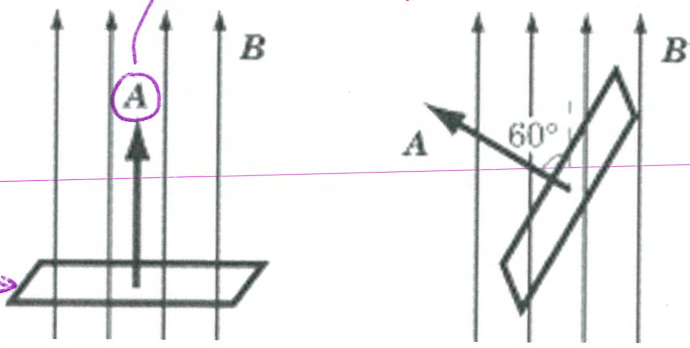
Electromagnetism #3 Name: SOLUTIONS

MAGNETIC FLUX

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

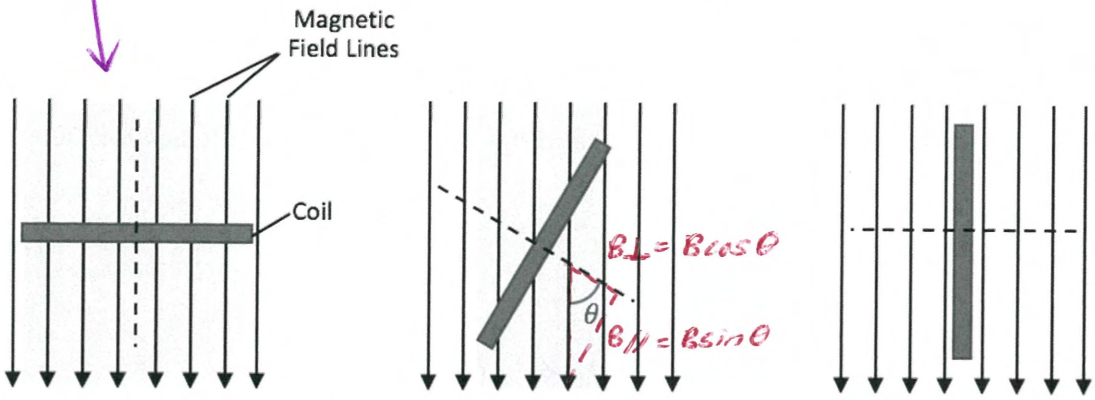
It is a measure of the number of field lines passing through a region (effectively a measure of the concentration of the magnetic field).

AREA VECTOR ($\perp$ TO PLANE OF COIL)
$\Rightarrow$ Normal line



PLANE OF THE COIL

WHEN B LINES ARE PERPENDICULAR TO PLANE OF COIL
$\vec{B}$ & $\vec{A}$ - ANGLE BETWEEN = 0
$\Rightarrow$ MAXIMUM magnetic Flux



MAX FLUX

ZERO FLUX

$\theta = 0°$ $\theta = 60°$ $\theta = 90°$

Note: Datasheet $\phi = BA_\perp$

$$\boxed{\phi = BA\cos\theta}$$

θ - Angle between B & the Normal to the Area Plane

ϕ - magnetic Flux [webers Wb]

1 Wb $\equiv$ 1 Tm^2

B - Magnetic Flux Density [T]

WHEN B LINES ARE PARALLEL TO PLANE OF COIL
$\vec{B}$ & $\vec{A}$ - ANGLE BETWEEN = 90°
$\Rightarrow$ ZERO magnetic Flux

Electromagnetism #3

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]

$\phi = BA$

$= 0.502(1.56 \times 10^{-2})$

$= 7.83 \times 10^{-3}$ Wb

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

[3.69 T]

$\phi = BA$

$B = \dfrac{\phi}{A} = \dfrac{6.09 \times 10^{-4}}{165 \times (10^{-3})^2}$

$= 3.69$ 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]

$\phi = BA$

$= (2 \times 10^{-2})(4 \times (10^{-2})^2)$

$= 8.00 \times 10^{-6}$ 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:

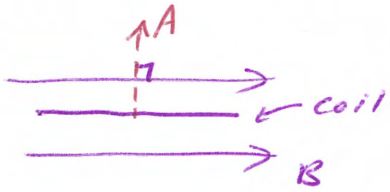
360° in 4.00 s

(a) 1.00 s

[0.00 Wb]

$\frac{1}{4}$ rotation ∴ coil is horizontal $\theta = 90°$

$\phi = 0.00$ Wb



OR $\phi = BA\cos\theta$

$= 1.50(3\times10^{-2})\cos 90°$

$= 0.00$ Wb.

(b) 2.00 s

[4.50×10^{-2} Wb]

$\frac{1}{2}$ rotation ∴ coil is vertical $\theta = 0°$

$\phi = BA$

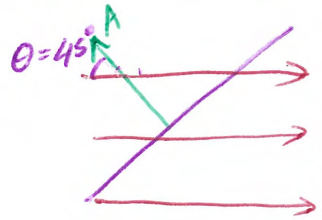
$= 1.5(3\times10^{-2})$

$= 4.50 \times 10^{-2}$ Wb

(d) 0.500 s

[3.18×10^{-2} Wb]

$\frac{1}{8}$ rotation ∴ coil is at 45°



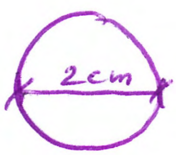
$\phi = BA\cos 45°$

$= 1.5(3\times10^{-2})\cos 45°$

$= 3.18 \times 10^{-2}$ Wb

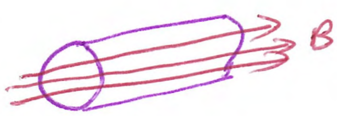
5. The flux density in a cylindrical iron rod of diameter 2.00 cm is 2.10 T. What is the total magnetic flux inside the rod?

[6.60×10^{-4} Wb]



$A = \frac{\pi D^2}{4}$

$= \frac{\pi (2\times10^{-2})^2}{4}$



$\phi = BA$

$= 2.10 \times \pi \times \frac{(2\times10^{-2})^2}{4}$

$= 6.60 \times 10^{-4}$ Wb

Electromagnetism #3

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

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

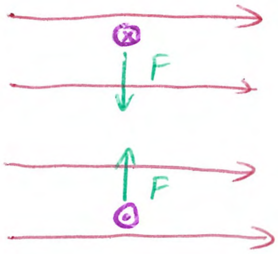
[35.9 T]

$\phi = BA$

$B = \dfrac{\phi}{A} = \dfrac{6.46 \times 10^{-2}}{(3 \times 10^{-2} \times 6 \times 10^{-2})} = 35.9\ T$

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

[2.58 x 10^{-5} N]



$F = BIl$

$= 35.9(12 \times 10^{-6})(6 \times 10^{-2})$

$= 2.58 \times 10^{-5}\ N$ PER SIDE

(PERPENDICULAR TO B & l)

7. At a certain place on the Earth's surface, the horizontal component of the Earth's magnetic field is 4.50 x 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 x 10^{-2} Wb]

