7

CHAPTER

Magnetism and Electro-magnetism

7.1. Magnetic Materials

Different materials can be classified as either magnetic materials or non-magnetic materials (air, glass, wood, paper, porcelain, plastic and rubber etc.). However, it should be noted that even though these non-magnetic materials cannot be magnetised, they allow the magnetic flux to pass through them. Magnetic materials may be further subdivided into following three groups as regards their magnetic properties :

1. Ferromagnetic Materials

These are the most important magnetic materials used in Electricity and Electronics. They are easily and strongly magnetised in the *same* direction as the field. They have high value of relative permeability from 50 to 5000 *i.e.*, they conduct magnetic flux 50 to 5000 times more easily than air. Most commonly used ferromagnetic materials are : iron, steel, nickel, cobalt and commercial alloys such as alnico, permalloy and supermalloy.

Alnico is a trade name for an alloy of aluminium, nickel, iron and cobalt. Permanent magnets made of alnico are commonly used in motors, generators, loudspeakers, microphones and meters etc. Permalloy (nickel and iron or cobalt, nickel and iron) has a relative permeability of the order of 100,000. Similarly, supermalloy is an alloy of nickel, iron, molybdenum and manganese.

2. Paramagnetic Materials

They become only slightly- or weakly-magnetised in a

strong magnetic field in the *same* direction as the field. They conduct magnetic flux only slightly better than vacuum (or air). This group includes aluminium, chromium, platinum and manganese etc. Their relative permeability is slightly greater than one.

3. Diamagnetic Materials

These include bismuth, antimony, copper, zinc, mercury, gold and silver which have a relative iron and cobalt. Permanent magnets made of alnico are commonly used in motors, generators, loudspeakers, microphones and meters etc. Permalloy (nickel and iron or cobalt, nickel and iron) has a relative permeability of the order of 100,000. Similarly, supermalloy is an alloy of nickel, iron, molybdenum and manganese.

14. Impedance Matching

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strong magnetic field in the *same* direction as the field. They conduct magnetic flux only slightly better than vacuum (or air). This group includes aluminium, chromium, platinum and manganese etc. Their relative permeability is slightly greater than one.

3. Diamagnetic Materials

These include bismuth, antimony, copper, zinc, mercury, gold and silver which have a relative permeability of less than one *i.e.*, they conduct magnetic flux less readily than air. They are also slightly magnetised but in a direction opposite to that of the magnetising field.

7.2. Ferrites

It is the name given to the recently-discovered ceramic materials that have the ferromagnetic properties of iron. Ferrites are made first by grinding a combination of iron oxide and an alkaline-earth material such as barium into a fine powder. This powder is then pressed into the desired shape and baked at a high temperature. It produces magnetic material which is highly magnetic having a relative permeability in the range 50 to 3000. However, unlike iron, it is an insulator so far as electric conduction is concerned. Like alloy magnets, ceramic magnets can also be shaped into any desired shape. Permanent ceramic magnets are used as gasket latches on refrigerator doors. Ferrite cores (usually adjustable) are used for RF transformers upto 20 MHz frequencies. Another application is ferrite beads. A bare wire is passed through one or more ferrite beads (Fig. 7.1). When current is passed through the wire, a magnetic field is produced. This field is concentrated by the beads into the wire which serves as a simple and economical RF choke.

Ferrite cores are used for RF transformers upto 20 MHz frequencies.

7.3. Types of Magnets

All magnets may be divided into (*i*) permanent magnets and (*ii*) electromagnets.

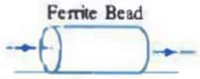

Fig. 7.1

1. Permanent Magnets (PM)

Once magnetised, they maintain their magnetic strength almost indefinitely. They are made of hard magnetic materials such as cobalt steel which is magnetised by induction in the manufacturing process. A very strong field is needed for this purpose. When magnetising field is removed, cobalt steel retains most of its induced magnetism due to its very high retentivity. Other high-retentivity materials are alnico and permalloy etc., which are used in PM loudspeakers. As the name indicates, permanent magnets will last indefinitely if not subjected to high temperature, to physical shock or to a strong demagnetising field. Moreover, they do not get exhausted with use.

