



جامعة بغداد

كلية التربية للعلوم الصرفة / ابن الهيثم

\*\*\* قسم الفيزياء \*\*\*

العام الدراسي (٢٠١٩ - ٢٠٢٠) م

محاضرات مادة الكهربائية والمغناطيسية

المرحلة الثانية

\*\* النظري \*\*

التدريسيين

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## Chapter one -

### التيار المتناوب Alternating current -

The alternating current: - The current varying with time  
~~I~~  $I$

The alternating voltage: - The voltage varying with time  
~~V~~  $V$   $I$ .

\* The alternating current are important.  
In technology and industry transmission of power over long distance is very much easier and more economical than direct current.

\* Let a coil have ( $N$ ) turns with section area ( $A$ ) rotating with constant angular velocity ( $\omega$ ) in uniform magnetic field ( $B$ ) develops a sinusoidal alternating emf

$$\mathcal{E} = NAB\omega \sin \omega t$$

$$\therefore \mathcal{E} = E_{\max} \sin \omega t$$

$$E_{\max} = NAWB \quad \sin \omega t = 1. \quad \text{bie}$$

$\mathcal{E}$  :- is alternating emf (instantaneous electro motive force).

$E_{\max}$  :- is the maximum of (emf).

$\omega$  :- is angular velocity  $= 2\pi f$

$f$  :- Frequency.

Suppose we connected the same coil to alternating source the alternating potential difference between the coil is :-

$$V = V_m \sin \omega t$$

$V$  :- is the instantaneous potential difference.

$V_m$  :- is the maximum potential difference.

In the same way we can find the instantaneous current.

$$i = i_m \sin \omega t$$

$i$  :- is the instantaneous current.

$i_m$  :- is the maximum current.

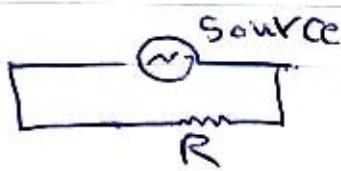
circuits containing resistance  
capacitance and inductance

دالیں کوئی سے ملے گا تو

1- (The resistance) نوٹ  
resistor of

Let ↑ resistance ( $R$ ) be connected between the terminal AC source. The instantaneous potential difference is  $V = V_m \sin \omega t$ .  
and the instantaneous current in the resistance.

$$i = \frac{V}{R} = \frac{V_m \sin \omega t}{R} \Rightarrow \therefore i = i_m \sin \omega t$$



$$i_m = \frac{V_m}{R}$$

(3)

The current and voltage are both proportional with ( $\sin \omega t$ ) so the current is in phase with voltage.

## 2- (The capacitor:-)

Suppose that a capacitor of capacitance ( $C$ ) is connected with the source. the instantaneous potential difference is:-

$$V = V_m \sin \omega t \dots \textcircled{1}$$

$$\therefore q_f = CV = C V_m \sin \omega t$$

$q_f$  :- the instantaneous charge on the capacitor

$$\therefore i = \frac{dq}{dt} \Rightarrow i = C V_m \omega \cos \omega t.$$

$$\therefore i = i_m \cos \omega t \dots \textcircled{2}$$

\* The current is not in phase with voltage

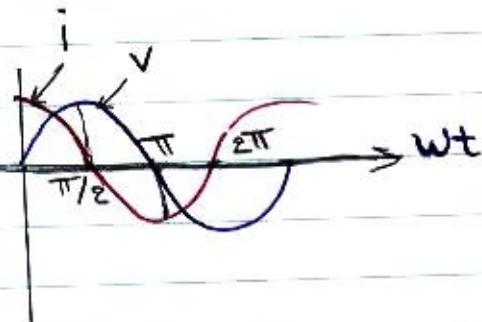
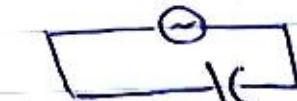
$$i = i_m \sin(\omega t + 90^\circ) \dots \textcircled{3}$$

\* we say the current leads the voltage by  $90^\circ$  or the voltage lags the current by  $90^\circ$

The maximum current  $i_m$  is given by:-

$$\therefore i_m = C V_m \omega.$$

$$\frac{V_m}{i_m} = \frac{1}{C\omega} = \frac{1}{2\pi f C} = X_C$$

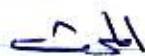


(4)

$X_C$  :- is called the capacitive reactance of Capacitor

$$X_C = \frac{1}{2\pi f C} \quad \text{the unit of } X_C \text{ is ohm (}\Omega\text{)}$$

3- The inductor



$$v = V_m \sin \omega t$$

Suppose a pure inductor having a self inductance ( $L$ ) is connected to an AC source since the instantaneous potential difference is ( $v = V_m \sin \omega t$ ) and the potential difference between terminals of an inductor equal ( $L \frac{di}{dt}$ ).

$$\text{we have } L \frac{di}{dt} = V_m \sin \omega t \quad \boxed{\Sigma = -L \frac{di}{dt}}$$

$$V_m \sin \omega t - L \frac{di}{dt} = \text{Zero}$$

$$\int di = \frac{V_m}{L} \int \sin \omega t$$

integration of both sides gives:-

$$i = \frac{V_m}{L \omega} (-\cos \omega t)$$

$$i = i_m (-\cos \omega t)$$

$$\therefore i = i_m [\sin(\omega t - 90^\circ)]$$

The current is not in phase with voltage the voltage leads the current by  $90^\circ$  or the current lags the voltage by  $90^\circ$ .

The maximum current  $i_m$  is given by

$$i_m = \frac{V_m}{L\omega} \quad \text{or} \quad X_L = \omega L = 2\pi f L.$$

$X_L$  :- called inductive reactance of an inductor.

$$\frac{V_m}{i_m} = \omega L = 2\pi f L = X_L$$

The unit of  $X_L$  is ohm ( $\Omega$ ).

مقدار مترادف

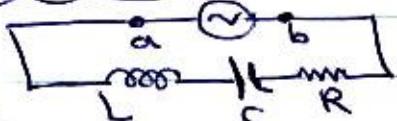
مقدار مترادف

مقدار مترادف

العالي

The R-L-C Series circuit

Let a series circuit composed of a resistor, an inductor and capacitor be connected to the terminal of an alternating source as shown.



