SECTION-C

D.C. MACHINES

DC MACHINES

INTRODUCTION

A DC machine is an electro-mechanical energy conversion device. It can convert Mechanical power into Electrical Power. When output electrical power is DC , it is called DC Generator. When it converts DC electrical power into mechanical power , it is known as DC Motor.

Basics of a Electric Machine

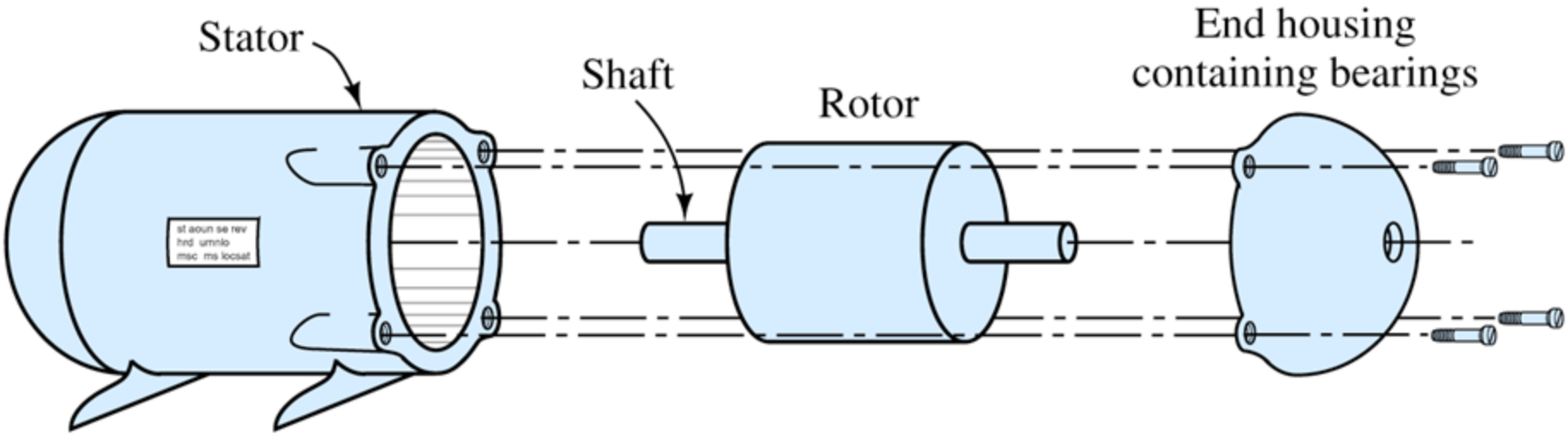
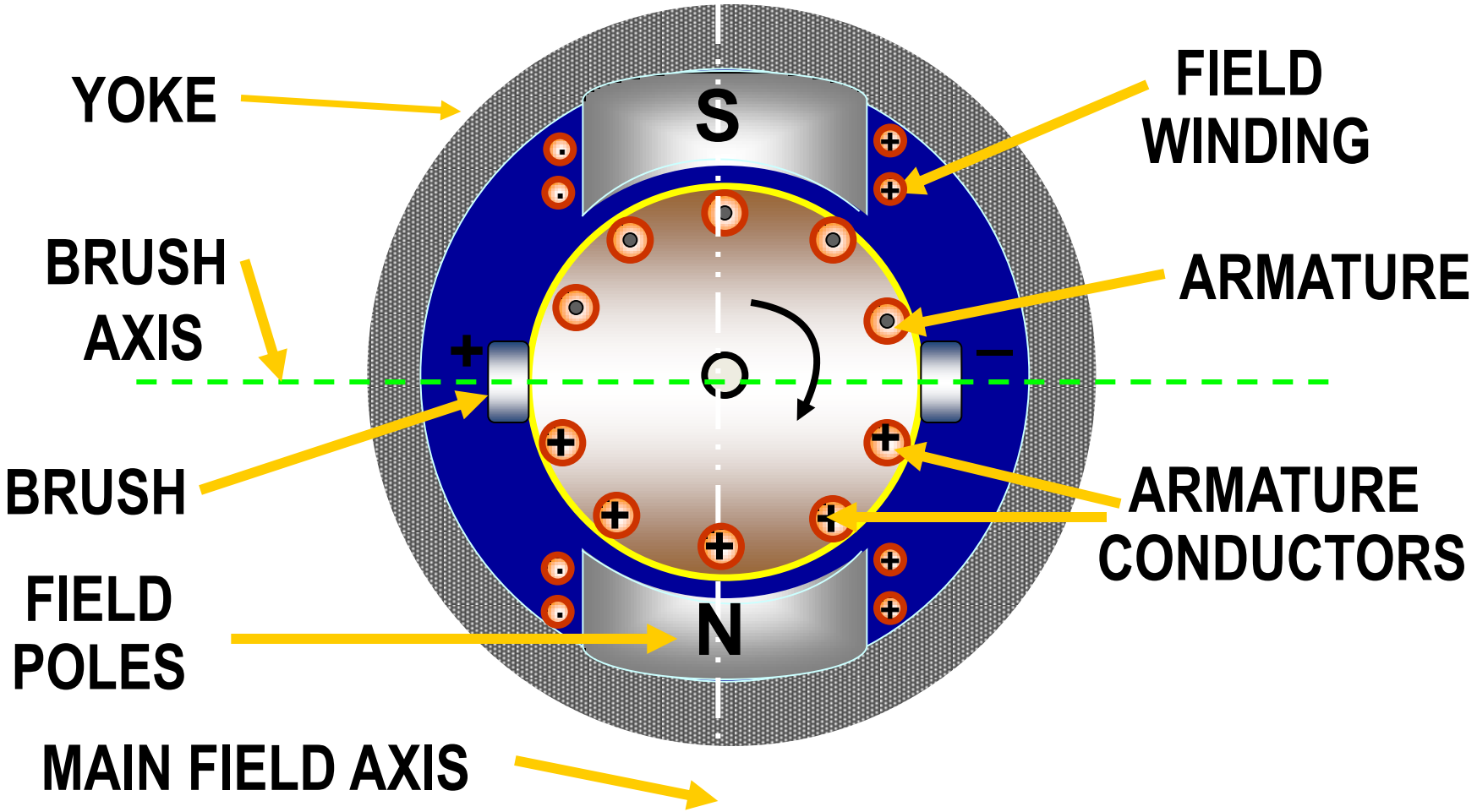


Figure An electrical motor consists of a cylindrical rotor that spins inside a stator.

DC MACHINES


YOKE
FIELD WINDING
BRUSH AXIS
ARMATURE
BRUSH
ARMATURE CONDUCTORS
FIELD POLES
MAIN FIELD AXIS
S
N
+
−

D.C. GENERATOR

Working Principle:

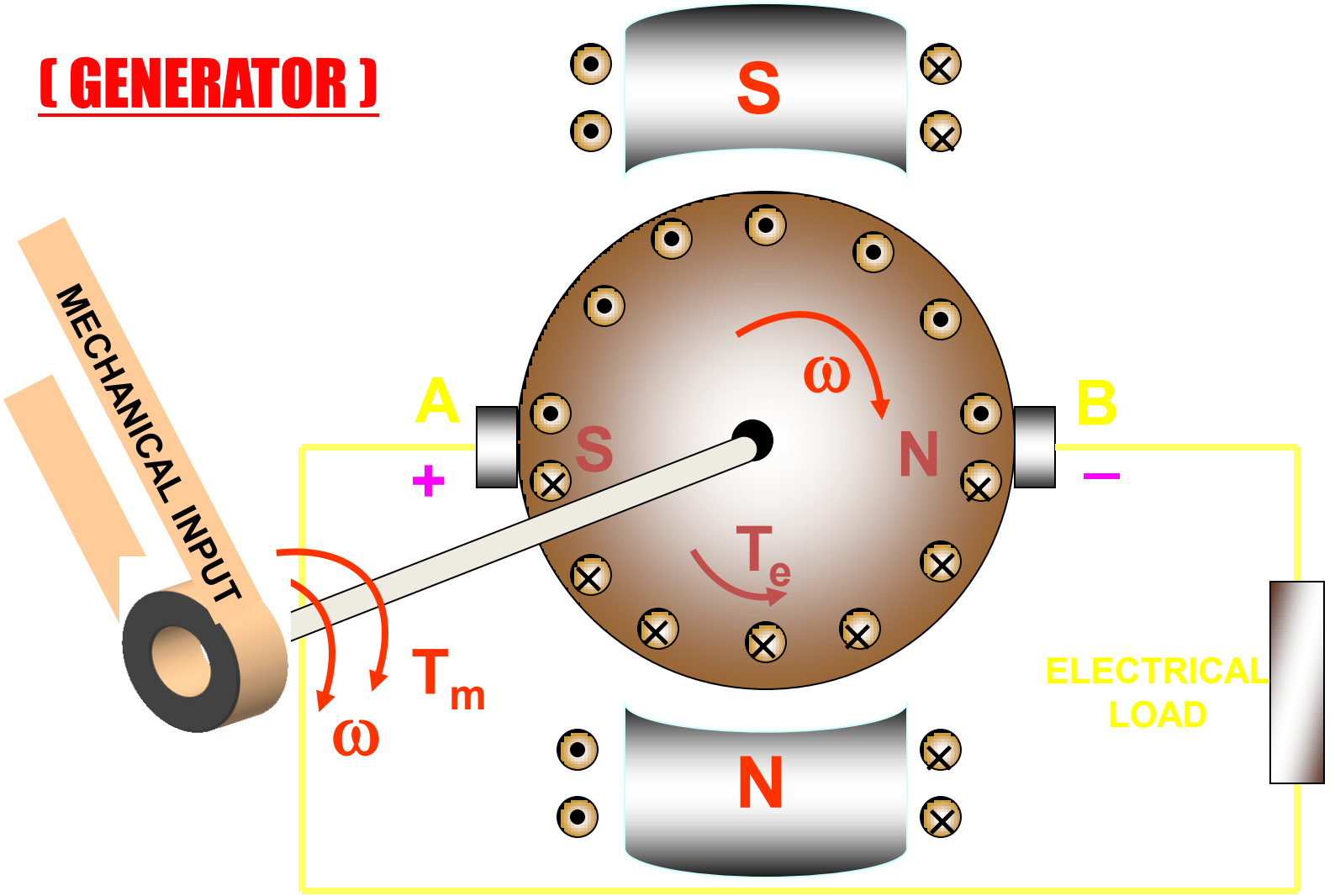
Generator has mainly two parts:

- Stator (Field winding)
- Rotor(Armature winding)

Stator is excited with D.C. and Rotor is moved with the help of prime-mover which is another motor. When a moving conductor is placed in a magnetic field the EMF is induced in it. The direction of EMF can be given with the help of Fleming's Right Hand rule. EMF induced in the rotor(armature) is of A.C. nature. It can be converted into D.C. with the help of commutator.

DC MACHINES

(GENERATOR)



DC GENERATOR

The field windings are shown as excited from external source. The polarity of electro-magnetic field will depend upon the direction of field current as shown in previous slide.

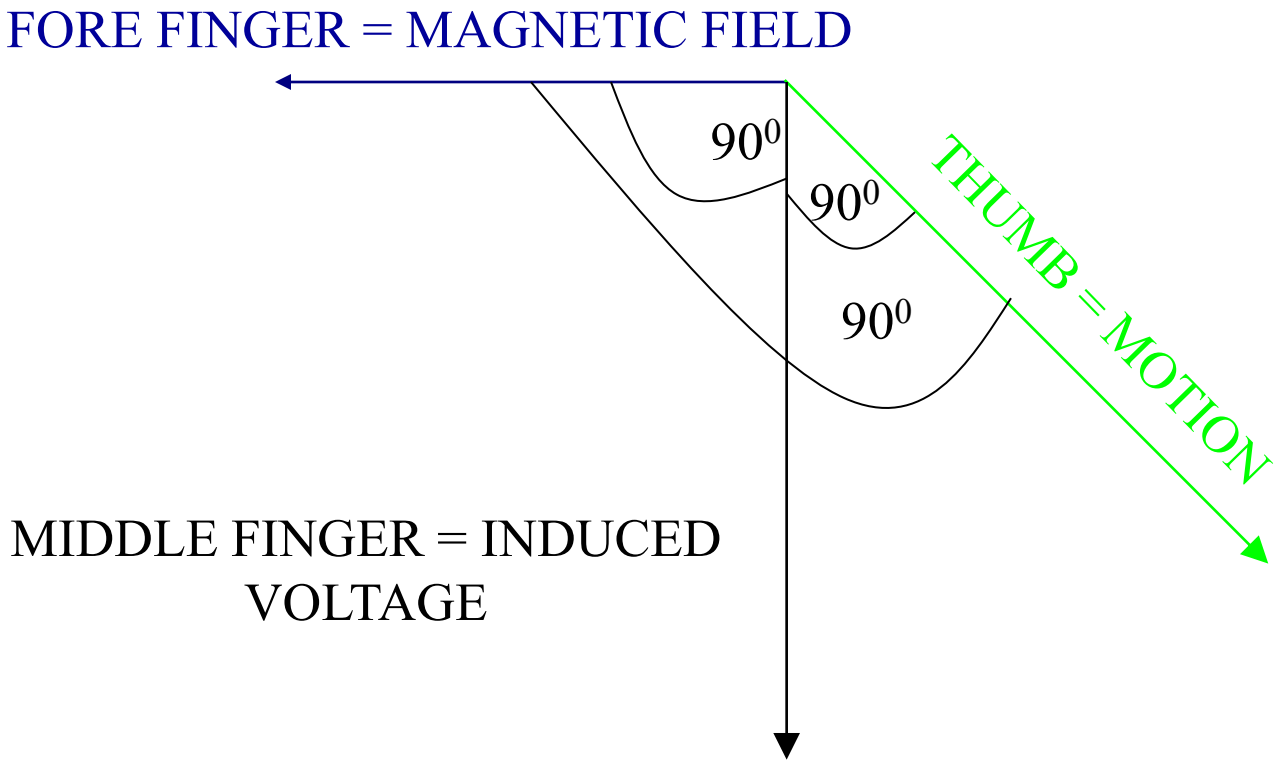
DC GENERATOR

The armature carries conductors in side the slots. Two brushes are placed at the right angle to the main field axis. The brushes are stationary whereas armature is free to rotate.

DC GENERATOR

When the armature is rotated in the magnetic field, an e.m.f will be induced in the armature conductors.The direction of the induced e.m.f can be found by applying Fleming's Right Hand Rule.

Fleming's Right Hand Rule Or Generator Rule



VOLTAGE = B *l u*

DC GENERATOR

The direction of induced e.m.f will depend upon the direction of rotation of armature , if polarity of field poles to be kept unchanged.When load is connected across the armature terminals , the current will flow through the armature circuit.

