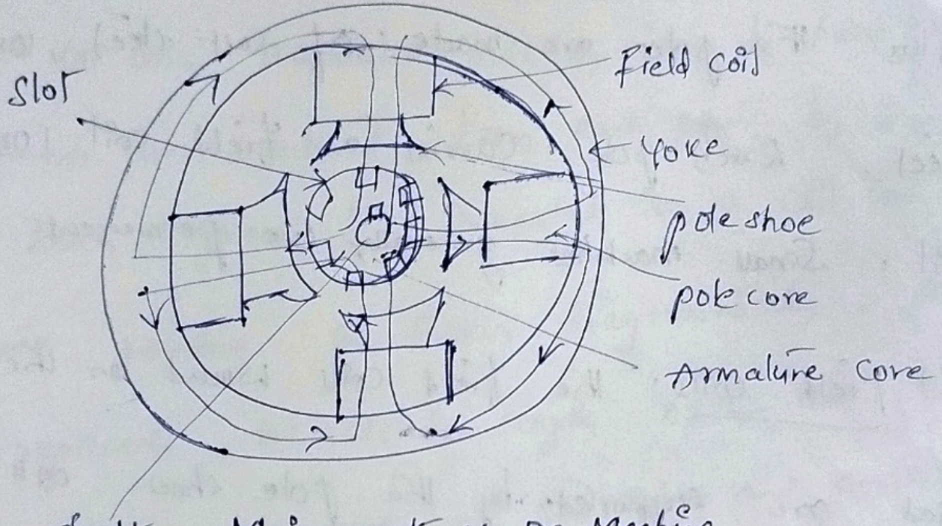
Construction of DC Machine



Main parts of DC Machine

(i) Yoke: It is the outermost cylindrical part which serves two purposes. First it acts as supporting frame for the machine, and second it provides a path for the magnetic flux. It is made of cast iron, cast steel, (or) forged steel. Usually small machines have cast iron yokes.

(ii) poles: The machine has salient poles. The pole cores are fixed inside the yoke, usually by bolts. The cross section of the pole core is rectangular. By attaching a pole shoe, the end of the pole ~~shoe~~ is made to have a cylindrical surface. The cross sectional area of the pole shoe is considerably larger than that of the pole core to leave as little interpole space as possible. This is done to reduce the leakage flux. The poles are made of cast steel, or forged steel. Each pole carries a field coil (or exciting coil). Small machines generally use permanent magnets.

(iii) Field coils: The field coils wound on the pole core and are supported by the pole shoes. All coils are identical and are connected in series such that on excitation by a dc source, alternate North and South poles are made. Thus a machine always have even number of poles. The magnetic flux distribution approximates a square wave as shown in fig. The flux is taken positive in the radially inward direction. Note that the yoke carries one half of the pole flux ϕ. Therefore the cross section of the yoke should be selected accordingly.

Rotor

Rotor is the inner cylindrical part having armature and commutator brush arrangement. It is mounted on the shaft.

(ii) Commutator

(4)

It consists of a large number of wedge shaped copper segments (or) bars, assembled side by side to form a ring. The segments are insulated from each other by thin mica sheets. Each segment is connected to a coil end of the armature winding as shown diagramatically, the radial lines represents the active lengths of the rotor conductors. The commutator is a part of the rotor and participates in its rotation.

Brushes

Two stationary brushes made of carbon, are pressed against the commutator with the help of a spring fitted in a brush-gear. The brush commutator system provides two related functions. (1) electrical connection is made with rotor (2) a steady (or) direct voltage is obtained from the alternating emf generated in the rotating conductors.

(3)

(i) Armature

The armature core consists of steel laminations each about 0.4 - 0.6 mm thick, insulated from one another the purpose of laminating the core is to reduce the eddy current loss. slots are stamped on the periphery of the laminations to accomodate the armature winding. The top of the slot has a groove in which a wedge canbe fixed. After the winding conductors are put into the slots the wedge is inserted. The wedge prevents the conductors from flying out due to the centrifugal force when the armature rotates. the axial length of the armature is same as that of the poles on the yoke. the term Conductor refers to the active portion of the winding namely that part which cuts the flux when the rotor rotates thereby generating an alternating emf.

