HYSTERSIS LOOP

- The graph showing how M or B increases with H from zero to maximum in one direction and then back through a zero to a maximum in opposite direction and finally back again through zero to the first maximum.
- The area under the curve gives the energy loss

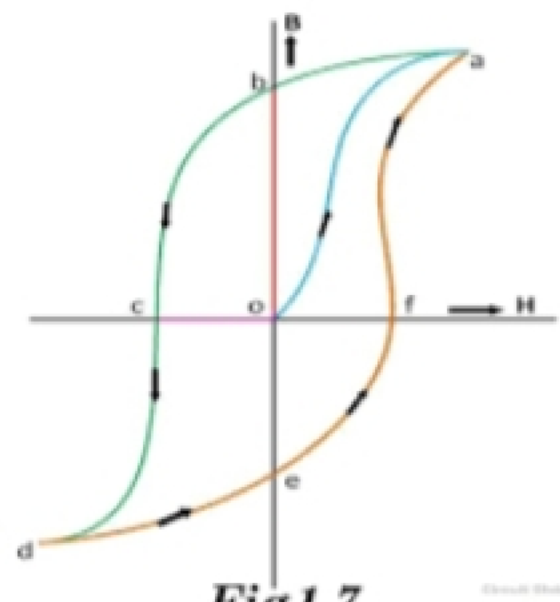
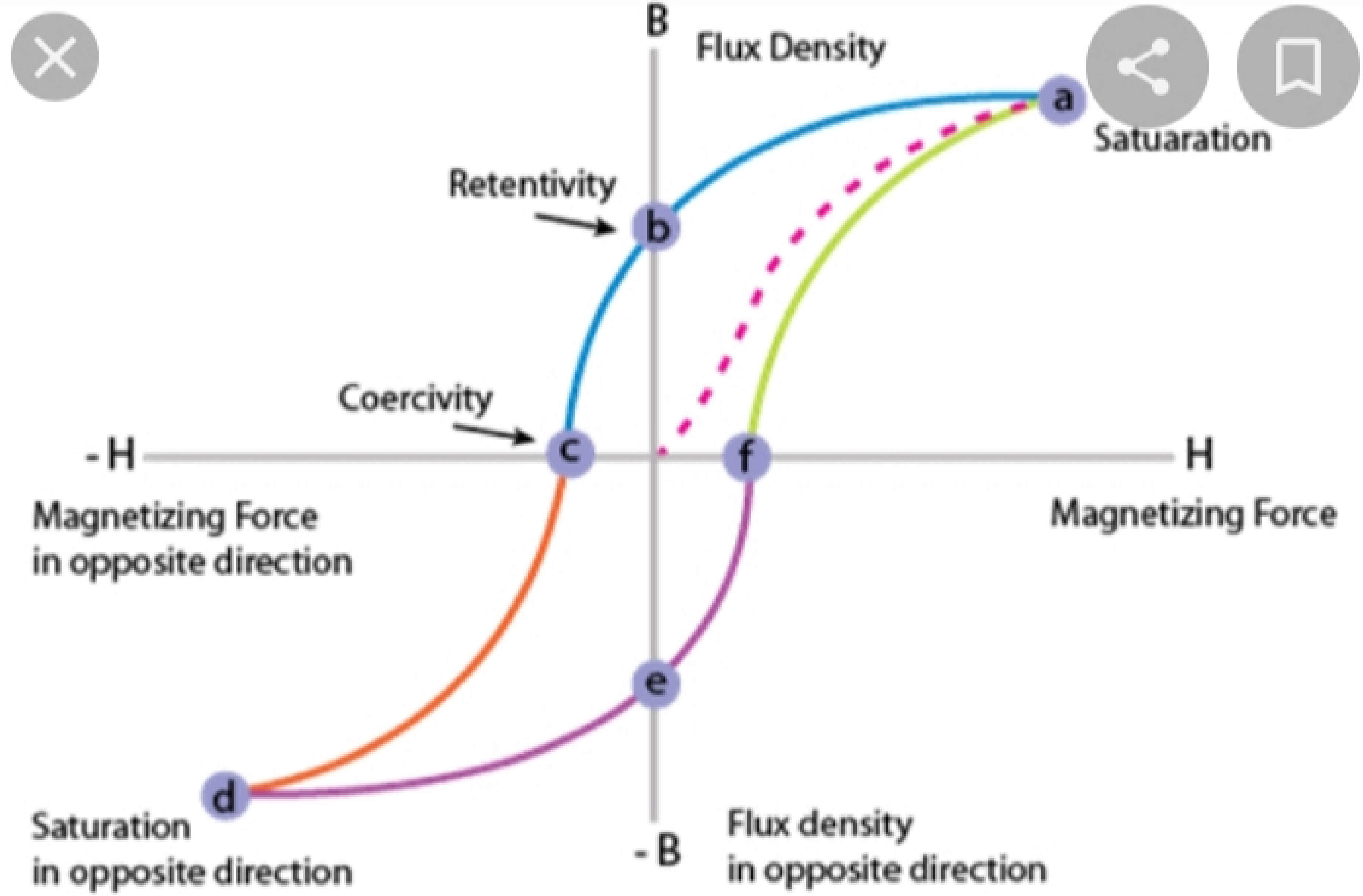