Operating Principle of a DC Machine

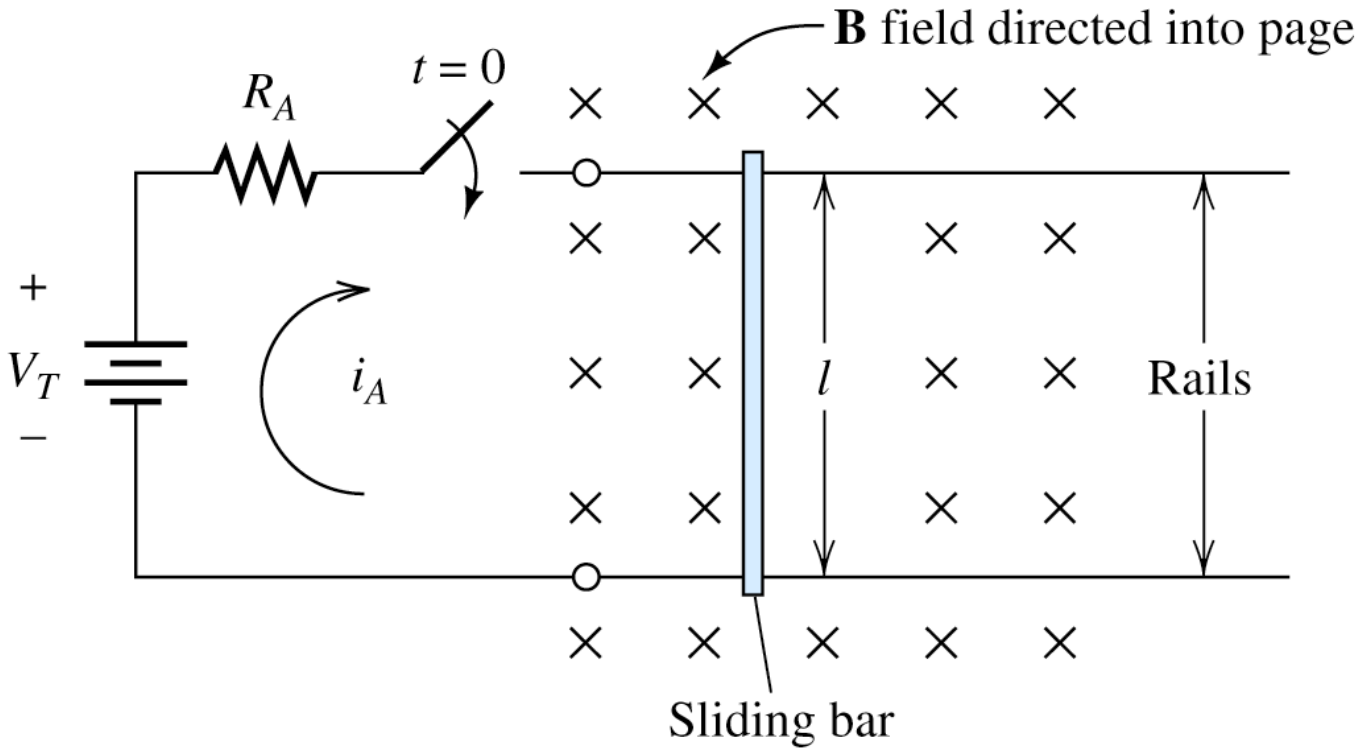
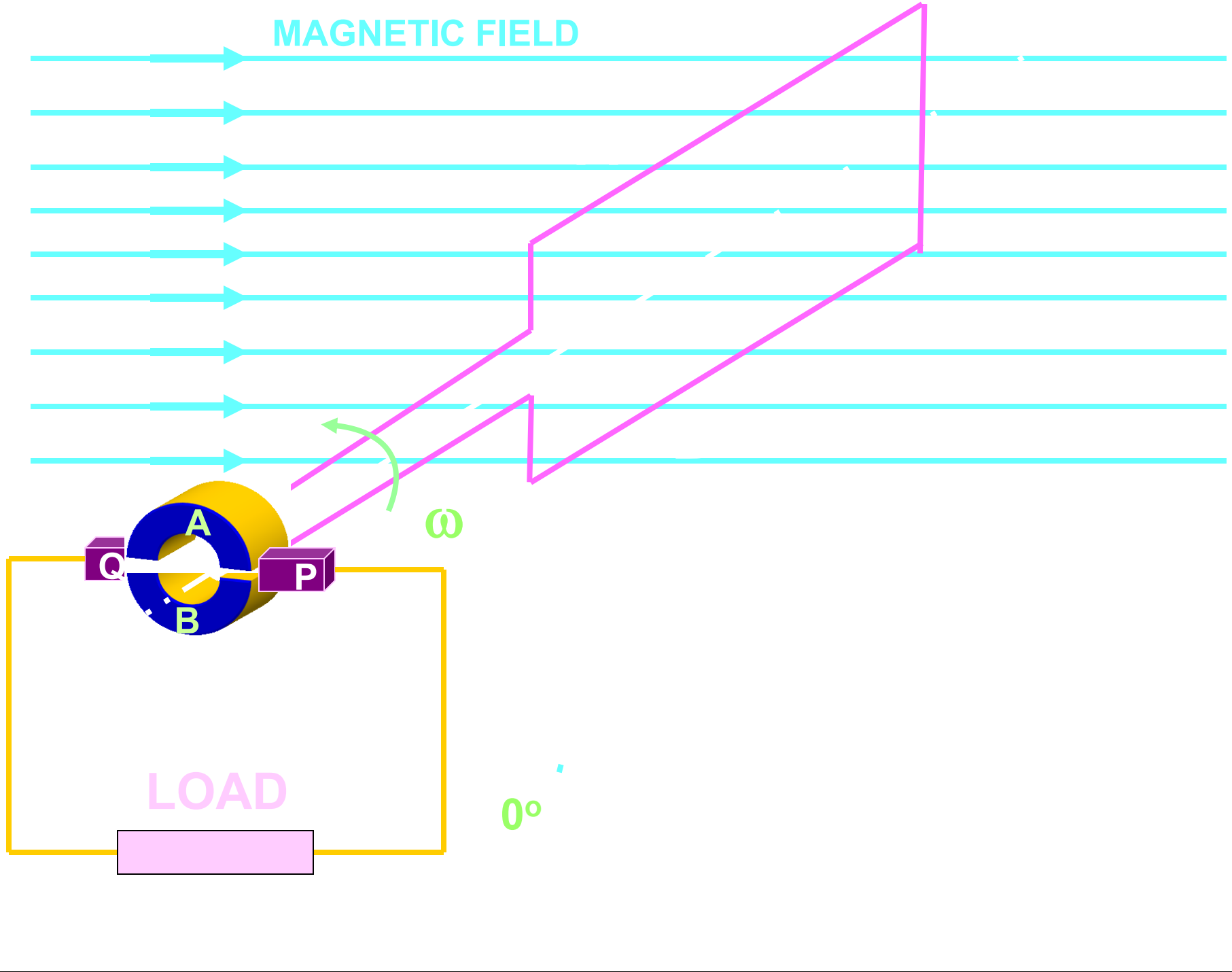
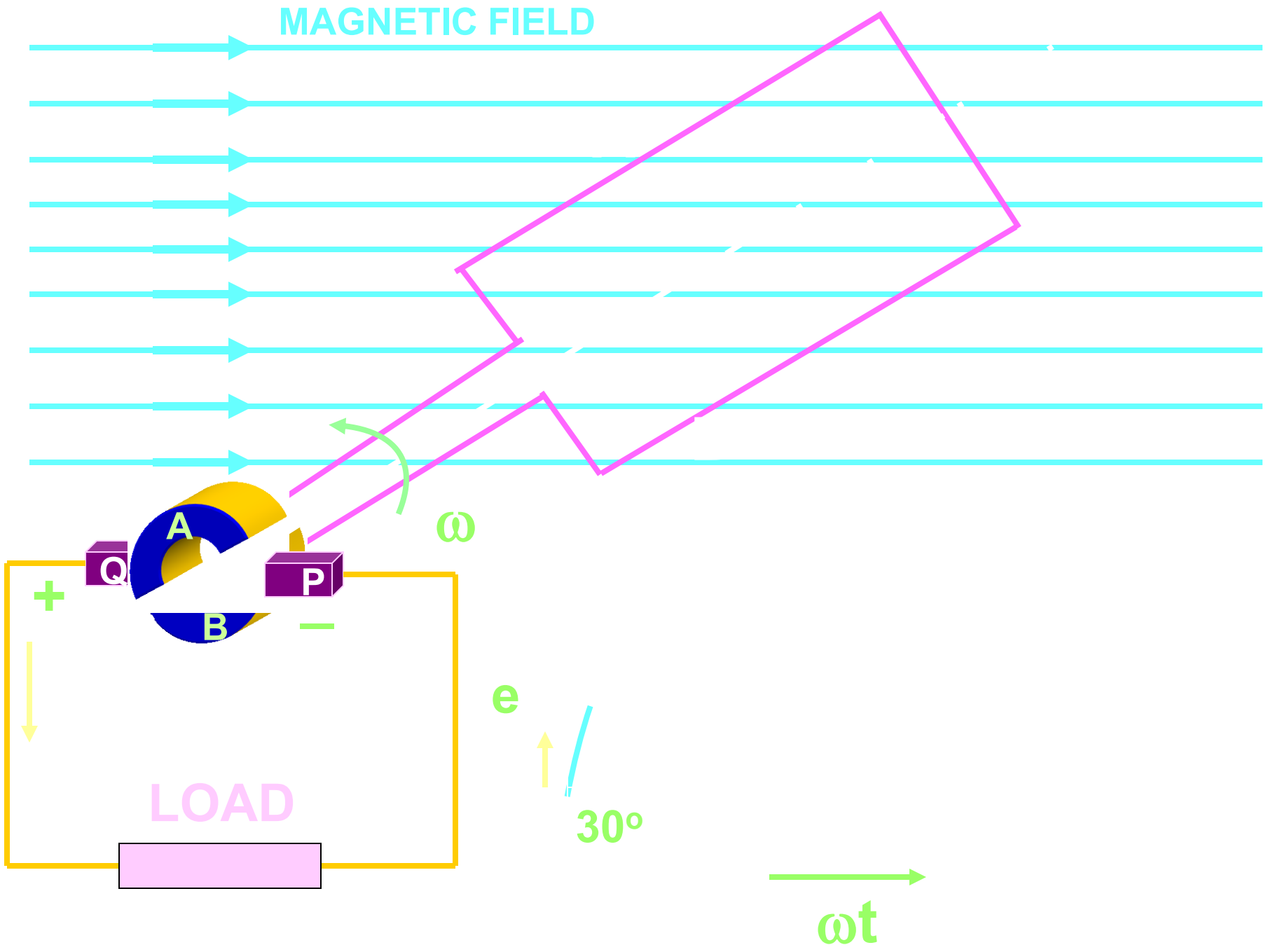
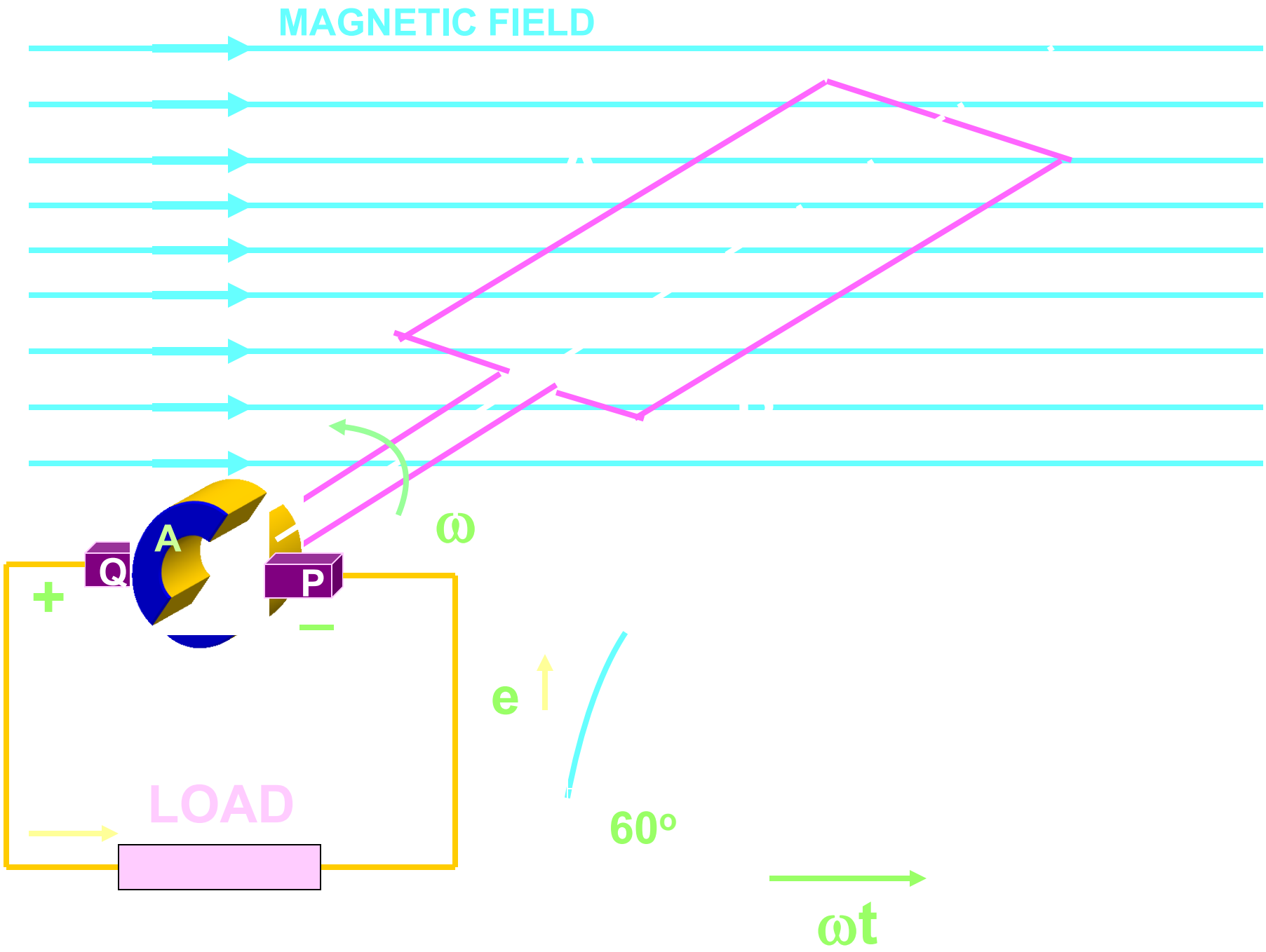
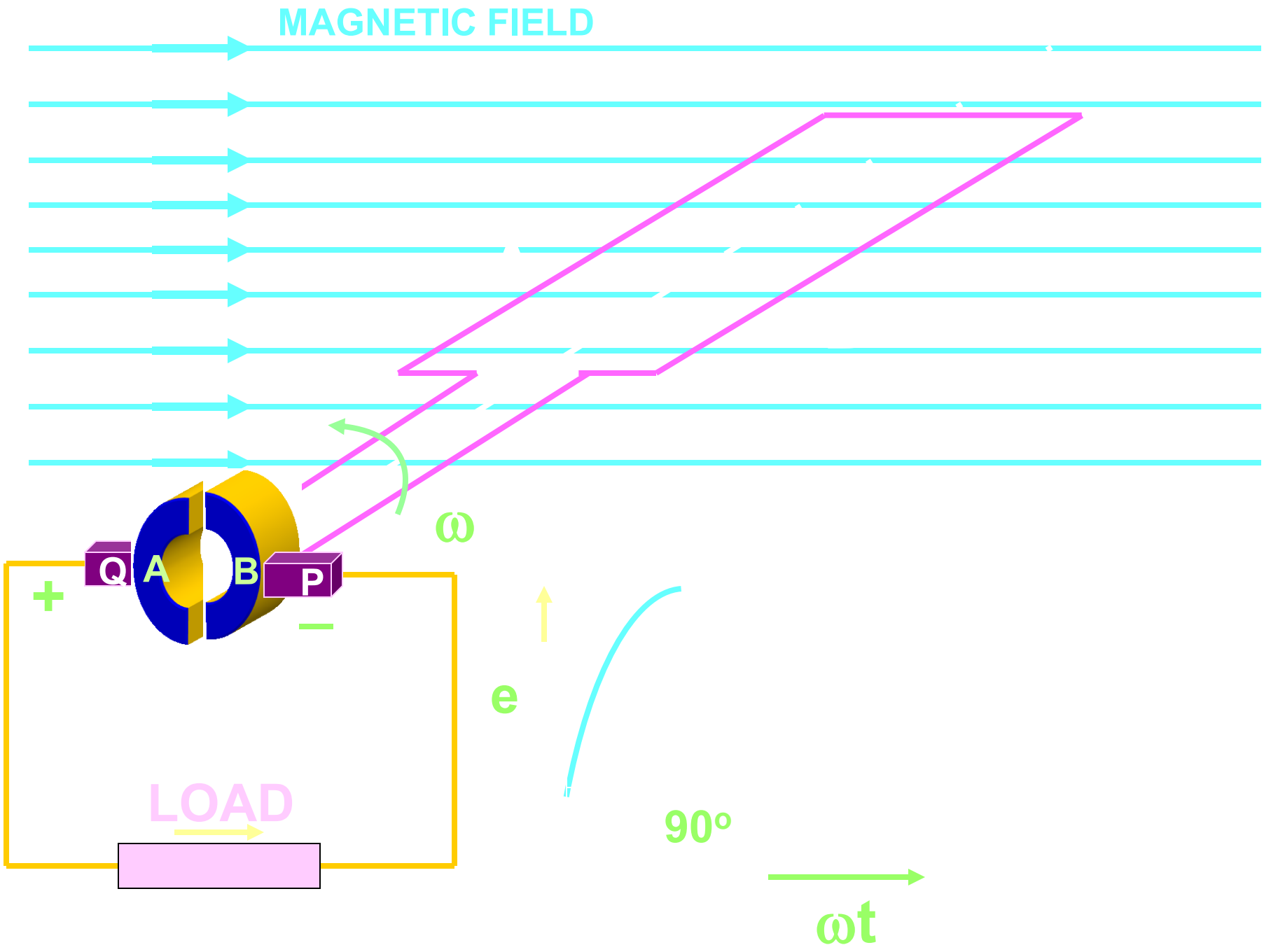