Section - II

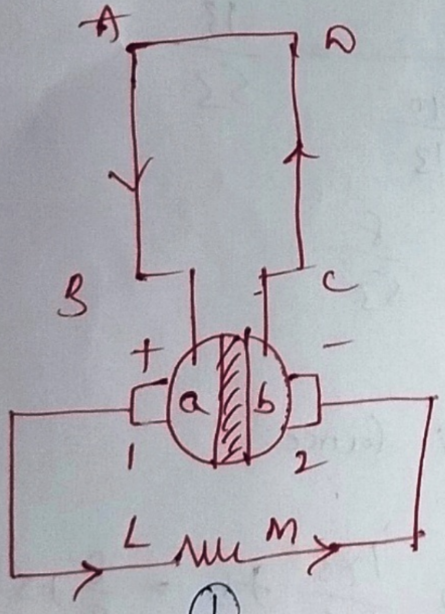
③. ⓐ. Explain the working principle of DC Generator

6M

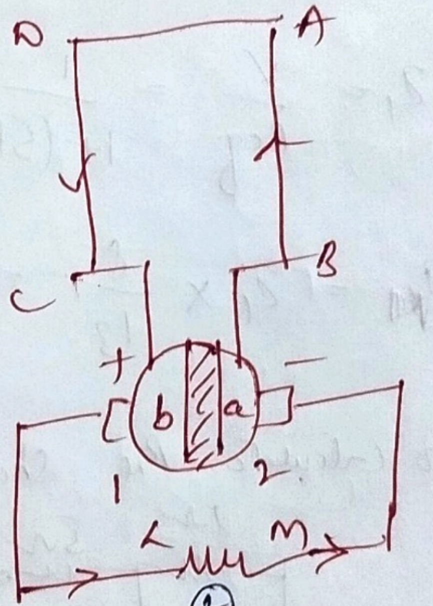
Working principle of DC Generator

"According to faraday's law of electromagnetic induction principle whenever conductor moves in a magnetic field it cuts magnetic lines of flux and emf is induced in it."

Working of simple Loop Generator



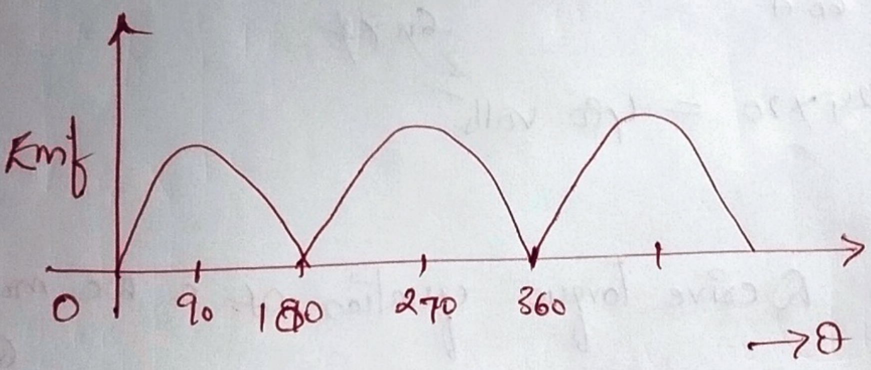
①



②

From figure① it is seen that in the first half of the revolution current always flows along ABLMCD, i.e, brush no 1 in contact with segment a.

In the next half revolution in figure② the direction of induced emf in coils reversed. But at the same time the position of segments a and b are also reversed which results that brush no 1 comes into touch with segment b. Hence the current in load again flows from L to M. The waveform of the current through load circuit is as shown in fig. This current is unidirectional



The positions of the brushes of the DC Generator are so that the change over of the segments a and b from one brush to another takes place when the plane of the rotating coil is at a right angle to the plane of the lines of force. It is to become in that position, the induced emf in the coil is zero.

Emf equation of DC Generator

Let

Z - Total no. of conductors

A - No. of parallel paths

ϕ - flux produced by each pole in weber (wb)

P - No. of poles in the Generator

N - speed in rpm

Therefore Total flux produced by all the poles $= \phi \times P$

time taken to complete one revolution $= \frac{60}{N}$

According to Faraday's law of induction the induced emf of the conductor is denoted by 'e' which is equal to rate of cutting the flux

i.e. $e = \frac{d\phi}{dt}$ and $e = \frac{\text{total flux}}{\text{time taken}}$

Induced emf of one conductor is $e = \frac{\phi P}{\frac{60}{N}} = \frac{\phi P N}{60}$

Induced emf of Generator's $E = \frac{\phi P N}{60} \times \frac{Z}{A}$ volts

$\frac{Z}{A}$ is No. of conductors connected in series.

Induced emf $E = \frac{Z \phi P N}{60 A}$ volts

for lap winding $A = P$ for wave winding $A = 2$

* Explain the principle of operation of DC motor and what is the back emf of DC motor.

Ans. **principle of operation of DC motor**

"whenever current carrying conductor is placed in a magnetic field it experiences a force". this force is given by $F = BIL$ Newton.

According Flemings left hand rule

thumb shows direction of current, Fore finger shows direction of force, middle finger shows direction of magnetic field.

When armature of DC motor rotates under the influence of the driving torque, the armature conductors move through the magnetic field and hence emf is induced in them as in a generator. the induced emf acts in opposite direction to the applied voltage as per Lenz's law and This emf is known as Back emf (E_b) (or) counter emf.