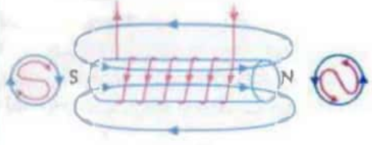

Fig. 7.2

2. Electromagnets

They consist of a coil of wire wound over a soft iron core. When current is passed through the coil, it produces a magnetic field which magnetises the core into a bar magnet with polarities as shown in Fig. 7.2. More current and more turns produce a stronger magnetic field which results in a stronger electromagnet. When current is switched off, field disappears

A buzzer uses copper wires in its electromagnets.

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and the iron core is no longer a magnet. This ability of an electromagnet to provide a strong magnetic force of attraction that can be turned OFF and ON has found many applications in lifting magnets, buzzers, bells, horns, relays and magnetic circuit breakers etc. A relay is just a switch with contacts which are opened or closed by an electromagnet. Another application of electromagnets is in the magnetic tape recording.

7.4. Demagnetising or Degaussing

Though magnetism is useful, still there are times when need arises to remove magnetism from certain objects. For example, wrist watches made of magnetic material will not keep correct time if they become magnetised. Similarly, metal cutting tools such as drills and reamers become magnetised due to Earth's magnetic field and start attracting metal chips and filings. This causes them to become dull in due course of time.

Such objects can be demagnetised by using a demagnetiser which consists of a multi-turn coil carrying alternating current. When the object to be demagnetised is placed inside the coil, the alignment of its molecular magnets is destroyed by the alternating magnetic field of the demagnetiser.

A permanent magnet may be demagnetised by heating it to a high temperature or by hammering it.

7.5. Magnetic Shielding

There is no known shield against magnetism *i.e.*, there is no material which does not allow magnetic flux to pass through it. In other words, there is no magnetic insulator. However, some materials have greater permeability than others. For example, iron allows magnetic flux to pass through more easily than air. This fact is made use of in protecting a certain object against the disturbing magnetic field of a nearby component. Suppose we want to protect or shield a meter from the unwanted magnetic field of a neighbouring magnet or Earth's magnetic field. It can be done by surrounding the meter by a ring of soft iron or any other ferromagnetic material as shown in Fig. 7.3. The magnetic flux finds it easier to pass through the ring than air thereby causing no disturbance to the working of the meter. This action is called *shielding*.

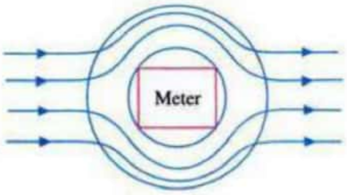

Fig. 7.3

7.6. Magnetic Terms and Units

Following terms are commonly used while discussing the subject of magnetism and electromagnetism.

1. Magnetic Flux (Φ)

The entire group of magnetic lines of force coming out of the N-pole of a magnet is called magnetic flux (Fig. 7.4).

Unit. Unit of magnetic flux is weber (Wb).

2. Flux Density (B)

It is given by the flux incident normally on a unit area As shown in Fig. 7.5, if a magnetic flux of Φ webers falls perpendicularly on an area of A m^2, then flux density is given by

$$B = \frac{\Phi}{A}$$

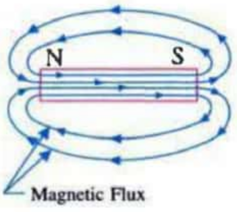

Fig. 7.4

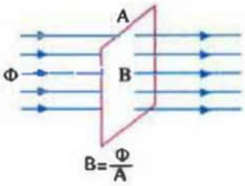

Fig. 7.5

Unit. Obviously, the unit for flux density is weber/metre^2 (Wb/m^2) which is also called Tesla (T).

3. Magnetic Field Strength (H)

It is also called intensity of magnetic field or (more commonly) magnetising force. As we know, each magnet has its own magnetic field consisting of lines of force which start from its *N*-pole.

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3. Magnetic Field Strength (H)

It is also called intensity of magnetic field or (more commonly) magnetising force. As we know, each magnet has its own magnetic field consisting of lines of force which start from its *N*-pole, pass through the surrounding medium, re-enter the *S*-pole and complete their path from *S* to *N*-pole through the body of the magnet. When a magnetic material is placed in the magnetic field, it becomes magnetised whereas non-magnetic materials remain unaffected.