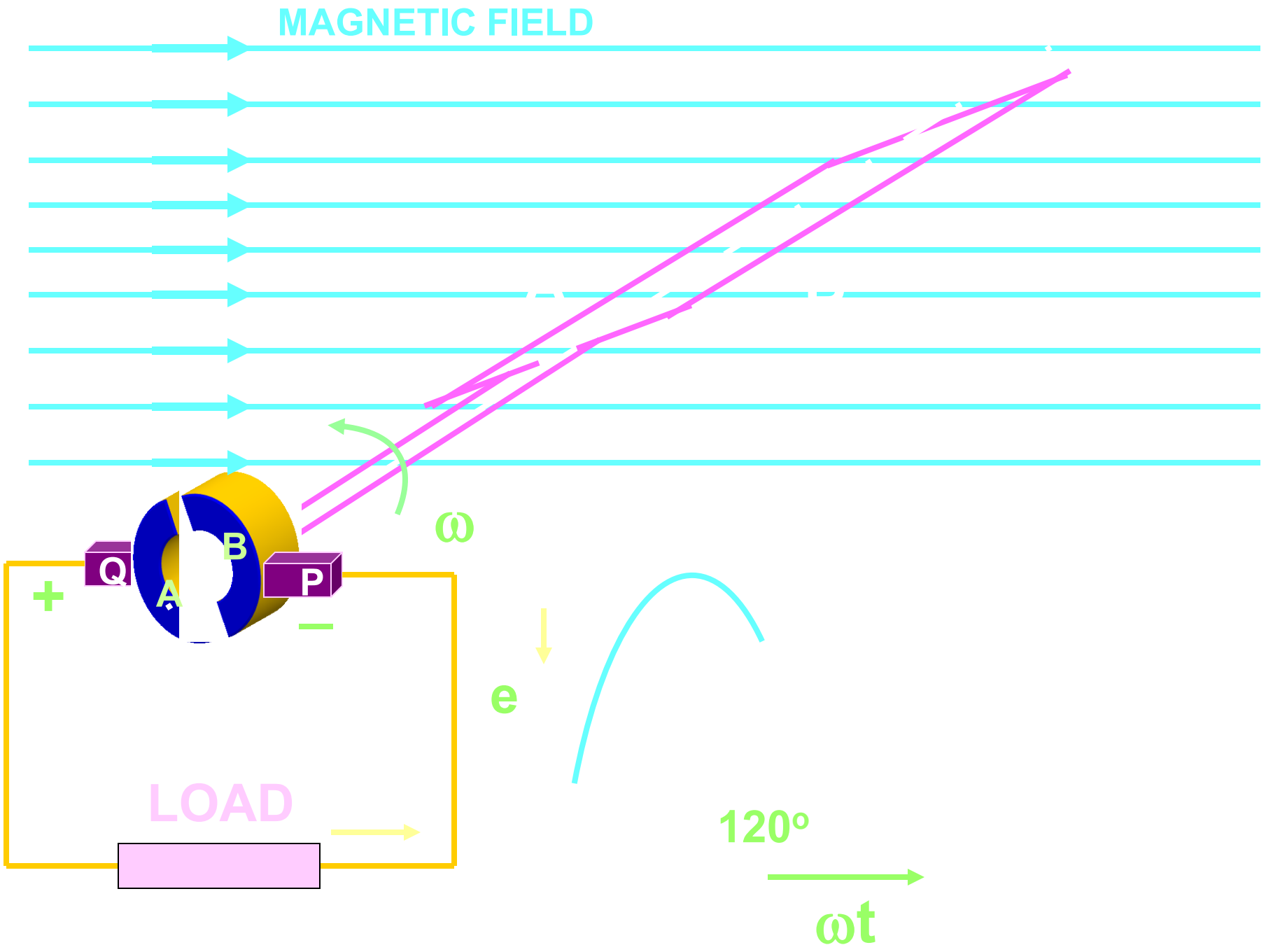
Figure 16.6 A simple dc machine consisting of a conducting bar sliding on conducting rails.

