ELECTRICAL FUNDAMENTALS

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PROPERTIES OF MAGNETISM

1) Like poles repel each other unlike poles attract each other
2) When freely suspended, it sets itself in a definite direction such that north pole points towards north and south pole towards south
3) It attracts small pieces of iron

LAWS OF MAGNETISM

1st law: like poles repel each other unlike poles attract each other

2nd law: according to 2nd law proved by Coulomb as the force exerted by one pole on the other pole is

(a) Directly proportional to the product of pole strength
(b) Inversely proportional to the square of the distance between them
(c) Nature of the medium surrounding the pole
(d) $F = K *M1*M2/d^2$

MAGNETIC INDUCTION

The phenomenon due to which the magnet can induce magnetism in the surrounding medium is called magnetic induction.

MAGNETIC FIELD

When the magnetism is felt in the surrounding medium is called magnetic field.

MAGNETIC LINES OF FORCE

The magnetic field of magnet is represented by imaginary lines around it which are called magnetic lines of force. The direction of lines of force is always originated from North Pole and terminated at South Pole.

MAGNETIC FLUX (Ø)

The total number of lines of force existing in a particular magnetic field is called magnetic flux. Its unit is weber.

POLE STRENGTH

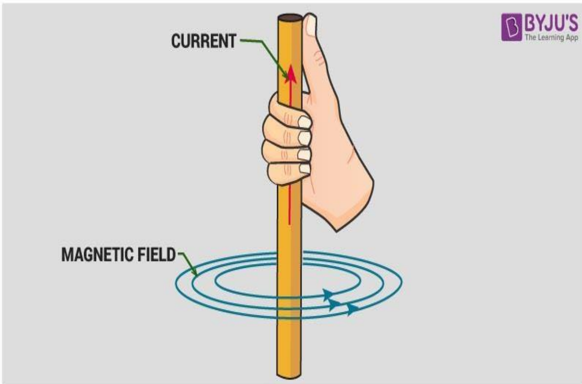
Force between the poles depends on the pole strengths. The poles have the capacity to radiate or accept certain number of magnetic lines of force.

MAGNETIC FLUX DENSITY

Magnetic flux density is defined as flux per unit area. its unit is weber per meter square or TESLA

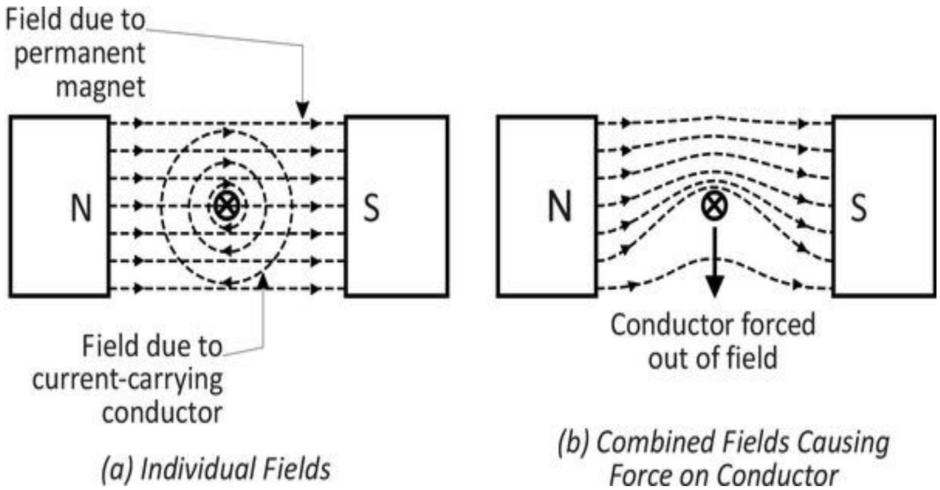
$$B = \frac{Ø}{A}$$

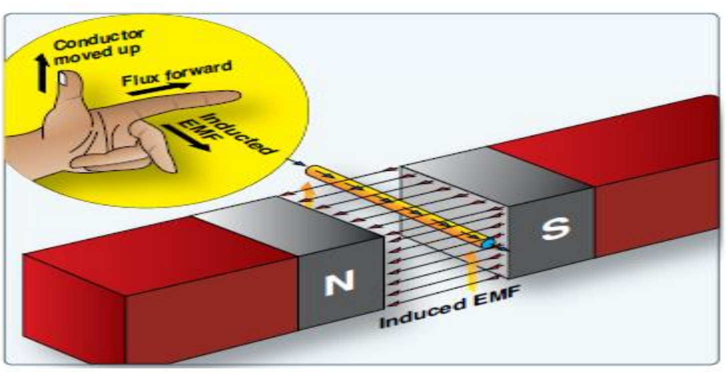
MAGNETIC FIELD DUE TO LONG STRAIGHT CONDUCTOR



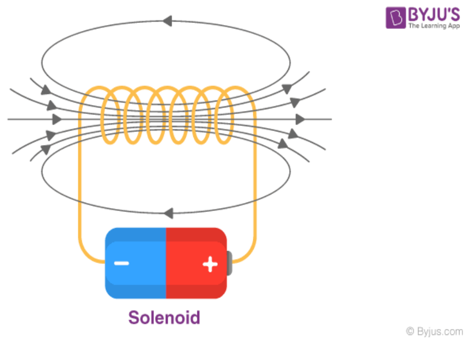
Consider a straight conductor carrying current, passing through a sheet of cardboard. Small tapings on the cupboard will cause the iron filings to set themselves in the concentric circular pattern. The direction depends on the direction of the current passing through the coil. When the straight conductor carries a current, it produces magnetic field all along its length. The lines of force are in the form of concentric circles in the planes right to the conductor.

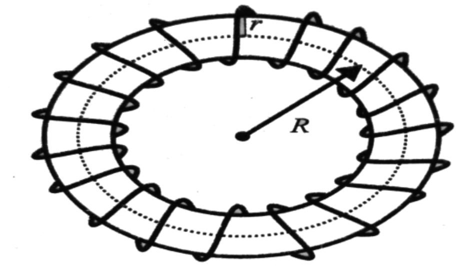
FORCE ON A CURRENT CARRYING CONDUCTOR IN A AMAGNETIC FIELD





SOLENOID/ TOROID





A solenoid is an arrangement in which long straight conductor is wound with number of turns close together to form a coil. The core may be air or magnetic material. When such conductor is excited by the supply then it produces a magnetic field which acts through the coil along its axis and also around it. Similarly when the coil is wound on the circular conductor then it is called Toroid.

PERMEABILITY

It is defined as the ability or ease with which the magnetic material forces the magnetic flux through a given medium.

