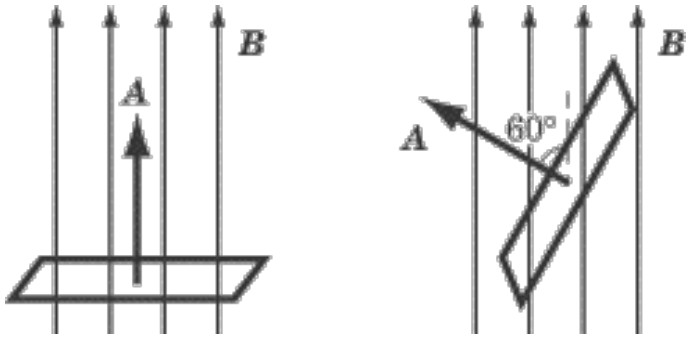
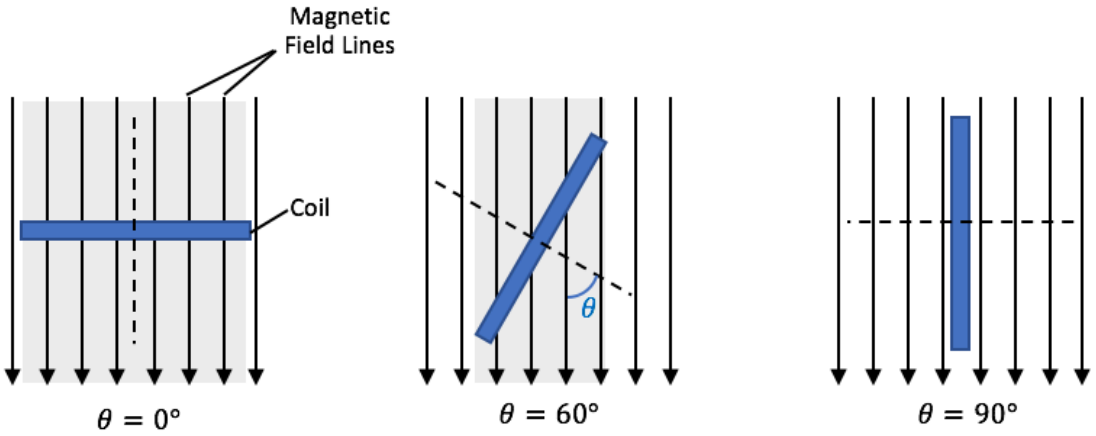
MAGNETIC FLUX

Magnetic Flux is the total amount of magnetic field passing through an area.

It is a measure of the number of field lines passing through a region (effectively a measure of the concentration of the magnetic field).





MAGNETIC FLUX – QUESTIONS

1. Calculate the total magnetic flux threading an area of 1.56×10^{-2} m^2 if the flux density is 0.502 T.

[7.83×10^{-3} Wb]

2. If 6.09×10^{-4} Wb threads an area of 165 mm^2, what is the magnetic flux density?

[3.69 T]

3. A coil has a cross-sectional area of 4.00 cm^2 and the flux density inside the coil is 2.00×10^{-2} T. Find the total magnetic flux inside the coil.

[8.00×10^{-6} Wb]

4. The plane of a singular rectangular coil of cross-sectional area 3.00×10^{-2} m^2 sits vertically in a horizontal magnetic field of flux density 1.50 T. If the coil rotates once every 4.00 s, calculate the magnitude of the flux threading the coil after:

(a) 1.00 s

[0.00 Wb]

(b) 2.00 s

[4.50×10^{-2} Wb]

(d) 0.500 s

[3.18×10^{-2} Wb]

5. The flux density in a cylindrical iron rod of diameter 2.00 cm is 2.10 T. What is the total magnetic flux inside the rod?

[6.60×10^{-4} Wb]

6. The rectangular coil of a galvanometer measures 3.00 cm x 6.00 cm and sits between the poles of a horse-shoe magnet which produces a magnetic flux of 6.46×10^{-2} Wb. Determine;

(a) the magnetic flux density produced by the magnet inside the coil.

[35.9 T]

(b) the force exerted on the 6.00 cm sides of the coil if it carries a current of 12.0 μA.

[2.58×10^{-5} N]

7. At a certain place on the Earth's surface, the horizontal component of the Earth's magnetic field is 4.50×10^{-5} T. A wire is oriented at right angles to this horizontal component is moving vertically so it cuts the field at right angles with a speed of 25.0 ms^{-1}. If the wire is 12.0 m long, what is the magnetic flux cut per second?

[1.35×10^{-2} Wb]

Electromagnetism #3

MOTORS

An electric motor is a device that converts electrical energy to mechanical energy.