$v = 25.0\ m/s$

$l = 12.0\ m$

$B = 4.50 \times 10^{-5}$

$\phi / s = ?$

In 1 s

$s = vt$

$= 25(1)$

$= 25.0\ m$

$A = sl = 25.0(12)$

$= 300\ m^2$

$\phi = BA$

$= 4.50 \times 10^{-5} \times 300$

$= 1.35 \times 10^{-2}\ Wb$

MOTORS

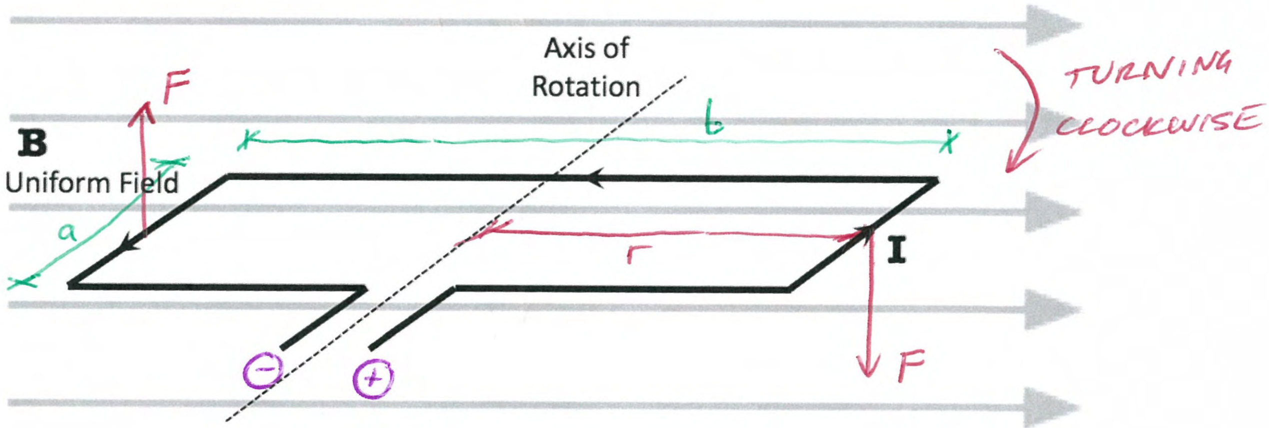
An electric motor is a device that converts electrical energy to mechanical energy.

electrical → mechanical

A DC Commutator motor consists of 4 main components.

1. ROTOR (a.k.a ARMATURE) THIS PART ROTATES (shaft connected)
   - COIL THROUGH WHICH CURRENT FLOWS USUALLY COPPER
2. STATOR THIS PART IS STATIONARY
   - MAGNETIC FIELD STRUCTURE CAN BE PERMANENT MAGNETS OR ELECTROMAGNETS
3. COMMUTATOR - SPLIT RING CONNECTED TO ROTOR
4. BRUSHES CONNECTED TO POWER SUPPLY. IN CONTACT WITH COMMUTATOR

THESE ALLOW CURRENT TO BE SUPPLIED TO ROTOR



ON SIDE 'b', I is // to B ⇒ NO FORCE

ON ONE SIDE 'a'

$F = I l B$

$= I a B$

TORQUE ON WHOLE MOTOR

$\tau = 2 \times \frac{b}{2} I a B$

$= a b I B$

TORQUE ON ONE SIDE 'a'

$\tau = r F \sin\theta \quad \theta = 90°$

$= r F$

$= \frac{b}{2} I a B$

2 LOTS

CLOCKWISE

$A = ab$ ← Area of coil

$\tau = AIB$ ← 1 coil

Let N = number of turns/coils

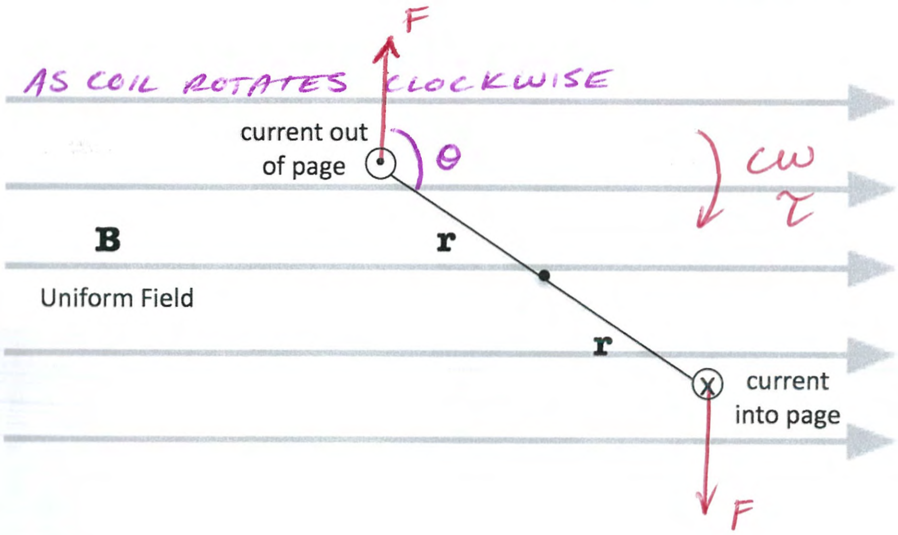
Not on datasheet

$$\boxed{\tau = NAIB\sin\theta}$$

Electromagnetism #3

Why does a motor turn?

- CURRENT FLOWS THROUGH ROTOR
  → PRODUCES ITS OWN MAGNETIC FIELD
- STATOR PRODUCES AN EXTERNAL MAGNETIC FIELD
  → MAGNETIC FIELD OF ROTOR INTERACTS WITH THAT OF STATOR
- INTERACTION OF MAGNETIC FIELDS
  ⇒ FORCE
- ON THE ROTOR, EQUAL FORCES IN OPPOSITE DIRECTIONS
  ⇒ TORQUE



F & B ARE ALWAYS PERPENDICULAR

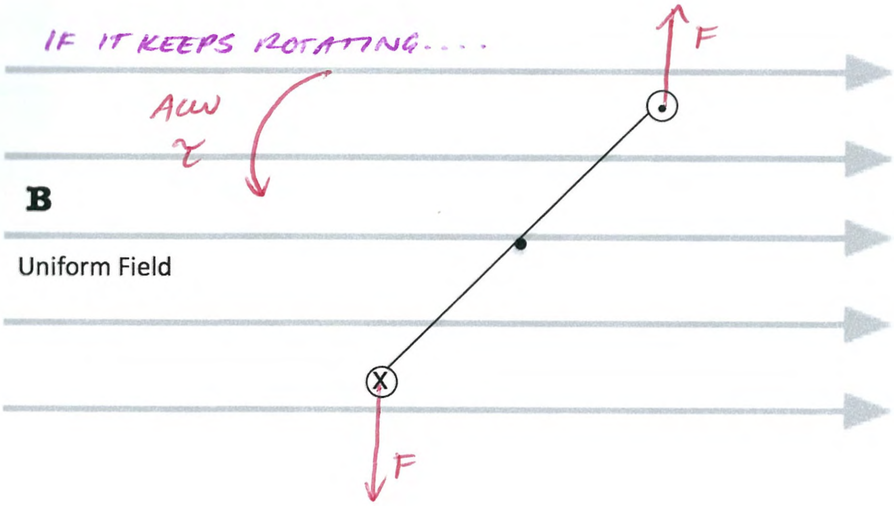
FORCE IS SAME

$\tau = rF\sin\theta$

$\theta > 90°$

$\sin\theta < 1$

TORQUE IS REDUCED

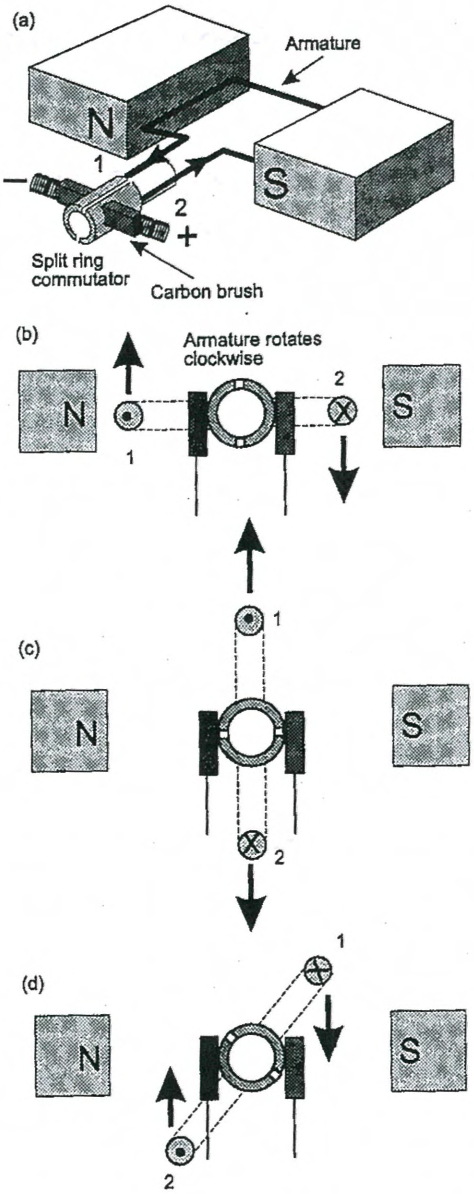


ONCE IT HAS ROTATED PAST 90°

→ TORQUE IS REVERSED.