The strength of a magnetic field at any point is measured by the force experienced by a *N*-pole of 1 Wb placed there. A uniform magnetic field is one whose strength remains the same everywhere (Fig. 7.7). It is represented by equally-spaced straight lines of flux.

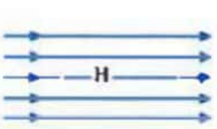

Fig. 7.6

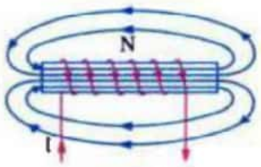

Fig. 7.7

Unit. The unit of H is newton/weber (N/Wb). It is the same thing as an ampere/meter (A/T) which is sometimes written as ampere-turn/meter (AT/m).

4. Magnetising Force of a Solenoid

As shown in Fig. 7.7, if *L* is the length of the iron core, the value of magnetising force produced by the electromagnetic is

$$H = \frac{NI}{l} \text{ A/m or AT/m}$$

5. Permeability

It is the ability of a magnetic material to conduct magnetic flux through it. If it allows the flux to pass through more easily or readily, it is said to have greater permeability. The permeability of a substance is measured both in absolute terms and in relative terms with respect to vacuum (or approximately, air).

(*a*) Absolute Permeability (μ)

Suppose there is a uniform magnetic field of strength *H* established in air as shown in Fig. 7.8. Further, suppose that a bar of a magnetic material, say, iron is placed in it as shown in Fig. 7.9. The iron bar gets magnetised by *induction*. Suppose, it develops a *polarity* of *m* weber. Then, induced flux developed by it is also *m* weber. The lines of induction flux emanate from its *N*-pole, go around and re-enter its *S*-pole and then continue from *S*- to *N*-pole within the magnet as shown in Fig. 7.9.

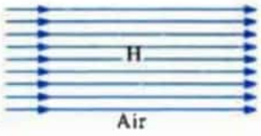

Fig. 7.8

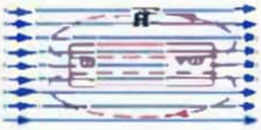

Fig. 7.9

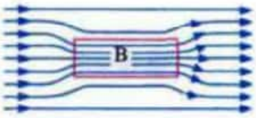

Fig. 7.10

These lines are seen to be in opposition to the lines of force of the main field *H outside* the magnet but in the same direction *within* it. The resultant field is shown in Fig. 7.10. If Φ is the *total* flux* passing through the bar and *A* is its pole area, then flux density within the bar is

$$B = \frac{\Phi}{A} \text{ tesla or Wb/m}^2$$

The absolute permeability of the bar is given by

$$\mu = \frac{B}{H} = \frac{\text{flux density}}{\text{magnetising force}}$$

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* There are two fluxes : one due to *H* and the other due to induced magnetism.

Its unit is henry/metre (H/m).

Also, $B = \mu H$ tesla

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(b) Relative Permeability (μ_r)

The absolute permeability of vacuum is denoted by μ_0 and has been allotted the value of $4\pi \times 10^{-7}$ H/m. Permeabilities of all other magnetic materials are expressed in terms of the absolute permeability of vacuum which has been selected (by mutual agreement) as the reference medium.

Suppose a certain medium has an absolute permeability of μ. Then, its relative permeability (μ_r) *i.e.*, permeability as compared to vacuum is given by

$$\mu_r = \frac{\mu}{\mu_0} = \frac{\text{absolute permeability of medium}}{\text{absolute permeability of vacuum}}$$

Being a mere ratio of two similar quantities, it has no unit.

Also $\mu = \mu_0\mu_r$

As an example, suppose mild steel has a relative permeability $\mu_r = 400$. Then, its absolute permeability is given by

$$\mu = \mu_0\mu_r = 4\pi \times 10^{-7} \times 400 \text{ H/m}$$
$$= 16\pi \times 10^{-5} \text{ H/m}$$

It is universal practice to give relative permeabilities of various media since μ can always be found by multiplying μ_r with μ_0 which is a universal constant.

6. Retentivity

It is the ability of a material to hold its magnetism after the magnetising force has been removed. Materials having high retentivity make good permanent magnets.

7. Hysteresis

Suppose the exciting coil of an electromagnet is energised by a source of alternating current (Fig. 7.11). As the current reverses its direction of flow through the coil, the flux also reverses its direction. Hence, the core also undergoes reversal of magnetisation. But it is found that magnetisation of the core does not reverse as quickly as the reversal of flux *i.e.*, the two are not in step with each other. This phenomenon is called hysteresis and is due to the retentivity of the magnetic material of the core.