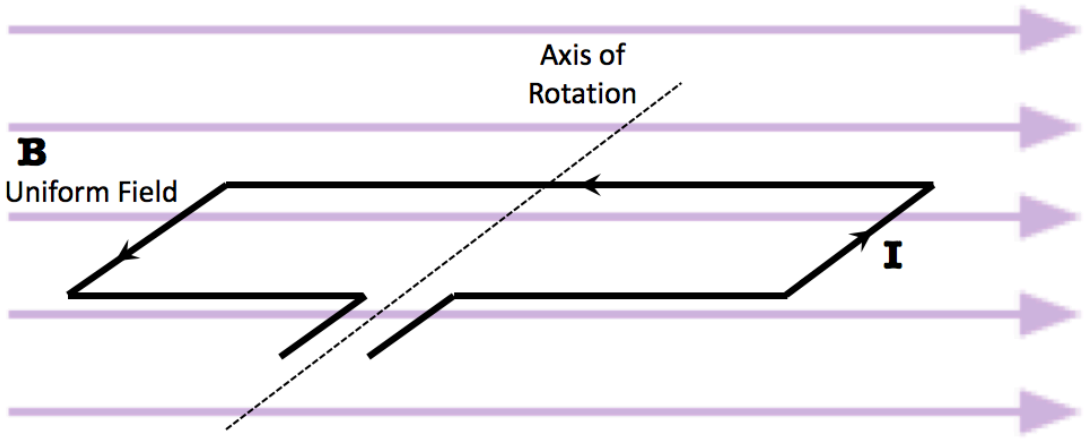
A DC Commutator motor consists of 4 main components.

1.

2.

3.

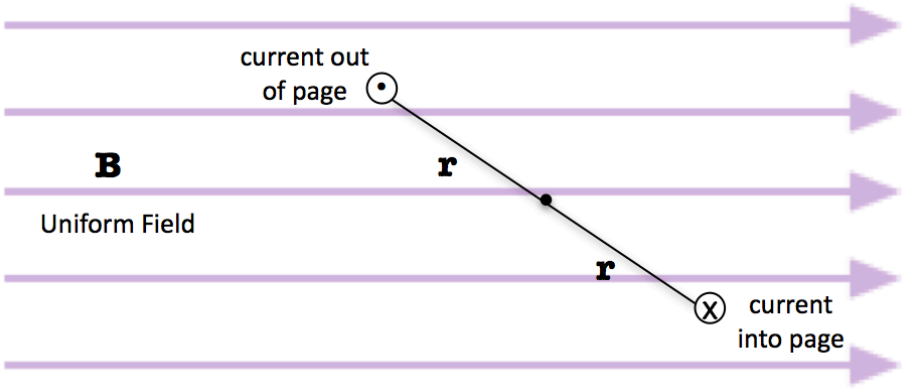
4.

