: ***i.e.*** $\boldsymbol{\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi a}}$, *a is the distance between two wires.*

Define One Ampere Current on the basis of force between two conductor

⇒One ampere is the amount of current which, when flowing through each of the two parallel long conductors placed at a distance of one metre from each other, will attract or repel each other with a force of $2 \times 10^{-7}\ N$ per metre of their length.

Chapter: Magnetic Properties of materials

1. *Define Magnetic permeability and magnetic Susceptibility?*

   ⇒***Magnetic Permeability: The degree to which magnetic lines of force can penetrate a substance placed in the magnetizing field.***

   ⇒***Magnetic Susceptibility: It is a measure of how easily and strongly a material can be magnetized.***

2. *Properties of Diamagnetic, Paramagnetic and Ferromagnetic Substance*

Diamagnetic Substance	***Paramagnetic Substance***	***Ferromagnetic Substance***
Feebly repelled by a magnet	***Feebly attract by a magnet***	***Strongly attract by a magnet***
Magnetized in opposite direction to external field	***Magnetized in the direction of an external field***	***Magnetized in opposite direction to the external field***
Ex. Copper	***Ex. Aluminium***	***Ex. Iron***

3. ***Define Curie Temperature:*** *The temperature above which ferromagnetic substance lose their property and becomes paramagnetic is called curie temperature.*
4. ***Magnetic Hysteresis:***
   - ∅ *Hysteresis curve*: ***Area of hysteresis curve give energy loss per cycle.***
   - ∅ ***Retentivity***: *The property of the magnetic material to retain magnetism even in the absence of magnetising field.*
   - ∅ ***Coercivity***: *The reverse magnetising field to completely demagnetized the material.*
   - ∅ ***Soft iron is used to construct electromagnet (Temporary magnet) because it has high retentivity and less energy loss per cycle.***
   - ∅ ***Steel is used to construct a permanent magnet as it has greater Coercivity.***
   - ∅ ***The Hysteresis Curve of Steel is thicker (has a large area of hysteresis per cycle) and that of iron is thinner (has a small area of hysteresis per cycle)***

Chapter: Electromagnetic Induction

1. ***Define Magnetic Flux:*** The number of magnetic lines of force crossing a closed area $'A'$ i.e. $\emptyset = BA\cos\theta$.
2. ***What are Faraday's law of electromagnetic induction?***

   1st law: *Whenever the amount of magnetic flux linked with a closed circuit changes, an emf is induced in the circuit. The induced emf lasts so long as the change in magnetic flux continues.*

   2nd law: *The magnitude of emf induced in a closed circuit is directly proportional to the rate of change of magnetic flux linked with the circuit. i.e.* $E = -\frac{d\emptyset}{dt}$

3. *State Lenz's law. Does Lenz's law obey the conservation of energy?*

   ⇒***Lenz's Law:*** *Lenz's law states that "the direction of the induced current is such that it always opposes the cause which produced it."*

   ⇒***Lenz's Law obeys the principle of conservation of energy because*** Mechanical energy is converted into electrical energy.

4. ***Direction of Induced current in coil:***
   - ∅ *If the north pole is moving toward the coil:* ***Anticlockwise (North Pole)***
   - ∅ *If the north pole is moving away from the coil:* ***clockwise (South Pole)***
   - ∅ *If the south pole is moving toward the coil:* ***clockwise (South Pole)***
   - ∅ *If the south pole is moving away from the coil:* ***Anticlockwise (North pole)***
5. *A copper ring is held horizontally and a bar magnet is dropped through the copper ring, will the acceleration of the falling magnet be equal to, less than or greater than the acceleration due to gravity?*

   ⇒***The acceleration of magnet will be less than 'g' because induced emf (current) in copper ring will opposes the motion of magnet.***

6. *An induced current has no direction of its own. Explain?*

   ⇒***An induced current has no direction of its own because it depends on the direction of magnetic field lines and change in magnetic flux through the coil.***

7. ***What is eddy current? Write some applications of eddy currents.***

   ⇒ *Eddy currents are loops of electrical current induced within conducting sheets or blocks by a changing magnetic field in the conductor. This causes a loss in energy in the form of heat.*

   ⇒***Applications***: *Electromagnetic damping, Induction Furnace, Electric Brakes etc.*

8. ***A piece of metal and a piece of non-conducting stone are dropped from the same height. Will they reach the earth at the same time?***

⇒No, the stone will reach the earth first with $(a = g)$, and when a metal piece falls from a certain height then eddy currents are produced in it due to the earth's magnetic field. Eddy's current opposes the motion of the metal piece. Hence metal piece falls with a smaller acceleration (as compared to g).

9. **What is AC generator. Write the working principle of AC generator?**

⇒ AC generator is an electrical instrument which is used to convert mechanical energy into sinusoidally varying electrical energy.

⇒ It works upon the principle that "when a closed conducting coil is rotated in uniform magnetic field, the flux linked with the coil changes continuously and an amount of emf will be induced in it.

What is self-Inductance of the coil? ⇒ The total magnetic flux linkage per unit current flowing in the coil.

10. **Energy Losses in transformer:**

⇒Copper Loss: Loss due to resistance of a copper wire.