The instantaneous potential voltage between a and b equal the sum of the instantaneous potential difference across R & L & C That is:-

$$i = i_R = i_L = i_C \quad , \quad V = V_R + V_L + V_C$$

$$V = V_m \sin \omega t$$

$$\therefore V = V_R + V_L + V_C$$

$$V_m \sin \omega t = i_R R + L \frac{di}{dt} + \frac{q}{C}$$

The above equation is complex and is difficult to find solution because the potential difference in vary phases then we can come to vector diagram called (phases diagram) all maximum potential difference across  $L$ ,  $R$ ,  $C$  put in vectors  $\overline{V_R}$ ,  $\overline{V_L}$ ,  $\overline{V_C}$ .

$$V_R = imR \quad V_L = imX_L \quad V_C = imX_C$$

use Pythagoras Law:-

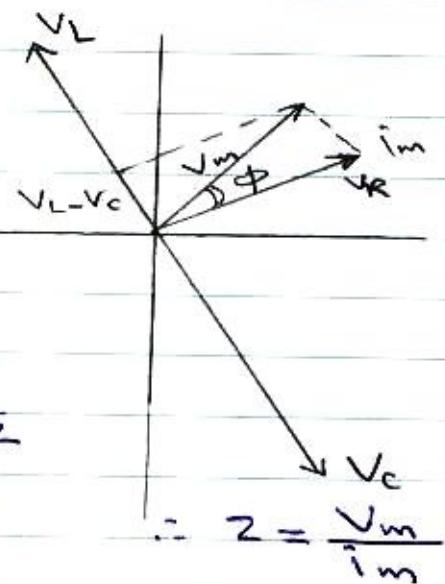
$$\therefore V_m = \sqrt{(V_R)^2 + (V_L - V_C)^2}$$

$$= im \sqrt{R^2 + (X_L - X_C)^2}$$

$$\therefore \frac{V_m}{im} = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\therefore Z = \sqrt{R^2 + (WL - \frac{1}{WC})^2}$$

$$\therefore Z = \sqrt{R^2 + (2\pi f L - \frac{1}{2\pi f C})^2}$$



$Z$  :- is called impedance of circuit and the unit of  $Z$  is ohm ( $\Omega$ ).

$$\omega = 2\pi f$$

$Z$  :- is called impedance of circuit and the unit of  $Z$  is ohm ( $\Omega$ )

$Z$  :- defined as the ratio of the maximum voltage to the maximum current.

-R-

$$\tan \phi = \frac{V_L - V_C}{V_R} = \frac{iC(X_L - X_C)}{iR} = \frac{X_L - X_C}{R}$$
$$= \frac{WL - \frac{1}{WC}}{R}$$

$\phi$  :- is called phase angle.

\* IF the inductive reactance  $X_L$  equal to capacitive reactance  $X_C$ , then ( $\phi = 0$ ) and the circuit become in resonance (و)

$$X_L = X_C$$

$$WL = \frac{1}{WC}$$

$$2\pi f L = \frac{1}{2\pi f C} \xrightarrow{\text{مترافق}} f = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$$

f :- is called resonance frequency for series hence the impedance Z is minimum at this frequency and is equal to the resistance R, but the current is maximum.

\* The R-L-C-parallel circuit

circuit is elements connected in parallel across AC source can be analyzed by the same procedure as for elements

in series

$$i_R = \frac{V_m}{R}, i_C = \frac{V_m}{X_C}, i_L = \frac{V_m}{X_L}$$



$$v = V_m \sin \omega t$$

$$v = V_R = V_L = V_C$$

$$i = i_R + i_C + i_L$$

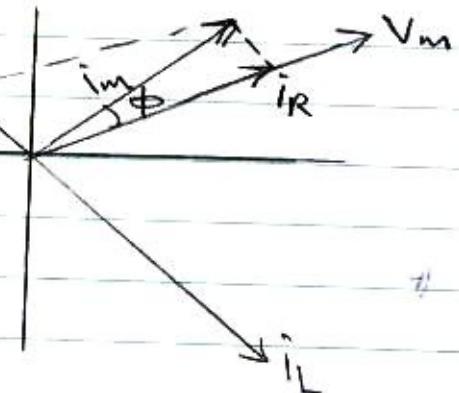
$$i_m = \sqrt{i_R^2 + (i_C - i_L)^2} \quad \text{against } i_C$$

$$= V_m \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$$

$$\frac{1}{Z} = \frac{i_m}{V_m} = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$$

$$\frac{1}{Z} = \sqrt{\left(\frac{1}{R}\right)^2 + (w_C - \frac{1}{wL})^2}$$

$$\frac{1}{Z} = \sqrt{\left(\frac{1}{R}\right)^2 + (2\pi f_C - \frac{1}{2\pi f_L})^2}$$



$\tan \phi = \frac{i_C - i_L}{i_R} = \frac{\frac{1}{X_C} - \frac{1}{X_L}}{\frac{1}{R}} = \frac{2\pi f_C - \frac{1}{2\pi f_L}}{\frac{1}{R}}$

If  $\frac{1}{X_L}$  equal to  $\frac{1}{X_C}$  then ( $\omega = \omega_0$ ) the circuit become in resonance if  $\frac{1}{X_L} = \frac{1}{X_C} \Rightarrow$

$$\frac{1}{2\pi f_L} = 2\pi f_C$$

$$\therefore f = \frac{1}{2\pi} \sqrt{\frac{1}{L C}}$$

$f$  is called the resonance frequency for parallel hence the impedance of circuit is maximum and the current is minimum.

Average and Root mean square  
Value of current

The effective current; ( $i_{eff}$ ) is the constant current which will develop the same heat in any resistance in the same specified time.