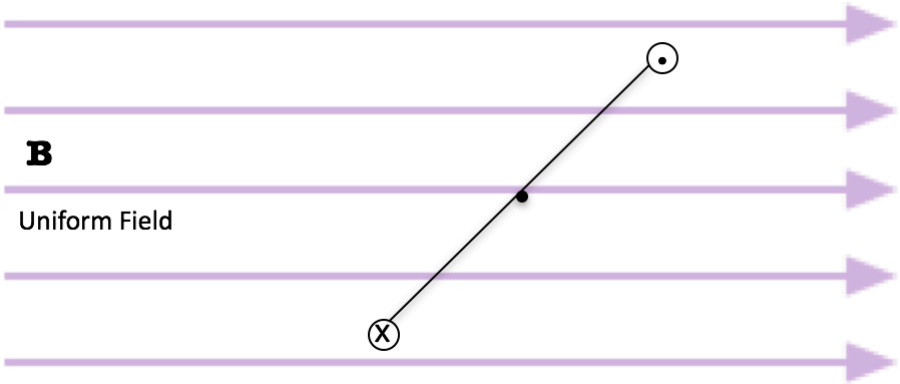


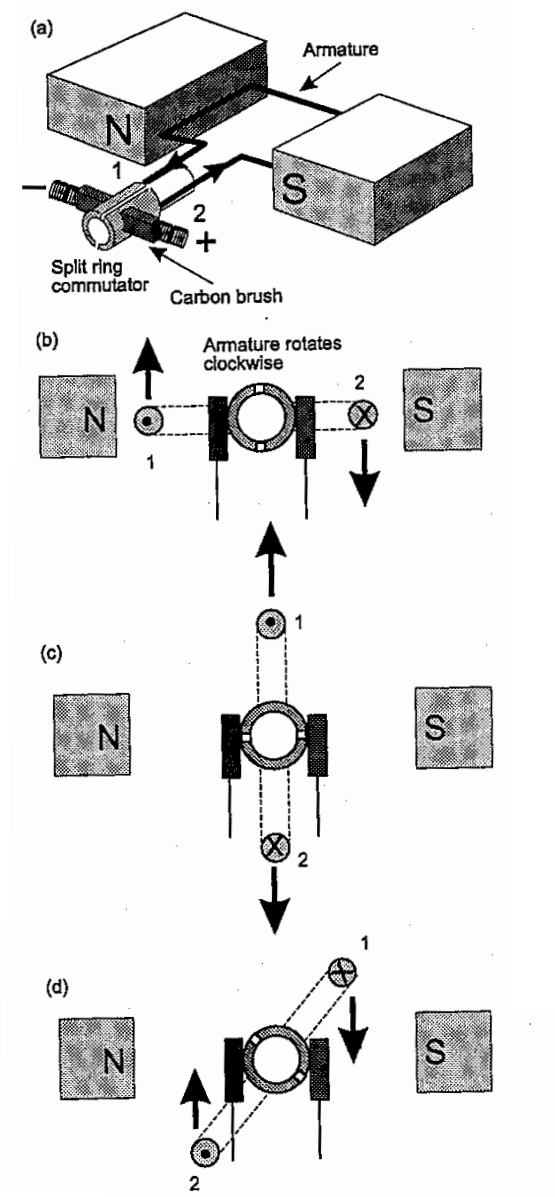
Electromagnetism #3

Why does a motor turn?

-
-
-
-







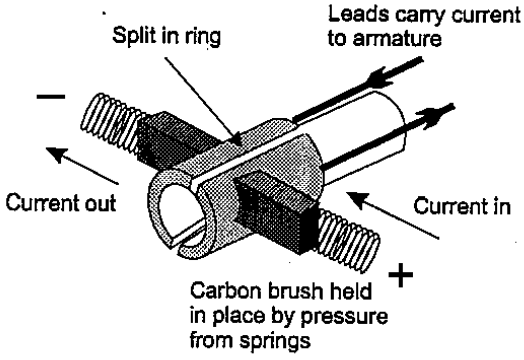
- As the armature rotates it will eventually reach a vertical position.
- At this point, the force on each side of the armature will act directly through the pivot – therefore there is no torque.
- Momentum will carry the armature just past the vertical but if the direction of the current is not reversed, the torque will now be in the opposite direction to what it was originally.

➡

- The split-ring commutator is required to change the direction of the current though the armature once every half a cycle. By doing this:

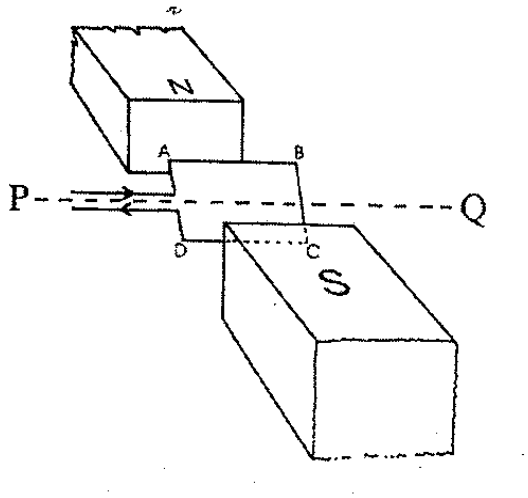
➡

➡



Electromagnetism #3

1. The coil ABCD (as shown in the diagram below) is free to rotate about the axis PQ. The coil consists of 25 turns and a current of 2.20 A passes through it. The coil is rectangular and AB = 55.0 mm and BC = 35.0 mm. B = 98.0 mT.



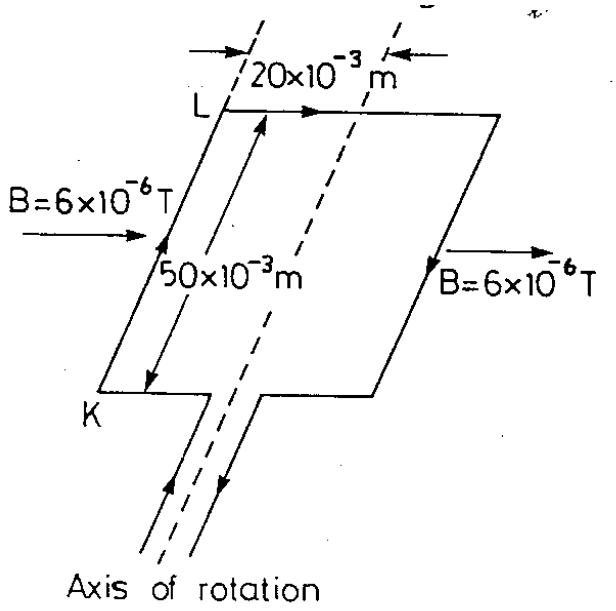
(a) On the diagram above show the direction of the force exerted on each side of the coil.