There it is possible to shield items from the effects of the flux by surrounding them with a material that offers an easier path for the lines of force. Some instruments that surrounded by a path of soft iron, offers very little opposition to magnetic flux. The lines of force take the easier path, the path of greater permeability, and are guided away from the instrument. Materials such as soft iron and other ferrous metals are said to have a high permeability. Air and other nonmagnetic materials are so close to this that they are also considered to have permeability of one. The nonferrous metals with permeability greater than one, such as nickel and cobalt, are called paramagnetic. The term ferromagnetic is applied to iron and its alloys, which have by far the greatest permeability. Any substance, such as bismuth, having a permeability of less than one, is considered diamagnetic.

ABSOLUTE PERMEABILITY (μ)

The magnetic field strength (H) decides the flux density (B) to be produces by the magnet around it, in a given medium (other than vacuum) μ

$$\mu = \frac{B}{H}$$

PERMEABILITY OF FREE SPACE OR VACUUM (μ_0)

If the magnet is place in a free space or vacuum or in air then ratio of flux densiyu and magnetic field strength is (μ_0) .

$$\mu_0 = \mathbf{4\Pi * 10^{-7}}$$

$$\mu_0 = \frac{B0}{H}$$

RELATIVE PERMEABILITY (μ_r)

It is defined as the ratio of flux density produced in a medium (other than free space) to the flux density produced in free space.

For air, relative permeability $\mu_r = 1$

$$\mu = \frac{B}{H}$$

$$\mu\mathbf{0} = \frac{B0}{H}$$

$$\frac{\mu}{\mu_0} = \frac{B}{B0}$$

$$\frac{B}{B0} = \mu_r$$

Hence,

$$\mu = \mu_0 \, \mu_r$$

MAGNETOMOTIVE FORCE

The flow of electrons is current which is basically due to electromotive force (emf) . Similarly the force behind the flow of flux or production of flux in a magnetic circuit is called magneto motive force (mmf).

$$mmf = NI$$

RELUCTANCE

Current flow is opposed by resistance of the material; similarly flow of flux is opposed by magnetic material called as reluctance (S)

$$S \propto \frac{l}{a}$$

$$S = K\frac{l}{a}$$

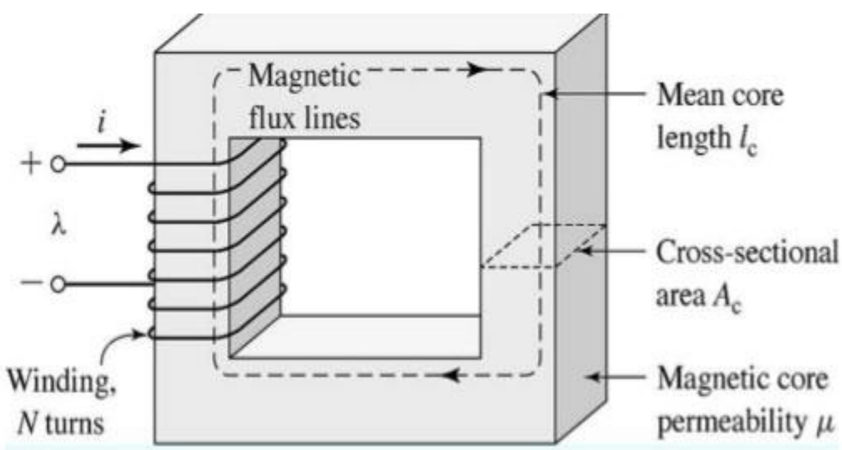
K = constant of proportionality

$$S = \frac{1}{\mu a}$$

$$S = \frac{l}{\mu 0 \times \mu r \times a}$$

Reluctance (S) $S = \frac{mmf}{\emptyset}$

MAGNETIC CIRCUIT



The closed path followed by magnetic lines of forces is called the **magnetic circuit**. In the **magnetic circuit**, magnetic flux or magnetic lines of force starts from a point and ends at the same point after completing its path. A **magnetic circuit** is made up of magnetic materials having high permeability such as iron, soft steel, etc. **Magnetic circuits** are used in various devices like electric motor, transformers, relays, generators galvanometer, etc.

Let, L = mean length of the magnetic circuit

A = cross-sectional area of the core

μr = relative permeability of the core

μ0 = Absolute permeability of the core

N = number of turns

I = Current flowing through the coil

Ø = flux

B = Flux density

$$H = \frac{NI}{L}$$

$$B = \mu \text{ x H}$$

$$\mu = \mu_0\ \mu_r$$

$$B = \mu_0\ \mu_r \frac{NI}{L}$$

$$B = Ø /A$$

$$\therefore Ø = B \times A$$

$$Ø = \frac{\mu_0\ \mu_r NIA}{L}$$

$$Ø = \frac{NI}{1} \times \frac{\mu_0\ \mu_r A}{L}$$

$$\text{mmf} = NI$$

$$S = \frac{l}{\mu 0 \times \mu r \times A}$$

$$Ø = \frac{\text{mmf}}{\text{reluctance}}$$

SERIES MAGNETIC CIRCUIT

The **Series Magnetic Circuit** is defined as the magnetic circuit having a number of parts of different dimensions and materials carrying the same magnetic field. Consider a circular coil or solenoid having different dimensions

$$S_T = S_1 + S_2 + S_3$$

$$S_T = \frac{L_1}{\mu_1 A_1} + \frac{L_2}{\mu_2 A_2} + \frac{L_3}{\mu_3 A_3}$$

$$Ø_T = \frac{\text{mmf}}{\text{reluctance}}$$

$$Ø_T = \frac{NI}{S_T}$$

$$S_1 + S_2 + S_3 = S_T$$

$$NI = S_T \times Ø_T$$

$$NI = (S_1 + S_2 + S_3) \times Ø$$

$$NI = (S_1 \times Ø) + (S_2 \times Ø) + (S_3 \times Ø)$$

mmf = NI

$$Ø = \frac{\text{mmf}}{\text{reluctance}}$$

$$(mmf_T) = (mmf_1) + (mmf_2) + (mmf_2)$$

Magnetic field strength = $H = \frac{NI}{L}$

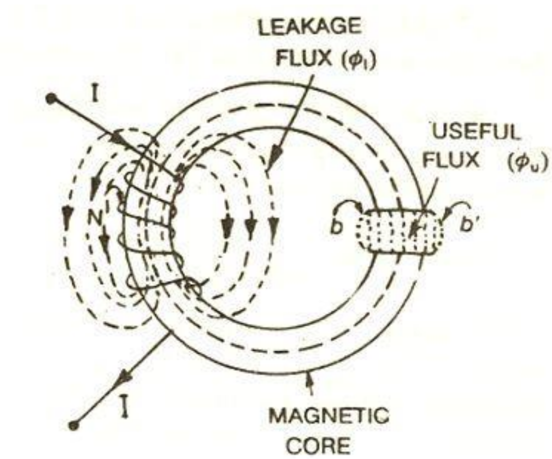
mmf = NI

$$NI = HL$$

$$mmf = HL$$

$$mmf_T = H_1L_1 + H_2L_2 + H_3L_3$$

SERIES MAGNETIC CIRCUIT WITH AIR GAP



A **magnetic circuit** is where a **magnetic** flux is circulated or follows through a closed area or path. An **air gap** is a non-**magnetic** part of a **magnetic circuits** and it is usually connected magnetically in **series** with the rest of the **circuit**. This allows a substantial part of the **magnetic** flux flows through the **gap.**