If we represent the constant current  $i_{eff}$ , the heat developed by it in resistance (R) in time (t) is

$$i_{eff}^2 RT = \int_0^T R i^2 dt \quad (i = i_m \sin \omega t)$$

$$i_{eff}^2 RT = R \int_0^T (i_m \sin \omega t)^2 dt$$

$$i_{eff}^2 \cdot T = i_m^2 \int_0^T \sin^2 \omega t dt$$

$$\therefore i_{eff}^2 = i_m^2 \left[ \frac{1}{T} \int_0^T \sin^2 \omega t dt \right]$$

\* The quantity  $\left[ \frac{1}{T} \int_0^T \sin^2 \omega t dt \right]$  represent an average of  $(\sin^2 \omega t)$  and given by  $(\sin^2 \omega t)$

$$\text{then } [\sin^2 \omega t = \frac{1}{2}]$$

$$\therefore i_{eff}^2 = i_m^2 \left( \frac{1}{2} \right)$$

$$i_{eff} = \frac{i_m}{\sqrt{2}} = 0.707 i_m$$

$$\therefore i_{rms} = i_{eff}$$

$$i_{rms} = i_{eff} = \frac{i_m}{\sqrt{2}}$$

$$(14) i_{r.m.s} = i_{eff} = \frac{i_m}{\sqrt{2}} = 0.707 i_m.$$

(14) in the same way the root-mean-square values of voltage.

$$V_{r.m.s} = V_{eff} = \frac{V_m}{\sqrt{2}} = 0.707 V_m.$$

### Power in AC-Circuit

القدرة في دوائر  
التيار المتناوب

The instantaneous power input ( $P$ ) to an AC circuit is  $P = VI$

$$V = V_m \sin \omega t$$

$$i = i_m \sin \omega t.$$

Where  $V$  is instantaneous source potential difference and  $i$  is the instantaneous source current.

If the circuit consists of pure resistance ( $R$ ) and  $i$ ,  $v$  are the same phase.

$$i = i_m \sin \omega t, \quad V = V_m \sin \omega t$$

$$\therefore P = i \cdot V = i_m V_m \sin^2 \omega t^{\frac{1}{2}}$$

$$P = i_m V_m \frac{1}{2} \Rightarrow P = \frac{i_m}{\sqrt{2}} \frac{V_m}{\sqrt{2}}$$

$$= i_{r.m.s} * V_{r.m.s}$$

if  $V_{\text{rms}} = I_{\text{rms}} \cdot R$  we where

$$P = \dot{I}_{\text{rms}}^2 \cdot R$$

Now suppose that the circuit consist of capacitor or inductor i and v varying in phase. ( $\neq \phi$ ).

$$i = i_m \sin \omega t , V = V_m \sin(\omega t + \phi)$$

$$P = i \cdot V = i_m V_m \sin \omega t [\sin(\omega t + \phi)]$$

$$= i_m V_m \sin \omega t [\sin \omega t \cos \phi + \sin \phi \cos \omega t]$$

$$= i_m V_m [\sin \omega t \cos \phi + \underline{\sin \omega t \cos \omega t} \sin \phi]$$

$$= i_m V_m \left[ \frac{1}{2} \cos \phi + \frac{1}{2} \sin \omega t \overset{\leftarrow}{\sin} \omega t \sin \phi \right]$$

$$= i_m V_m \left[ \frac{1}{2} \cos \phi + 0 \right] = \frac{i_m V_m}{2} \cos \phi$$

$$\therefore P = \frac{i_m}{\sqrt{2}} \frac{V_m}{\sqrt{2}} \cos \phi$$

$$= i_{\text{rms}} \cdot V_{\text{rms}} \cos \phi$$

$$\sin \omega t =$$

$$\omega = 2\pi f$$

$$5 \sin 2\pi f \cdot t$$

$$= 2\pi \cdot \frac{1}{t} \cdot t$$

$$= \sin 2\pi = 0$$

The factor  $\cos\phi$  is called the (power factor) of a pure resistance ( $\phi = 0$ ),  $\cos\phi = 1$

$$\therefore P = V_{\text{rms}} \cdot I_{\text{rms}} \cdot \cos\phi$$

For a capacitor or inductor  $\phi = 90^\circ$ ,  $\cos\phi = 0$   
and  $P = 0$

## Problems of chapter-1 -

Q-1/ The capacitance of the capacitor is ( $40\text{MF}$ ) and alternating current passing through its [ $i = 20 \sin 2\pi t$ ] Find the equation of voltage effected between terminals of capacitor?

Q-2/ In an R-L-C series circuit ( $R = 20\Omega$ )

( $X_L = 30\Omega$ ) and  $X_C = (50\Omega)$  Connected to alternating source the voltage between its (220 volt) and its frequency is (50 Hz) find.

- (a) the current passing through the circuit?
- (b) the potential voltage between every element?
- (c) the power factor?
- (d) the power of circuit?
- (e) the magnitude of L, C?

Q-3/ In an R-L-C series circuit ( $R = 100\Omega$ ) ( $L = 0.5\text{H}$ )

and ( $C = 10\text{MF}$ ) connected with A.C source if the current passing through circuit (4 amp) and the frequency (50 Hz) find the total voltage and the voltage between the terminals of element?

Q-4/ An inductor of self inductance ( $0.02\text{H}$ ) an alternating current passing through the inductance is [ $i = 10 \sin 2\pi t$ ] find the equation of voltage between the terminals of inductor?

Q.5/ In an R-C series circuit ( $C = 30 \mu F$ ) connected to alternating source of frequency (60 Hz) if the current leads to voltage by angle ( $60^\circ$ ) find the magnitude of resistance (R)?

Q.6/ In an R-L series circuit ( $R = 10 \Omega$ ) and ( $L = 0.04 H$ ) connected to alternating source the voltage effected between the terminals of inductor is [ $V = 245 \sin 200t$ ] Find

- (a) The voltage equation between the terminals of the circuit?
- (b) The current equation passing through circuit?
- (c) The impedance?
- (d) The power supplied in circuit?
- (e) The power supplied in resistor?

Q.7/ In an R-L-C parallel circuit ( $R = 20 \Omega$ ) ( $L = 1.6 mH$ ) and ( $C = 20 \mu F$ ) connected to A.C source the voltage difference between the source is [ $V = 50 \sin 500t$ ] Find

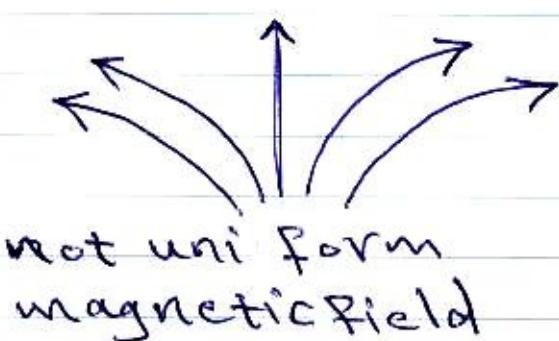
- (a) The equation current in every branch of circuit?
- (b) The main current?
- (c) The power supplied in resistance for ten minutes?