(b) In which direction (looking **from** P) is the coil rotating?

(c) Determine the force exerted on the side AB of the coil.

(d) Determine the torque on the coil.

2. A rectangular wire loop has dimensions as shown. If the horizontal (from left to right) magnetic field has a strength of 6.00×10^{-6} T;

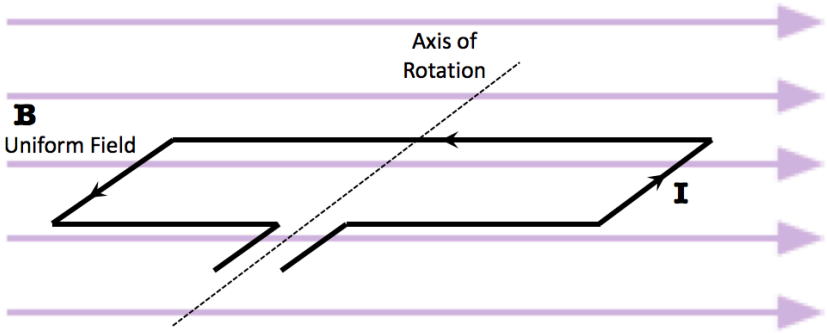


(a) What force is experienced by KL when a current of 5.00 A flows in the loop?

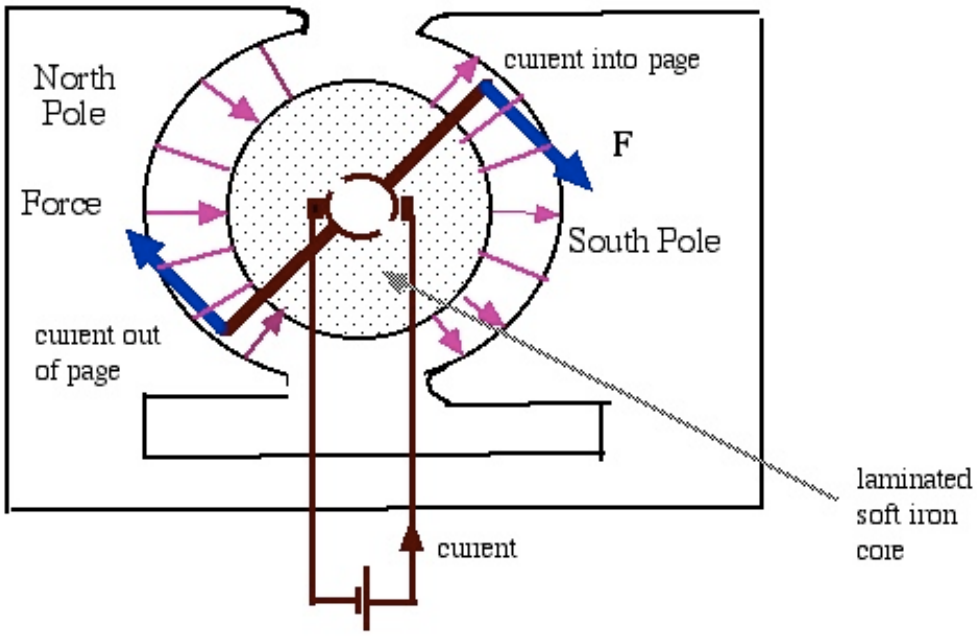
(b) In which direction is the coil rotating?

(c) What is the torque on the loop?

MAXIMISING TORQUE



In a uniform field the plane of the coil is not always parallel to the field lines – this means the torque will vary.