$$S_i = \frac{L_i}{\mu A_i}$$

$$S_g = \frac{L_g}{\mu A_g}$$

$$S_T = \frac{L_i}{\mu A_i} + \frac{L_g}{\mu A_g}$$

$$\emptyset = \frac{\text{mmf}}{\text{reluctance}}$$

mmf = NI

$$NI = \emptyset S_i + \emptyset S_g$$

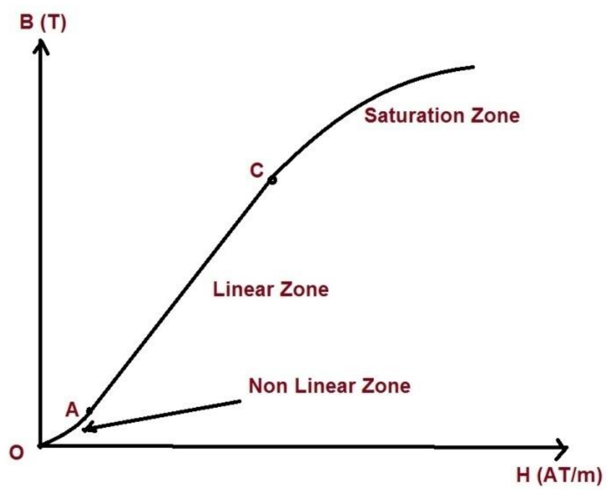
MAGNETIC LEAKAGE AND FRINGING

Most of the applications which are using magnetic effects of an electric current are using flux in the air gap for their operation, such devices are generators, motors etc, such devices consists of magnetic with air gap and flux in air gap is used to produce the required effect. Such flux available in air gap which is utilized to produce the desired effect is called useful flux.

$$Useful\ flux = \emptyset_u$$

The flux available in the iron ring will pass through the air gap (that is it should complete the path.

B – H CURVE



V is directly proportional to the current I

V = H

$H \propto I$

$I \propto \emptyset$

$H \propto I \propto \emptyset$

$$\emptyset \propto B$$

$$H = \frac{NI}{L}$$

$$H \propto I$$

$$I \propto Ø$$

$$B = \frac{Ø}{\mathrm{A}}$$

$$B \propto Ø$$

$$Since\ H \propto I\ then\ I \propto Ø$$

$$H \propto Ø$$

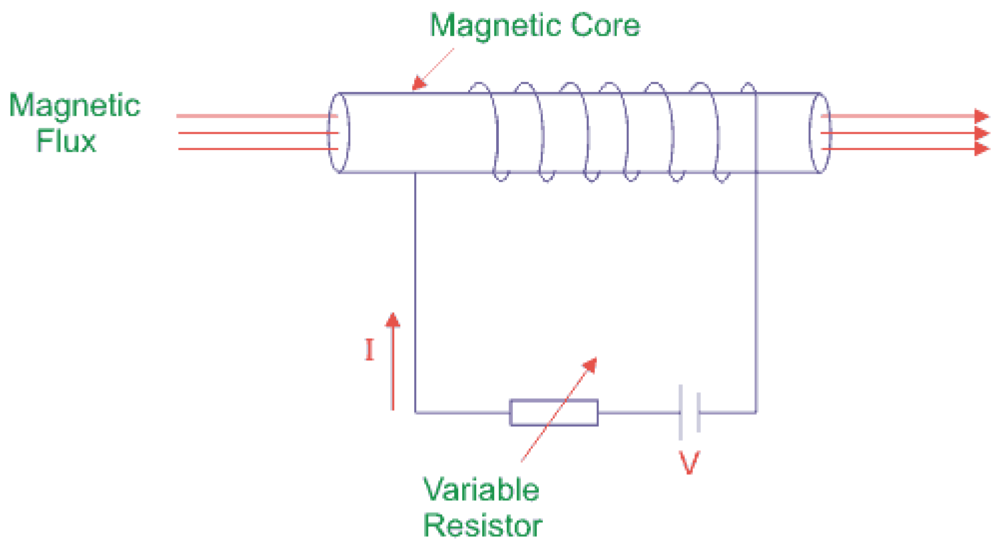
$$Since\ B \propto Ø\ then\ H \propto Ø$$

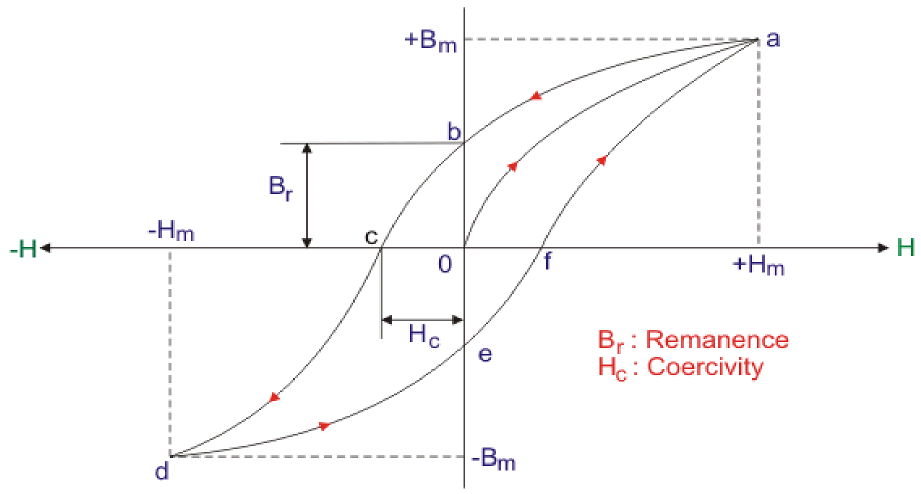
$$B \propto H$$

As H (V) is increased, I is increased. As I is increased, Ø is increased. As Ø is increased B is increased.

HYSTERESIS LOOP

Where, N = no. of turn of coil and l is the effective length of the coil. The magnetic flux density of this core is B which is directly proportional to magnetizing force H.