## - Chapter Two -

### The Magnetic Field المجال المغناطيسي

The magnetic field : Is any region in which forces may be observed to act on small magnetic or on small current bearing elements.

- \* The direction of the magnetic field at any point is the direction of the force.
- \* Magnetic field is a vector quantity
- \* we shall use the symbol  $(B)$  for the magnetic field.
- \* A magnetic field can be represented by line such that the direction of line through a given point is that same as that of magnetic field vector  $(B)$  at that point.
- \* In a uniform magnetic field that field lines are straight and parallel.
- \* Some time we call the magnetic field by magnetic induction vector.



## Magnetic induction Vector تعريف فیلیم ایجاد

The number of those lines per unit area normal to their direction is made equal to the magnitude of the induction. Hence the induction of point can be expressed in "line per unit area".

\* In the (mks) system a line of induction is called a weber.

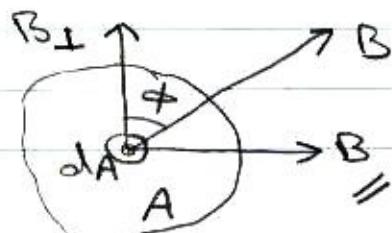
\* In this system the magnetic induction ( $B$ ) expressed in in Weber per square meter ( $\text{Weber/m}^2$ ) is called Tesla ( $T$ ) or in (cgs) system a line induction is called a maxwell and magnetic induction is express in ( $\text{maxwell/cm}^2$ ) on maxwell per square centimeter is called (gauss).

$$1 \text{ Tesla} = 10^4 \text{ gauss.}$$

\* The magnetic flux ( $\phi$ ) :- فیلیم

The total number of line of induction crossing on area at right angle.

\* It is a vector quantity and the direction of  $\phi$  of the same direction of induction lines.



Any surface can be divided into elements of area  $dA$  as shown in the figure for each element we obtain the components of ( $B$ ) normal ( $\perp$ ) and tangent  $\parallel$  to the surface at the position of the element.

$$B_{\perp} = B \cos \theta \quad \& \quad B_{\parallel} = B \sin \theta.$$

the magnetic flux

$$d\phi = B_{\perp} dA$$

$$d\phi = B \cos \theta dA$$

$$\therefore \phi = \int d\phi = \int B \cdot dA = \int B \cos \theta dA$$

\* In special case where ( $B$ ) is uniform over plane surface with total area. ( $A$ ).

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

Q:- The angle between Vector  $\vec{A}$  and Vector  $\vec{B}$ .

\* If  $B$  is perpendicular to the surface ( $\cos \theta = 1$ ) and ( $\phi = BA$ ) - The unit of  $\phi$  is weber.

$$(\phi = \text{Tesla} \cdot \text{m}^2 = \frac{\text{Weber}}{\text{m}^2} \cdot \cancel{\text{m}^2} = \text{Weber}).$$

\* Some time we called  $\phi$  as magnetic flux density.

## القوة المغناطيسية في مجال مغناطيسي

### Force on a moving charge in magnetic field

A positive charge ( $q$ ) moving with velocity ( $v$ ) in magnetic field ( $B$ ), magnetic force appear on charge thus force is given by :-

$$F = q(v \times B)$$

$$F = qvB \sin\theta.$$

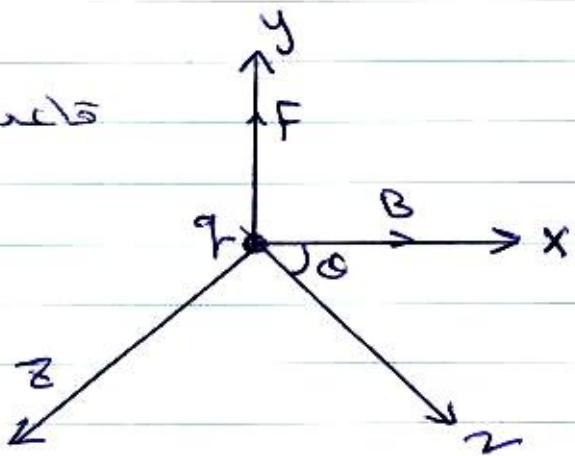
$\theta$  :- is the angle between  $v$  and  $B$  vectors the force is perpendicular on both  $\vec{B} \times \vec{v}$  it mean perpendicular on plan in which these two vector.

\* The force mean perpendicular on the plane in which these two vectors.

$$B = \frac{F}{qv \sin\theta}$$

(٣٢٢)  
Left hand rule:- قاعدة اليد اليسرى

The thumb in the direction of force the first finger the direction of field the second finger in the direction of vector  $\vec{v}$ .



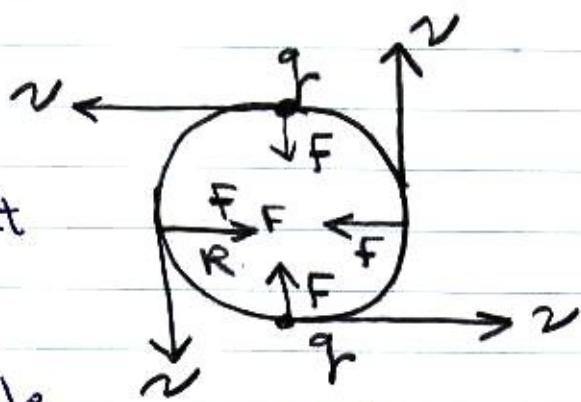
## Motion of charged particles in magnetic field

Complex Jl3 Jol's aigwll  $\rightarrow$  hskz

Let a positively particle ( $q$ ) point moving with velocity  $v$  in uniform magnetic field ( $B$ ) the direction of  $v$  is at right angle with  $B$ .

Force  $F$  ( $F = qvB$ ) is exerted on the particle, thus force has direction perpendicular to  $v$  the velocity  $v$  changes only in direction.

\* If the particle moving from (P) to (Q) the direction  $F$  and  $v$  will have changed as shown the magnitude of  $F$  is constant, if the magnitude of  $q$  or  $v$  and  $B$  constant. The particle therefore moves by force which its magnitude constant.



But its direction is always at right angle to  $v$ .