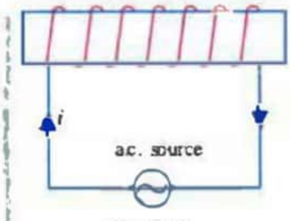


Fig. 7.11

Hysteresis leads to net loss of energy which is called hysteresis loss. This loss depends directly on

(*i*) maximum flux density B_{max} established in the core

(*ii*) frequency of reversal of magnetisation.

8. Permeance

It is the reciprocal of reluctance and resembles electrical conductance. Its unit is henry.

9. Reluctivity

It is specific reluctance and corresponds to electrical resistivity which is 'specific resistance'.

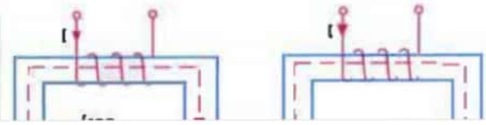
7.7. Ohm's Law for Magnetic Circuit

In Fig. 7.12 (*a*) is shown a magnetic circuit having iron path only, whereas in Fig. 7.12 (*b*) there is a small air gap in the circuit. Like electric circuit, a magnetic circuit also has three quantities interconnected by a law similar to Ohm's law.

The three quantities are :

1. Magnetomotive Force (MMF)

It resembles voltage or *electromotive force* (EMF) in an electric circuit and is responsible for



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The three quantities are :

1. Magnetomotive force (MMF)

It resembles voltage or *electromotive force* (*EMF*) in an electric circuit and is responsible for producing magnetic flux in a magnetic circuit. Its value is given by the product of current through the coil and its number of turns *i.e.*, *NI*. Its unit is ampere-turn*.

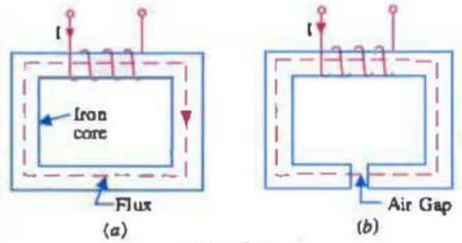

Fig. 7.12

2. Magnetic flux (Φ)

It resembles *current* in an electric circuit. It consists of magnetic lines of force and its unit is weber.

3. Reluctance (S)

It resembles *resistance* in an electric circuit. It represents the opposition which a core offers to the production of flux through it. Its value is

$$S = \frac{l}{\mu A} = \frac{l}{\mu_0 \mu_r A}$$

Its unit is 'reciprocal' henry *i.e.*, per henry.

Ohm's law for magnetic circuit is

$$\text{flux} = \frac{\text{mmf}}{\text{reluctance}} = \frac{NI}{S}\,\text{weber}$$

$$= \frac{NI}{l/\mu A}\,\text{weber} = \frac{\mu NAI}{l}\,\text{weber} = \frac{\mu_0 \mu_r NAI}{l}\,\text{weber}$$

Example 7.1. *A mild-steel ring having a cross-sectional area of 5 cm^2 and a mean circumference of 40 cm has a coil of 200 turns wound uniformly around it. Calculate*

(*i*) *reluctance of the ring*

(*ii*) *current required to produce a flux of 800 μ Wb in the ring.*

Take relative permeability of mild-steel as 380.

Solution. (*i*) $\frac{l}{\mu_0 \mu_r A} = \frac{0.4}{4\pi \times 10^{-7} \times 380 \times (5 \times 10^{-4})} = 1.675 \times 10^6$ **henry^{-1}**

(*ii*) Now, $\Phi = \frac{NI}{S}$ $\quad\therefore\quad 800 \times 10^{-6} = \frac{200 \times I}{1.675 \times 10^6}$ $\quad\therefore\quad I = 6.7$ **A**

7.8. Transformer

It is a static (or stationary) piece of apparatus that

1. transfers electric power from one circuit to another having mutual inductance with it.
2. Does so without change of frequency.
3. Does it by electromagnetic induction.

Constructionally, transformers may be either isolation transformers (with electrically-insulated primary and secondary windings) or autotransformers (with electrically-connected primary and secondary windings). The two are shown in Figs. 7.13 and 7.14 respectively.