IF WE WANT CONSTANT ROTATION WE MUST

REVERSE THE CURRENT EVERY HALF CYCLE



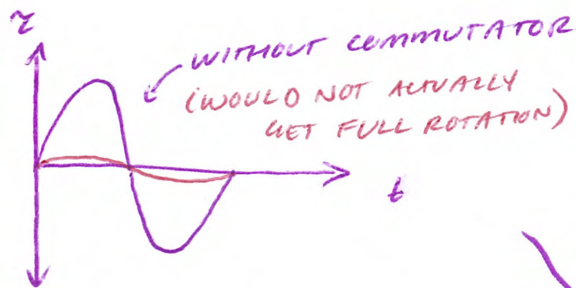
- As the armature rotates it will eventually reach a vertical position.
- At this point, the force on each side of the armature will act directly through the pivot – therefore there is no torque.
- Momentum will carry the armature just past the vertical but if the direction of the current is not reversed,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

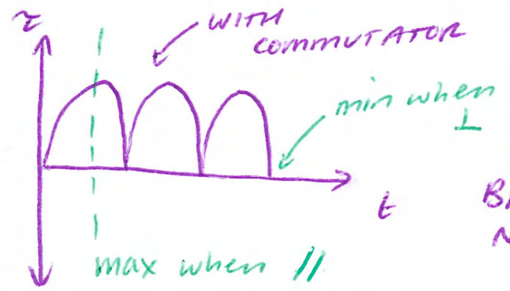
➡ THE MOTOR WOULD NOT TURN (IT WOULD OSCILLATE ABOUT VERTICAL)

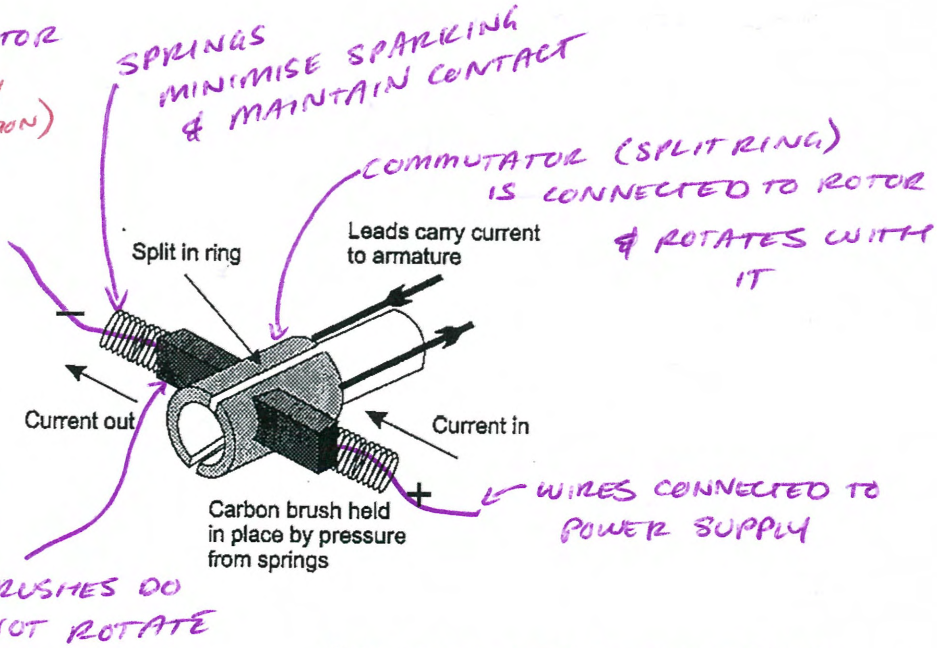
- The split-ring commutator is required to change the direction of the current though the armature once every half a cycle. By doing this:

➡ DIRECTION OF CURRENT IN EACH SIDE OF THE MOTOR (LHS & RHS) IS ALWAYS THE SAME

➡ TORQUE ALWAYS ACTS IN ONE DIRECTION

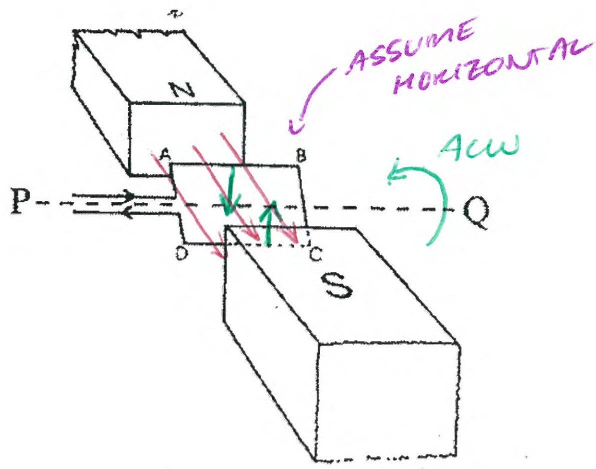






BRUSHES AND COMMUTATOR ARE WEARING PARTS

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.



$N = 25$

$I = 2.20 A$

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

NO FORCE ON AD OR BC (IF HORIZONTAL)

(IF NOT HORIZONTAL, COMPONENT OF B CAUSES FORCE TO CENTRE OF ROTOR - OFFSET BY OPPOSITE SIDES)

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

ANTI CLOCKWISE

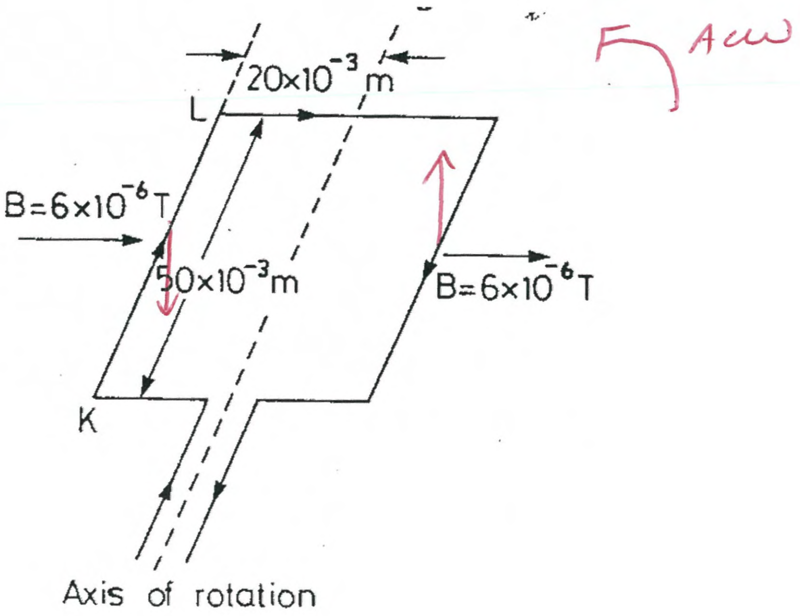
(c) Determine the force exerted on the side AB of the coil.

$$F = BIl \times N$$
$$= (98\times10^{-3})(2.20)(55\times10^{-3})\times 25$$
$$= 2.96\times10^{-1} N \text{ DOWN}$$

(d) Determine the torque on the coil.

$$\tau = 2rF$$
$$= 2\times\left(\frac{35\times10^{-3}}{2}\right)(2.96\times10^{-1})$$
$$= 1.04\times10^{-2} Nm \text{ ANTICLOCKWISE}$$

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?

$F = BIl$

$= 6 \times 10^{-6} (5.00)(50 \times 10^{-3})$

$= 1.50 \times 10^{-6}$ N DOWN

(b) In which direction is the coil rotating?