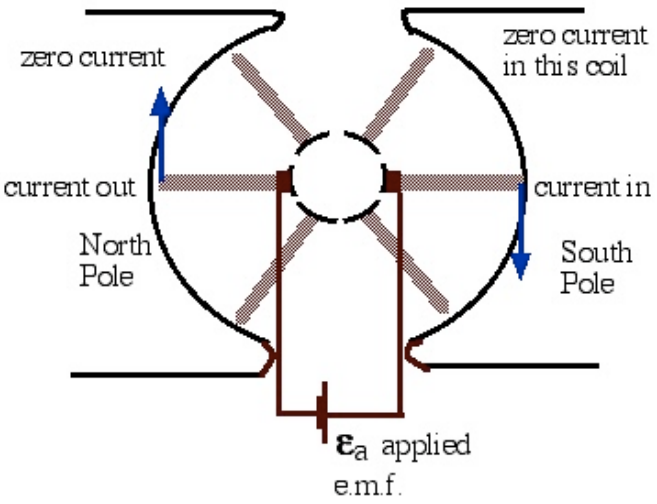
In a radial field, the plane of the coil is almost always parallel to the field lines.

Electromagnetism #3

An alternative method to maximise torque is to use a multi split-ring commutator and multiple coils.

Current flows through the coil that will provide the maximum torque at that point in time. i.e. it flows through the coil that is parallel to the magnetic field at that point in time.

A multi split-ring commutator can also be used in conjunction with a radial magnetic field.



Three coils at 60º

To maximise the torque of a motor:

1.

-
-
-

2.

-
-
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3.

-
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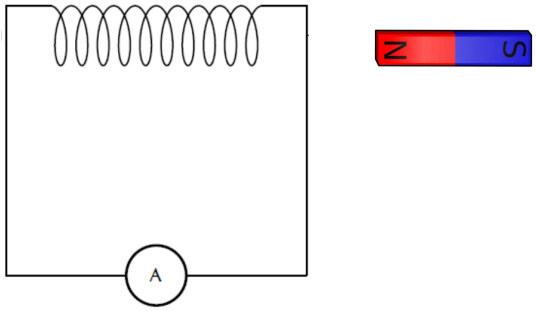
4.

-
-

5.

-
-

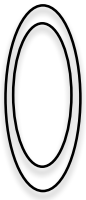
ELECTROMAGNETIC INDUCTION

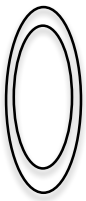


FARADAY'S LAW OF INDUCTION:

LENZ'S LAW

Example:





Electromagnetism #3

Why Lenz's Law?

It is required by:

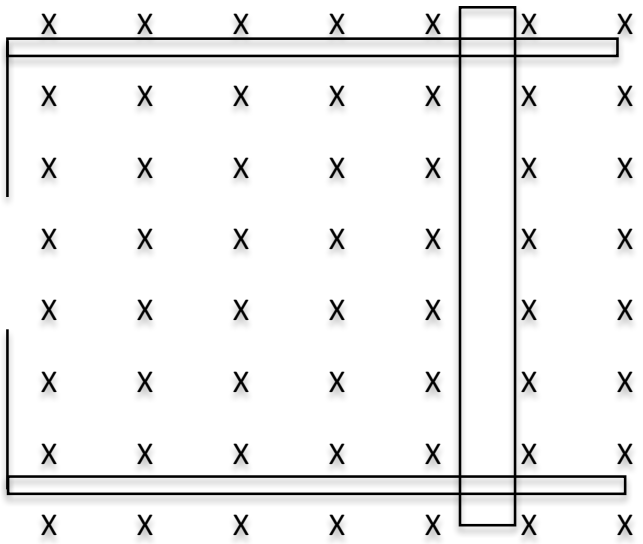
If the current in the loop attracted an approaching North Pole (or vice versa), therefore causing it to accelerate:

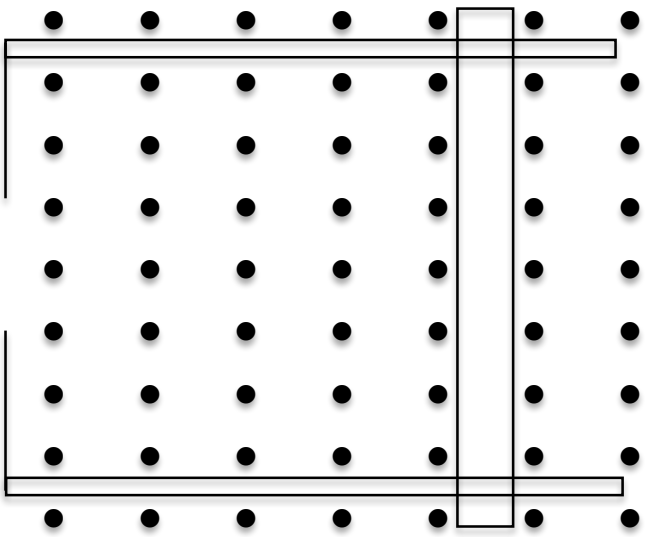
-

The magnet cannot accelerate unless there is work being done on it. We cannot get something from nothing – it is not possible.