Q.No. 3 (b). A 4 pole wave wound connected armature has 720 conductors and its rated speed is 1000 rpm. If the useful flux is 20 milli webers. Calculate the generator voltage.

6M

Sol: Given that $P = 4$ $\quad A = 2$ wave

$Z = 720$ $\quad N = 1000$ rpm

$\phi = 20 \times 10^{-3}$ Wb $\quad E_g = ?$

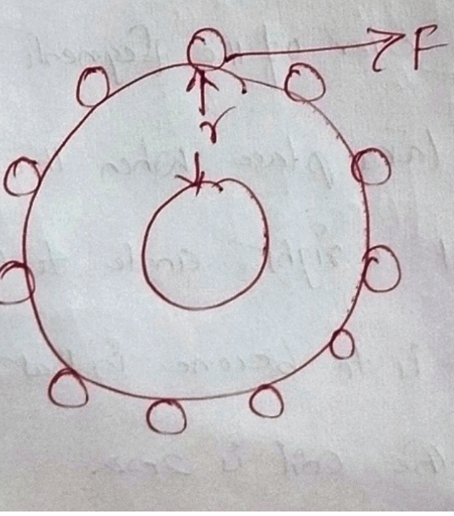
$$E_g = \frac{Z\phi P N}{60A} = \frac{720 \times 20 \times 10^{-3} \times 4 \times 1000}{60 \times 2}$$

$E_g = 24 \times 20 = 480$ volts

Q.No. 4 (a). Derive torque equation of a DC motor.

6M

Torque Equation



Torque (or) moment (or) moment of force is the Tendency of a force to rotate (or) move an object about an axis. A force is a push (or) pull, likewise Torque is a twist to an object. Mathematically

Torque $T = F \times r$

Let T_g = armature (or) gross torque (N-m) $= F \times r$

r = radius of the armature in rpm.

N = Speed in rpm $= \frac{N}{60}$ rps.

Work done / revolution = Force × distance moved per revolution

$$W.\text{done} = F \times 2\pi r \ \text{N-m}$$

$$\frac{Wd}{\text{second}} = F \times 2\pi r \times \frac{N}{60} \ \text{Nm}$$

$$W.\text{done} = \frac{2\pi N}{60}(F \times r) \ \text{Nm}/\text{second} \ \text{(or) watt}$$

$$\text{Work done} = \frac{2\pi N T_g}{60} \ \text{watt}$$

The expression for voltage in dc motor is given by

$$V = E_a + I_a R_a \quad \text{multiplying by } I_a$$

$$V I_a = E_a I_a + I_a^2 R_a$$

Electrical input = Electrical power equivalent to mechanical power developed + armature copper loss.

Mechanical power developed = $E_b I_a$ watt

$$\frac{2\pi N T_g}{60} = E_b I_a$$

$$\frac{2\pi N T_g}{60} = \frac{Z\phi P N}{60 A} \times I_a$$

$$T_g = \frac{1}{2\pi} \frac{\phi P Z I_a}{A}$$

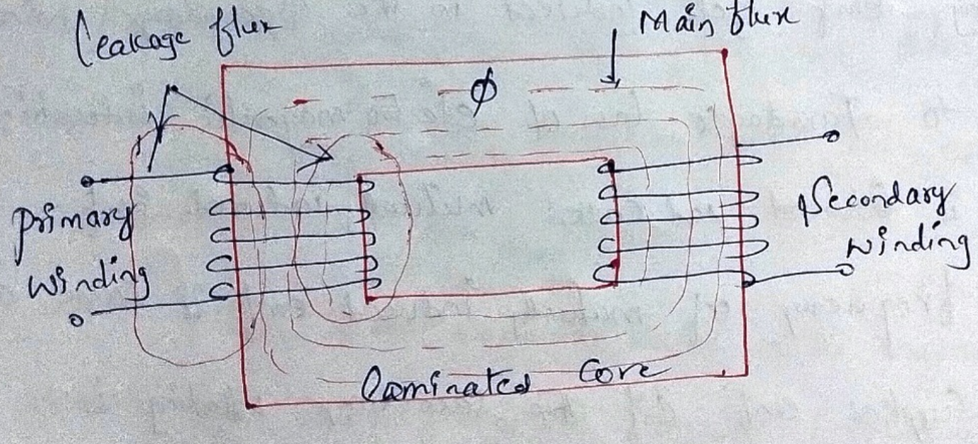
$$\boxed{T_g = 0.159 \frac{\phi P Z I_a}{A} \ Nm}$$

Transformer

* Function of a Transformer

Electrical Transformer is a static electrical machine which transforms electrical power from one circuit to another circuit, without changing frequency. Transformer can increase (or) decrease the voltage with corresponding decrease (or) increase in current.