\* The orbit  $\curvearrowleft$  of particle is circle described with constant tangential velocity ( $v$ ) since the centripetal  $\curvearrowleft$  acceleration ( $\frac{v^2}{R}$ ) by from Newton's Law.

$$F = qvB = m \frac{v^2}{R}$$

where  $m$  is the mass of the particle the radius of the circular orbit is

$$R = \frac{mv}{qB} \quad \text{مسافة الدورة (R)}$$

the angular velocity is:-

$$\omega = \frac{v}{R} = \frac{qvB}{m} \quad \text{السرعة الماوية}$$

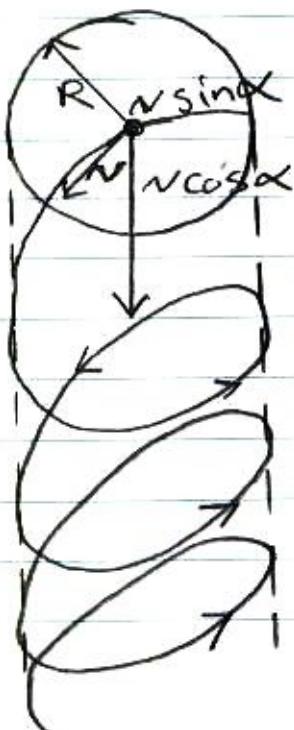
= constant.

\* If the direction of initial velocity  $v$  is not perpendicular to  $B$ , The particle moves in a helix ماربة.

\* The cross-section of the helix is a circle of radius

$$R = \frac{mv \sin \alpha}{qB} \quad (\text{متر})$$

$\alpha$  :- is the angle between  $v$  and  $B$



\* If some charged particles with same mass and charged projected ~~in~~ perpendicular to with uniform field.

With different speed the particles moving in circle orbits with different radius, but the same angular velocity ( $\omega$ ) & it mean in same frequency  $f$

$$f = \frac{\omega}{2\pi} = \frac{qB}{2\pi m}$$

$$\omega = 2\pi f$$

$$\omega = \frac{qB}{m}$$

ملاحظة

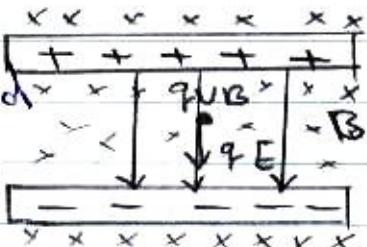
Notes:-

أي مقدار دارج  
لا يغير المدارات

Moving charged particle in both electrical and magnetic field perpendicular to them.

حركة جسم متحركة في مجالين كهربائي وفقاً معاً

If a positive charged particle with velocity ( $v$ ) inter space contained electric field and magnetic field perpendicular to other.



$$\vec{F}_E = \vec{E} \cdot q$$

$$\vec{F}_m = q \vec{v} \times \vec{B}$$

particle will effected to both field resultant forces (magnetic force and electric force) appear at one time and its effect on the particle.

$$F_E = Eq \quad \text{and} \quad F_m = qvB \quad \angle = 90^\circ$$

If  $F_E \neq F_m$  the particle is moving in an acceleration and its deflection in motion resultant. Then if  $F_E = F_m$  the resultant forces = zero  $\rightarrow$  The particle is moving in straight line and in same velocity  $v$ .

$$\vec{F}_E = \vec{F}_m \Rightarrow Eq = qvB \Rightarrow v = \frac{E}{B}$$

The velocity of charged particle.

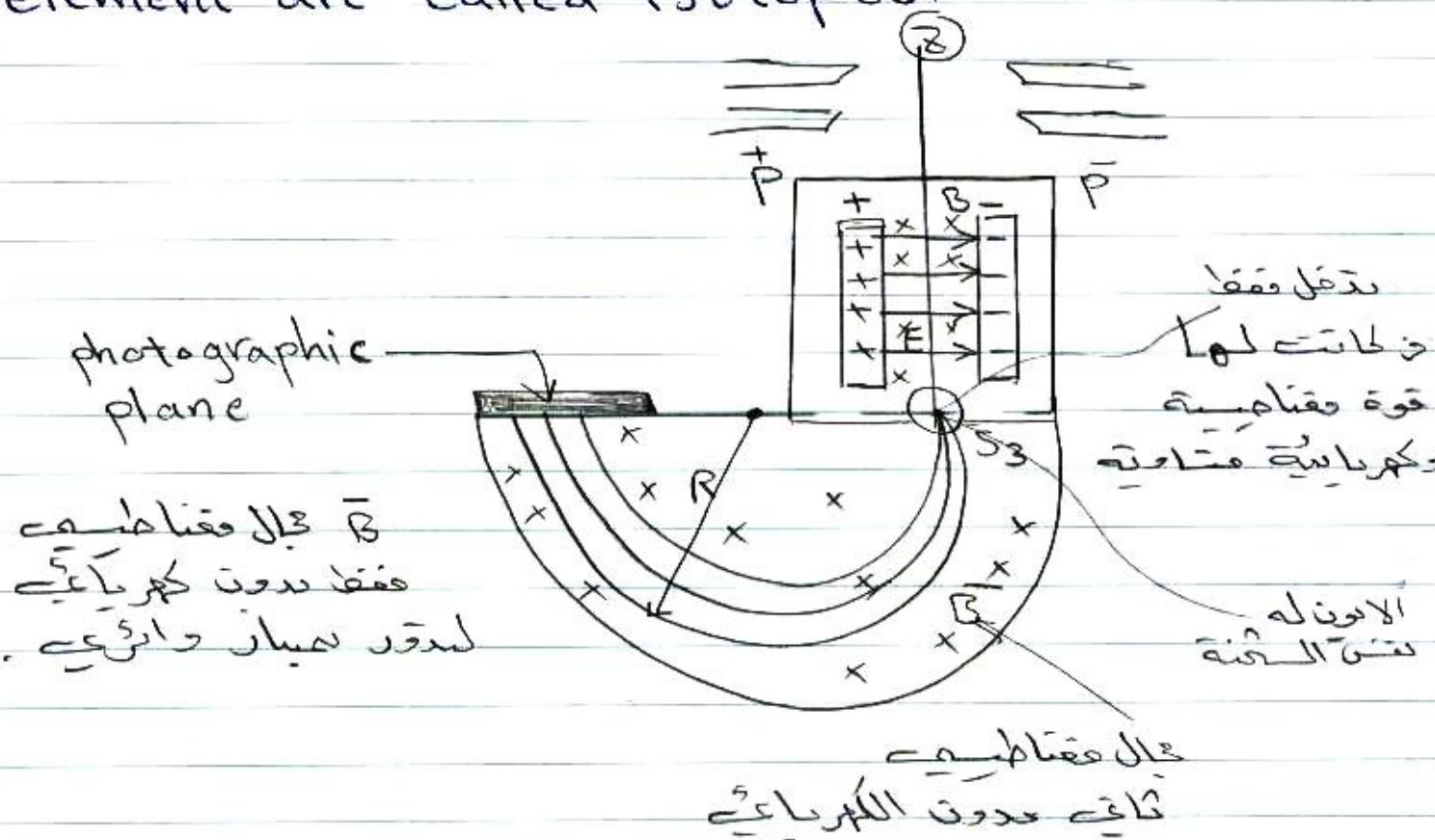
## Mass spectrometer :-

مُلْعَافِتُ الْكَلَلِ

The mass spectrometer is used chiefly for the study and separation of isotopes.