Autotransformer

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* Strictly speaking, it should be ampere only because turn has no units.

The two-winding isolation trans-

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Autotransformer

---

[*] Strictly speaking, it should be ampere only because turn has no units.

The two-winding isolation transformer may be further subdivided into

(*i*) core type transformer .... in which the windings surround a considerable part of the core (Fig. 7.15).

(*ii*) shell type transformer .... in which the core surrounds a considerable part of the windings (Fig. 7.16).

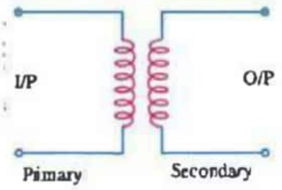


Fig. 7.13

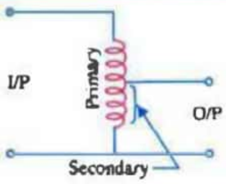
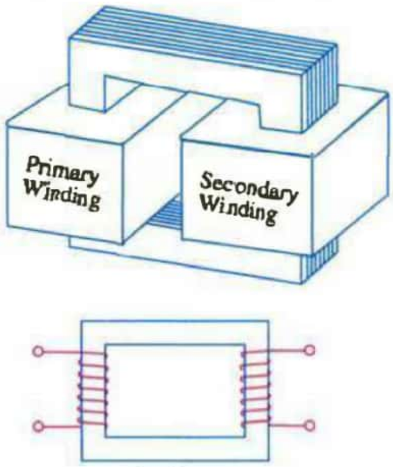


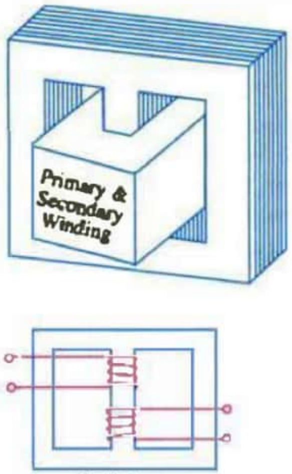
Fig. 7.14

As seen, core-type transformer is made up of a package of thin rectangular silicon steel laminations. Each lamination is coated with an insulating varnish and the total core pressed together. The primary and secondary windings are placed on each side of the common core (Fig. 7.15).



Core Type

Fig. 7.15



Shell Type

Fig. 7.16

The shell type construction also consists of similar laminations. The two windings are wound in layers and fit over the centre section of the core as shown in Fig. 7.16.

Functionally, the transformers used in electronic circuits can be classified according to the frequency range over which they operate such as :

1. Audio Frequency (AF) Transformers

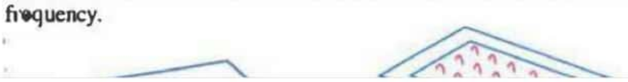
They are designed to operate over the audio frequency (AF) range of 20 Hz to 20 kHz, have laminated core and are usually smaller than power transformers. They are primarily used for impedance matching and, in some cases, for voltage amplification. Two such typical transformers are shown in Fig. 7.17. Such transformers are usually designated according to their applications as input or output transformer, microphone transformer, modulation transformer and interstage transformer etc. Usually, they are rated by their primary and secondary impedances and current-carrying capability.

Fig. 7.17

2. Radio Freqdency (RF) Transformers

They are designed to operate at high frequencies (above audio range) and are referred to either as intermediate frequency (IF) transformers or radio frequency transformers. They may have air core

or ferrite core (mostly adjustable). Most of the RF transformers have either one or both of the windings tuned *i.e.*, in conjunction with capacitor, they form a resonant circuit which works best at one particular frequency.



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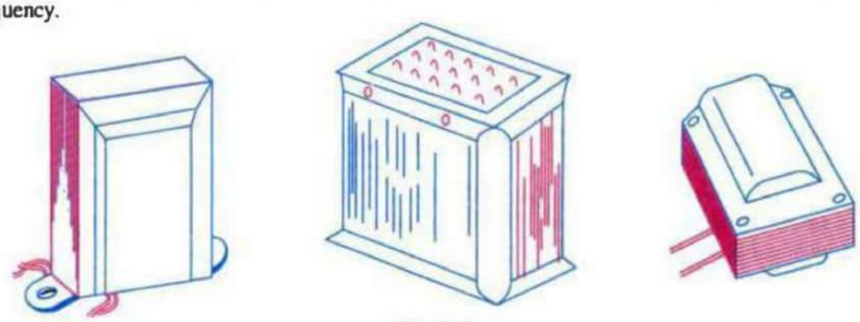

Fig. 7.18

3. Power Transformers

Usually, they have laminated core and have one primary winding but several secondary windings insulated from each other (Fig. 7.18). They are commonly used in the power supply of electronic equipment and provide various ac voltage necessary for the production of dc voltages. Typical transformers of this type are shown in Fig. 7.18.