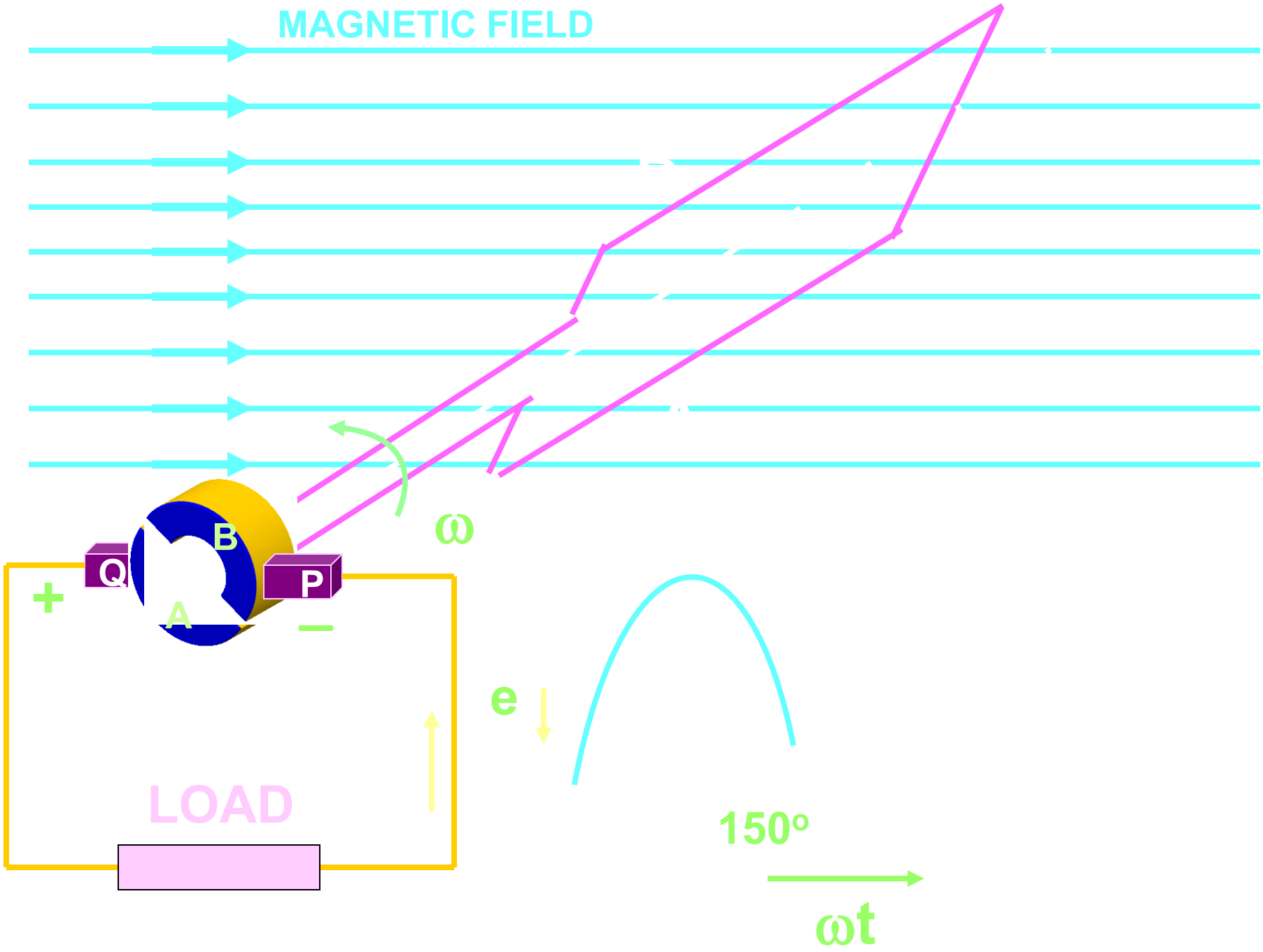

MAGNETIC FIELD
A
Q
P
B
ω
LOAD
0°

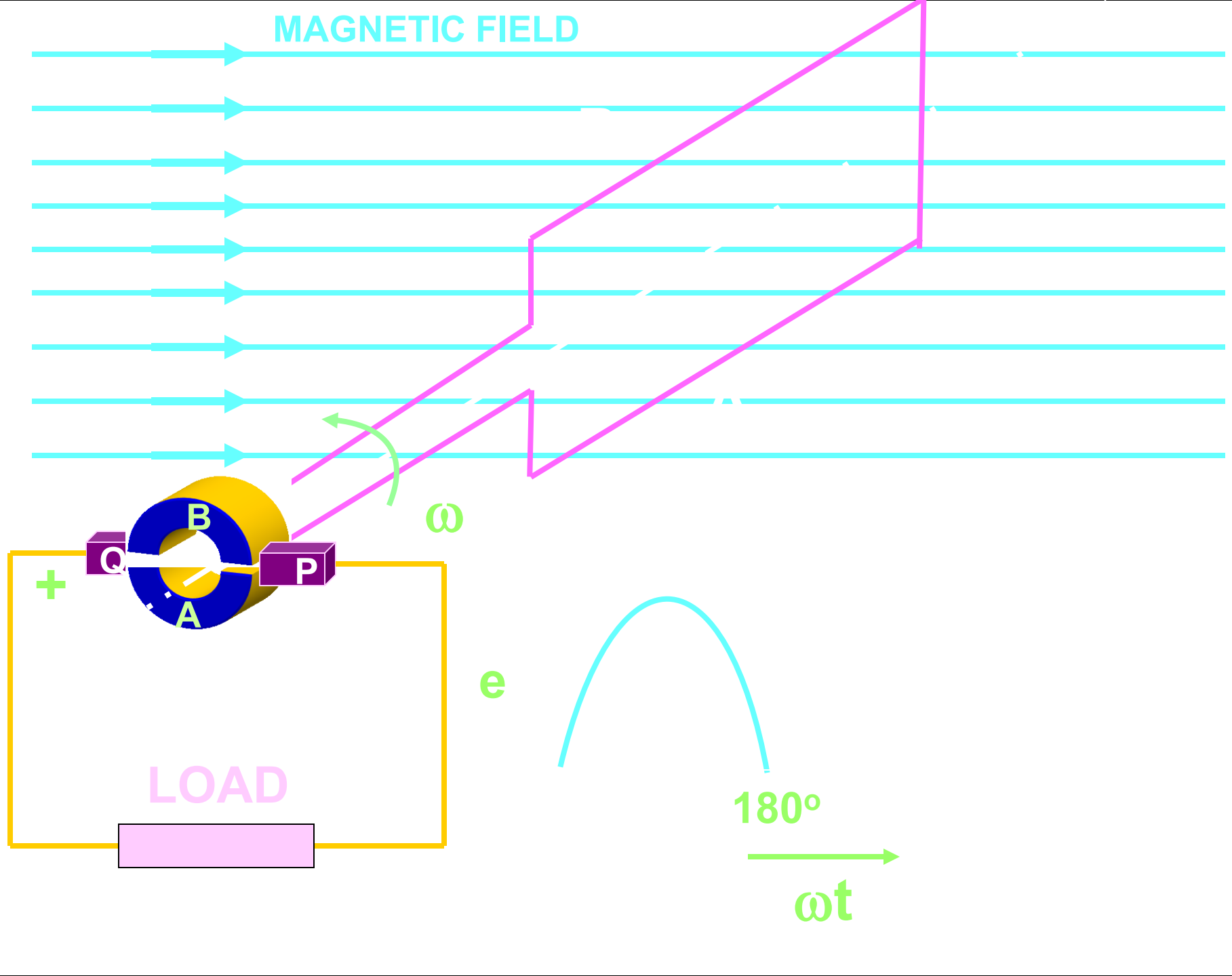

MAGNETIC FIELD
A
B
Q
P
+
–
ω
e
30°
LOAD
ωt

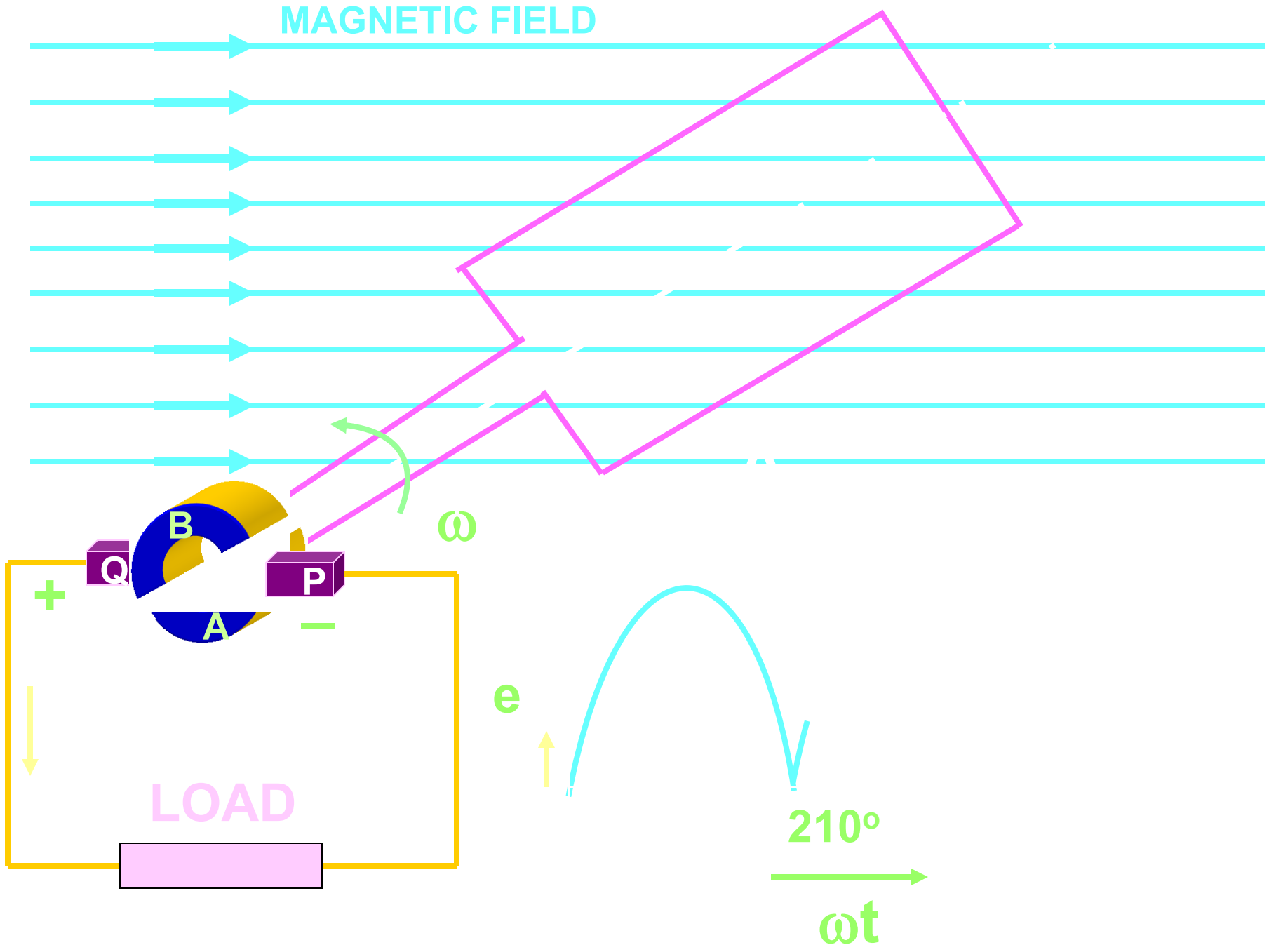

MAGNETIC FIELD
A
Q
P
+
−
ω
LOAD
e
60°
ωt

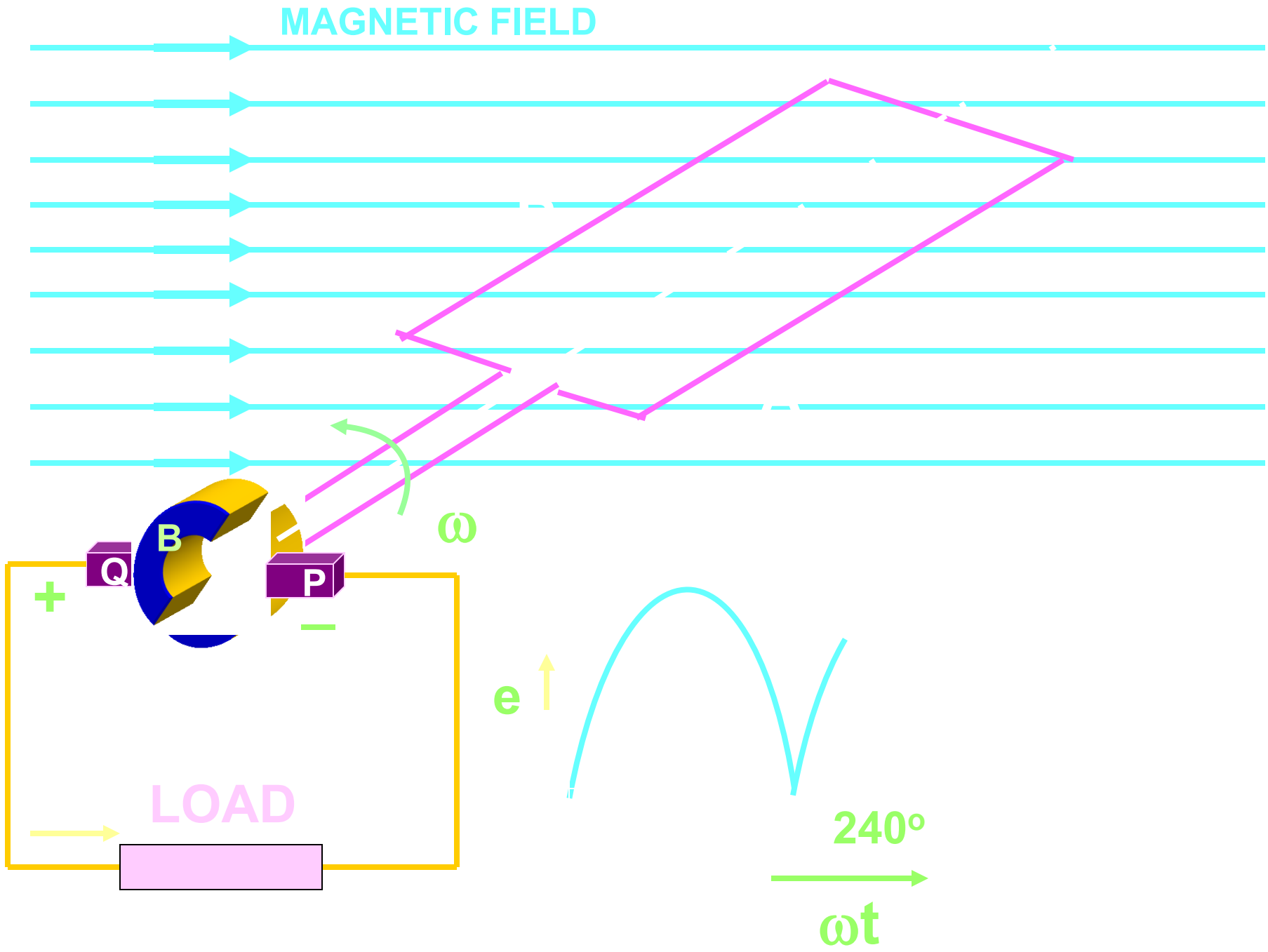

MAGNETIC FIELD
Q
A
B
P
+
–
ω
e
LOAD
90°
ωt

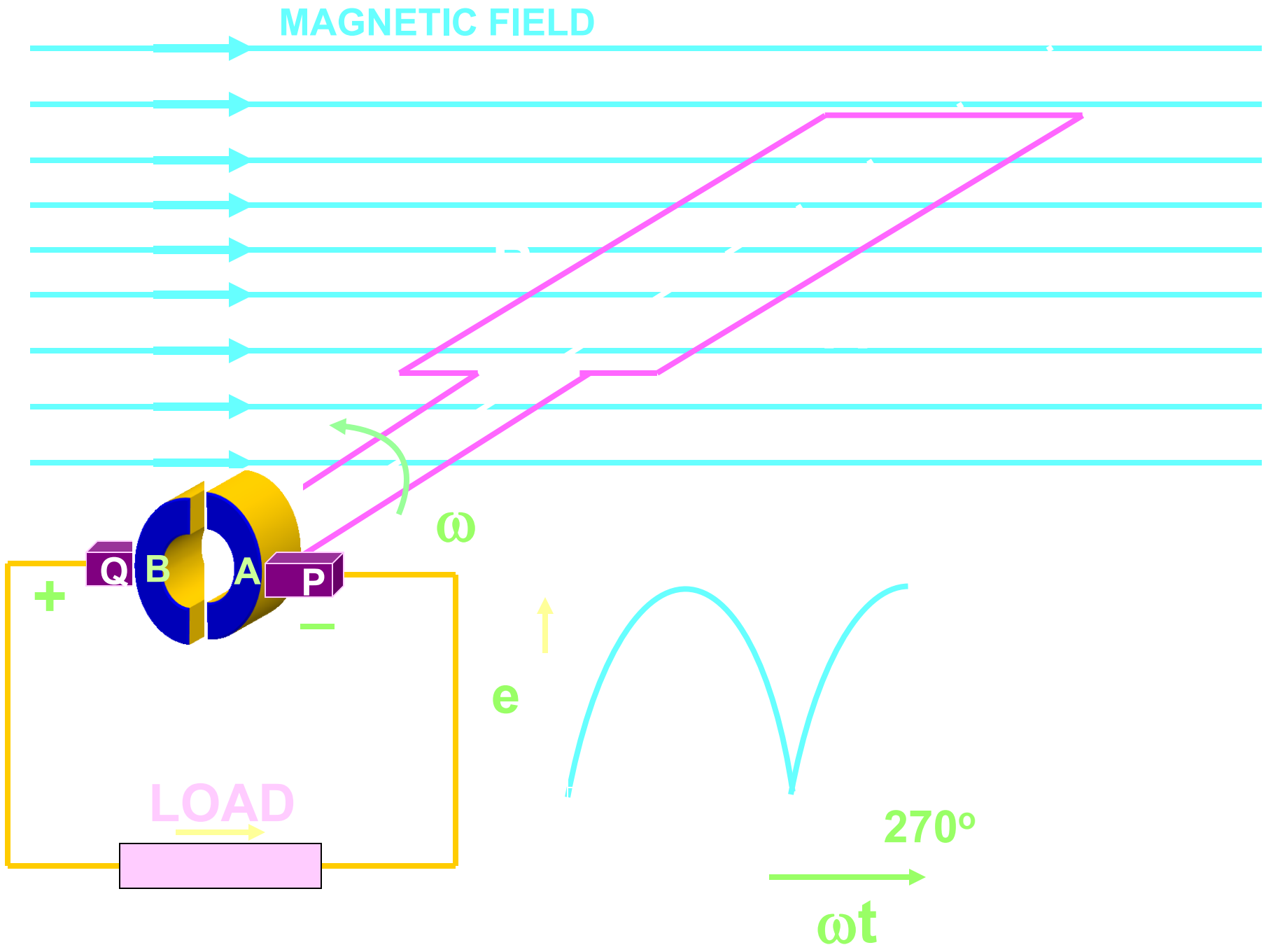

MAGNETIC FIELD
ω
B
Q
A
P
+
–
e
LOAD
120°
ωt

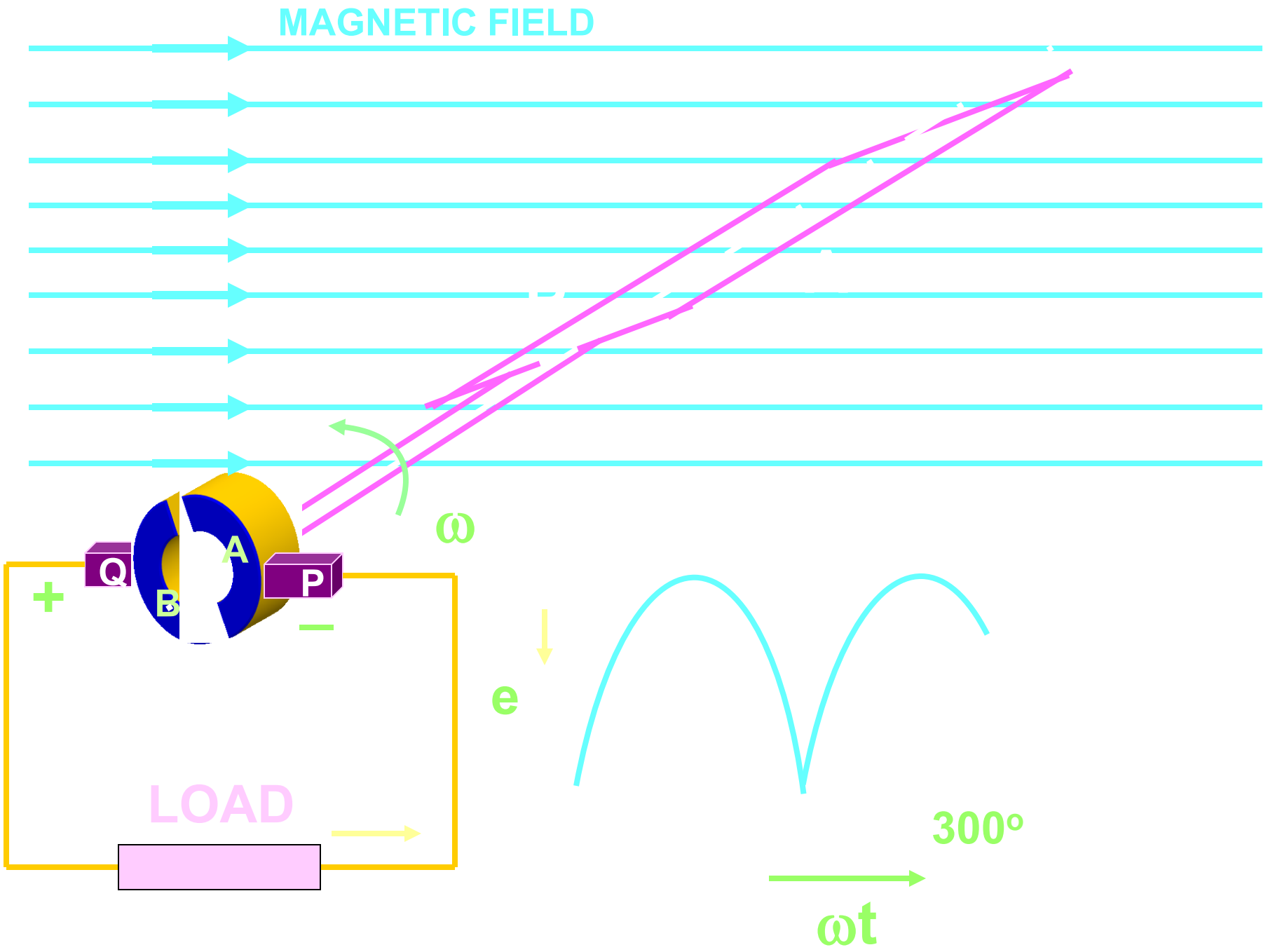

MAGNETIC FIELD
B
Q
P
A
+
–
ω
e
LOAD
150°
ωt

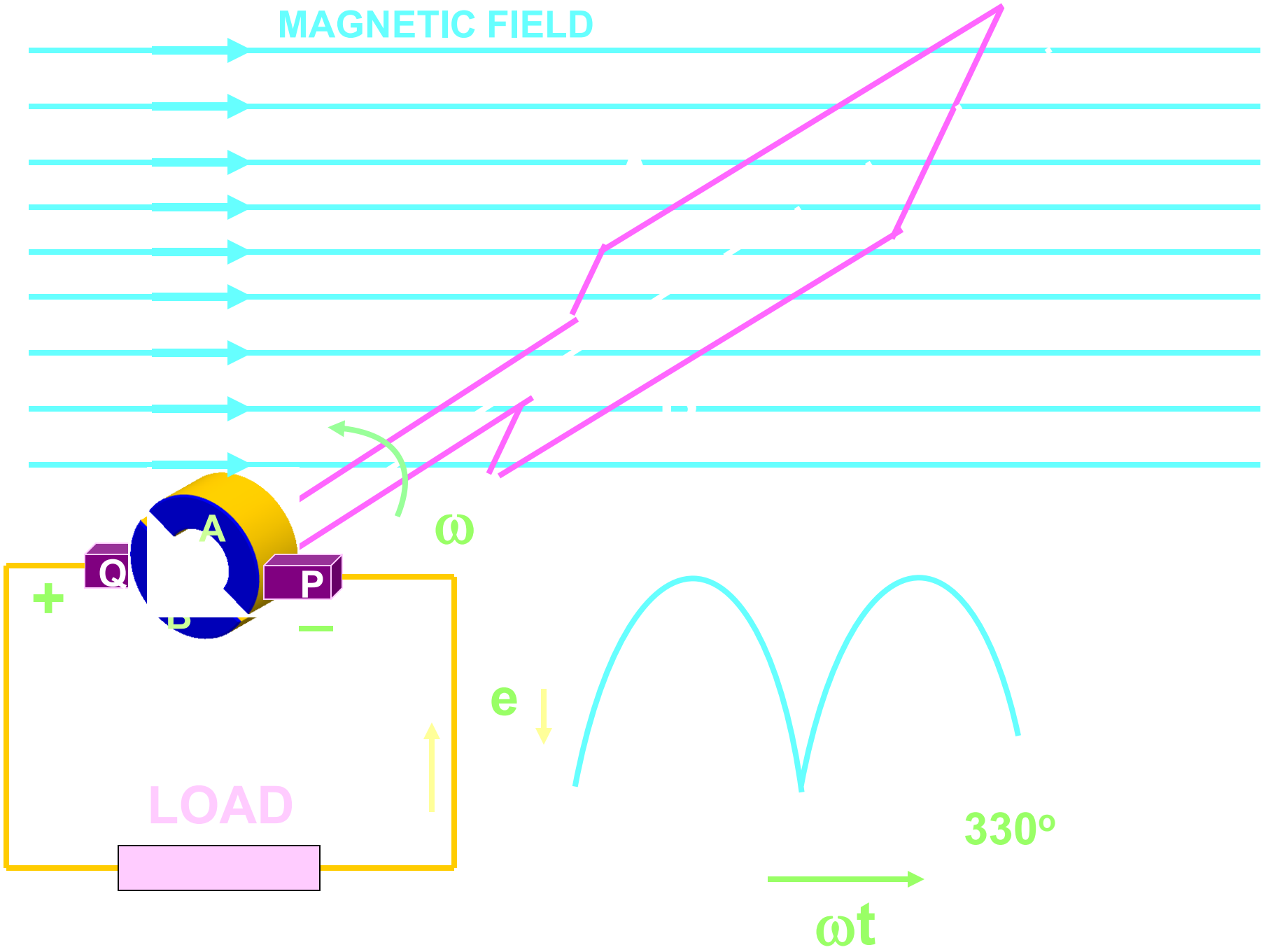

MAGNETIC FIELD
B
Q
P
A
+
ω
e
LOAD
180°
ωt

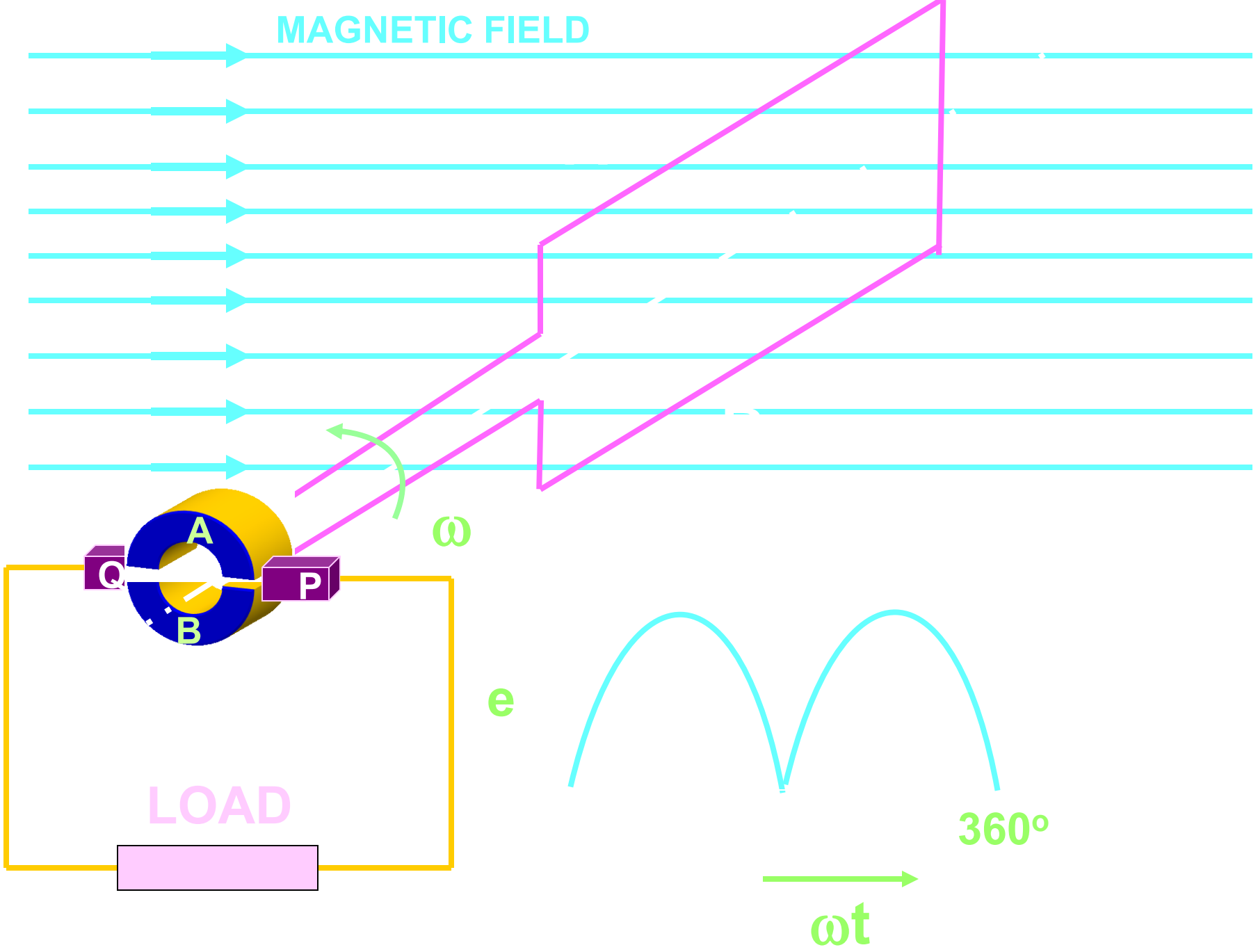

MAGNETIC FIELD
B
Q
P
A
ω
+
–
LOAD
e
210°
ωt


MAGNETIC FIELD
B
Q
P
+
−
ω
e
LOAD
240°
ωt


MAGNETIC FIELD
Q
B
A
P
+
–
ω
e
LOAD
270°
ωt


MAGNETIC FIELD
ω
A
B
Q
P
+
−
LOAD
e
300°
ωt


MAGNETIC FIELD
A
Q
P
B
+
–
ω
e
LOAD
330°
ωt


MAGNETIC FIELD
A
B
Q
P
ω
e
LOAD
360°
ωt