Isotopes:- الطَّلَائِي

many elements have several kinds of atoms this atoms that have the same atomic number but differ in mass, such as element are called isotopes.



Mass spectrograph is an instrument which has a source of ions ( $Z$ ) the ions pass through slits ( $S_1$ ) and ( $S_2$ ) and move down into the electric field between the two plates ( $p$ ) and ( $\bar{p}$ ).

In the region of the electric field there is also magnetic field ( $B$ ) perpendicular to the paper thus the ions enter a region of crossed electric and magnetic field.

- \* only those ions whose speed is equal to  $(V = \frac{E}{B})$  pass through this region.
- \* Ions with other speed are stopped by the slits ( $S_3$ ) thus all ions that emerge from ( $S_3$ ) have the same velocity ( $v$ ) the region of crossed field is called velocity selector.
- \* Below ( $S_3$ ) the ions enter a region where there is another magnetic field ( $\bar{B}$ ) perpendicular to the paper (but no electric field) - Here the ions move in circular path of radius  $R$ .

we find that  $R = \frac{mv}{qB} \rightarrow v = \frac{E}{B}$

$$\therefore R = m \frac{\frac{E}{B}}{qB} = \left(\frac{E}{qB^2}\right)m$$

$$\therefore R = \left(\frac{E}{qB^2}\right)m.$$

Hence the ratio  $\left(\frac{E}{qB^2}\right)$  is the same for all ions (constant).

and the radius  $a(R)$  of its path proportional to the mass ( $m$ ) of the ion:

$$R_1 = \left(\frac{E}{qB^2}\right)m_1$$

$$R_2 = \left(\frac{E}{qB^2}\right)m_2.$$

## The Cyclotron:

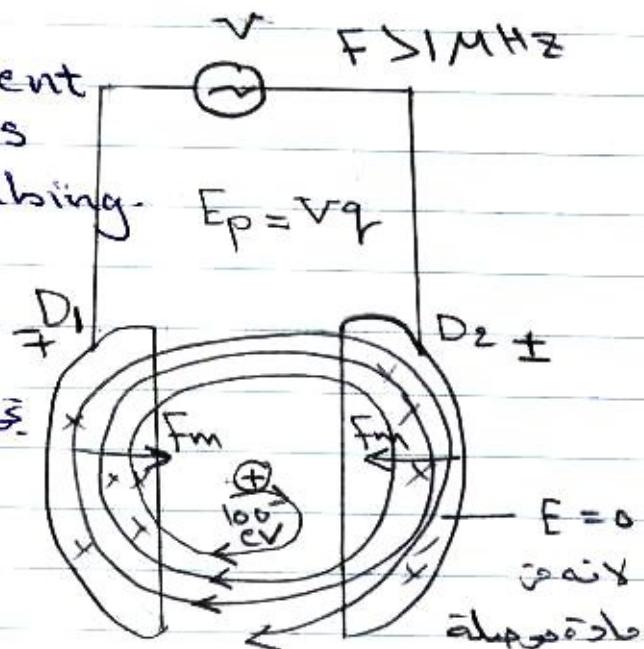
السيكلotron

The cyclotron is an instrument used to acceleration the ions to purpose of nuclear Bombing.

$$F \geq 1 \text{ MHz}$$

$$E_p = Vq$$

The cyclotron contained of a pair of halves of metal cylindrical which is hollow chambers <sup>جوف</sup> is called (dees) the shape of the dees like (D).



\* The whole apparatus is placed between the poles <sup>أقطاب</sup> of powerful <sup>عالي</sup> electromagnetic which provides the magnetic field whose direction is perpendicular to the ends of the cylindrical container <sup>المكعب</sup>.

\* A source of ions (deutrons)  ${}^2\text{H}$  are commonly used in located near the midpoint of the gap between the dees.

The dees are connected to the terminals of an electric circuit potential voltage (V).

\* The electric field in the gap between the dees is directed first toward one and then towards the other. But the electric field inside the plates equal zero.

\* Consider an ion of charge ( $+q$ ) and mass ( $m$ ) emitted from the ion source in an instant when  $D_1$  is positive the ion is accelerated by the electric field in the gap between the dees and enter the field free region within pole  $D_2$  with speed, say of ( $v_1$ ) it will travel in a circular path of radius ( $R = \frac{mv}{qB}$ ) because there is magnetic field only within the dees.

\* If now in the time required for the ion to complete a half circle, the electric field has reversed so that its direction toward  $D_1$  with a large velocity ( $v_2$ ) therefore moves in a half circle of larger radius within  $D_2$  to emerge again in the gap.

The angular velocity ( $\omega$ ) of the ion is ( $\omega = \frac{v}{R}$ )  
 $= (\frac{Bq}{m})$

the steps continuous and in every step the radius and velocity increasing and path of ion become spherical cycle

After that the ion moving out of dees by another magnetic field if ( $R'$ ) represented the outside radius of the dees and ( $v_{max}$ ) the speed of the ion when traveling in path of this radius.

$$(v_{max} = B R' \frac{q}{m})$$

\* The cyclotron operates successfully only with relatively massive ~~small~~ particles such as protons or deuterons and when the frequency of voltage ( $f_0$ ) equal to frequency of ion through the travelling in magnetic field ( $f$ ).

\* The cyclotron stop when the velocity of ion equal the velocity of light ( $c$ ). because the mass varying by the relation:-

$$m = m_0 / \sqrt{1 - \frac{v^2}{c^2}}$$

## Problems of Chapter -2 -

Q1:- An electron moves in a circular path of radius (1-2 cm) perpendicular to an uniform magnetic field. The speed of the electron is ( $10^6 \text{ m/s}$ ) What is the total magnetic flux encircled by the orbit?