7.9. Transformer Working

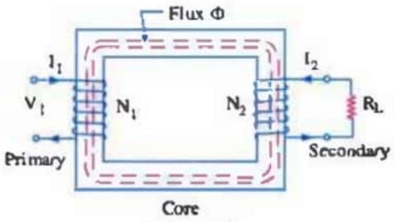

Fig. 7.19

Consider the core-type transformer shown in Fig. 7.19. It consists of two highly inductive coils which are electrically separate but magnetically linked through an iron core of low reluctance. The two coils possess high mutual inductance. If one coil is connected to source of alternating voltage, an alternating flux is set up in the laminated core most of which is linked with the other coil. Hence, mutually-induced voltage is produced in the second coil. If the second coil circuit is closed, a current flows in its and so electric energy is transfered (entirely magnetically) from the first coil to the second coil. The first coil in which electric energy is fed is called *primary* winding and the other from which energy is drawn out is called *secondary* winding. Whether secondary voltage V_2 is more or less than primary voltage V_1 depends on the turn ratio of the transformer. It is found that

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

If $N_2 > N_1$, then $V_2 > V_1$ and the transformer is called ***step-up*** transformer, since it steps up the input primary voltage. If $N_2 < N_1$, then $V_2 < V_1$ and the transformer is called *step down* transformer.

Voltage transformation ratio (K) of a transformer is given by V_2/V_1.

$$\therefore \qquad K = \frac{V_2}{V_1} = \frac{N_2}{N_1} \qquad \text{or} \qquad V_2 = KV_1$$

As seen, voltage transformation ratio equals the turn ratio.

Assuming an ideal transformer and equal power factor for both windings,

$$\text{input power} = \text{output power}$$

$$V_1 I_1 = V_2 I_2 \qquad \therefore \; I_2 = I_1 / K$$

$$\therefore \qquad \frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{1}{K}$$

It is obviously from the above that a transformer which is *step-up for voltage is step-down for current*. If voltage is increased five times, current becomes one-fifth because output power has to

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It is obviously from the above that a transformer which is *step-up for voltage is step-down for current*. If voltage is increased five times, current becomes one-fifth because output power has to equal the input power (in an ideal case). It means that current ratio is reciprocal of voltage ratio.

Suppose, we have transformer with $N_1 = 100$ and $N_2 = 600$. Let $V_1 = 200$ V and $I_1 = 3$ A. Then,

$$K = \frac{N_2}{N_1} = \frac{600}{100} = 6; \qquad V_2 = KV_1 = 6 \times 200 = 1200 \text{ V}$$

$$I_2 = I_1/K = 3/6 = 0.5 \text{ A}$$

It is seen that secondary voltage is 6 times the primary voltage but, at the same time, secondary current is one-sixth of the primary current.

$$P_1 = 200 \times 3 = 600 \text{ W}; \qquad P_2 = 1200 \times 0.5 = 600 \text{ W}$$

As seen, the two powers are equal.

It is worth noting that whatever the actual value of primary and secondary volts, *the voltage/turn is the same in both windings*. In the above case

Primary volts/turn = 200/100 = 2 V; Secondary volts/turn = 1200/600 = 2 V

The two values are equal even though V_1 and V_2 are themselves unequal.

7.10. Transformer Impedance

Each transformer winding has its own resistance, inductive reactance and hence impedance. As shown in Fig. 7.20,

$$\text{Primary impedance, } Z_1 = \sqrt{R_1^2 + X_1^2}\,; \quad \text{Secondary impedance, } Z_2 = \sqrt{R_2^2 + X_2^2}$$

Another very interesting thing about these impedances is that they assume different values when *viewed from the other winding*. For example, when Z_2 is viewed from primary winding, it assumes a value $Z_2' = Z_2 / K^2$. But, when Z_1 is viewed from secondary, it appears to have a value of $Z_1' = K^2 Z_1$. This fact is made use of in the working of an impedance-matching transformer (Art. 7.14).