Fig 1.7
B-H Curve


B
Flux Density
a
Satuaration
Retentivity
b
Coercivity
c
- H
f
H
Magnetizing Force
in opposite direction
Magnetizing Force
e
d
Saturation
in opposite direction
- B
Flux density
in opposite direction

DESCRIPTION OF LOOP

- At **O**,H=0 and M=0,when H increases , M also increases till **a**, i.e. saturation point.
- Decrease H,M decreases slowly . At **b** , H=0 but B has some value , known as remanence or retentivity.
- Decreasing H in negative value, at **c**, B=o but H has a negative value, known as coercivity.
- Further decreasing H , saturation point is again reached at **d**.
- Now decrease H to zero , we get point **e**, at which again H=0
- Now on increasing H,the cycle is repeated back and we reach at point **a**.
- Closed curve **abcdefa** is hystersis curve.

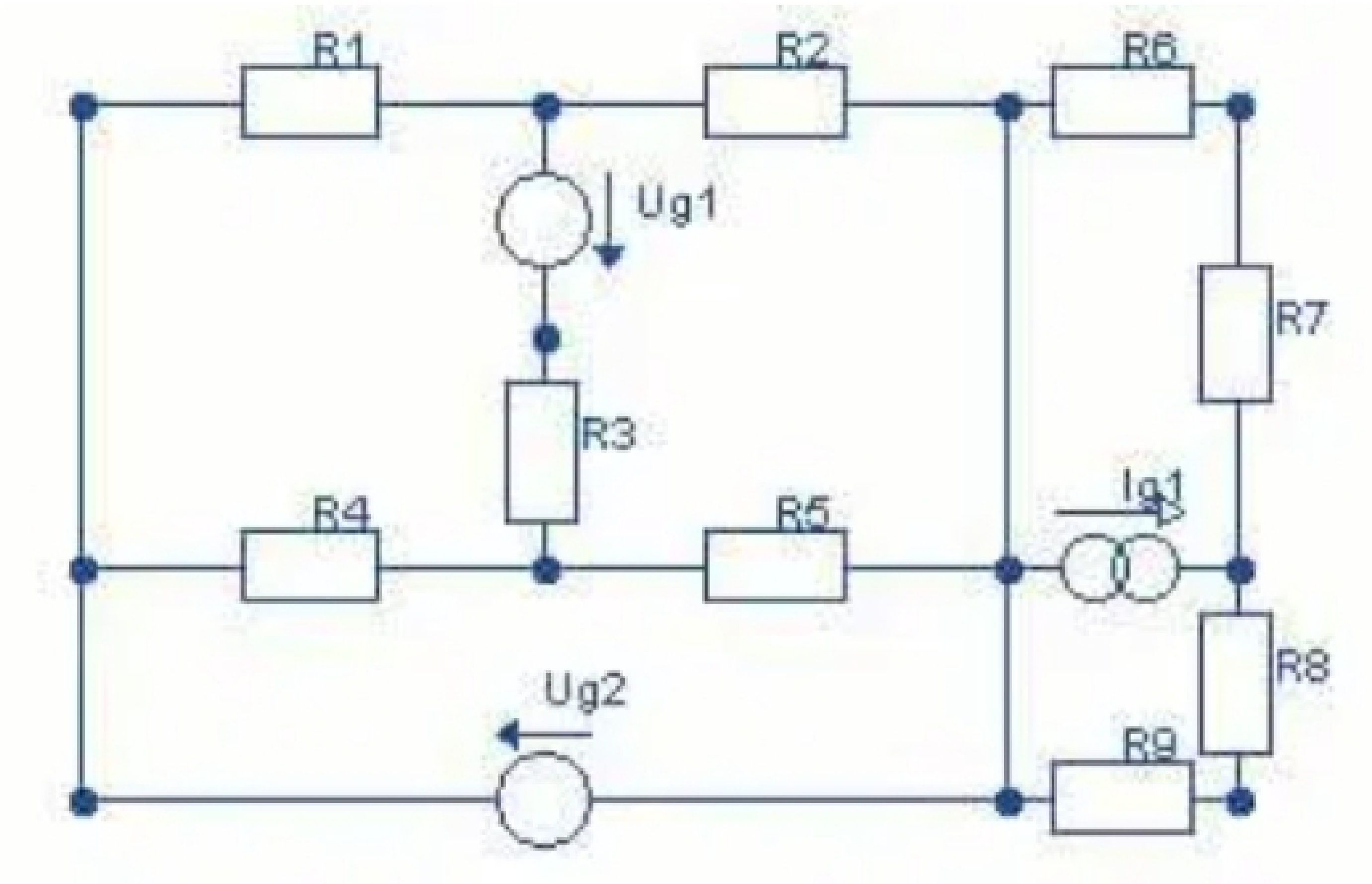
CONCLUSIONS

- **Electric coercivity**, is the minimum external electric field required to destroy the residual magnetism is called the coercivity.
- **Retentivity** is the value of intensity of magnetisation retained by the ferromagnetic substance when the magnetising field is switched off.
- Materials used to make **permanent magnets** should have high value of retentivity and coercivity.
- Material used to make **electromagnets** high retentivity and low coercivity

What is a Linear Circuit?

Basically, a linear circuit is an electrical circuit and the parameters of this circuit such as Resistance, Capacitance, Inductance, etc. are always constant.

That is, we can say that a linear circuit is called a circuit that changes the parameters of the circuit with changes in voltage and current.