MAIN CONSTRUCTIONAL FEATURES

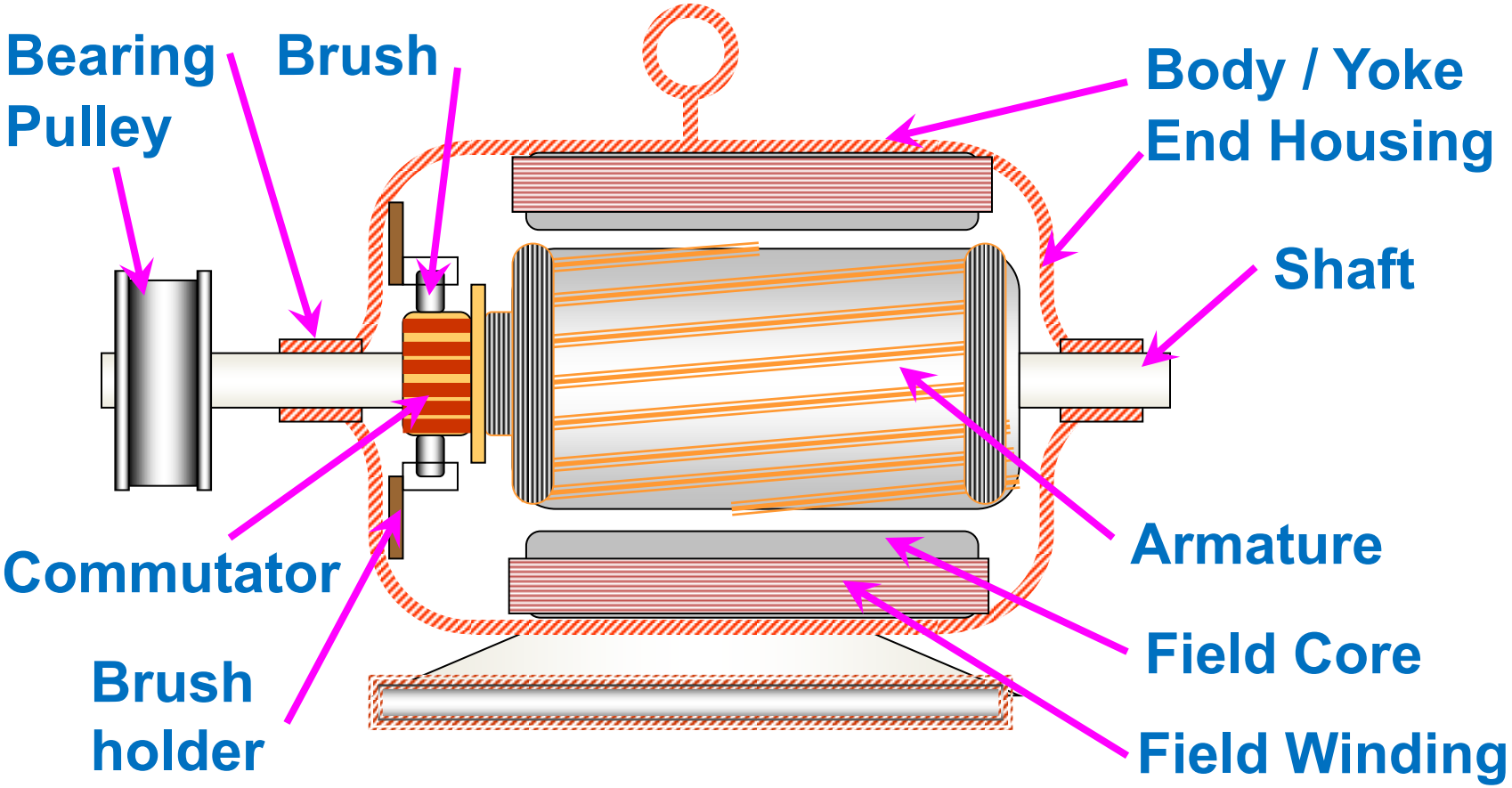
1. BODY OR MAGNETIC FRAME OR YOKE
2. POLE CORE AND POLE SHOES
3. FIELD or EXCITING COILS
4. ARMATURE CORE
5. ARMATURE WINDING
6. COMMUTATOR

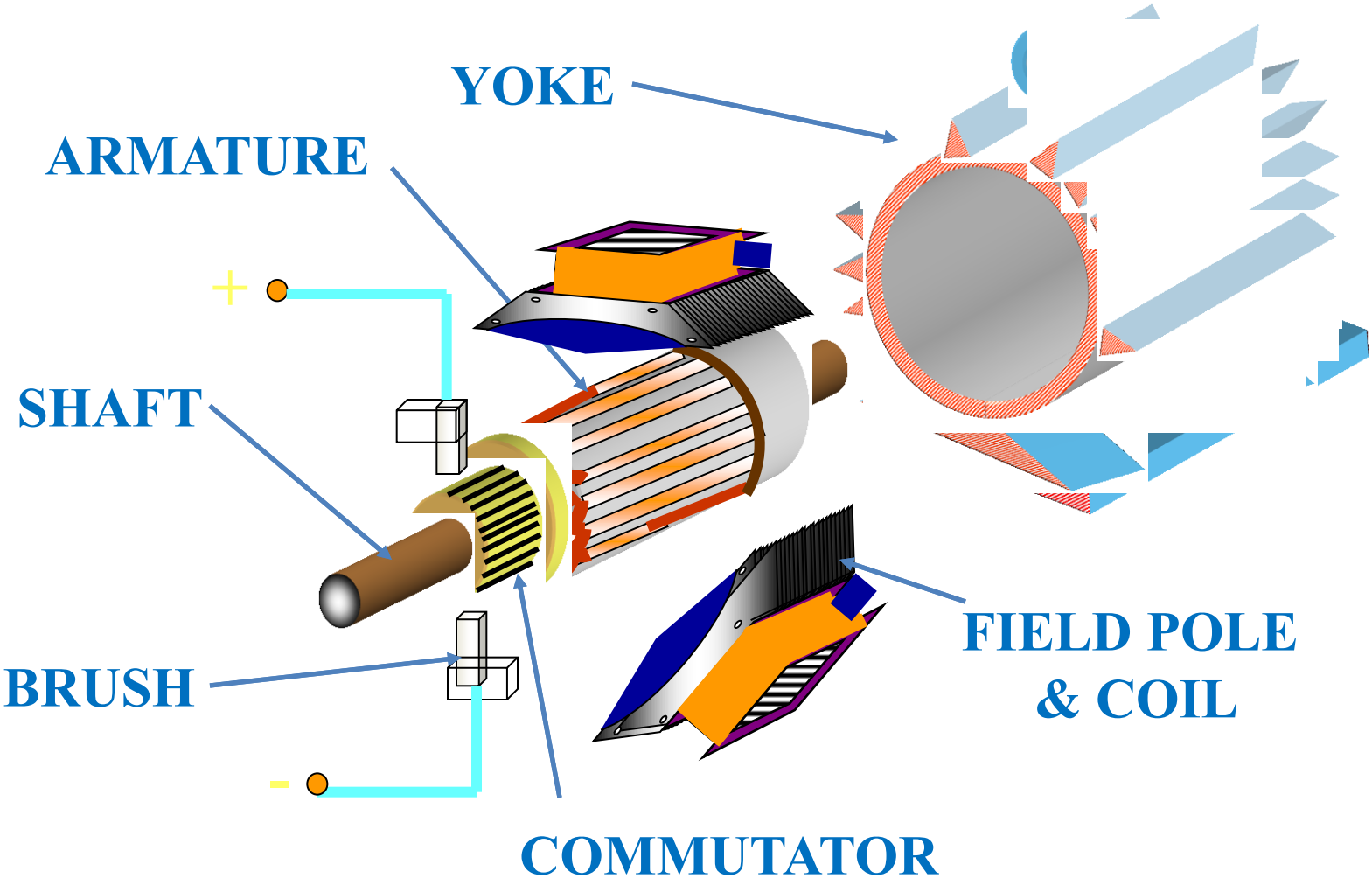
MAIN CONSTRUCTIONAL FEATURES

7. BRUSHES
8. END HOUSINGS
9. BEARINGS
10. SHAFT

DC MACHINES

MAIN CONSTRUCTIONAL FEATURES

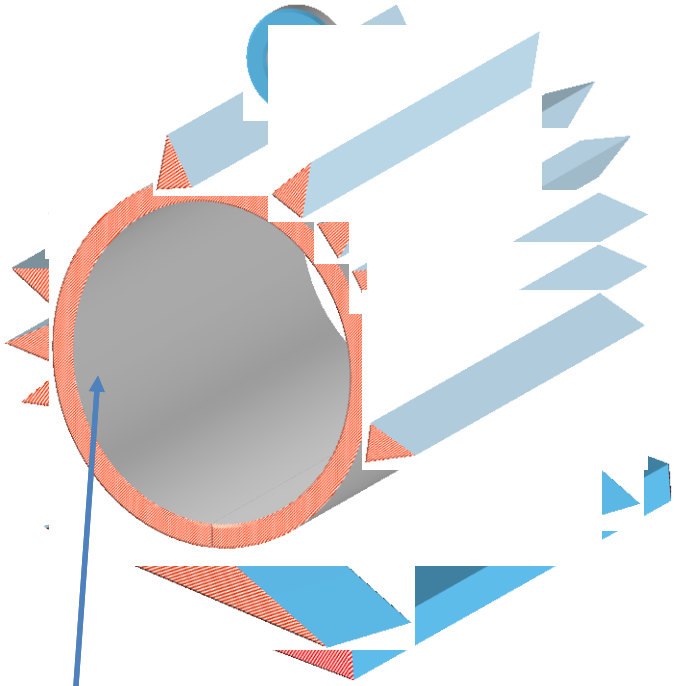



YOKE
ARMATURE
SHAFT
BRUSH
FIELD POLE
& COIL
COMMUTATOR

MAIN CONSTRUCTIONAL FEATURES

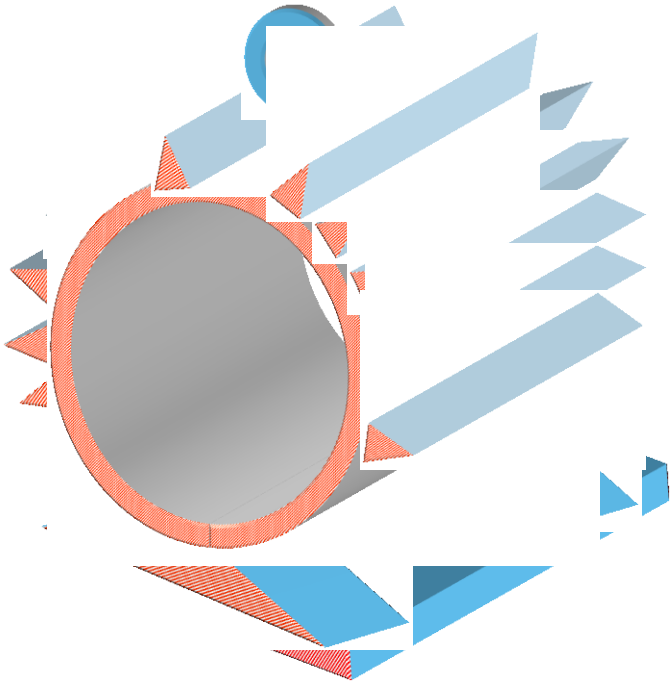
1. MAGNETIC FRAME or YOKE :

The outer cylindrical frame to which main poles and inter poles are fixed and by means of the machine is fixed to the foundation is called YOKE.



MAIN CONSTRUCTIONAL FEATURES

1. MAGNETIC FRAME or YOKE :

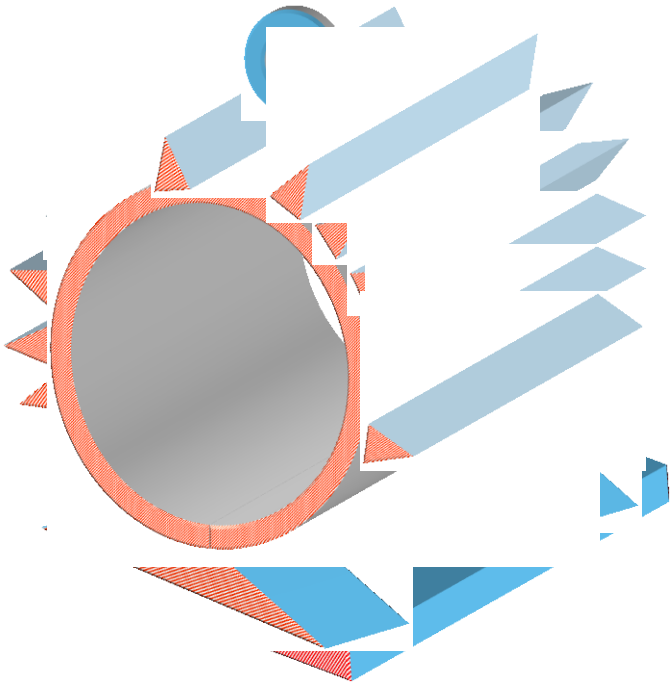


It serves two purposes:

a) It provides mechanical protection to the inner parts of the machines.