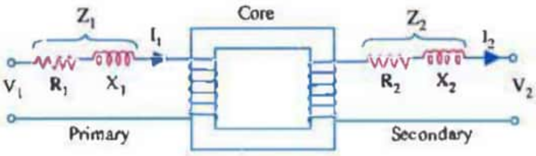


Fig. 7.20

Example 7.2. *A power transformer has 100 primary turns and 600 secondary turns. If primary voltage is 120 V and full-load primary current is 12 A, find secondary*

(i) voltage V_2 and (ii) current I_2.

Solution. Here $K = N_2/N_1 = 600/100 = 6$

(i) $V_2 = K V_1 = 6 \times 120 = 720$ V; (ii) $I_2 = I_1/K = 12/6 = 2$ A

Example 7.3. *A low-voltage soldering rod taking 40 A at 12 V is to be operated from the secondary of a 240 V transformer. Calculate*

(i) turn ratio of the transformer and (ii) primary current.

Solution. (i) $\frac{V_2}{V_1} = \frac{12}{240} = \frac{1}{20} \qquad \therefore \; \frac{N_2}{N_1} = \frac{1}{20}$

Obviously, it is a step-down transformer having $K = 1/20$

(ii) $I_1 = KI_2 = \frac{1}{20} \times 40 = 2\text{A}$

7.11. Can a Transformer Operate on DC ?

Solution. (*i*) $\frac{V_2}{V_1} = \frac{12}{240} = \frac{1}{20}$ $\quad\therefore\quad$ $\frac{N_2}{N_1} = \frac{1}{20}$

Obviously, it is a step-down transformer having $K = 1/20$

(*ii*) $I_1 = KI_2 = \frac{1}{20} \times 40 = 2A$

7.11. Can a Transformer Operate on DC ?

A transformer cannot operate on a steady or unchanging dc voltage such as that of a battery. It requires a voltage which rises and falls. Since an ac voltage not only changes its magnitude but its direction as well (Fig. 7.21), it is used to operate the transformers.

However, a transformer will operate from dc voltage if this voltage also undergoes changes. Transformers used for audio amplifiers work on pulsating dc voltage (Fig. 7.22). Main thing which causes the transformer to work is the *change* in voltage. It is immaterial whether the voltage changes from positive to negative values as in Fig. 7.21 or from positive to zero values as in Fig. 7.22 (it could, in fact, be from minus to zero values as well).

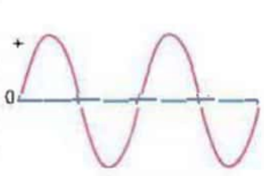


Fig. 7.21

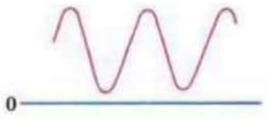


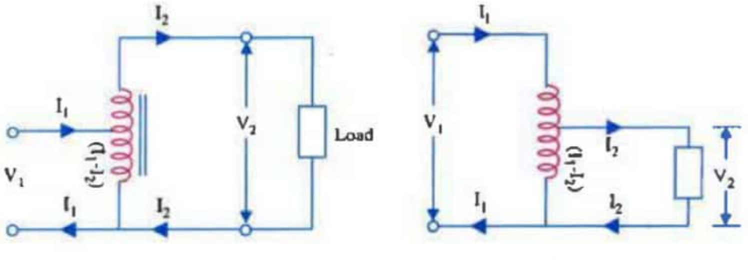
Fig. 7.22

7.12. RF Shielding

Coils are often encased in a metal cover, usually of copper or aluminium, in order to protect them from external varying flux of RF currents. Otherwise, unwanted eddy currents would be induced in them. Purpose of RF shielding is different from magnetic shielding (Art. 7.5) which protects against steady flux only. The shield cover not only isolates the coil from external varying magnetic fields but also minimizes the effect of coil's own RF currents on other external circuits.

7.13. Autotransformer

It is a transformer with one winding only, part of it being common to both primary and secondary. Here, primary and secondary are not electrically isolated from each other as is the case in a 2-winding transformer. However, its theory and operation are similar to that of a 2-winding transformer. Because of one winding, it is compact, efficient and cheaper.