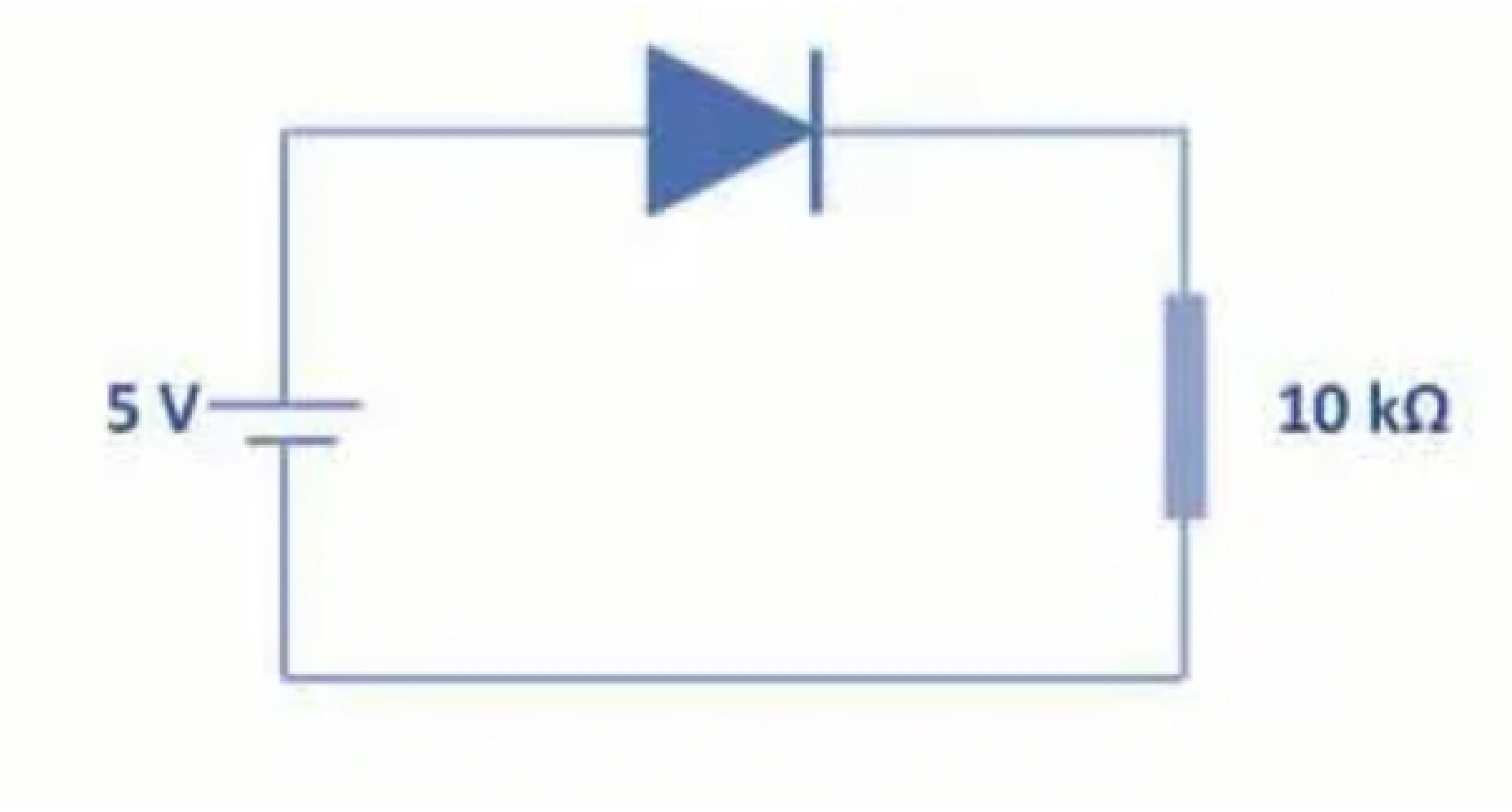


Linear circuit

The non-linear circuit is also an electrical circuit, but the voltage and current change in this circuit change the parameters of the circuit such as Waveforms, Resistance, Inductance, etc.

The non-linear circuit is also an electrical circuit, but the voltage and current change in this circuit change the parameters of the circuit such as Waveforms, Resistance, Inductance, etc.

That is, a non-linear circuit is called a circuit in which the voltage or current changes the parameters of the circuit.



Non-Linear Circuits

Forces and Energy

$$W = -U \Rightarrow U = -\int F dx$$

$$F_x(x) = -\frac{\partial U(x)}{\partial x}$$

e.g. spring $\quad U = \frac{1}{2} kx^2 \ \square \ F = -\frac{\partial[\frac{1}{2} kx^2]}{\partial x} = -kx$

$$\underline{F}(x, y, z) = -\square \frac{\partial U(x, y, z)}{\partial x} \underline{i} + \frac{\partial U(x, y, z)}{\partial y} \underline{j} + \frac{\partial U(x, y, z)}{\partial z} \underline{k} \square = -\underline{\square} U(x, y, z)$$

- Partial Derivative – derivative wrt one variable, others held constant
- Gradient operator, said as grad(f)

Determination of Torque from Energy

For a system with a rotating mechanical terminal, the mechanical terminal variables become the angular displacement θ and the torque *T*. Therefore, equation for the torque:

$$T = -\left.\frac{\partial W_f(\lambda, \theta)}{\partial \theta}\right|_{\lambda}$$

where the partial derivative is taken while holding λ constant.

Energy and Coenergy

The coenergy is defined as

$$\mathbf{W_f'} = \int_0^i \lambda \, \mathbf{di}$$

From the figure of λ - *i* characteristic,

$$W_f' + W_f = \lambda \, i$$

Note that $W_f' > W_f$ if the λ - *i* characteristic is non linear and $W_f' = W_f$ if it is linear.