- Step 1:
  When supply current I = 0, so no existence of flux density (B) and magnetizing force (H). The corresponding point is 'O' in the graph above.
- Step 2:
  When current is increased from zero value to a certain value, magnetizing force (H) and flux density (B) both are set up and increased following the path o – a.
- Step 3:
  For a certain value of current, flux density (B) becomes maximum (B_{max}). The point indicates the magnetic saturation or maximum flux density of this core material. All element of core material get aligned perfectly. Hence H_{max} is marked on H axis. So no change of value of B with further increment of H occurs beyond point 'a'.
- Step 4:
  When the value of current is decreased from its value of magnetic flux saturation, H is decreased along with decrement of B not following the previous path rather following the curve a – b.
- Step 5:
  The point 'b' indicates H = 0 for I = 0 with a certain value of B. This lagging of B behind H is called hysteresis. The point 'b' explains that after removing of magnetizing force (H), magnetism property with little value remains in this magnetic material and it is known as residual magnetism (B_r). Here o – b is the value of residual flux density due to retentivity of the material.

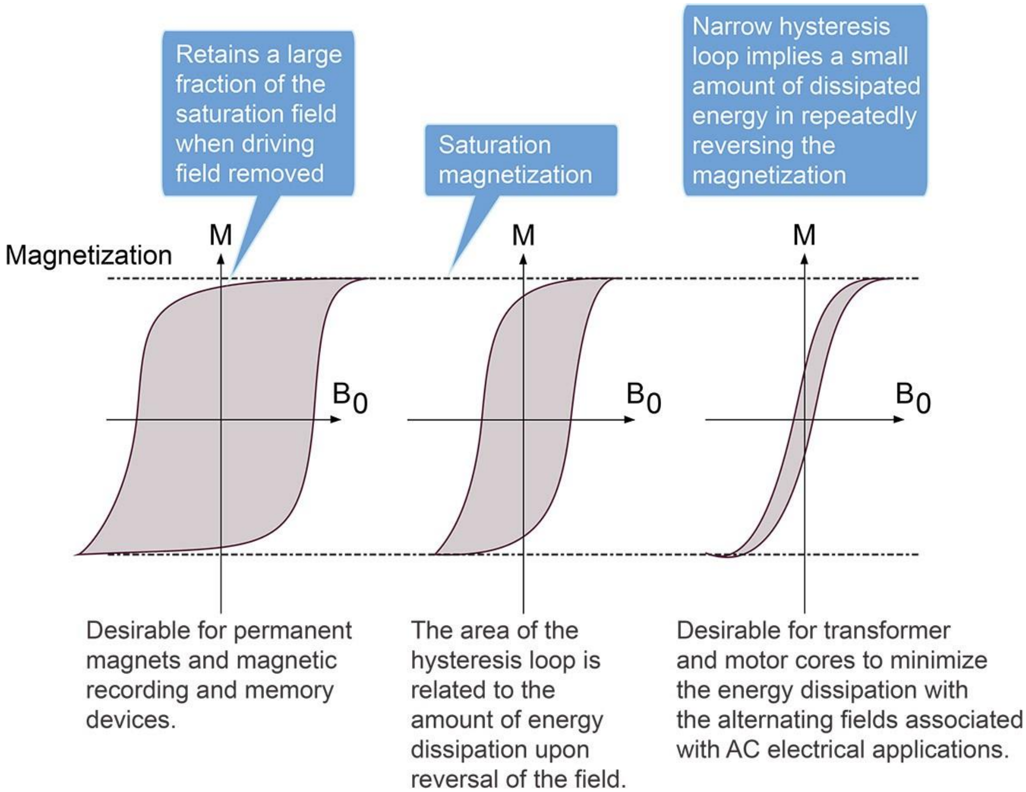
- Step 6:
  If the direction of the current I is reversed, the direction of H also gets reversed. The increment of H in reverse direction following path b – c decreases the value of residual magnetism (B_r) that gets zero at point 'c' with certain negative value of H. This negative value of H is called coercive force (H_c)
- Step 7:
  H is increased more in negative direction further; B gets reverses following path c – d. At point 'd', again magnetic saturation takes place but in opposite direction with respect to previous case. At point 'd', B and H get maximum values in reverse direction, i.e. ($-B_m$ and $-H_m$).
- Step 8:
  If we decrease the value of H in this direction, again B decreases following the path de. At point 'e', H gets zero valued but B is with finite value. The point 'e' stands for residual magnetism ($-B_r$) of the magnetic core material in opposite direction with respect to previous case.
- Step 9:
  If the direction of H again reversed by reversing the current I, then residual magnetism or residual flux density ($-B_r$) again decreases and gets zero at point 'f' following the path e – f. Again further increment of H, the value of B increases from zero to its maximum value or saturation level at point a following path f – a.

The path a – b – c – d – e – f – a forms hysteresis loop. [NB: The shape and the size of the hysteresis loop depend on the nature of the material chosen]

IMPORTANCE OF HYSTERESIS LOOP

The main advantages of **hysteresis loop** are given below.

1. Smaller hysteresis loop area symbolizes less hysteresis loss.
2. Hysteresis loop provides the value of retentivity and coercivity of a material. Thus the way to choose perfect material to make permanent magnet, core of machines becomes easier.
3. From B-H graph, residual magnetism can be determined and thus choosing of material for electromagnets is easy.



HYSTERESIS

Hysteresis of a magnetic material is a property by virtue of which the flux density (B) of this material lags behind the magnetizing force (H).

COERCIVE FORCE

Coercive force is defined as the negative value of magnetizing force (-H) that reduces residual flux density of a material to zero.

RESIDUAL FLUX DENSITY

Residual flux density is the certain value of magnetic flux per unit area that remains in the magnetic material without presence of magnetizing force (i.e. H = 0).

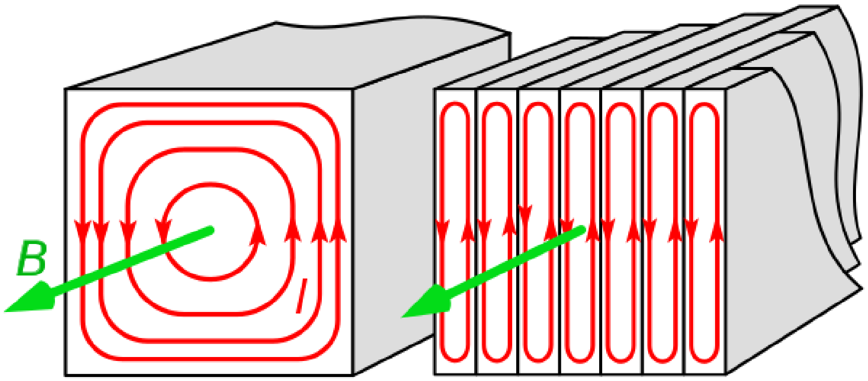
RETENTIVITY

It is defined as the degree to which a magnetic material gains its magnetism after magnetizing force (H) is reduced to zero.