⇒Eddy current loss (Iron loss): Loss in the form of heat from the iron core

⇒Hysteresis Loss: Due to continuous magnetization and Demagnetization.

For Numerical:

∅ Motional EMF: $\boldsymbol{E = Bvl\sin\theta}$, B =magnetic field intensity, v =velocity, l =length

∅ Induced Emf: $E = -N\frac{d\emptyset}{dt}$, N =number of turns, and $\emptyset$ =magnetic flux

∅ Emf induced in rotating coil/AC generator: $E = E_0 \sin\omega t$, $E_0 = NBA\omega$ (max EMF)

∅ Self-Inductance: $L = \frac{\emptyset}{I}$, $I = Current$

∅ Energy Stored in Inductor: $U = \frac{1}{2}LI^2$

Chapter: Alternating Current

∅ AC is more dangerous because its peak value is $\sqrt{2}$ times its rms value.

∅ Equation of AC: $V = V_0 \sin\omega t$. The frequency of AC of Nepal is $50Hz$,

∅ $I_{avg} = 0.637I_0$ and $V_{avg} = 0.637V_0$

∅ $I_{rms} = 0.707I_0$ and $V_{rms} = 0.707V_0$

∅ AC through Resistor: $V = V_0 \sin\omega t$ and $I = I_0 \sin\omega t$, **Phase difference is zero.**

∅ AC through Inductor: $V = V_0 \sin(\omega t + \frac{\pi}{2})$ and $I = I_0 \sin\omega t$, **Phase difference is $\frac{\pi}{2}$ Voltage leads current by phase angle $\frac{\pi}{2}$**

- Inductive reactance is the effective opposition offered by the inductor to the flow of ac current in the circuit, Inductive reactance ($X_L = \omega L = 2\pi fL = \frac{V_0}{I_0} = \frac{V_{rms}}{I_{rms}}$ (It is measured in Ohm 'Ω' or Henry/s)
- **$X_L \propto f$, higher frequency of AC, greater will be the opposition. (Inductor acts as a insulator for high frequency AC)**
- **In DC circuit, $f = 0$, $X_L = 2\pi fL = 0$ (short circuit), A pure inductance offers zero resistance to DC**

∅ AC Through Capacitor: $V = V_0 \sin(\omega t - \frac{\pi}{2})$ and $I = I_0 \sin\omega t$, **Phase difference $=\frac{\pi}{2}$ current leads voltage by phase angle $\frac{\pi}{2}$.**

- Capacitive reactance is the effective opposition offered by the capacitor to the flow of ac current in the circuit, capacitive reactance ($X_c = \frac{1}{C\omega} = \frac{1}{2\pi fC} = \frac{V_0}{I_0} = \frac{V_{rms}}{I_{rms}}$ (It is measured in Ohm 'Ω' or Henry/s)
- **$X_L \propto \frac{1}{f}$, higher frequency of AC, lesser will be the opposition. A pure capacitance offers zero resistance to high frequency AC**
- **In DC circuit, $f = 0$, $X_c \propto \frac{1}{f} = \infty$ (Open circuit) Thus, capacitor acts as a perfect insulator in DC circuit.**
- **Capacitor blocks DC but provides an easy path for AC current.**

∅ AC through LR circuit: $V = I\sqrt{X_L^2 + R^2}$, Here,
$Z = \sqrt{X_L^2 + R^2} = \sqrt{(2\pi fL)^2 + R^2}$ is impedance of series LR circuit. Phase Angle is Positive. Voltage lead current.

∅ AC through RC circuit: $V = I\sqrt{X_c^2 + R^2}$, Here,
$Z = \sqrt{X_c^2 + R^2} = \sqrt{(\frac{1}{2\pi fC})^2 + R^2}$ is impedance of series RC circuit. Phase Angle is Negative. Voltage lags current.

∅ Series LCR circuit: $V = I\sqrt{R^2 + (X_l - X_c)^2}$, Here $Z = \sqrt{R^2 + (X_l - X_c)^2}$, is called impedance of LCR circuit. And, $Z = \sqrt{R^2 + \left(2\pi fl - \frac{1}{2\pi fc}\right)^2}$

- **Resonance in series LCR circuit: When** $X_l = X_c$, then $Z = R$ and circuit allows maximum current for a certain frequency of source is called resonance.
- **The circuit offers minimum impedance and maximum current, the circuit behaves purely resistive and phase difference is zero.**
- **For resonance frequency:** $X_l = X_c \Longrightarrow 2\pi fL = \frac{1}{2\pi fc} \Longrightarrow \boldsymbol{f = \frac{1}{2\pi\sqrt{LC}}}$

Power Consumed in Series LCR: $P_{avg} = E_{rms}I_{rms}\cos\emptyset$, here $\cos\emptyset$ is called power factor.

Wattless Current: The current flowing through the pure capacitor or inductor which consumes no power is called Wattless current.

Choke Coil: It is an ideal inductor which is used to change current in AC circuit without loss of energy.

Why choke coil is more preferred than rheostat: Choke coil is an ideal inductor which is used to change current in AC circuit without loss of energy. But, rheostat is a resistive circuit which consumes power while changing current in the circuit.