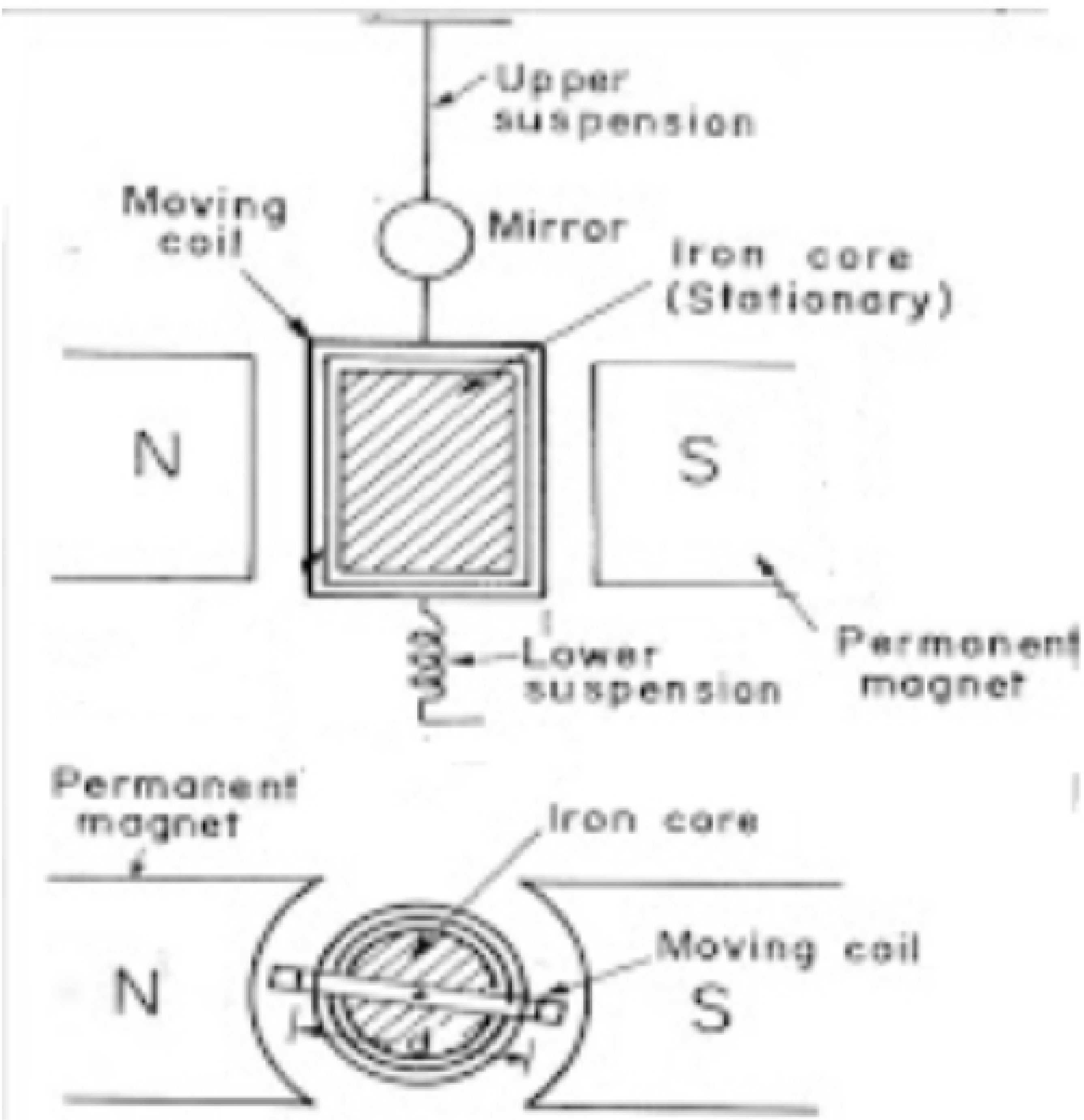
The quantity of coenergy has no physical significance. However, it can be used to derive expressions for force (torque) developed in an electromagnetic system

Moving Coil Galvanometer

Moving coil galvanometer is an electromagnetic device that can measure small values of current. It consists of permanent horseshoe magnets, coil, soft iron core, pivoted spring, non-metallic frame, scale, and pointer.

Principle of Moving Coil Galvanometer

Torque acts on a current-carrying coil suspended in the uniform magnetic field. Due to this, the coil rotates. Hence, the deflection in the coil of a moving coil galvanometer is directly proportional to the current flowing in the coil.