HYSTERESIS LOSS

Hysteresis loss is caused by the magnetization and demagnetization of the core as current flows in the forward and reverse directions. As the magnetizing force (current) increases, the magnetic flux increases. But when the magnetizing force (current) is decreased, the magnetic flux doesn't decrease at the same rate, but less gradually. Therefore, when the magnetizing force reaches zero, the flux density still has a positive value. In order for the flux density to reach zero, the magnetizing force must be applied in the negative direction.

EDDY CURRENT



These circulating **currents** are called **Eddy Currents**. ... They will occur when the conductor experiences a changing magnetic field. As these **currents** are not responsible for doing any useful work, and it produces a **loss** (I^2R **loss**) in the magnetic material known as an **Eddy Current Loss**.

A sectional view of the magnetic core is shown in the figure above. When the changing flux links with the core itself, it induces emf in the core which in turns sets up the circulating current called **Eddy Current**. And these current in return produces a loss called eddy current loss or **(I^2R) loss,** where I is the value of the current and R is the resistance of the eddy current path.

If the core is made up of solid iron of larger cross-sectional area, the magnitude of I will be very large and hence losses will be high. To reduce the eddy current loss mainly there are two methods.

- By reducing the magnitude of the eddy current.

  The magnitude of the current can be reduced by splitting the solid core into thin sheets called laminations, in the plane parallel to the magnetic field. Each lamination is insulated from the other by a thin layer of coating of varnish or oxide film.

  By laminating the core, the area of each section is reduced and hence the induced emf also reduces. As the area through which the current is passed is smaller, the resistance of eddy current path increases.

- The eddy current loss is also reduced by using a magnetic material having a higher value of resistivity like silicon steel

APPLICATIONS OF EDDY CURRENTS

As you know that by the effect of Eddy Current the heat which is produced is not utilized for any useful work as they are a major source of energy loss in AC machines like transformer, generators, and motors. Therefore, it is known as an Eddy Current Loss. However, there are some uses of this eddy current like in Induction heating.

- In the case of **induction heating**, an iron shaft is placed as a core of an induction coil. A large amount of heat is produced at the outermost part of the shaft by the eddy current when the high-frequency current is passed through the coil. At the centre of the shaft, the amount of heat reduces. This is because the outermost periphery of the shaft offers a low resistance path for the eddy currents. This process is used in automobiles for surface hardening of heavy shafts.
- The effect of eddy current is also used in electrical instruments like in induction type energy meters for providing braking torque
- For providing damping torque in permanent magnet moving coil instruments.
- Eddy current instruments are used for detecting cracks in metal parts.
- Used in trains having eddy currents brakes.

1. When comparing magnetic and electrical circuits, the flux of magnetic circuit is compared with which parameter of electrical circuit?
    - EMF
    - **Current**
    - Current density
    - Conductivity
2. The unit of magnetic flux
    - Henry
    - **Weber**
    - Ampere turns/Weber
    - Ampere/meter
3. Relative permeability of vacuum is
    - **1**
    - 1 H/m
    - ¼
    - **$\mu = 4\Pi * 10^{-7}$**
4. Permeability in magnetic circuit corresponds to-------- in electric circuits
    - resistance
    - resistivity
    - conductance
    - **conductivity**
5. Conductance is analogous to
    - Inductance
    - Flux
    - Reluctance
    - **Permeance**
6. Permanent magnets are made of
    - **Alnico alloys**
    - Cast iron
    - Aluminum
    - Wrought iron
7. Reciprocal of reluctance is
    - Reluctivity
    - Permeability
    - Susceptibility
    - **Permeance**
8. Unit of reluctance is
    - Meter/Henry
    - Henry/meter
    - Henry
    - **1/Henry**
9. Conductivity is analogous to
    - Retentivity
    - Resistivity

- **Permeability**
- Inductance

10. What happens to the MMF when the magnetic flux decreases?
    - Increases
    - **Decreases**
    - Remains constant
    - Becomes zero

Explanation: Ohm's law for the magnetic circuit's states that the MMF is directly proportional to the magnetic flux hence as the magnetic flux decreases, the MMF also decreases**.** $\mathbf{I} \propto \emptyset$

02

11. Can we apply Kirchhoff's law to magnetic circuits?
- **Yes**
- No
- Depends on the circuit
- Insufficient data provided

Explanation: Magnetic circuits have an equivalent to the potential difference of electric circuits. This is the magnetic potential difference which allows us to apply Kirchhoff's laws to magnetic circuit analysis.

12. What is MMF?
- Magnetic Machine Force
- **Magneto motive Force**
- Magnetic Motion Force
- Magnetomotion Force

Explanation: MMF stands for magnetomotive force. Actually, it is not a force. It is analogous to potential in electric field.

13. The equivalent of the current I in magnetic ohm's law is?
- **Flux**
- Reluctance
- Mmf
- Resistance

Explanation: The equivalent of current in magnetic ohm's law is flux as: V=IR is equivalent to F=ϕS.

14. In practical magnetic circuits, the air-gap is kept
    - Very large
    - **Very small**
    - Large
    - None of above
15. Due to fringing at the air gaps in a magnetic circuit, the effective area of the air gaps is
    - **Increased**
    - Decreased
    - Same

- None of above

16. The magnetising force (H) and magnetic flux density (B) are connected by the relation
    - B = μrH/μ0
    - **B = μH**
    - B = H/μrμ0
    - B = μr/Hμ0
17. Unit of mmf is
    - **AT**
    - Weber/ampere
    - Henry
    - AT/m
18. Laminated cores in electrical machines are used to reduce
    - Copper loss
    - **Eddy current loss**
    - hysteresis loss
    - All of above
19. Those materials are well used for making permanent magnets which have ------ retentivity and -------coercivity
    - High low
    - High high
    - Low high
    - Low low
20. The magnetic materials are best suited for making motor and transformer cores which have -------- permeability and ------- hysteresis loss
    - High low
    - High high
    - Low high
    - Low low
21. In a magnetic material hysteresis loss takes place initially due to
    - Flux density lagging behind magnetization force
    - Rapid reversals of its magnetization
    - Molecular friction
    - **Its high retentivity**
22. A ferrite core has less eddy current loss than iron because
    - Ferrite has high resistance
    - Ferrites are magnetic
    - Ferrites have low permeability
    - Ferrites have high hysteresis
23. Silicon steel is used in electrical machines because it has
    - Low coercivity
    - Low retentivity
    - **Low hysteresis loss**
    - High coercivity
24. If area of hysteresis loop of a material is large then hysteresis loss in the material will be
    - Zero
    - Small

- **Large**
- None of above

25. Air gap is usually inserted in magnetic circuit
    - Increase mmf
    - Increase the flux
    - **Prevent saturation**
    - None of above
26. The relative permeability of ferromagnetic material is
    - Less than 1
    - More than 1
    - More than 10
    - **More than 100 or 1000**
27. Hard steel is suitable for making permanent magnet because
    - **It has good residual magnetism**
    - Its hysteresis loop have large area
    - Its mechanical strength is high
    - Its mechanical strength is low
28. The property of a material which opposes the creation of magnetic flux in it is known as
    - Reluctivity
    - Magneto motive force
    - Permeance
    - **Reluctance**
29. Ohm's law for magnetic circuits is __________
    - **F=ϕS**
    - F=ϕ/S
    - $F=\phi^2S$
    - $F=\phi/S^2$

Explanation: Ohm's law for magnetic circuits states that the MMF is directly proportional to the magnetic flux where reluctance is the constant of proportionality.