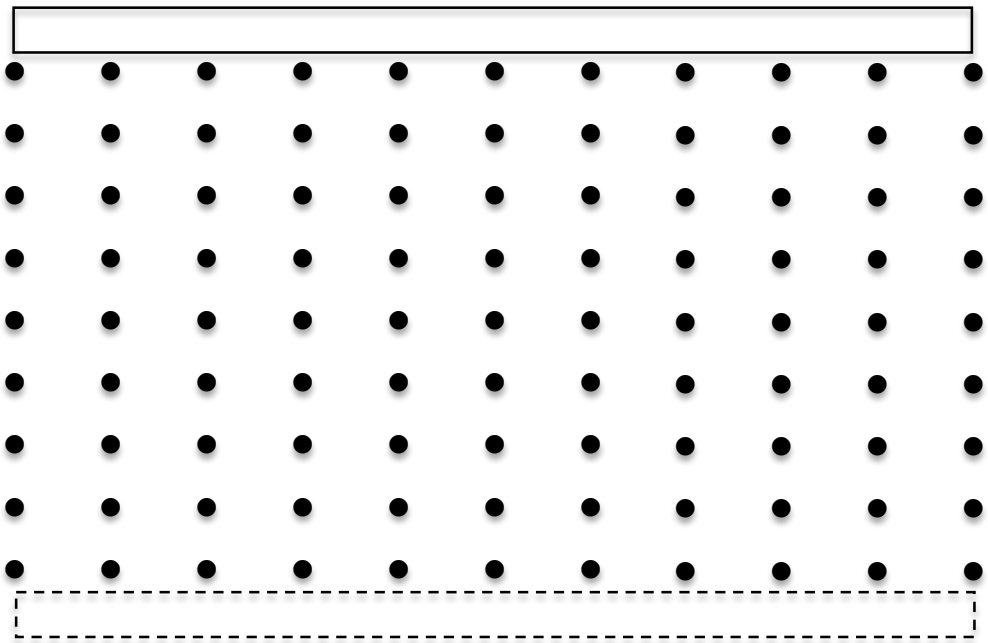
More examples:

- In a piece of metal there are positive and negative charged particles.
- When a rod moves in an external magnetic field, forces will be exerted on the charged particles (both positive and negative).
- The forces on the different particles will be in the opposite directions leading to a separation of charge – an emf (voltage).
- In real life the protons in the positively charged nuclei are not able to move freely. The free conduction electrons can, however, and so we still end up with one end of the rod having a more negative potential than the other (so we still end up with an emf).
- This is identical to the separation of charge we have in a cell, expect that in the cell the separation of charge is due to a chemical reaction, not motion within a magnetic field.





MOTIONAL EMF



INDUCED EMF - EXAMPLES

1. A coil consisting of 50 turns of wire has an area of 1.50×10^2 cm^2 and is rotating in a field of 5.00 mT. If it takes the plane of the coil 0.0500 s to go from a position parallel to the field to a position perpendicular to it. What is the emf induced in the coil?

2. What is the emf induced between the ends of a vertical rod 25.0 cm long that is moving in a northerly direction through a magnetic field (directed to the west) of 3.50×10^2 mT at 5.00 ms^{-1}. Which end will have the higher potential (i.e. be more positive)?

INDUCED EMF – QUESTIONS

1. The wing of a plane is 8.50 m long. If the plane is travelling at 8.40×10^2 kmh^{-1} in a region where the Earth's magnetic field has a vertical component of 6.40×10^{-4} T, what magnitude of emf could be produced in the wings?

[1.27 V]

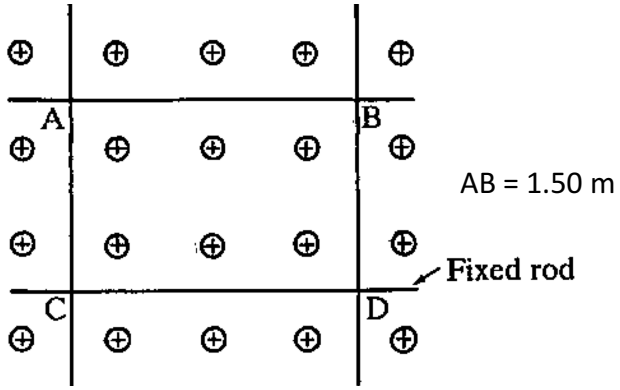
2. What magnitude of emf would be induced in a horizontal wire 2.50×10^2 cm long placed at the equator, when it is moving horizontally west at a rate of 2.05 ms^{-1}? The earth's field has a vertical intensity of 4.00×10^{-5} T.