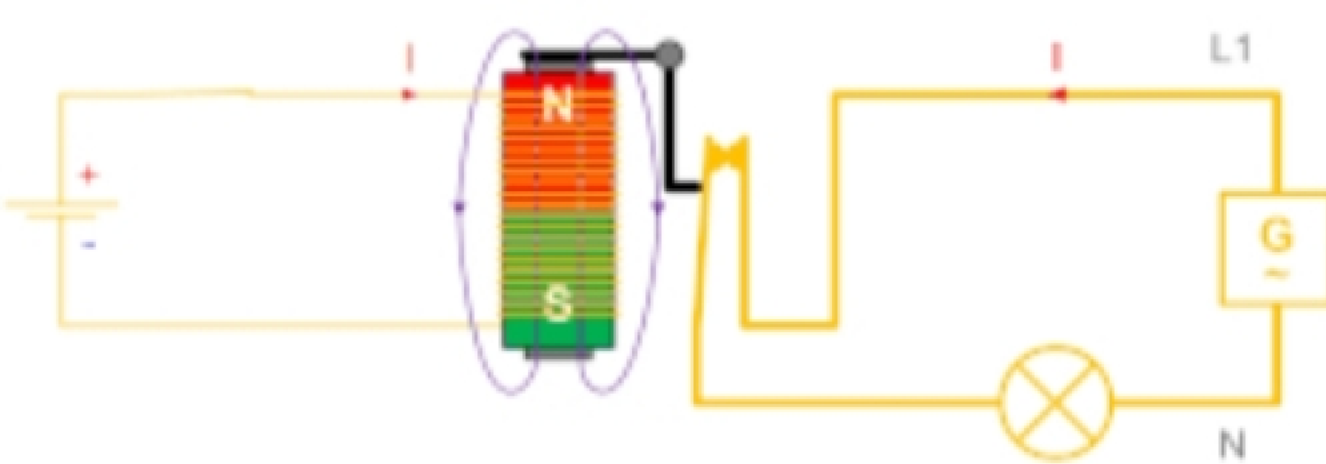
[source: Redefining The Knowledge]

The Moving Coil Galvanometer

The principle contact materials used for relays with nominal contact ratings within the range 5 to 50A are most commonly **silver nickel, silver cadmium oxide and silver tin oxide**. Silver nickel has been around almost forever.

The traditional form of a relay uses an electromagnet to close or open the contacts, but other operating principles have been invented, such as in solid-state relays which use semiconductor properties for control without relying on moving parts. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called *protective relays*.

Latching relays require only a single pulse of control power to operate the switch persistently. Another pulse applied to a second set of control terminals, or a pulse with opposite polarity, resets the switch, while repeated pulses of the same kind have no effects. Magnetic latching relays are useful in applications when interrupted power should not affect the circuits that the relay is controlling.



Operation without flyback diode, arcing causes degradation of the switch contacts.

Rotor eccentricity in electrical machines determines the non-uniformity of the air-gap and gives rise to an unbalanced magnetic pull (UMP), which causes vibrations and noise emission, speeds up the bearing wear and can produce a rub between rotor and stator. In the paper, an overview about this subject is presented, by classifying the researches according to the type of machine (induction, synchronous, brushless), the type of eccentricity (static or dynamic) and the type of studied effect (definition of the fault indicators, calculation of the UMP, modelling the dynamic behaviour of the machine).

2 ELECTROMAGNETIC FORCES IN ELECTRICAL MACHINES WITH ROTOR ECCENTRICITY

In rotating electrical machines, the radial forces acting upon the surface of the rotor are very large, but they are balanced when the rotor is concentric with the stator (Fig. 1). Similarly, the tangential forces produce only an axially rotating moment. If the rotor becomes eccentric, then UMP occurs. The phenomenon can be described as an imbalance of the radial and tangential forces acting upon the rotor (or the stator) surface, so that a net radial force is developed. This force can cause vibration and noise. If the shaft is very flexible, the rotor can rub on the stator with possible serious damage to the stator core and windings.