(*a*) (*b*)

Fig. 7.23

Fig. 7.23 (*a*) shows a step-up autotransformer whereas Fig. 7.23 (*b*) shows a step-down type. As with other transformers, this step-up or step-down ratio depends on the turn ratio between the primary and secondary. Fig. 7.24 shows an audio output stage of an automobile radio that uses a step-down autotransformer.

Such a transformer is also used as an adjustable transformer for both stepping up or stepping down the input voltage (Fig. 7.25). It is often used for a light dimmer or for adjusting power to a radio transmitter.

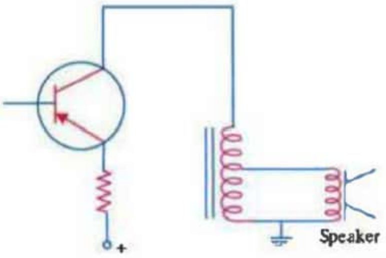


Fig. 7.24

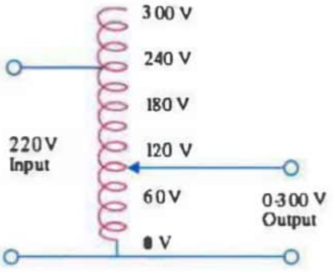
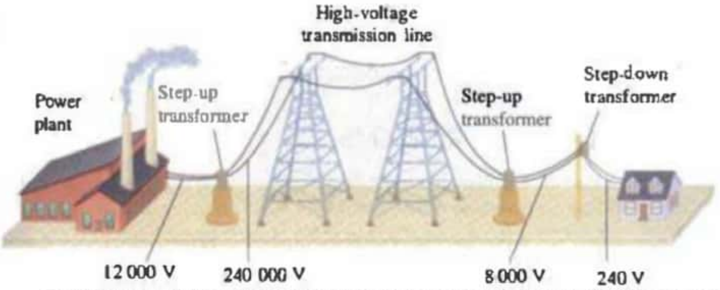


Fig. 7.25



Transformers play an important role in the transmission of electric power.

Example 7.4. *The primary and secondary voltages of an autotransformer are 500 V and 400V respectively. Show on a diagram, the current distribution in the transformer if secondary current is 100 A.*

Solution. $K = V_2/V_1$

$= 400/500 = 0.8$

Here, $I_2 = 100$ A --given

$I_1 = KI_2$

$= 0.8 \times 100 = 80$ A

As seen, current in the common portion of the winding is 20 A. Circuit diagram is shown in Fig. 7.26.

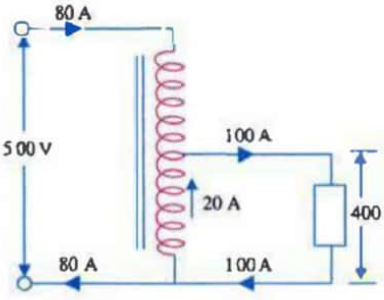


Fig. 7.26

7.14. Impedance Matching

For maximum transfer of power from one circuit to another the two should have equal impedances (Art. 4.9). If they do not have equal impedances, a transformer with suitable turn ratio can be used to achieve this impedance match. In electronic circuitry, it often becomes necessary to connect a circuit of high output impedance to one of low input impedance*. What it really means is that a certain circuit working at a high voltage but low current (hence high impedance) has sometime to be coupled to another circuit which requires lower voltages but higher current (hence low impedance). If two such circuits are coupled directly, energy transfer will not be maximum. In such cases, a transformer is used as an impedance-matching device because it can do the job of increasing or decreasing the voltages and currents very efficiently.

Suppose a circuit of *output* impedance 300 Ω is to be coupled to a circuit of *input* impedance 3 Ω. The turn-ratio (N_2/N_1) of the transformer should be such that when 3 Ω impedance in its secondary

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* Usually, a higher-voltage low-current circuit is called a high impedance circuit, while a low-voltage higher-current one is referred to as low-impedance circuit.

is viewed by its primary, it should appear as 300 Ω. Now, when viewed from primary side, a 3 Ω resistance is seen as equal to $3/K^2$ (Art. 7.9).

Hence, for equal matching $\frac{3}{K^2} = 300$