ANTICLOCKWISE

(c) What is the torque on the loop?

$\theta = 90°$

$\tau = 2rF\sin\theta$ $\quad \sin 90 = 1$

$= 2(20 \times 10^{-3})(1.50 \times 10^{-6})$

$= 6.00 \times 10^{-8}$ Nm ANTICLOCKWISE

MAXIMISING TORQUE

$\tau = rF\sin\theta$

θ - Angle between r & F

As rotor turns $\theta \rightarrow 180°$

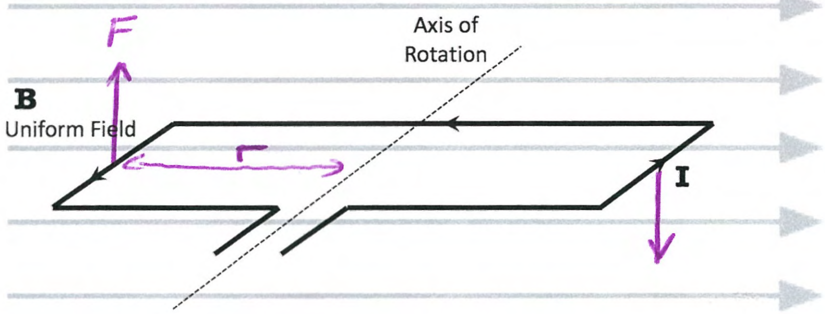
At vertical $\theta = 180°$

As rotor turns $\theta \rightarrow 90°$

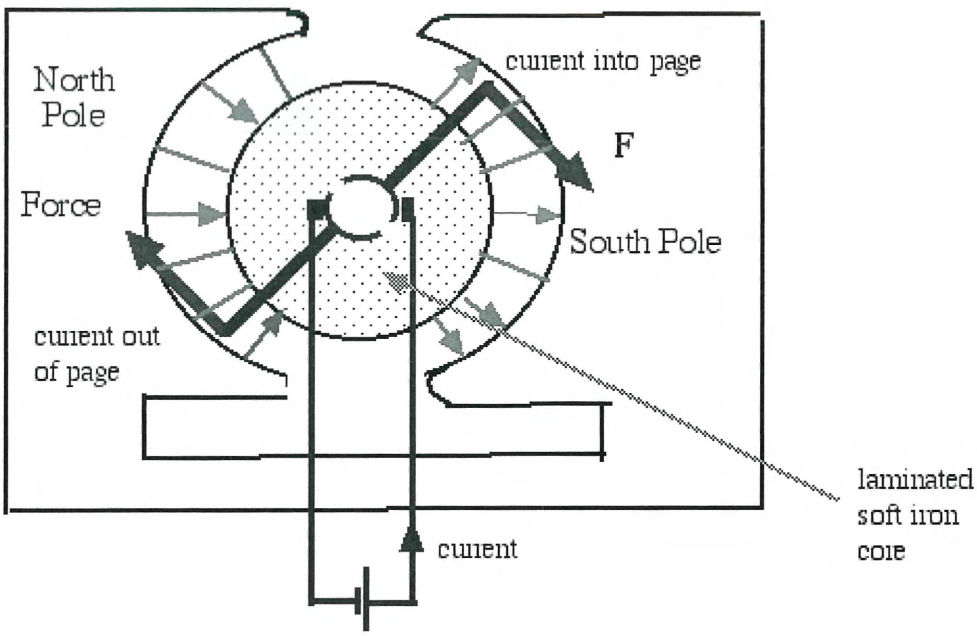
F & B are always perpendicular

τ is reduced when $\theta > 90°$

τ is at maximum when plane of coil is parallel to B.



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.

θ always $\rightarrow 90°$

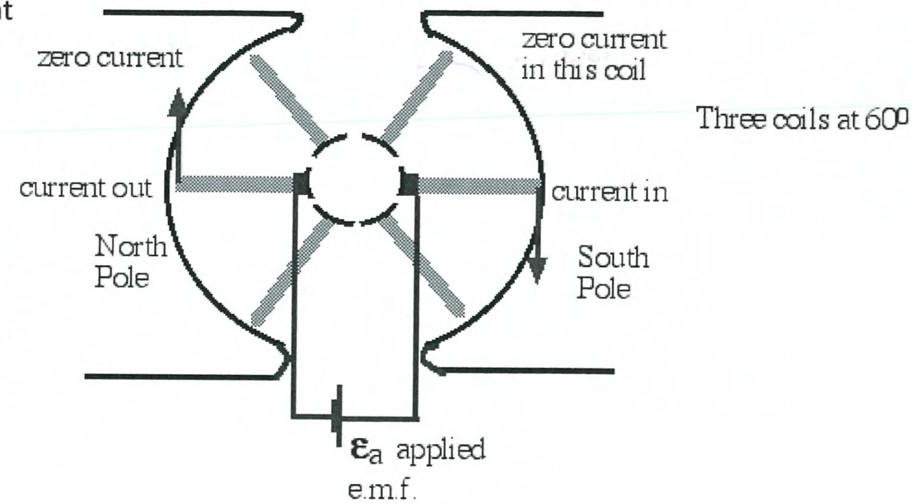
$\tau \rightarrow$ max value at all points in the rotation.

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.



To maximise the torque of a motor:

$$\tau = BANI\sin\theta$$

1. INCREASE B (MAGNETIC FLUX DENSITY)

- STRONGER MAGNET
- ELECTROMAGNET
- INCLUDE A SOFT IRON CORE
- COST ↑
- WEIGHT ↑

2. INCREASE NUMBER OF TURNS

- RESISTANCE ↑
- FOR A GIVEN V, I ↓
- COST ↑
- WEIGHT ↑
- SIZE ↑

3. INCREASE AREA OF COIL

- RESISTANCE ↑
- FOR A GIVEN V, I ↓
- COST ↑
- WEIGHT ↑
- SIZE ↑

4. INCREASE CURRENT (INCREASE OUTPUT OF POWER SOURCE)

- $P = I^2R$ IF I ↑ GREATER DISSIPATIVE HEATING ~resistive
- COST ↑

5. $\theta \rightarrow 90°$

- MULTI SPLIT RING COMMUTATOR
- RADIAL FIELD COST ↑

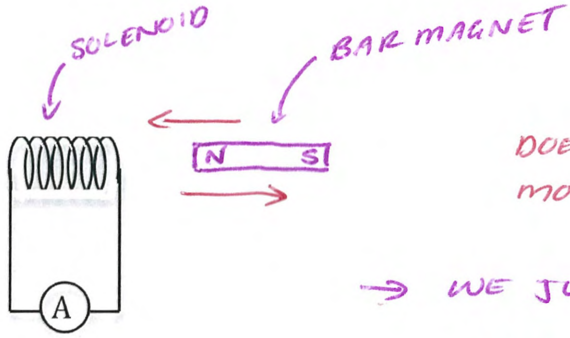
Electromagnetism #3

ELECTROMAGNETIC INDUCTION

THE PRODUCTION OF ELECTRIC CURRENT FROM AN INTERACTION WITH A MAGNETIC FIELD

CURRENT IS PRODUCED WHEN THE MAGNET IS MOVED RELATIVE TO THE COIL

'CUTTING FIELD LINES'



DOESN'T MATTER WHICH MOVES, COIL OR MAGNET

→ WE JUST NEED RELATIVE MOTION BETWEEN THE TWO.