30. Point out the right statement

Magnetic leakage is undesirable in electric machines because it

- **Lowers their power efficiency**
- Increases the cost manufacture
- Leads to their increased weight
- Produces fringing

31. What will be ampere turns required to produce a flux of 0.4 Weber in a magnetic circuit of reluctance 100 AT/web
    - **40AT**
    - 250AT
    - 400AT

Explanation: S = 100AT/ web, **φ = 0.4 web,**

$$\emptyset = \frac{\text{mmf (F)}}{\text{reluctance (S)}}$$

32. A coil of 2000 turns , place in an iron ring of mean circumference 0.3m takes a current of 0.5 A, find the field intensity

- 333AT/m
- **3,333AT/m**
- 1,200AT/m

Explanation:

$$H = \frac{NI}{L}$$

FORMULAS

1) Magnetic field strength or magnetic field intensity, $H = \frac{NI}{L}$

2) Absolute Permeability $\mu = \frac{B}{H}$
3) relative permeability $\mu_r = 1$
4) permeability of free space $\mu_0 =$ **$4\Pi*10^{-7}$**
5) $\mu = \mu_0\ \mu_r$
6) Reluctance $S = \frac{l}{\mu 0 \times \mu r \times a}$
7) Flux = $\emptyset = \frac{\text{mmf}}{\text{reluctance}}$
8) Mmf = NI
9) $NI = HL$

10) $mmf = HL$

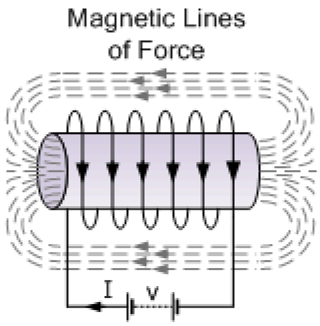
11) $NI = \emptyset S_i + \emptyset S_g$

12) $I \propto \emptyset$

13) $B \propto H$

ELECTROMAGNETIC INDUCTION

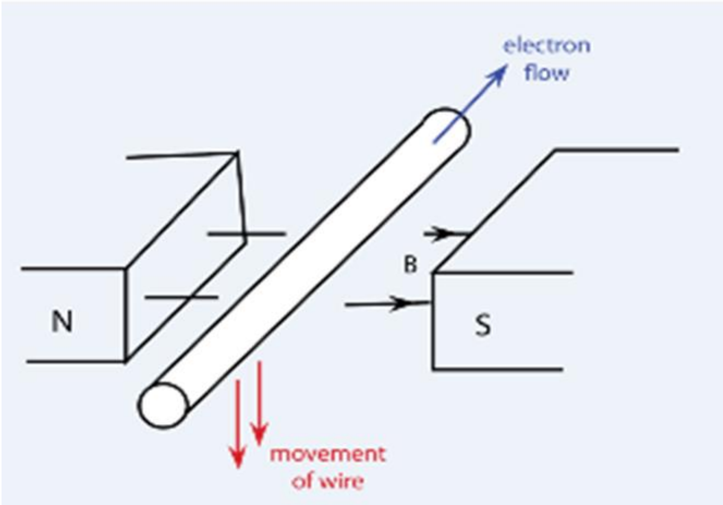
If the wire is wound into a coil, the magnetic field is greatly intensified producing a static magnetic field around itself forming the shape of a bar magnet giving a distinct North and South pole.



The magnetic flux developed around the coil being proportional to the amount of current flowing in the coils windings as shown. If additional layers of wire are wound upon the same coil with the same current flowing through them, the static magnetic field strength would be increased.

Therefore, the magnetic field strength of a coil is determined by the *ampere turns* of the coil. With more turns of wire within the coil, the greater the strength of the static magnetic field around it.

Likewise, if we kept the bar magnet stationary and moved the coil back and forth within the magnetic field an electric current would be induced in the coil. Then by either moving the wire or changing the magnetic field we can induce a voltage and current within the coil and this process is known as **Electromagnetic Induction** and is the basic principle of operation of transformers, motors and generators.

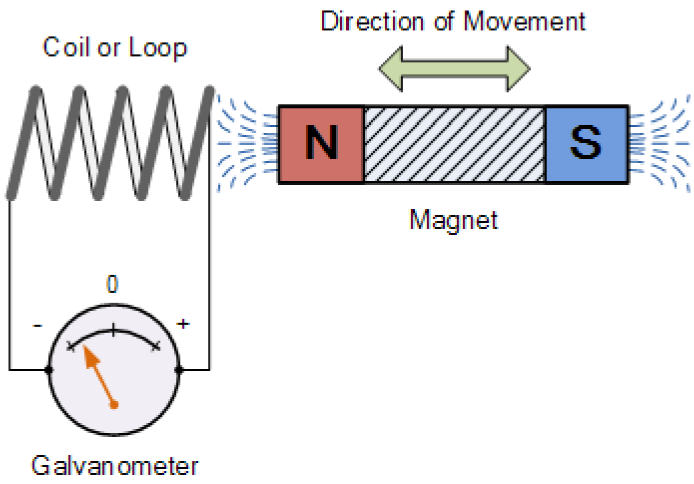


Electromagnetic Induction was first discovered way back in the 1830's by **Michael Faraday**. Faraday noticed that when he moved a permanent magnet in and out of a coil or a single loop of wire it induced an ElectroMotive Force or emf, in other words a Voltage, and therefore a current was produced.

So what Michael Faraday discovered was a way of producing an electrical current in a circuit by using only the force of a magnetic field and not batteries. This then lead to a very important law linking electricity with magnetism, **Faraday's Law of Electromagnetic Induction**. When the magnet shown below is moved "towards" the coil, the pointer or needle of the Galvanometer, which is basically a very sensitive centre zero'ed moving-coil ammeter, will deflect away from its centre position in one direction only. When the magnet stops moving and is held stationary with regards to the coil the needle of the galvanometer returns back to zero as there is no physical movement of the magnetic field.