[2.05×10^{-4} V]

3. A voltage of 1.54 mV is induced in the axle of a train. If the train axle is 2.91 m long and the train travelling at 40.0 kmh^{-1}, what is the strength of the vertical component of the earth's magnetic field at this place?

[4.76×10^{-5} T]

4. The conducting rod AB makes contact with the metal rails CA and DB. The apparatus is in a uniform magnetic field of flux density 0.700 T.



(a) Find the magnitude and direction of the emf induced in the rod AB when it moves away from CD at 2.00 ms^{-1}.

[2.10 V, left end is at the higher potential]

(b) If the resistance of the circuit ABCD is 0.400 Ω, find the magnitude of the force required to keep the rod in motion.

[5.51 N]

(c) Calculate the rate at which mechanical work is done on the rod AB (neglect friction).

[11.0 W]

5. A coil of 50 turns with a cross-sectional area of 2.00×10^2 cm^2 is situated in a field of 6.55×10^{-2} T, which diminishes to 3.05×10^{-2} T in 50.0 milliseconds. Calculate the magnitude of the induced emf.

[0.700 V]

6. A coil of 30 turns and area 0.0400 m^2 is placed in a horizontal field of 2.00×10^{-2} T so that the flux enters the face of the coil perpendicularly. If the coil has a resistance of 20.0 Ω and is connected to an ammeter of 30.0 Ω resistance, calculate the current through the ammeter when the plane of the coil is:

(a) Rotated to the horizontal in 0.0100 s.

[4.80×10^{-2} A]

(b) Completely reversed in 0.0500 s.

[1.92×10^{-2} A]

7. A linear generator consists of a conducting rod sliding on a pair of parallel conducting rails 1.20 m apart with a magnetic field intensity of 1.40 T perpendicular to the plane of the rails. The induced emf is 62.0 V and the generator delivers power to a 12.0 Ω resistor.

(a) Calculate the speed of the sliding rod.

[36.9 ms^{-1}]

(b) What force is required to push the rod?

[8.68 N]

(c) Calculate the amount of electrical power dissipated as heat in the resistor.

[3.20 x 10^2 W]

GENERATORS

An electrical generator is a device that converts mechanical energy to electrical energy.

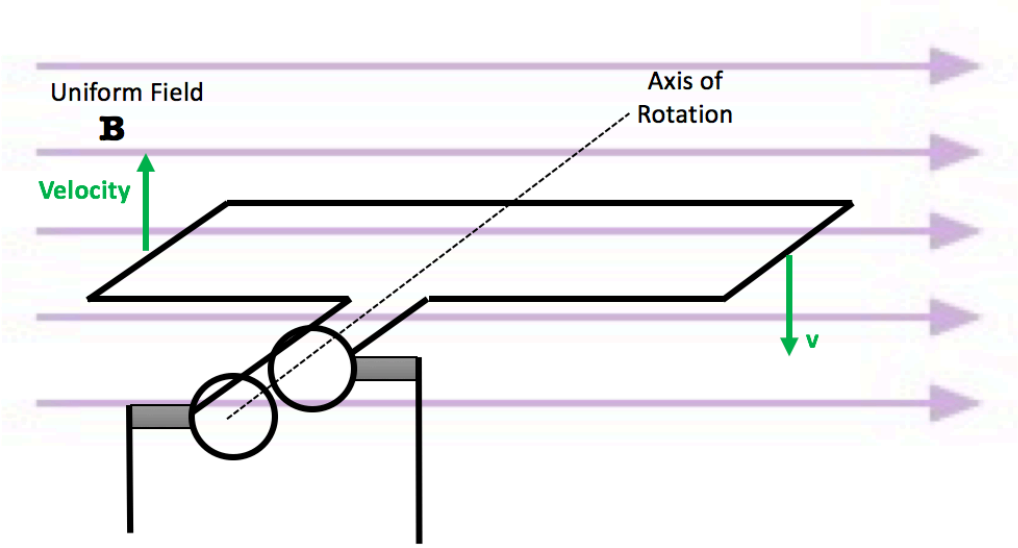
An AC generator consists of 4 main components.

1.

2.