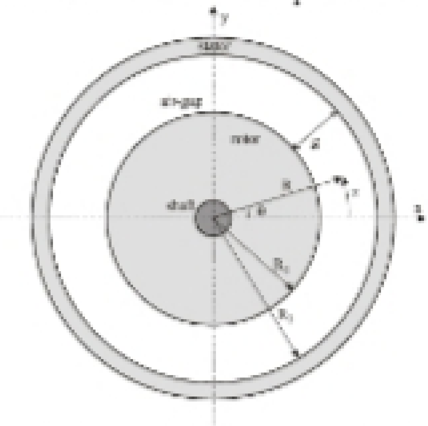


Figure 1 – Rotor concentric with stator

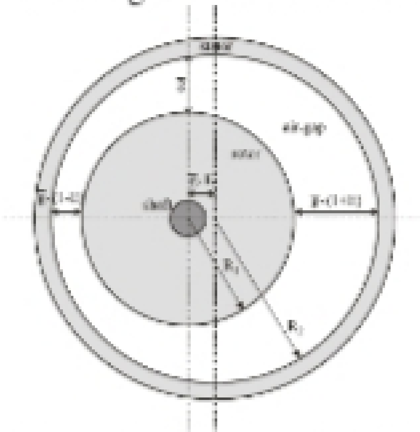


Figure 2 – Rotor with static eccentricity

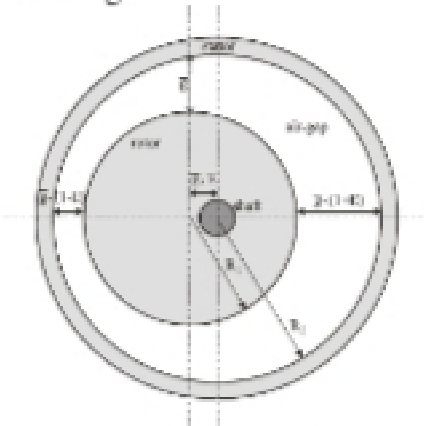


Figure 3 – Rotor with dynamic eccentricity

Two forms of eccentricity, which can also exist together, are classified:

- static, when the position of minimum radial length of the air-gap is fixed in the space (Fig. 2); in this case the rotor axis coincides with the shaft axis, but does not coincide with the stator axis. So, the rotor is symmetrical with respect to its axis and rotates about this one; moreover, the rotor axis is parallel to the stator axis. Static eccentricity may be due to manufacturing tolerances or bearing wear;

3. INDICATORS OF ROTOR ECCENTRICITY

3.1 Indicators of static and dynamic eccentricity in induction motors

Many studies have analysed induction motors in order to define indicators of rotor eccentricity. These studies have shown that the typical signature of an eccentric motor can be observed in both current and vibration spectra and can be employed to determine also the type (static or dynamic) and the severity of the eccentricity (1,6,7,22).

Rotor eccentricity can be detected by means of:

- harmonic components that take into account both stator and rotor slotting effects, due to the fact that stator and rotor are not perfectly smooth (1,7); the frequencies that have to be monitored are defined as a function of the number of stator slots and rotor bars: this information is not always available for the motors installed in industrial plants;
- harmonic components that do not consider slotting effects and are simply function of the supply frequency f_s and the rotational frequency of the rotor f_r (6).

In induction motors, the relationship between f_r and f_s is well known: $f_r = (1\text{-}s)\, f_s / pp$, where pp is the number of pole pairs and s is the slip (generally equal to 0.01÷0.02 at full load). In (6) the authors have shown that the magnitude of the sidebands currents at the frequencies:

$$f_{1,2} = f_s \pm f_r \quad (1)$$

are strongly dependent on the severity of both dynamic and static eccentricity. Moreover, the effect of dynamic eccentricity on these sidebands increases from full-load to no-load condition. Nevertheless, these sideband currents could be caused by other malfunctions, not associated with rotor eccentricity, like load torque anomalies or broken rotor bars. Therefore, monitoring the vibration of the casing may also be helpful to detect rotor eccentricity.

The casing vibration is a consequence of the attractive force between rotor and stator produced by the air-gap magnetic field; its fundamental component is at twice supply frequency ($2f_s$) (13). In induction motors, the dynamic eccentricity produces other non-twice supply frequency vibrations in addition to the rotational velocity vibration of frequency f_r:

$$f_{3,4} = 2f_s \pm f_r \quad (2)$$

The magnitude of the vibration components at $2f_s$, f_r, f_3 and f_4 increases rapidly with both static and dynamic eccentricity, especially at no-load condition. In particular, static eccentricity has only a little influence on the f_r component (6).