Likewise, when the magnet is moved "away" from the coil in the other direction, the needle of the galvanometer deflects in the opposite direction with regards to the first indicating a change in polarity. Then by moving the magnet back and forth towards the coil the needle of the galvanometer will deflect left or right, positive or negative, relative to the directional motion of the magnet.

Electromagnetic Induction by a Moving Magnet



Likewise, if the magnet is now held stationary and ONLY the coil is moved towards or away from the magnet the needle of the galvanometer will also deflect in either direction. Then the action of moving a coil or loop of wire through a magnetic field induces a voltage in the coil with the magnitude of this induced voltage being proportional to the speed or velocity of the movement.

Then we can see that the faster the movement of the magnetic field the greater will be the induced emf or voltage in the coil, so for Faraday's law to hold true there must be "relative motion" or movement between the coil and the magnetic field and either the magnetic field, the coil or both can move.

FARADAY'S LAW OF INDUCTION

From the above description we can say that a relationship exists between an electrical voltage and a changing magnetic field to which Michael Faraday's famous law of electromagnetic induction states: "that a voltage is induced in a circuit whenever relative motion exists between a conductor and a magnetic field and that the magnitude of this voltage is proportional to the rate of change of the flux".

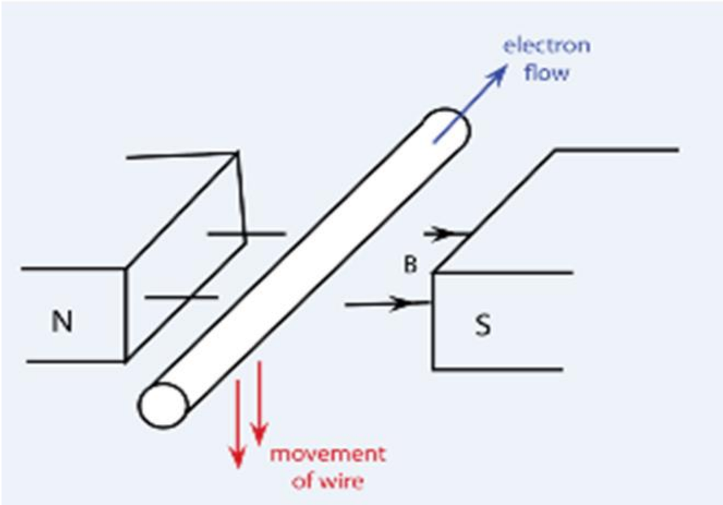
In other words, **Electromagnetic Induction** is the process of using magnetic fields to produce voltage, and in a closed circuit, a current.

So how much voltage (emf) can be induced into the coil using just magnetism. Well this is determined by the following 3 different factors.

- 1). Increasing the number of turns of wire in the coil – By increasing the amount of individual conductors cutting through the magnetic field, the amount of induced emf produced will be the sum of all the individual loops of the coil, so if there are 20 turns in the coil there will be 20 times more induced emf than in one piece of wire.
- 2). Increasing the speed of the relative motion between the coil and the magnet – If the same coil of wire passed through the same magnetic field but its speed or velocity is increased, the wire will cut the lines of flux at a faster rate so more induced emf would be produced.
- 3). Increasing the strength of the magnetic field – If the same coil of wire is moved at the same speed through a stronger magnetic field, there will be more emf produced because there are more lines of force to cut.

If we were able to move the magnet in the diagram above in and out of the coil at a constant speed and distance without stopping we would generate a continuously induced voltage that would alternate between one positive polarity and a negative polarity producing an alternating or AC output voltage and this is the basic principle of how an electrical generator works similar to those used in dynamos and car alternators.

In small generators such as a bicycle dynamo, a small permanent magnet is rotated by the action of the bicycle wheel inside a fixed coil. Alternatively, an electromagnet powered by a fixed DC voltage can be made to rotate inside a fixed coil, such as in large power generators producing in both cases an alternating current.



Flux linkage = flux x number of turns of coil

flux linkage = N x Ø

initial flux linkage = N Ø1

final flux linkage = N Ø2

rate of change of flux linkage = $\frac{NØ2-NØ1}{t}$

rate of change of flux = enduced emf (e)

e = $\frac{NØ2-NØ1}{t}$

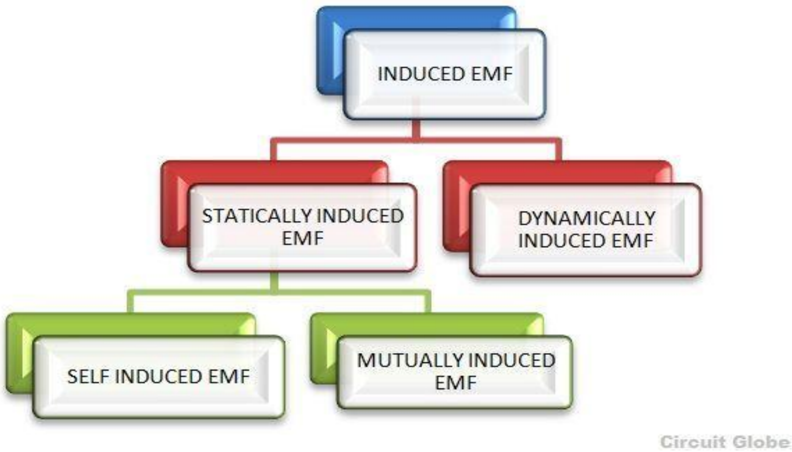
e = $\frac{N\,dØ}{dt}$

LENZ'S LAW

The direction of an induced emf produced during the process of EMI is always such that it tends to set up a current opposing the basic cause responsible for inducing that emf.

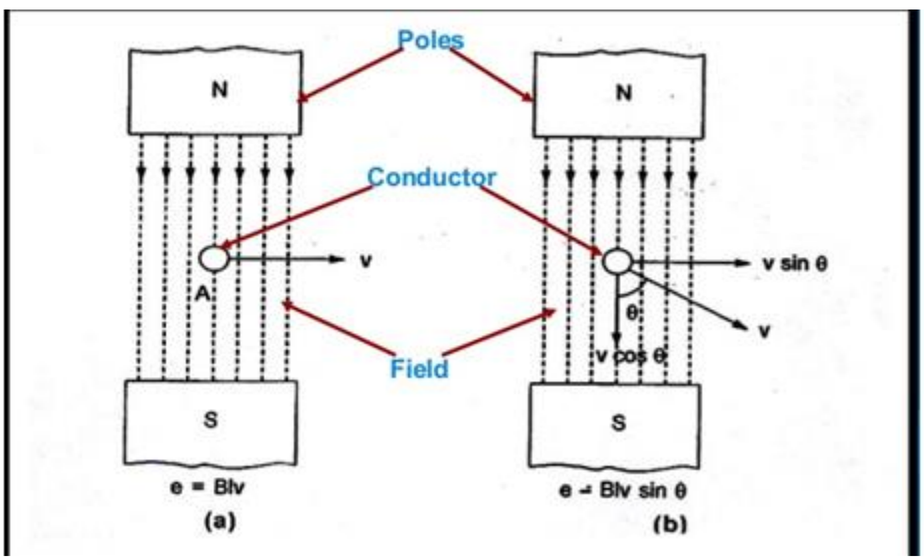
e = - $\frac{N\,dØ}{dt}$

INDUCED EMF



DYNAMICALLY INDUCED EMF

Dynamically induced emf means an emf induced in a conductor when the conductor moves across a magnetic field.