FARADAY'S LAW OF INDUCTION:

IF THE MAGNETIC FLUX THROUGH AN AREA BOUNDED BY A CIRCUIT IS CHANGED, AN emf EQUAL TO THE RATE OF CHANGE OF FLUX WILL BE INDUCED.

emf - Electromotive Force (potential difference)

$$emf = \boxed{\varepsilon = -N\frac{\Delta\phi}{t}}$$

$\phi = BA\cos\theta$

CHECK DATASHEET FOR VARIATIONS PROVIDED

N - Number of turns

$\Delta\phi$ - Change in flux [Wb]

t - Time [s]

Related to the direction of the induced emf

Not mathematically 'negative'

Electromagnetism #3

LENZ'S LAW

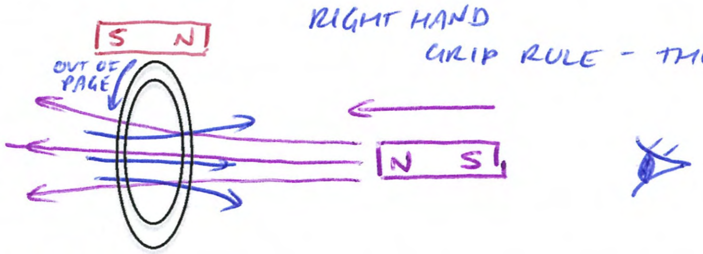
THE DIRECTION OF THE INDUCED emf (CURRENT) WILL BE SUCH AS TO OPPOSE THE CHANGE THAT INDUCED IT

e.g. If the ϕ is increasing in the loop, the direction of the induced current will be such that its associated magnetic field will be in a direction to decrease the ϕ in the loop. $\Rightarrow$ IT IS OPPOSING CHANGE

Example:

RIGHT HAND GRIP RULE - THUMB TO NORTH POLE

CURRENT MUST BE ANTICLOCKWISE

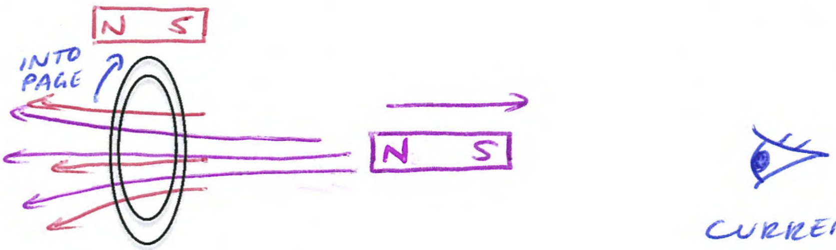


ϕ IS INCREASING AS MAGNET MOVES TOWARDS IT

WANT TO INDUCE FIELD LINES IN OPPOSITE DIRECTION

$\rightarrow$ INDUCED $\mathcal{E}$ MUST PRODUCE A CURRENT WITH AN ASSOCIATED MAGNETIC FIELD IN OPPOSITE DIRECTION TO THE APPLIED FIELD

TRYING TO REPEL



CURRENT MUST BE CLOCKWISE

ϕ IN COIL IS DECREASING

$\rightarrow$ INDUCED $\mathcal{E}$ MUST PRODUCE A CURRENT WITH AN ASSOCIATED MAGNETIC FIELD IN THE SAME DIRECTION TO THE APPLIED FIELD

TRYING TO ATTRACT

NO RELATIVE MOTION = NO CURRENT

Electromagnetism #3

Why Lenz's Law?

It is required by: THE LAW OF CONSERVATION OF ENERGY

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

- The rate of change of flux $\frac{\Delta\phi}{t}$ would increase

➡ INDUCED emf ↑ (Faraday's Law)

➡ INDUCED CURRENT IN THE COIL ↑

➡ MAGNITUDE OF B ASSOCIATED WITH INDUCED CURRENT ↑

➡ ... THE APPROACHING MAGNET WOULD ACCELERATE EVEN MORE

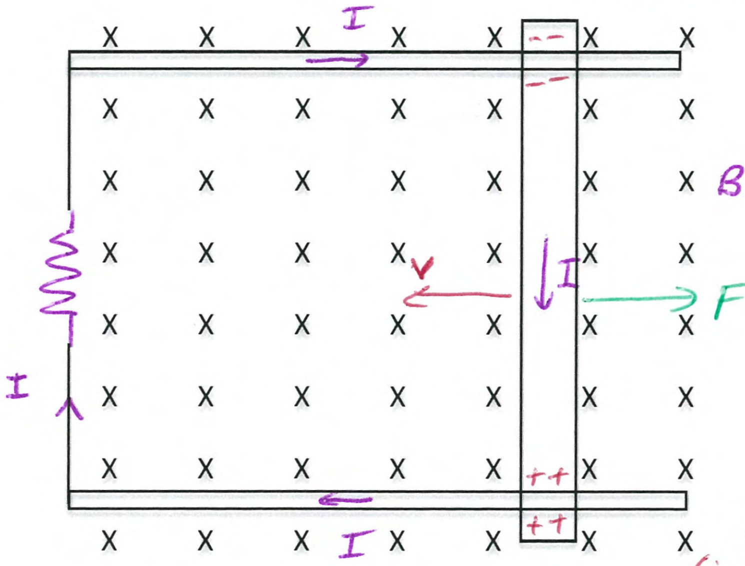
The magnet cannot accelerate unless there is work being done on it. We cannot get something from nothing – it is not possible.

Electromagnetism #3

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.

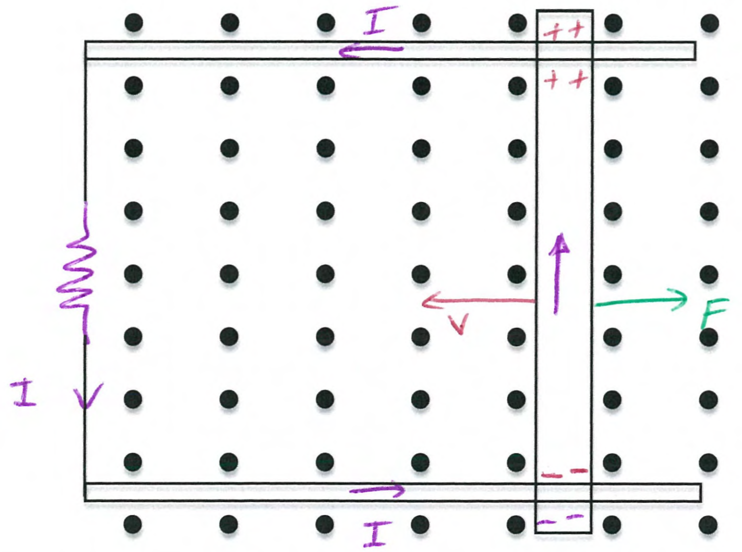
Rod moves with velocity 'v'



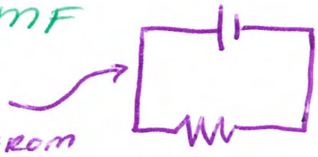
- Φ through circuit decreases with time
- Induced $\mathcal{E}$ / current will oppose this change
- $\therefore$ B from induced current must be pointing into page
  $\Rightarrow$ CW current

In the rod there are ⊕ and ⊖ (in real life ⊕ can't move but ⊖ can)

- As long as the rod keeps moving there will be separation of charge
  $\rightarrow$ EMF



SEPARATION OF CHARGE IS SIMILAR TO THAT FROM A CHEMICAL RX

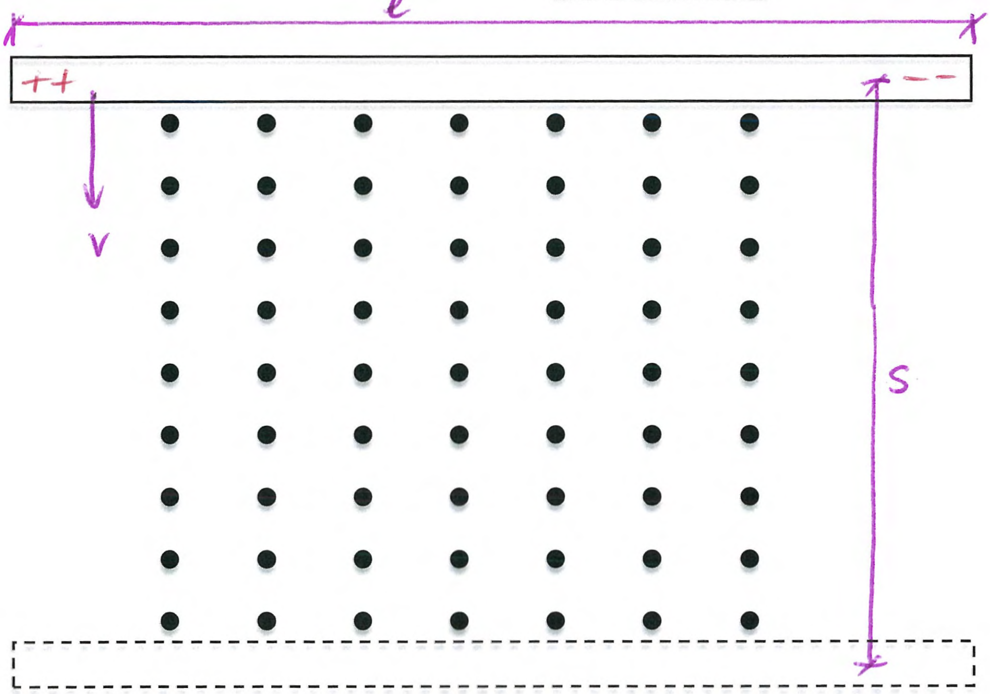


There will be a force due to the current flowing in the bar (the magnetic field of current is interacting with B_{ext})