Q-2:- proton moving from rest through potential difference equal ( $4 \times 10^5 \text{ V}$ ) and its entered perpendicular to uniform magnetic field ( $B = 0.4 \text{ Tesla}$ ) find the radius of the circular path of proton and its angular velocity?

Q-3:- proton moving with speed ( $2 \times 10^5 \text{ m/s}$ ) in region of uniform magnetic field ( $B = 0.01 \text{ Tesla}$ ) with direction of ( $60^\circ$ ) with the magnetic field find  
a - the radius of circular path.  
b - the distance which is the proton moving with the same of field direction through one circular time?

Q.4:- A particle having a mass of ( $0.5\text{ g}$ ) carries a charge of ( $2.5 \times 10^{-8}\text{ C}$ ). The particle is given an initial horizontal velocity of ( $6 \times 10^4\text{ m/s}$ ) what is the magnitude and direction of the minimum magnetic field that will keep the particle moving in horizontal direction?

Q.5:- In a TV picture tube an electron in the beam is accelerated by a potential difference of ( $20000\text{ V}$ ) then it passes through a region of transverse magnetic field where it moves in a circular arc with radius ( $12\text{ cm}$ ) what is the magnitude of the field?

### - Chapter -3 -

الforce على موصل سريع حمل تيار كهربائي هو ممدوح في مجال مغناطيسي  
Magnetic force on current carrying conductors:-

force on conductor

العوّة على موصل

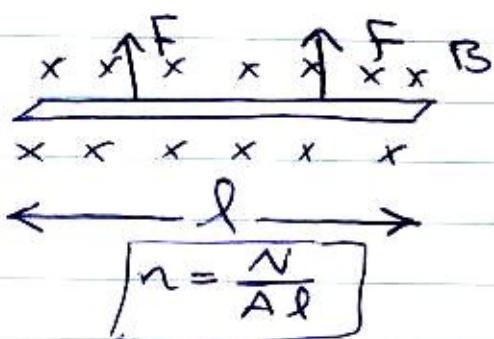
وضع

When a current carrying conductor lies in magnetic field magnetic force are exerted on the moving charges within the conductor. Now let there is a straight conductor wire of length ( $l$ ) and cross section ( $A$ ) & within which there is current. The current is in a magnetic field ( $B$ ) perpendicular to the conductor.

There is a force represent on every moving charge within it:-

$$F = qvB \sin\theta$$

But the number of charge in Wire is ( $nAl$ )



The resultant forces ( $F$ ) is therefore

$$F = qvB \sin\theta * (nAl) \quad \text{--- ①}$$

$$I = neVA \Rightarrow v = \frac{i}{neA} \quad \text{--- ②}$$

$$i = \frac{q}{t}$$

التيار يعتمد على عدد الجسيمات المoving في الوحدة time = n

submit :-

$$\text{Sub } ② \text{ in } ① \Rightarrow F = i l B \sin \theta \quad \begin{array}{l} \text{القوة المولدة على الماء} \\ \text{معادلة عامة} \end{array}$$

$$\vec{F} = i (\vec{l} \times \vec{B}) \quad \text{vector equation}$$

$\theta$  :- is the angle between the direction of conductor ( $l$ ) or and the field ( $B$ ).

If the conductor is not straight and if the magnetic field is not uniform. The relation become -

$$dF = i B dl \sin \theta$$

العوامل المؤثرة

هي  $i$   $B$   $dl$   $\sin \theta$

العوامل الشائعة بالتكامل

The direction of  $l$  is the same of moving  $i$  current direction. The unit of  $F$  is (Newton).

\* The maximum value of force effected to the wire, when  $\theta = 90^\circ$

[When ( $B$ ) perpendicular ( $l$ )]  $\circ F$  is perpendicular to ( $B$ ) and ( $l$ )  $\{ B + l \} \leftarrow F_1$

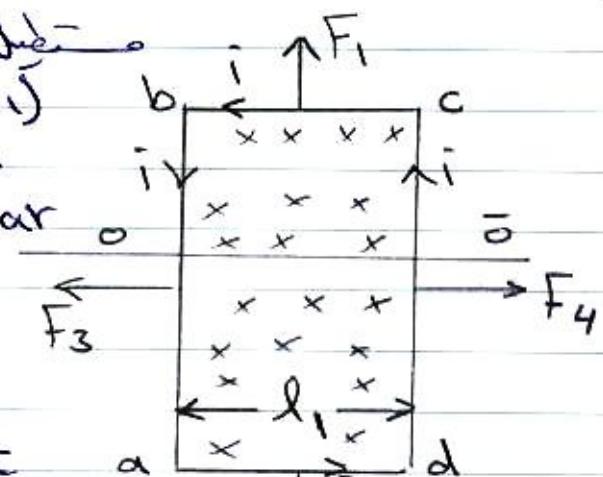
To find the direction we can used (right hand rule)

اتجاه المولدة

القوى والحرف المليح  $\rightarrow$  طاردة  $\rightarrow$  القوى والحرف المليح  $\rightarrow$  طاردة

## Force and Torque on a complete circuit:-

Let there is a rectangular loop with side of length ( $l_1$ ) and ( $l_2$ ) - There is a uniform magnetic field perpendicular on the loop surface.



The loop is rotated about a axis ( $o\bar{o}$ ) and it carries current. Suppose that there is one turn of loop:

There is equal and opposite force of magnetic  $F_1 = -F_2 = ilB_1$  are exerted on  $l_1$ , and also there is equal and opposite forces of magnitude  $F_3 = -F_4 = iBl_2$  are exerted on ( $l_2$ )

\* The total forces on the loop is (Zero) (The forces on opposite sides are equal and opposite). Hence there is No Torque.