B = Flux Density

L = active length of conductor

V = velocity in m/s

Let this conductor be moved through distance dx, in small time interval dt.

Area covered by conductor = l x dx m^2

$B = Ø/A$

Flux cut by conductor = flux density x area covered

$$Ø = B \times l \times dx$$

$$e = flux \frac{cut}{time}$$

$$e = d\frac{Ø}{dt}$$

$$e = \frac{BLdx}{dt}$$

dx/dt = rate of change of displacement

= velocity

= V

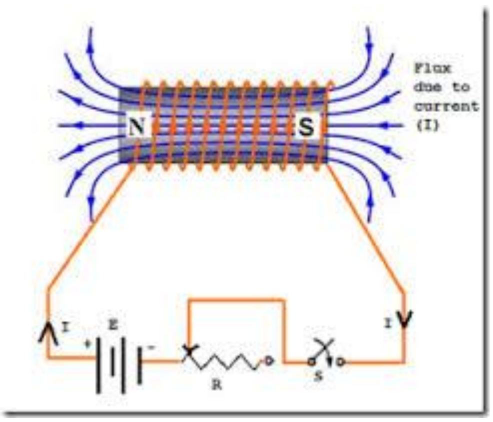
e = BlV

The component VSinθ is perpendicular to the direction of flux and therefore responsible for the induced emf. The other component VCosθ is parallel to the direction of flux.

So , e = BlVSinθ

STATICALLY INDUCED EMF

IF flux is due to coil itself then emf is called as self induced emf.



Consider a coil with and arrangement to change the current through coil continuously. Its result is to change the flux produced by it. This coil is considered to be kept in a charging magnetic field produced by the change of its own current. According to Faraday's law , the emf will be induced in the coil and since it is due to its own changing current, the emf is called as self induced emf.

$$L = \frac{NØ}{I}$$

The inductance of a coil having N turns and a current of I amperes producing total Ø flux linking all the turns.

$$Ø = \frac{\text{mmf (F)}}{\text{reluctance (S)}}$$

$$Ø = \frac{NI}{\frac{l}{\mu 0 \times \mu r \times A}}$$

$$Ø = \frac{\mu 0 \times \mu r \times A\ NI}{l}$$

Multiplying both sides by N

$$NØ = \frac{\mu 0 \times \mu r \times A\ N^2 I}{l}$$

$$\frac{NØ}{I} = \frac{\mu 0 \times \mu r \times A\ N^2}{l}$$

$$L = \frac{\mu 0 \times \mu r \times A\ N^2}{l}$$

$$Ø = \frac{NI}{\frac{l}{\mu 0 \times \mu r \times A}}$$

Differentiating both sides

$$Ø = \frac{NI}{\frac{l}{\mu 0 \times \mu r \times A}}$$

$$\frac{d\,Ø}{dt} = \frac{\mu 0 \times \mu r \times AN}{l} \times \frac{dI}{dt}$$

We know that , e = - $\frac{N\,dØ}{dt}$

$$e = -N\,\frac{\mu 0 \times \mu r \times AN}{l} \times \frac{dI}{dt}$$

$$e = -N^2\,\frac{\mu 0 \times \mu r \times A}{l} \times \frac{dI}{dt}$$

$$e = -L\,\frac{dI}{dt}$$

33. Who introduced the right-hand rule for determining the direction of the induced EMF?

- **Fleming**
- Lenz
- Maxwell
- Faraday

34. Whenever there is a change in magnetic flux with respect to an electric conductor or a coil, an EMF is induced in the conductor is Faraday's

- **first law**
- third law
- second law
- fourth law

35. In which device is the principle of statically induced emf used?

- **Transformer**
- Motor
- Generator

- Battery

36. Statically induced emf's magnitude depends on the

- **Rate of change of flux**
- Coil resistance
- Flux magnitude
- None of these

37. Principle of dynamically induced emf is used in a

- Choke
- Transformer
- **Generator**
- Thermo-couple

38. According to Faraday's law, EMF stands for

- Electromagnetic field
- Electromagnetic force
- Electromagnetic friction
- **Electromotive force**

39. Calculate the emf when a coil of 100 turns is subjected to a flux rate of 0.3 tesla/sec.

- 3
- 30
- **-30**
- -300

Explanation: The induced emf is given by emf = -Nd Ø/dt. Thus emf will be -100 x 0.3 = -30 units.

40. The H quantity is analogous to which component in the following?

- B
- D
- **E**

- V

Explanation: The H quantity refers to magnetic field intensity in the magnetic field. This is analogous to the electric field intensity E in the electric field.

41. The magnetic flux density is directly proportional to the magnetic field intensity. State True/False.

- **True**
- false

Explanation: The magnetic field intensity is directly proportional to the magnetic field intensity for a particular material (Permeability). It is given by B = μH.

42. Find the magnetic field intensity due to a solenoid of length 12cm having 30 turns and current of 1.5A.

- 250
- 325
- 175
- **375**

H = NI/L

43. Identify which of the following is the unit of magnetic flux density?

- Weber
- Weber/m
- **Tesla**
- Weber^{-1}

Explanation: The unit of magnetic flux density is weber/m^2. It is also called as tesla.

44. Calculate the magnetic flux mmf = 17AT and the reluctance is 3AT/Wb.

$Ø = \frac{\text{mmf (F)}}{\text{reluctance (S)}}$ = 5.67

45. A coil of 5000 turns , place in an iron ring with the length of 0.5m takes a current of 0.5 A, find the field intensity

H = NI/L

H = 5000

46. Find mmf when number of turns on the coil is 200 and current through the coil given through DC supply is 5A

Mmf = NI

= 1000

47. Find the flux density of a magnetic material when field intensity is 20AT and relative permeability is 1

B = μ H

= 20

48. A coil of 400 turns has a flux of 0.1 weber linking with it when carrying current of 1A. Determine the inductance of the coil.

L = $\frac{NØ}{I}$ =

40

49. Find the induced emf when flux changes from 0.3 to 0.5 weber in 1 sec. the coil has 100 number of turns.

e = - $\frac{N\,dØ}{dt}$

- 100 (0.5 – 0.3)/1

-100 *0.2

-20 V