→ RETARDING FORCE

→ ACTS IN SUCH A DIRECTION AS TO PREVENT CHANGE

MOTIONAL EMF



THE BAR MOVES THROUGH A DISTANCE 's' IN TIME 't'

$$s = tv$$

AREA COVERED BY BAR IN TIME 't'

$$A = sl$$
$$= tvl$$

$$\phi = BA$$
$$= Btvl \rightarrow$$ Change in Flux in the area

$$\mathcal{E} = \frac{\Delta\phi}{t} = \frac{Bl\cancel{t}v - 0}{\cancel{t}}$$

$$\boxed{\mathcal{E} = vlB}$$

$B \perp B$

$\mathcal{E}$ measured in V

$1V \equiv 1JC^{-1}$

Electromagnetism #3

INDUCED EMF - EXAMPLES

1. A coil consisting of 50 turns of wire has an area of 1.50 x 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?

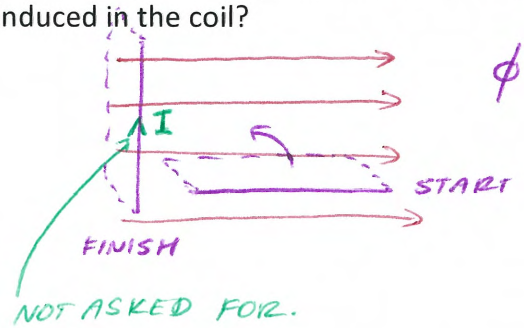
$N = 50$

$A = 1.50 \times 10^2 \times (10^{-2})^2$

$= 1.50 \times 10^{-2}\ m^2$

$B = 5.00 \times 10^{-3}\ T$

$t = 0.05\ s$



ϕ IS INCREASING

$$\mathcal{E} = \frac{-N\Delta\phi}{t} = \frac{-NBA}{t}$$

$$= \frac{50(5.00\times10^{-3})(1.50\times10^{-2})}{0.05}$$

$$= 7.50 \times 10^{-2}\ V$$

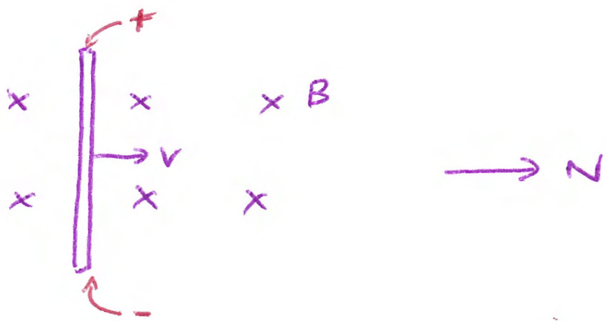
2. What is the emf induced between the ends of a vertical rod 25.0 cm long that is moving in a northerly direction through a magnetic field (directed to the west) of 3.50 x 10^2 mT at 5.00 ms^{-1}. Which end will have the higher potential (i.e. be more positive)?

$l = 25.0 \times 10^{-2}$

$B = 3.50 \times 10^2 \times 10^{-3}$

$= 3.50 \times 10^{-1}\ T$

$v = 5.00\ m/s$



$$\mathcal{E} = vlB$$

$$= 5(25.0\times10^{-2})(3.50\times10^{-1})$$

$$= 4.38 \times 10^{-1}\ V$$

TOP END IS 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]

$v = 840 \times 10^2 / 3.6$
$= 233.3$ m/s

$B = 6.40 \times 10^{-4}$

$l = 8.50$m

$\mathcal{E} = lvB$
$= 8.50(233.3)(6.40 \times 10^{-4})$
$= 1.27$ 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]

$l = 2.50 \times 10^2 \times 10^{-2}$
$= 2.50$m

$v = 2.05$ m/s

$B = 4.00 \times 10^{-5}$ T

$\mathcal{E} = lvB$
$= (2.50)(2.05)(4 \times 10^{-5})$
$= 2.05 \times 10^{-4}$ 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?

[$4.7\cancel{7}^{6} \times 10^{-5}$ T]

$l = 2.91$m

$v = 40/3.6 = 11.11$ m/s

$\mathcal{E} = 1.54 \times 10^{-3}$

$B = ?$

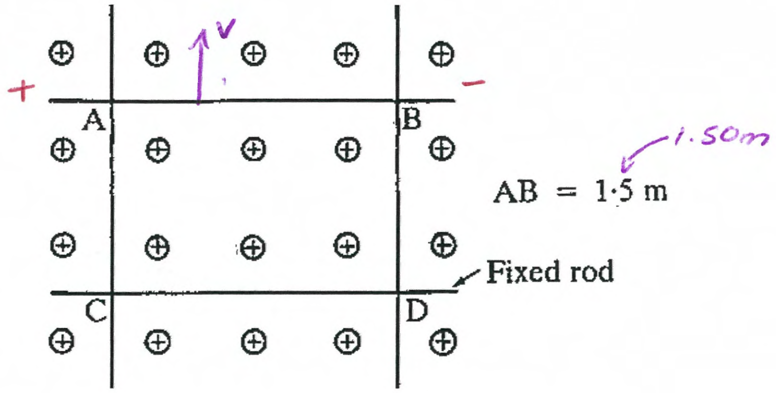
$\mathcal{E} = lvB$

$B = \dfrac{\mathcal{E}}{lv}$

$= \dfrac{1.54 \times 10^{-3}}{(2.91)(11.11)}$

$= 4.76 \times 10^{-5}$ 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]

$\mathcal{E} = lvB$

$= (1.50)(2)(0.7)$

$= 2.10\text{ V}$ LEFT END 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]

$V = IR$ $\quad V = \mathcal{E}$

$I = \frac{\mathcal{E}}{R} = \frac{2.10}{0.400} = 5.25\text{ A}$

$F = BIl$

$= (0.7)(5.25)(1.5)$

$= 5.51\text{ N}$

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

[11.0 W]

$W = F.s$

$P = \frac{W}{t}$ Rate work is done = POWER.

$P = \frac{Fs}{t} = Fv$

$= 5.51(2)$

$= 11.0\text{ W}$

ASSUME ⊥

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

[0.700 V]

$$\mathcal{E} = \frac{N\Delta\phi}{t} = \frac{50(7.00\times10^{-4})}{(50\times10^{-3})} = 7.00\times10^{-1}\ V$$

$$\phi = BA$$
$$\Delta\phi = \Delta B\cdot A = (6.55\times10^{-2} - 3.05\times10^{-2}) \times (2.00\times10^2\times(10^{-2})^2) = 7.00\times10^{-4}\ wb$$

6. A coil of 30 turns and area 0.0400 m^2 is placed in a horizontal field of 2.00 x 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 x 10^{-2} A]

$R_T = 20 + 30 = 50.0\,\Omega$ series connection with ammeter

$\mathcal{E} \equiv V$

$$\mathcal{E} = -\frac{N\Delta BA}{t} = \frac{30(2.00\times10^{-2})(0.04)}{0.01} = 2.40\ V$$

$$I = \frac{V}{R} = \frac{\mathcal{E}}{R} = \frac{2.40}{50} = 4.80\times10^{-2}\ A$$

(b) Completely reversed in 0.0500 s.