MAIN CONSTRUCTIONAL FEATURES

1. MAGNETIC FRAME or YOKE :



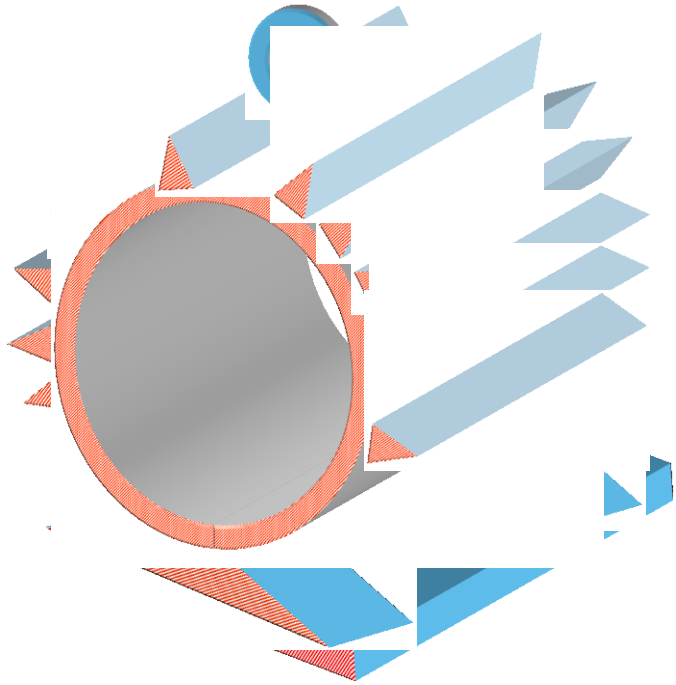
b) It provides a low reluctance path for the magnetic flux.

The yoke is made of cast iron for smaller …

MAIN CONSTRUCTIONAL FEATURES

1. MAGNETIC FRAME or YOKE :

machines and cast steel or fabricated rolled steel for larger machines.

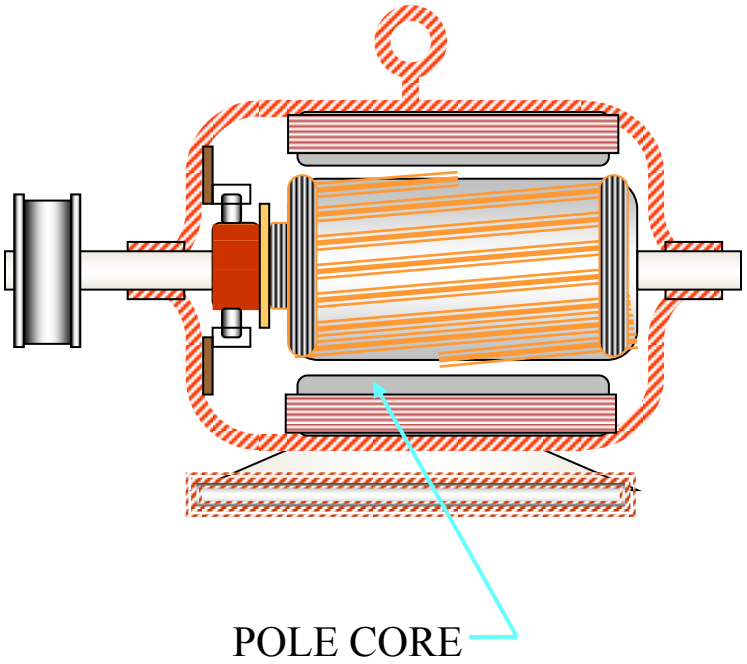


MAIN CONSTRUCTIONAL FEATURES

2. POLE CORE AND POLE SHOES :

The pole core and pole shoes are fixed to the yoke by bolts. They serves the following purpose :

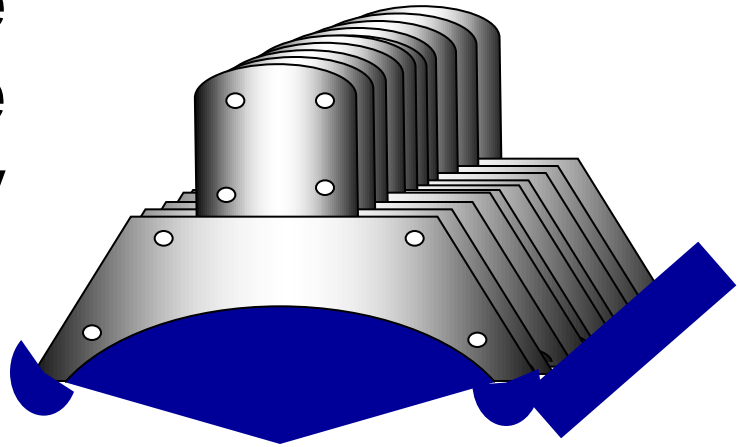
a) They support the field or exciting coils.



MAIN CONSTRUCTIONAL FEATURES

2. POLE CORE AND POLE SHOES :

b) They distribute the magnetic flux on the armature periphery more uniformly.



MAIN CONSTRUCTIONAL FEATURES

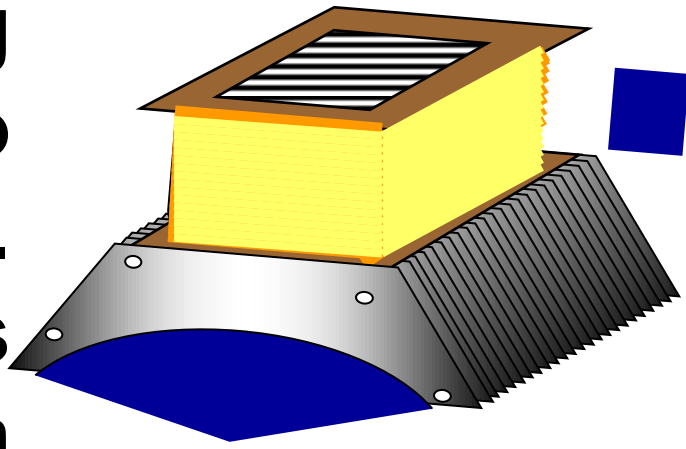
2. POLE CORE AND POLE SHOES :

c) The pole shoes have larger X- section, so the reluctance of the magnetic path is reduced. The pole core and pole shoes are made of laminated steel assembled by riveting together under hydraulic pressure.

MAIN CONSTRUCTIONAL FEATURES

3. FIELD or EXCITING COILS :

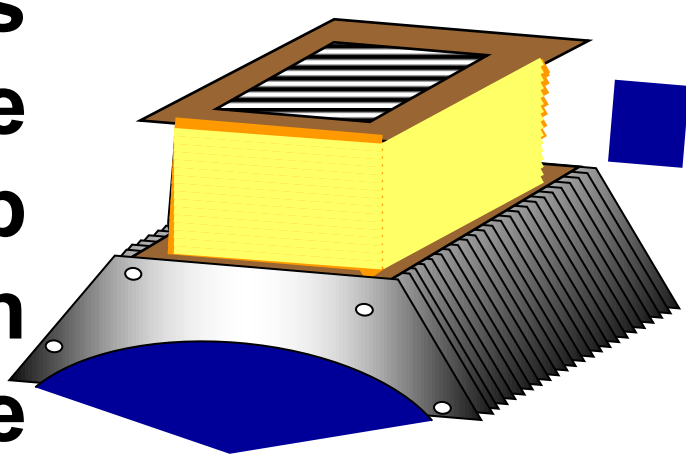
Field coils or exciting coils are used to magnetize the pole core. Enameled copper wire is used for the construction of these coils.



MAIN CONSTRUCTIONAL FEATURES

3. FIELD or EXCITING COILS :

When direct current is passed through these coils/ winding, it sets up the magnetic field which magnetize the pole core to the reqd. flux.



MAIN CONSTRUCTIONAL FEATURES

4. ARMATURE CORE:

Armature is a rotating part of the DC machine, reversal of flux takes place, so hysteresis losses are produced. To minimize this loss, silicon steel is used for the construction.

MAIN CONSTRUCTIONAL FEATURES

4. ARMATURE CORE:

The rotating armature cuts the main magnetic field , therefore an e.m.f is induced in the armature core. This e.m.f circulates eddy currents in the core which results in eddy current loss in it.

MAIN CONSTRUCTIONAL FEATURES

4. ARMATURE CORE:

The armature core is laminated to reduce the eddy current loss.

Armature core serves the following purposes:

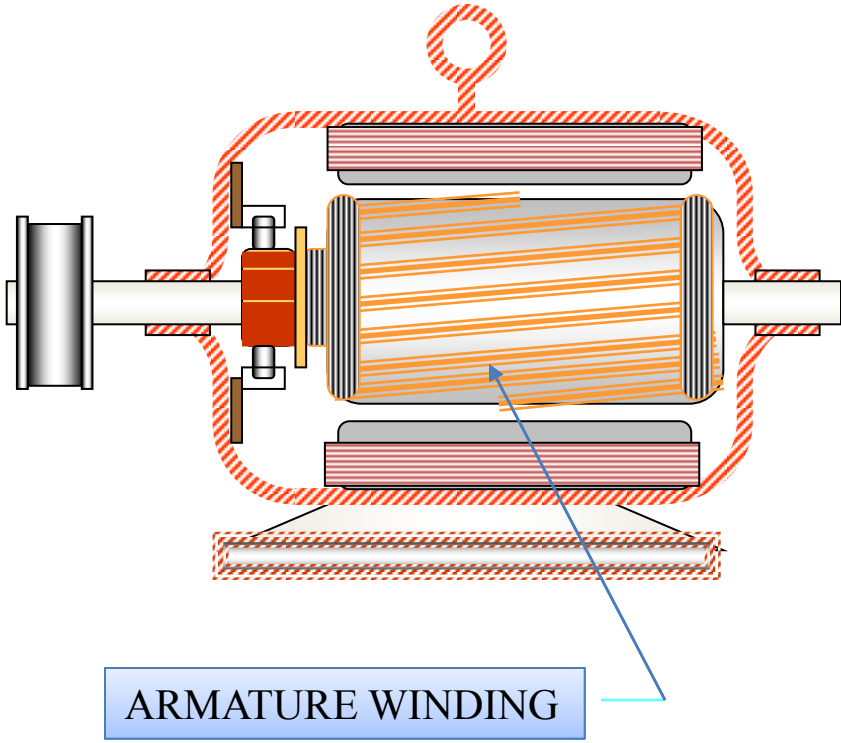
a) It houses the conductors in the slots.

b) It provides an easy path for magnetic flux

MAIN CONSTRUCTIONAL FEATURES

5. ARMATURE WINDING ;

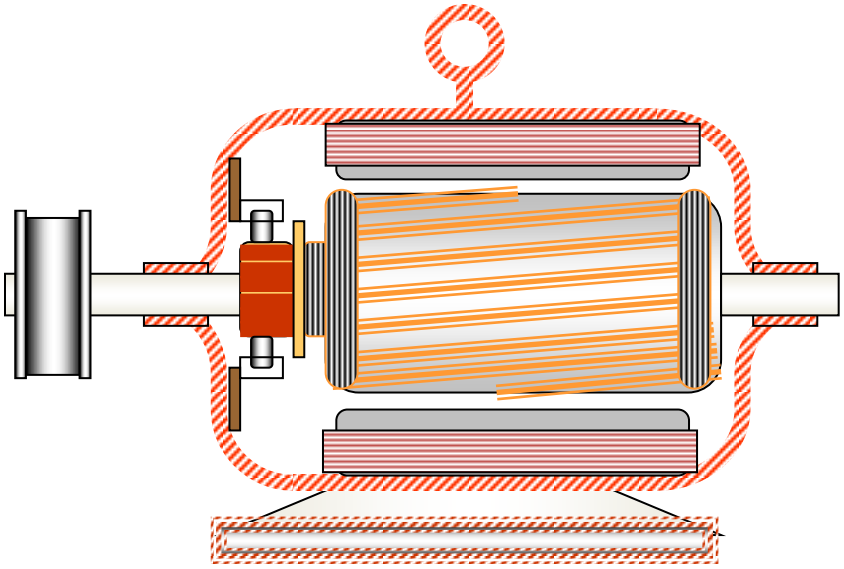
The no. of conductors in form of coils placed in the slots of the armature and suitably inter connected are called winding .



MAIN CONSTRUCTIONAL FEATURES

5. ARMATURE WINDING ;

This is the armature winding where conversion of power takes place i.e. in case of generator, mechanical power is converted into electrical power and in case of a motor, electrical power is converted into mechanical power.



MAIN CONSTRUCTIONAL FEATURES

5. ARMATURE WINDING ;

Depending upon the types of inter connection. of coils , the winding can be classified into two types;

i) Lap Winding;

The conductors/coils are connected in such a way that no of parallel paths are equal to no. of poles.

MAIN CONSTRUCTIONAL FEATURES

5. ARMATURE WINDING ;

If machine has ‘P’ no. of poles and ‘Z’ no. of conductors, then there will be ‘P’ no. of parallel paths.And each path will have ‘Z/P’ no of conductors in series. Also the no. of brushes are equal to no. of parallel paths. Out of which half of the brushes will be positive and remaining will be negative.

MAIN CONSTRUCTIONAL FEATURES

5. ARMATURE WINDING ;

ii) Wave Winding;

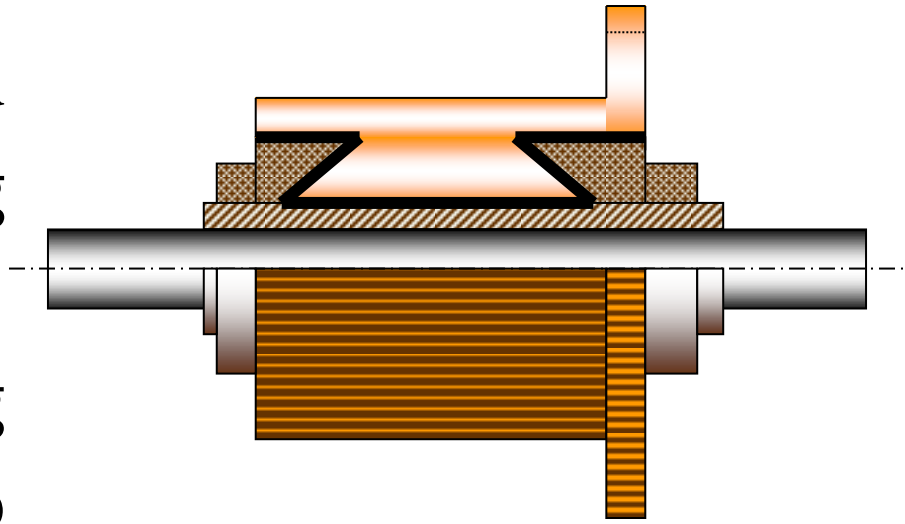
The conductors are so connected that they are divided into two parallel paths only , irrespective of the no. of poles. If machines has 'Z' no. of conductors, there will be only two parallel paths and each will be having 'Z/2' no. of conductors connected in series with only two brushes.