* working principle of Transformer



The basic principle behind working of a transformer is the phenomenon of mutual induction between two windings linked by common magnetic flux. Basically a transformer consists of two inductive coils, primary winding and secondary winding. The coils are electrically separated but magnetically linked to each other.

When primary winding is connected to a source of alternating voltage, alternating magnetic flux is produced around the winding. The core provides magnetic path for the flux, to get linked with the secondary winding. Most of the flux gets linked with the secondary winding which is called as 'useful flux' and main flux and the flux which does not get linked with secondary winding is called leakage flux. As the flux produced is alternating emf gets induced in the secondary winding according to Faraday's law of electro magnetic induction. This emf is called mutually induced emf. And the frequency of mutually induced emf is same as that of supplied emf. If the secondary winding is closed circuit, then mutually induced current flows through it and hence the electrical energy is transferred from one circuit to another circuit

⊛ Emf equation of Transformer

Let the voltage V_1 applied to the primary of a Transformer with secondary open circuited, be sinusoidal. Then the current I_e due to applied voltage V_1, will also be a sine wave the MMF $N_1 I_e$ and therefore, the core flux ϕ will follow the variations of I_e very closely. that is the flux is in time phase with the current I_e and varies sinusoidally. If I_e is zero, ϕ is zero and if I_e is maximum positive, ϕ is also maximum positive and so on. therefore if the applied voltage V_1 has sine wave form, the flux must also have a sine waveform. Let the sinusoidal variation of flux ϕ be expressed as $\phi = \phi_{max} \sin \omega t$

where ϕ_{max} is the maximum value of the magnetic flux in webers and $\omega = 2\pi f$ is the angular frequency in rad/sec, and f is the frequency in Hz.

The emf e_1 in volts induced in the primary N_1 turns by the alternating flux ϕ is given by

$$e_1 = -N_1 \frac{d\phi}{dt}$$

$$= -N_1 \omega \phi_{max} \cos \omega t = N_1 \omega \phi_{max} \sin(\omega t - \frac{\pi}{2})$$

Its maximum value E_{1max} occurs when $\sin(\omega t - \frac{\pi}{2})$ is equal to 1.

$\therefore \quad E_{1max} = N_1 \omega \phi_{max}$

and $\quad e_1 = E_{1max} \sin(\omega t - \frac{\pi}{2})$

$\therefore$ Rms value of emf E_1 induced in primary winding is given by $\quad E_1 = \frac{E_{1\,max}}{\sqrt{2}} = \frac{2\pi}{\sqrt{2}} f N_1 \phi_{max}$

$$E_1 = \sqrt{2}\,\pi f N_1 \phi_{max} \rightarrow eq\,①$$

The emf induced (E_1) in N_1 turns must be in such a direction as to oppose the cause i.e I_e as per Lenz's law therefore the direction e_1 in N_1 primary turns is given by

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

$$V_1 = -E_1$$

The emf induced in secondary

$$e_2 = -N_2 \frac{d\phi}{dt} = -N_2 \omega \phi_{max} \cos\omega t$$

$$= N_2 \omega \phi_{max} \sin(\omega t - \frac{\pi}{2})$$

$$= E_{2max} \sin(\omega t - \frac{\pi}{2})$$

Rms value of emf induced in secondary winding is given by

$$E_2 = \frac{E_{2max}}{\sqrt{2}} = \sqrt{2}\,\pi f N_2 \phi_{max} \rightarrow eq\,②$$

From eq① and ②

$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

$$\frac{E_1}{N_1} = \frac{E_2}{N_2} = \sqrt{2}\,\pi f \phi_{max}.$$

⑦ Applications of Induction ~~Machines~~ Motors

Squirrel cage motors with relatively low rotor resistance are used for 1. fans
2. Centrifugal pumps
3. Machinery Tools
4. wood working Tools

Squirrel cage rotors with relatively high rotor resistance used for

1. Compressors,
2. Crushers
3. reciprocating pumps.

Squirrel Cage rotor with higher rotor resistance used for intermittent loads like 1. punching presses
2. Shears
3. hoists
4. elevators.

⑦ Applications of stepper Motors.

1. Floppy disc drives
2. flat bed scanners
3. computer printers
4. plotters,
5. slot Machines
6. Image scanners
7. Compact disc drives
8. Intelligent lighting
9. Camera lenses
10. CNC Machines
11. 3D printers.

Applications of BLDC Motors

1. Computer hard drives & DVD / CD players
2. Electric vehicles, hybrid vehicles, and electronic bicycles.
3. Industrial robots, CNC Machine tools, and simple belt driven systems.
4. Washing Machines, Compressors and dryers.
5. Fans, pumps, blowers