[1.92 x 10^{-2} A]

If completely reversed, $\Delta\phi = -2\phi$ OF ORIGINAL DIRECTION

$-\phi + -\phi = -2\phi$

REMOVE ORIGINAL — REPLACE WITH OPP ϕ

$$\mathcal{E} = \frac{-2N\Delta BA}{t} = \frac{2(30)(2.00\times10^{-2})(0.04)}{0.05} = 0.960\ V$$

$$I = \frac{\mathcal{E}}{R} = \frac{0.960}{50} = 1.92\times10^{-2}\ A$$

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}]

$$\mathcal{E} = \ell v B$$

$$v = \frac{\mathcal{E}}{\ell B} = \frac{62.0}{(1.20)(1.40)}$$

$$= 36.9 \, m/s$$

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

[8.68 N]

$$F = BI\ell \qquad I = \frac{V}{R} = \frac{62}{12} = 5.167 \, A$$

$$= (1.40)(5.167)(1.20)$$

$$= 8.68 \, N$$ IN DIRECTION OF VELOCITY

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

[3.20 x 10^2 W]

$$P = I^2 R$$

$$= 5.167^2 (12)$$

$$= 3.20 \times 10^2 \, W$$

GENERATORS

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

WE NEED TO PROVIDE THE MECHANICAL ENERGY TO TURN THE TURBINE.

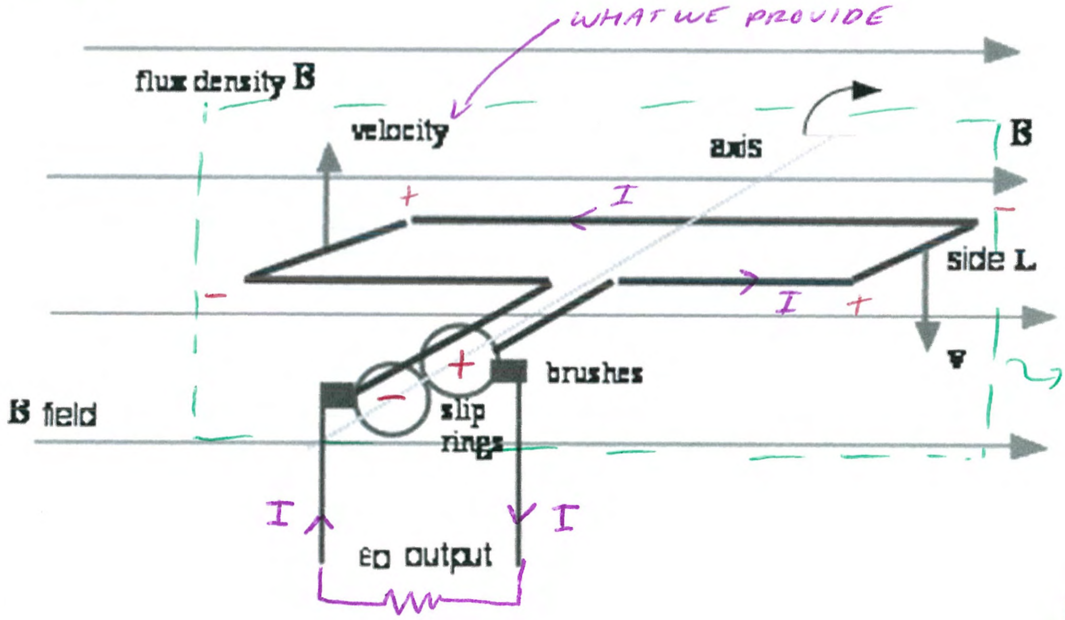
An AC generator consists of 4 main components.

1. ROTOR (ARMATURE)

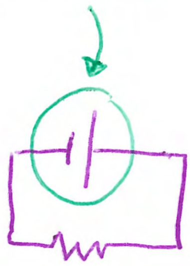
2. STATOR - MAGNETIC FIELD STRUCTURE

3. SLIP RINGS

4. BRUSHES



SOURCE OF EMF



AS THE COIL ROTATES IT CUTS THE MAGNETIC FIELD LINES (MAGNETIC FLUX INSIDE THE COIL CHANGES)

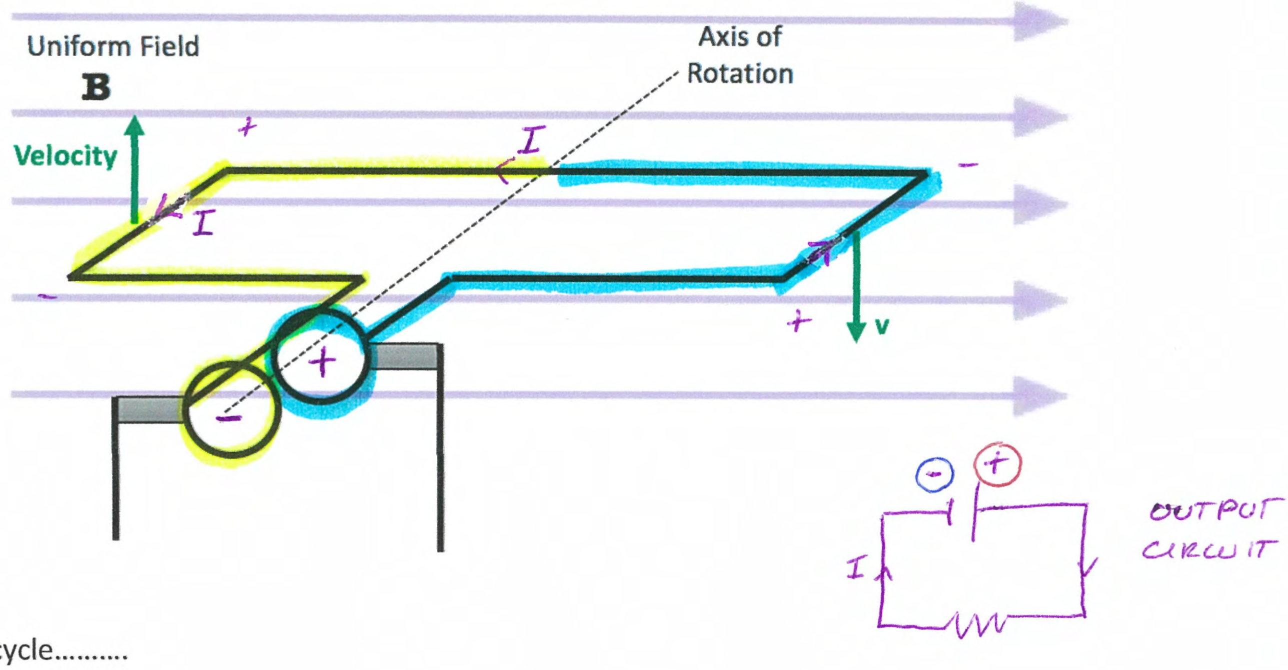
→ emf INDUCED $\varepsilon = -\frac{N\Delta\phi}{t}$