MAIN CONSTRUCTIONAL FEATURES

6. COMMUTATOR

It is the most important part of a DC machine and serves the following purpose :-

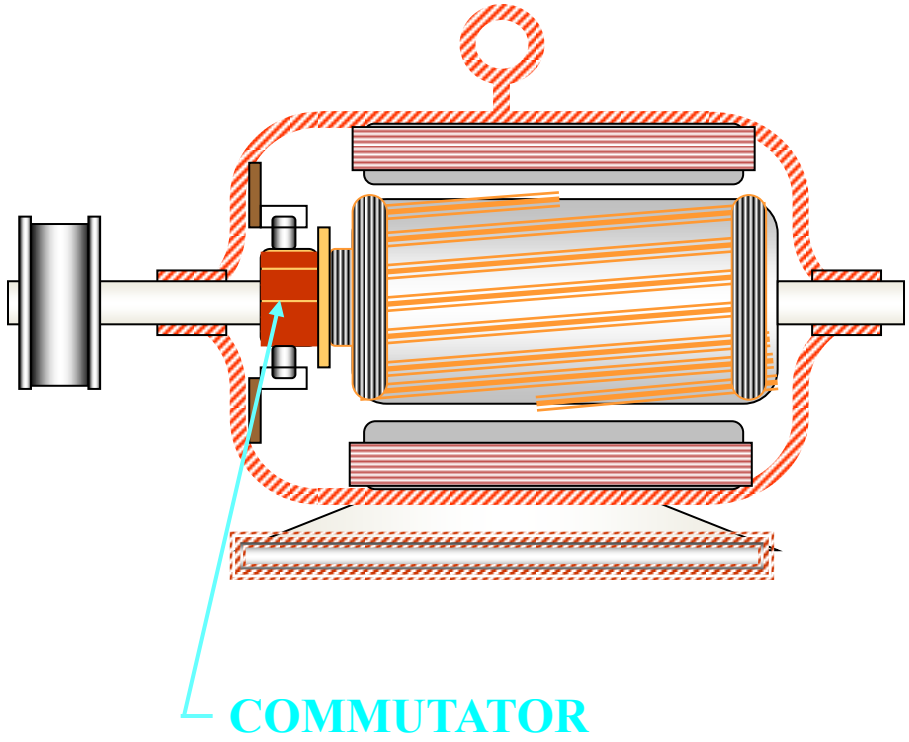
i) It connects the rotating armature conductors to the stationary external circuit through the brushes.



MAIN CONSTRUCTIONAL FEATURES

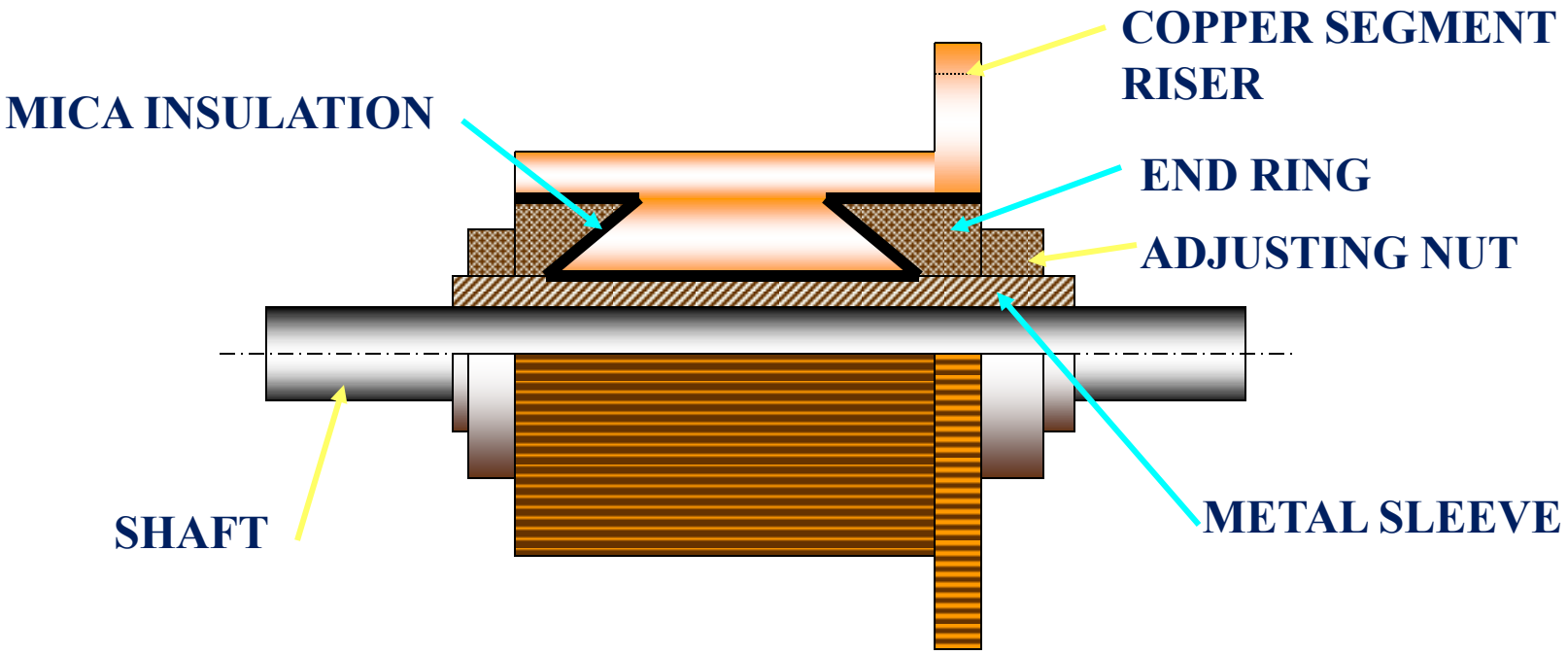
6. COMMUTATOR

ii) It converts altering current induced in the armature conductors into unidirectional current in the external load circuit in generating action and it converts alternating torque into unidirectional torque produced in the armature in motoring action.



MAIN CONSTRUCTIONAL FEATURES

6. COMMUTATOR



MAIN CONSTRUCTIONAL FEATURES

6. COMMUTATOR

The commutator is of cylindrical shape and is made of wedge shaped hard drawn copper segments. The segments are insulated from each other by a thin sheet of mica. The segments are held together by means of two V-shaped rings that fit into the V-grooves cut into the segments. Each armature coil is connected to the commutator segment through riser.

MAIN CONSTRUCTIONAL FEATURES

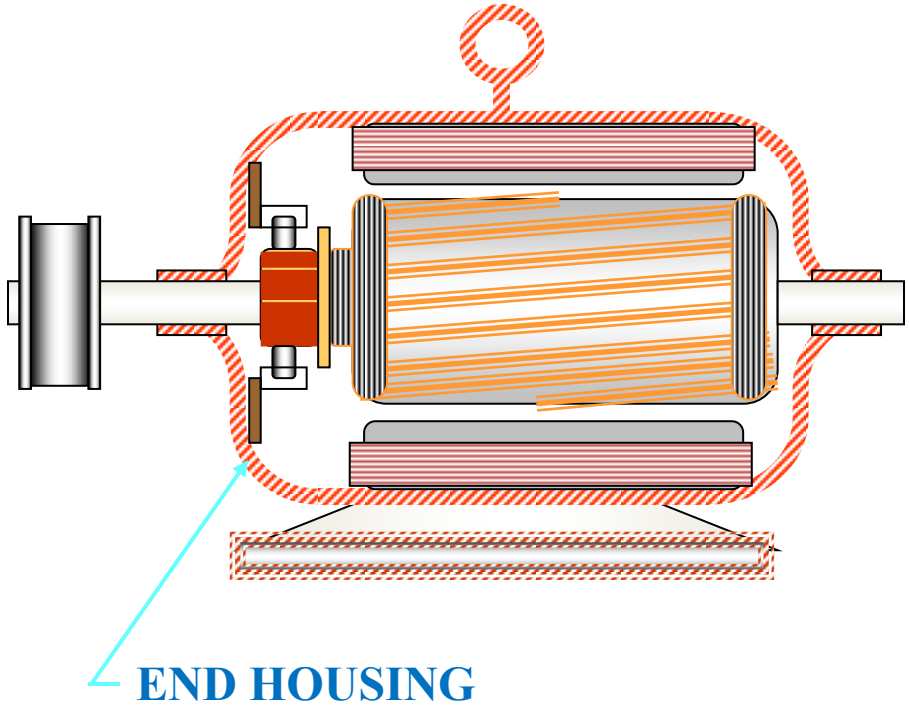
7. BRUSHES

Brushes are made of high grade carbon. They form the connecting link between armature winding and the external circuit. The brushes are held in particular position around the commutator by brush holders.

MAIN CONSTRUCTIONAL FEATURES

8. END HOUSINGS

They are attached to the ends of main frame and support bearing . The front housing supports the bearing and the brush assembly whereas rear housing supports the bearing only.



MAIN CONSTRUCTIONAL FEATURES

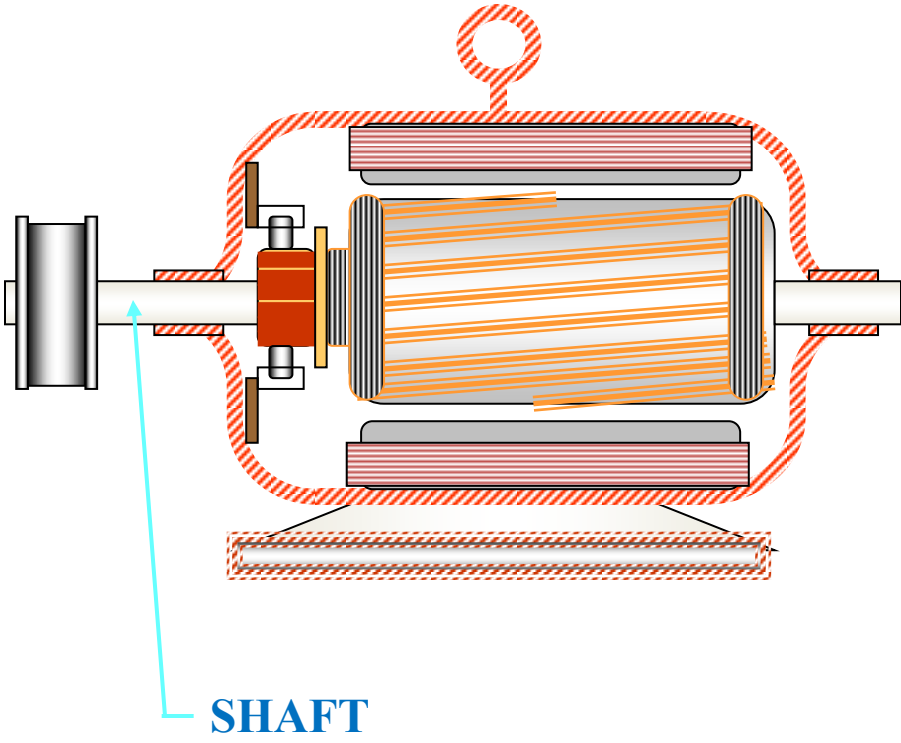
9. BEARINGS

The function of the bearing is to reduce friction between the rotating and stationary parts of the machines. These are fitted in the end housings. Generally, high carbon steel is used for the construction of the bearings.

MAIN CONSTRUCTIONAL FEATURES

10. SHAFT

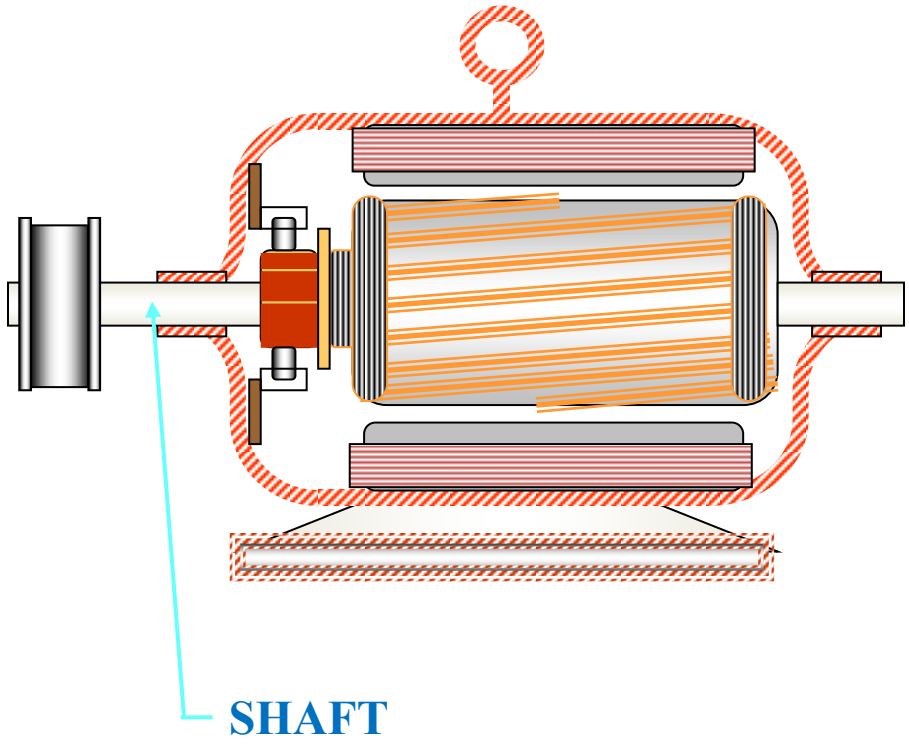
The function of shaft is to transfer mechanical power to the machine or from the machine . Shaft is made of mild steel with maximum breaking strength.



MAIN CONSTRUCTIONAL FEATURES

10. SHAFT

All the rotating parts like armature core, commutator, cooling fan etc. are keyed to the shaft.



Armature Reaction(AR)

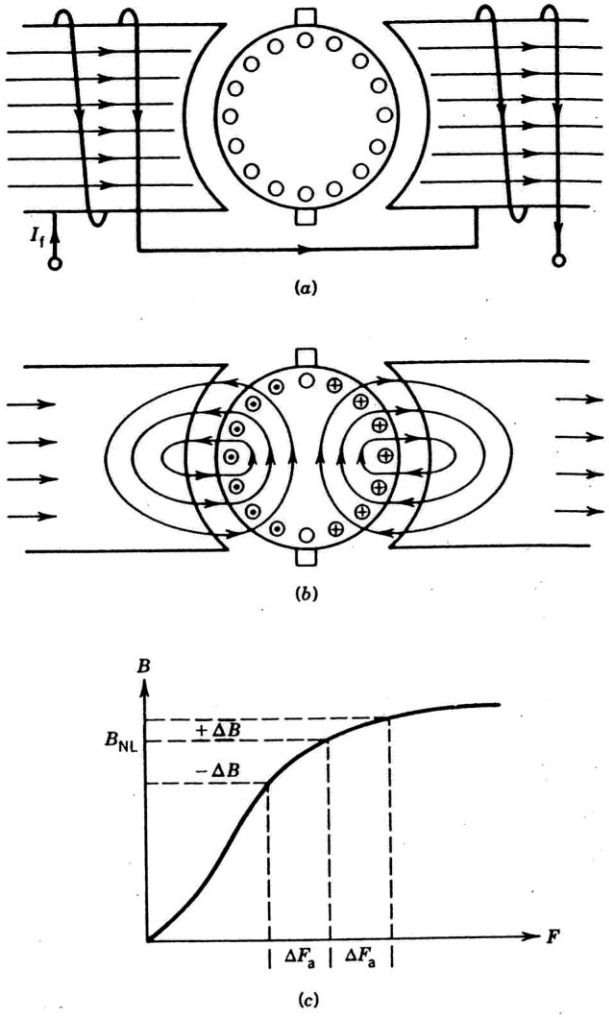


FIGURE 4.30 Armature reaction effects.