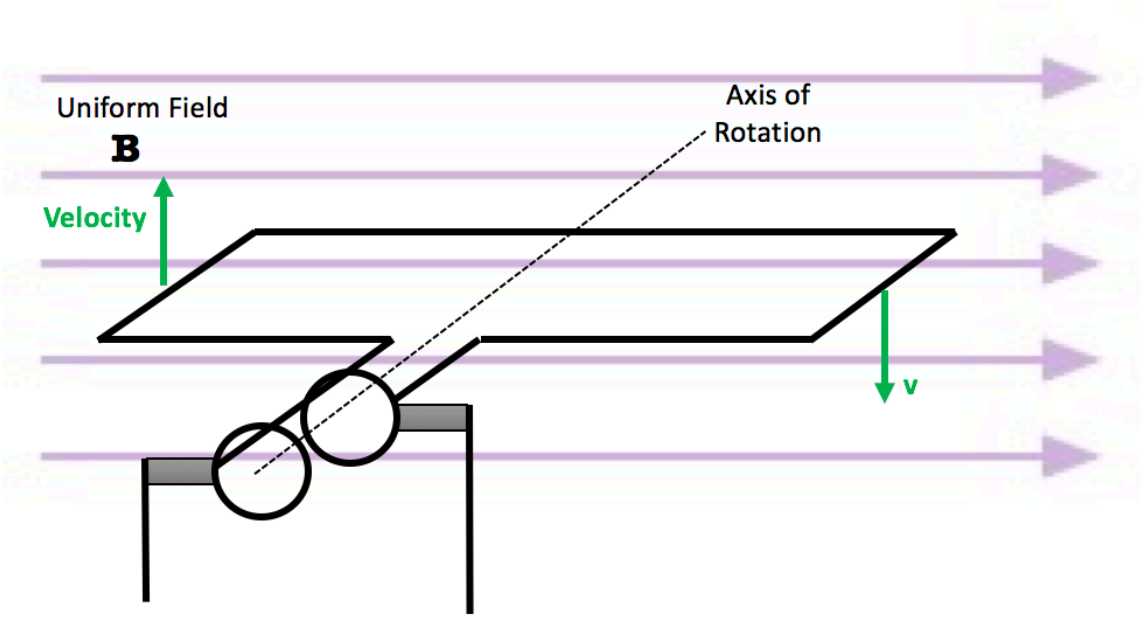
3.

4.

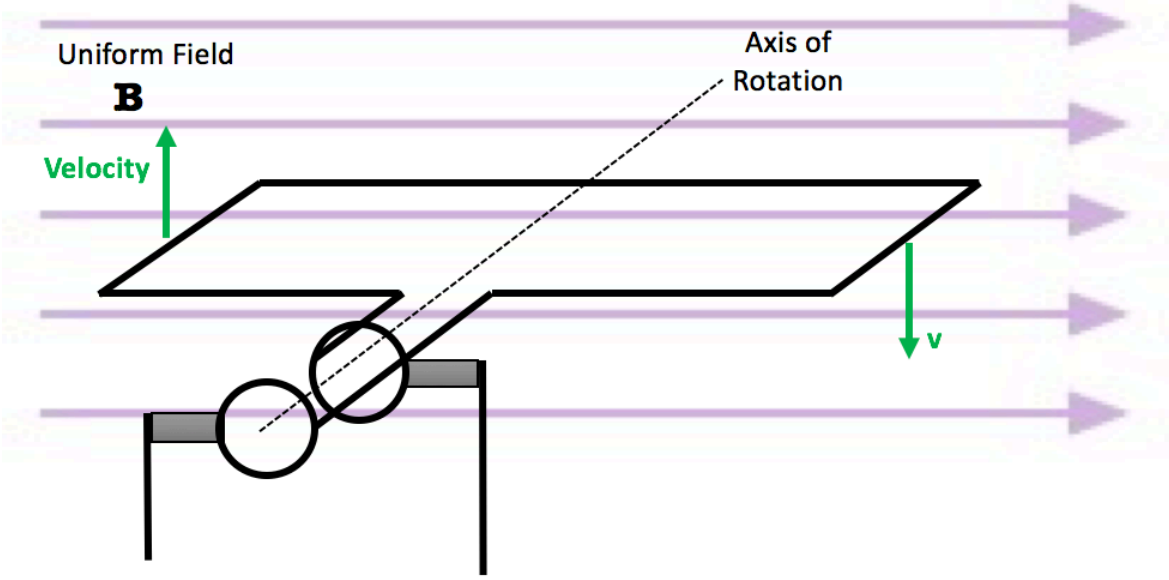


Electromagnetism #3

Why is AC produced (when using slip rings)?



After half a cycle…….



To produce DC, a split-ring commutator can be used in place of the slip rings- the magnitude of the current will still change, but not the direction.

Electromagnetism #3

AC current can be represented as a sine wave.

What is the relationship between induced emf and magnetic flux?

Heuristically:

Mathematically:

Electromagnetism #3

If you are calculus inclined……..

Equations we all need to know……..