INDUCED CURRENT WILL CHANGE DIRECTION EVERY TIME THE FLUX THROUGH THE COIL REACHES A MAXIMUM

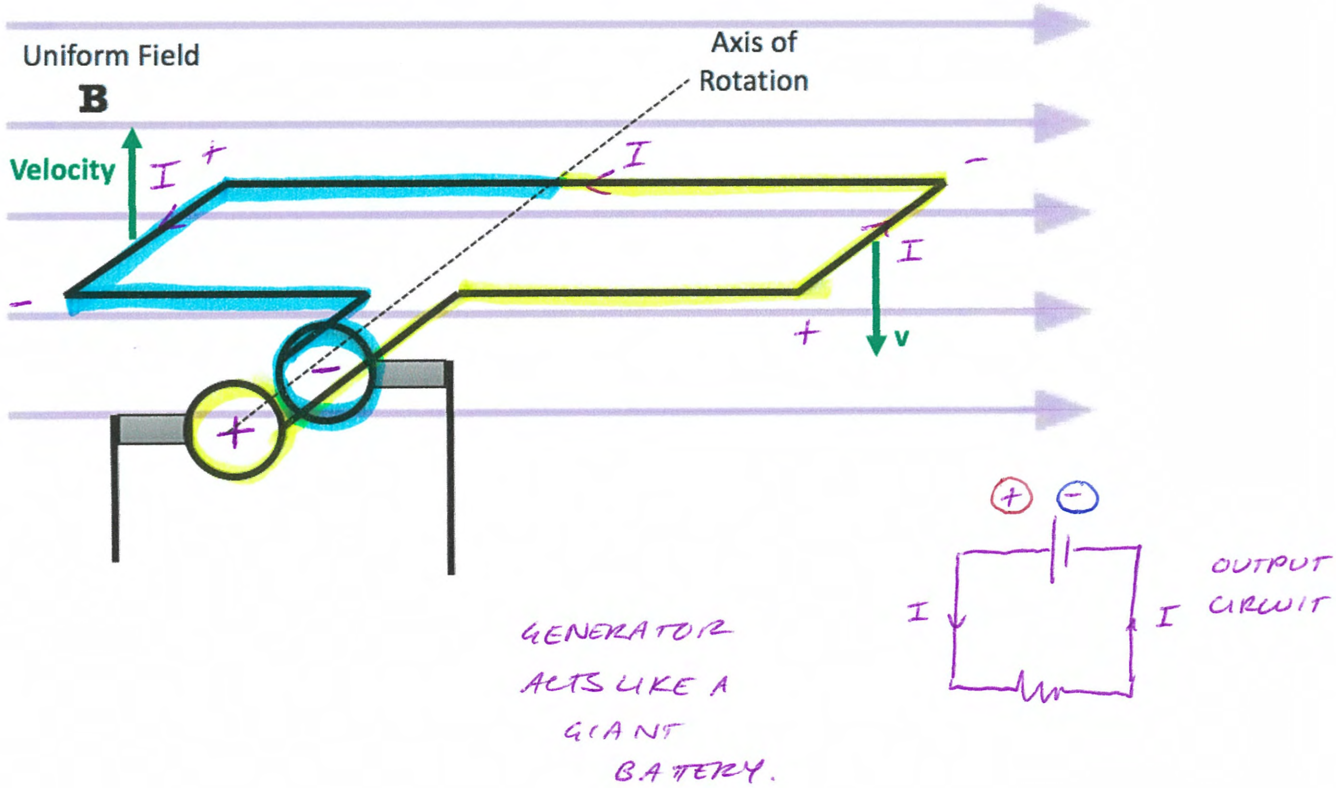
(i.e WHEN PLANE OF COIL IS PERPENDICULAR TO FIELD)

Electromagnetism #3

Why is AC produced (when using slip rings)?



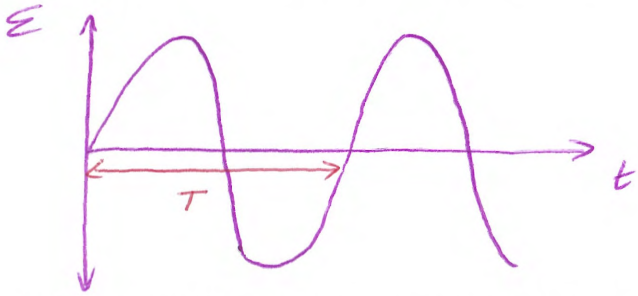
After half a cycle..........



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.

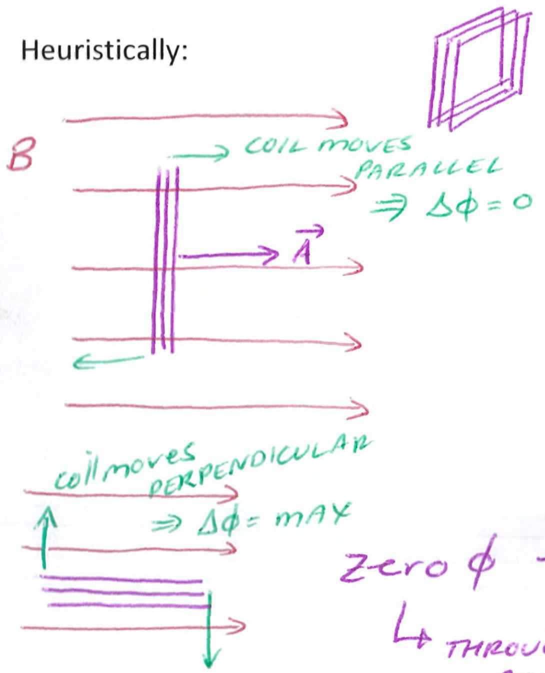


Frequency - No. of oscillations / cycles in 1s [Hz] [s^{-1}]

$f = \frac{1}{T}$ The frequency of the AC depends on the rate of rotation of the generator.

What is the relationship between induced emf and magnetic flux?

Heuristically:



MAXIMUM MAGNETIC FLUX (THROUGH AREA)
→ ZERO INDUCED EMF

AREA VECTOR (NORMAL TO PLANE OF COIL) IS MOVING PARALLEL TO FIELD B.

→ NO FIELD LINES ARE BEING CUT
→ NO INDUCED emf

Zero ϕ → max $\mathcal{E}$ ϕ & $\mathcal{E}$ are 90° out of phase

↳ THROUGH AREA OF COIL

Mathematically:

DETERMINE THE VELOCITY OF COIL IN TERMS OF FREQUENCY & RADIUS

$v = \frac{s}{t}$ s = CIRCUMFERENCE OF A CIRCLE INSCRIBED BY THE COIL

$= 2\pi r$

t = time for 1 revolution

$= \frac{1}{f}$

$v = \frac{2\pi r}{\left(\frac{1}{f}\right)} \Rightarrow \boxed{v = 2\pi r f}$

Electromagnetism #3

If you are calculus inclined...........

$s = tv$

$\theta = t\omega$

ANGULAR VELOCITY MEASURED IN °/s

$$\phi = BA\cos\theta$$

$$\mathcal{E} = -\frac{\Delta\phi}{\Delta t} = \frac{-d\phi}{dt}$$

$$= \frac{-d(BA\cos\theta)}{dt}$$

$$= \frac{-d(BA\cos\omega t)}{dt}$$

$$= -BA\frac{d\cos\omega t}{dt}$$

$$= -BA\omega(-\sin\omega t)$$

$$\mathcal{E} = BA\omega\sin\theta$$

SINE & COSINE ARE BY DEFINITION 90° OUT OF PHASE

ϕ & $\mathcal{E}$ are 90° OUT OF PHASE

Equations we all need to know...........

$$\mathcal{E} = BA\omega \quad (\theta = 90°)$$

$$= BA\,2\pi f$$

$$\boxed{\mathcal{E} = 2\pi BANf}$$

$$\mathcal{E} = 2\pi BANf$$

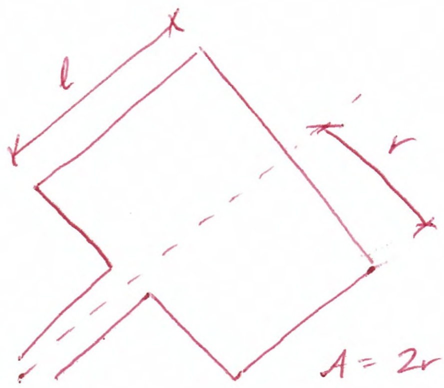
$$= (2\pi)(B)(2\ell r)(Nf)$$

Rearranging

$$= 2\pi rf\,(B)(2\ell)(N)$$

$$= v(B)(2\ell)(N)$$

$$\boxed{\mathcal{E} = 2Nv\ell B}$$



$A = 2r\ell$

$v = 2\pi rf$