- AR is the magnetic field produced by the armature current
- AR aids the main flux in one half of the pole and opposes the main flux in the other half of the pole
- However due to saturation of the pole faces the net effect of AR is demagnetizing

Effects of Armature Reaction

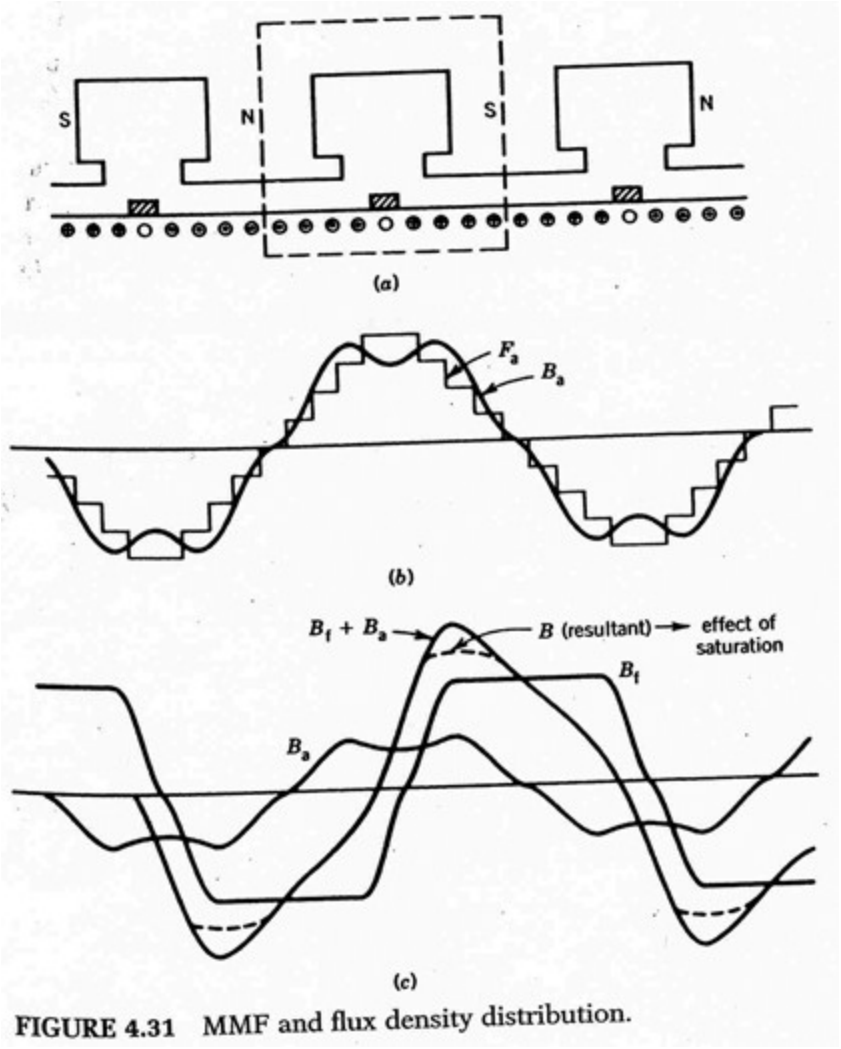


FIGURE 4.31 MMF and flux density distribution.

The magnetic axis of the AR is 90^0 electrical (cross) out-of-phase with the main flux. This causes commutation problems as zero of the flux axis is changed from the interpolar position.

Minimizing Armature Reaction

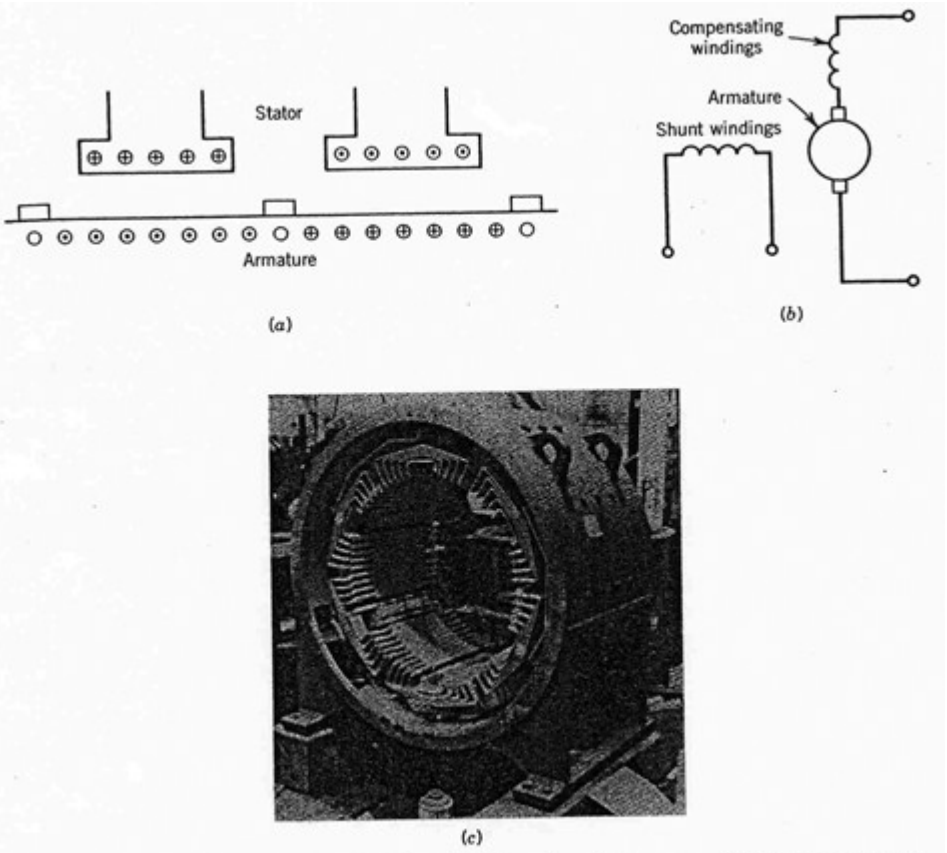


FIGURE 4.33 Compensating winding. (*a*) Developed diagram. (*b*) Schematic diagram. (*c*) Photograph. (Courtesy of General Electric Canada Inc.)

- Since AR reduces main flux, voltage in generators and torque in motors reduces with it. This is particularly objectionable in steel rolling mills that require sudden torque increase.
- Compensating windings put on pole faces can effectively negate the effect of AR. These windings are connected in series with armature winding.

Minimizing commutation problems

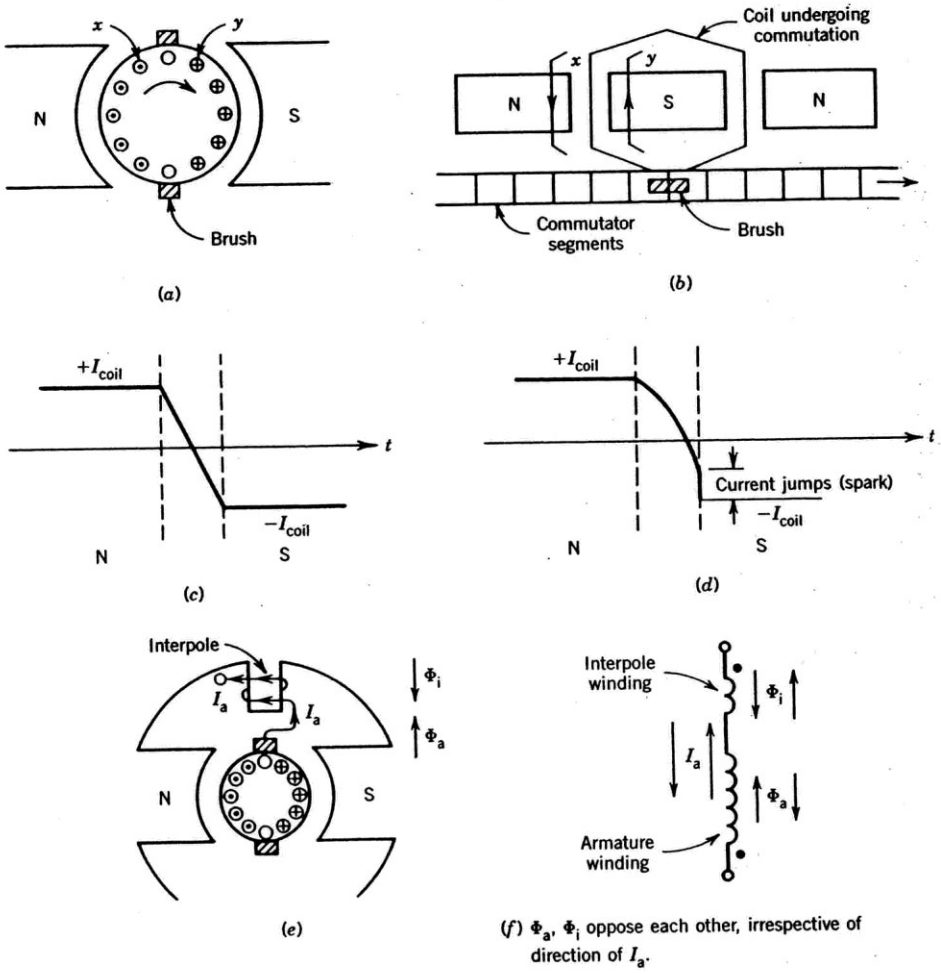


FIGURE 4.46 Current communication in dc machine.

- Smooth transfer of current during commutation is hampered by
a) coil inductance and
b) voltage due to AR flux in the interpolar axis. This voltage is called reactance voltage.

- Can be minimized using interpoles. They
produce an opposing field that cancels out the AR in the interpolar region. Thus this winding is also connected in series with the armature winding.

Voltage build-up of shunt generators

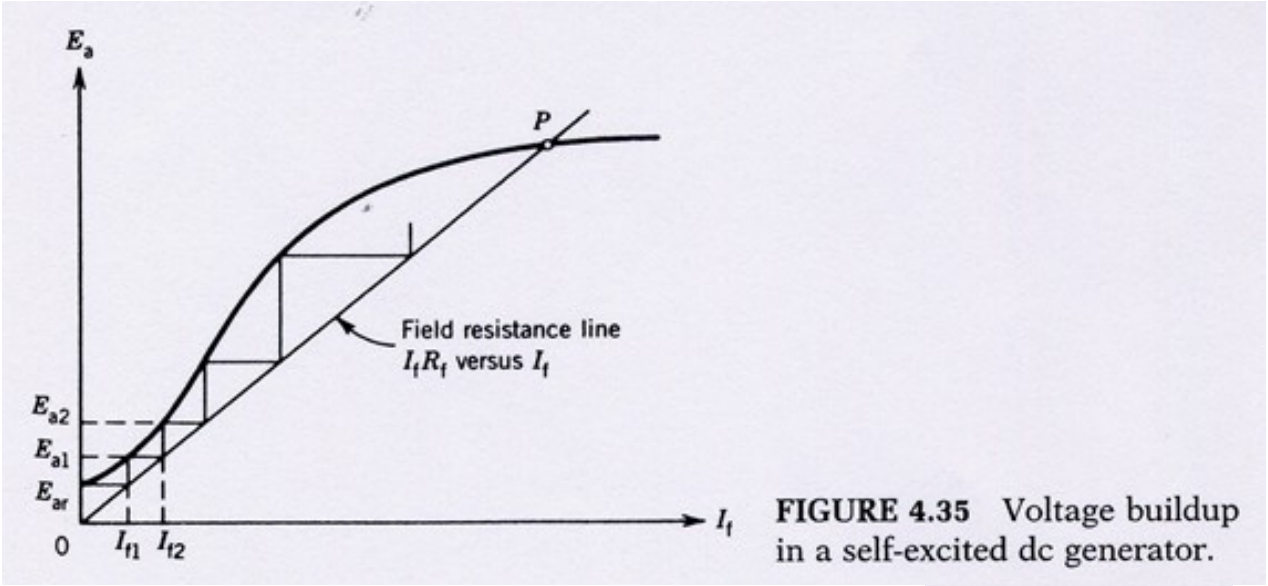


FIGURE 4.35 Voltage buildup in a self-excited dc generator.

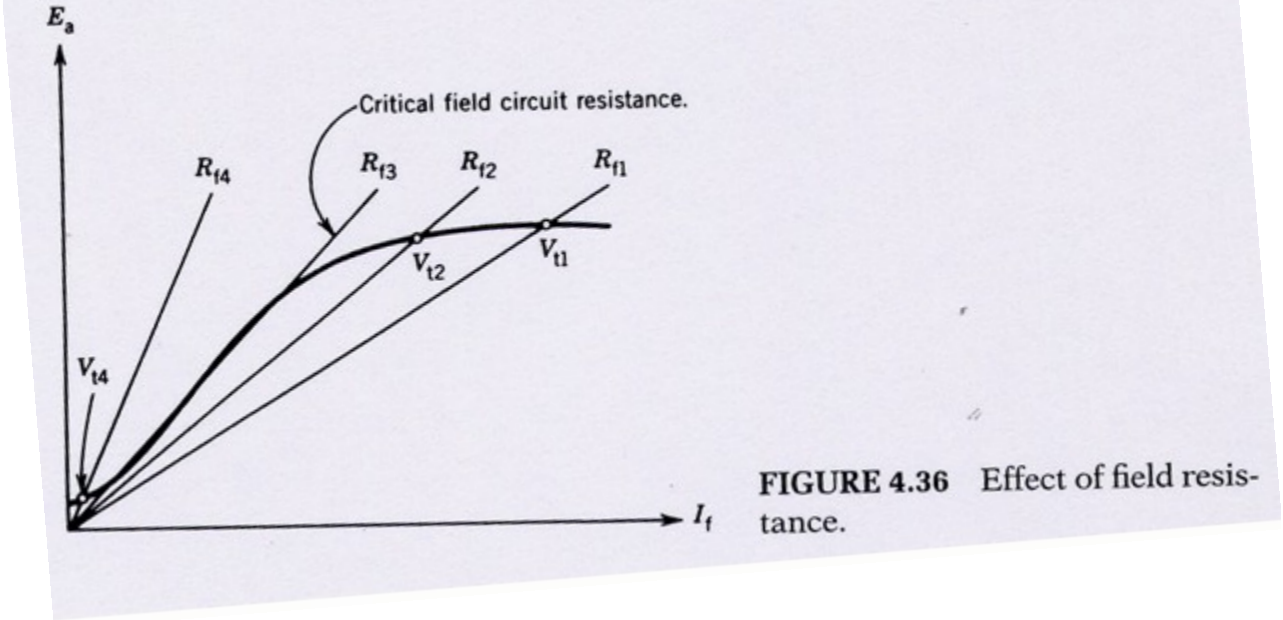
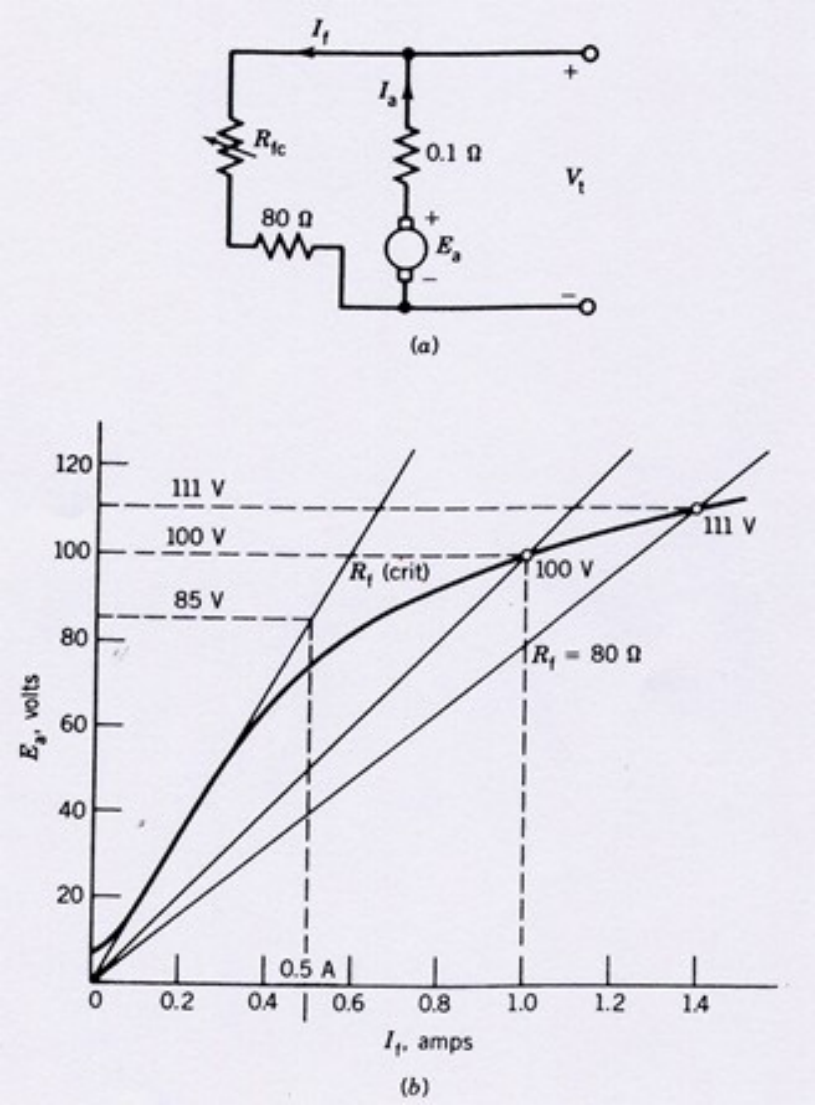


FIGURE 4.36 Effect of field resistance.

Example on shunt generators' buildup



For proper voltage build-up the following are required:

- Residual magnetism
- Field MMF should aid residual magnetism
- Field circuit resistance should be less than critical field circuit resistance