If the magnetic field effected to the loop surface by angle ( $\theta$ ), therefore Torque is exerted on them:-

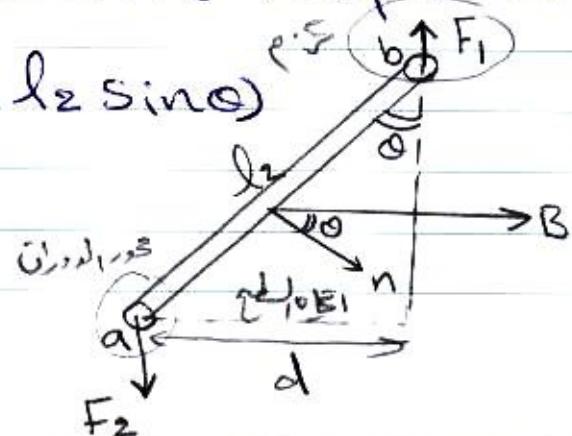
$$\tau = F_1 \cdot d = F_1 \cdot (l_2 \sin\theta)$$

$$F_1 = iBl_1$$

$$\tau = (iBl_1)(l_2 \sin\theta)$$

$$\therefore \tau = iBA \sin\theta$$

$$\text{and } A = l_1 \cdot l_2$$



$$\tau = iBA \sin\theta$$

\* The Torque is maximum when  $\theta = 90^\circ$

$$\vec{\tau} = i(\vec{B} \times \vec{A}) \quad \text{لقة الراجمة}$$

if the loop having N turns then:-

$$\vec{\tau} = N(iAB \sin\theta) \rightarrow \text{لـ N عن المغات}$$

$$\vec{\tau} = Ni(\vec{A} \times \vec{B})$$

The magnitude of  $(NiA)$  is called the (dipole moment) عزم ثانوي النقط المقاوم لـ  $M$  of magnetic dipole

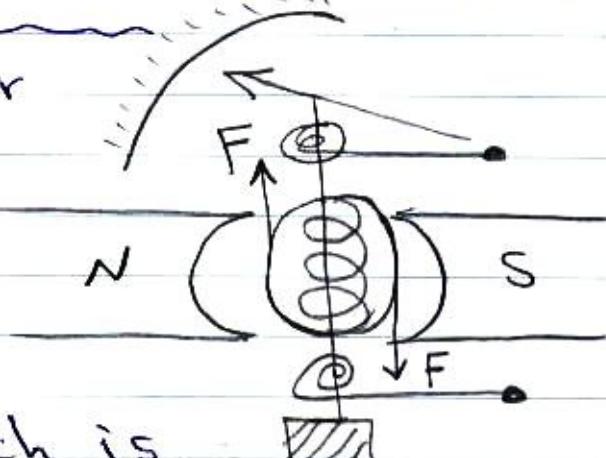
$$\therefore \vec{\tau} = MB \sin\theta$$

$$\vec{\tau} = (\vec{\mu} \times \vec{B}) \quad : \quad \mu = NiA$$

\* The above equation is valid only when magnetic field is uniform and uniform magnetic surface also for not uniform surface.

## كلناموفتر الملف المتحرك Moving coil Galvanometer

The galvanometer used for the detection or measurement of small current.



If it consists of coil which is coiling about iron cylinder between magnetic poles اقطاب (S+N), the coil is suspended by a fine conducting wire مسلك وصله connected to pointer حومي which moves on scale, the other terminals of the coil is connected to the spiral ملحوظة which is working control. تأثير سطرة

\* When the current sent through the coil, the coil rotates in the direction of this couple, hence the couple Torque is:-

$$\therefore \tau = NiAB \sin\theta \quad : \quad \theta = 90^\circ$$

$$\therefore \tau = NiAB$$

Due to these torque, the coil rotation and there is restoring torque which is produced

$$(\tau = k\phi)$$

( $\phi$ ):- rotation angle زاوية الدوران

(K) :- Restoring constant. ثابت المعاودة

The coil will stopped rotating when the Torque is equal.

$$K\phi = NIAB \cdot$$

قوة معاودة قوة جذب المغناطيسي

$$\therefore i = \left( \frac{K}{NAB} \right) \phi$$

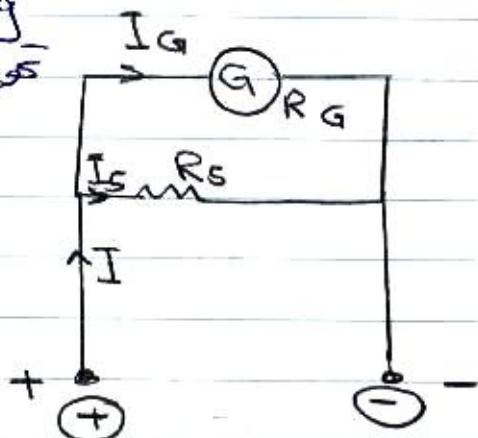
The quantity of  $\left( \frac{K}{NAB} \right)$  is constant for one Galvanometer.

Hence the current is proportional to deflection angle  $\phi$ .

## Ammeters:-

$\text{A} \leftarrow \text{G}$  جو میں

Ammeter is used to measuring of current we can convert the galvanometer to an ammeter by connect a shunt resistor ( $R_s$ ) in the parallel with the galvanometer resistance ( $R_g$ ).



$$\therefore V_g = V_s \quad (\text{میں})$$

$$\therefore I_g R_g = I_s R_s \quad \textcircled{1}$$

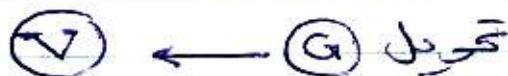
$$\therefore I = I_s + I_g$$

$$\therefore I_s = I - I_g \quad \textcircled{2}$$

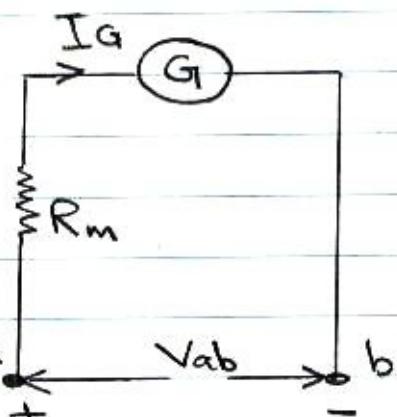
$$\therefore R_s = \frac{I_g R_g}{I - I_g}$$

shunt resistance  
متاویہ میزبانی

Voltmeter:-



Voltmeter is used to measuring potential difference between two terminals.



We can convert the galvanometer to voltmeter by connect a large resistance called multi resistance. میلٹری ریزنسنے

(R<sub>m</sub>) in the series with the galvanometer resistance (R<sub>G</sub>).

$$V_{ab} = I_G R_G + I_G R_m \quad \text{میلٹری}$$

$$V_{ab} - I_G R_G = I_G R_m$$

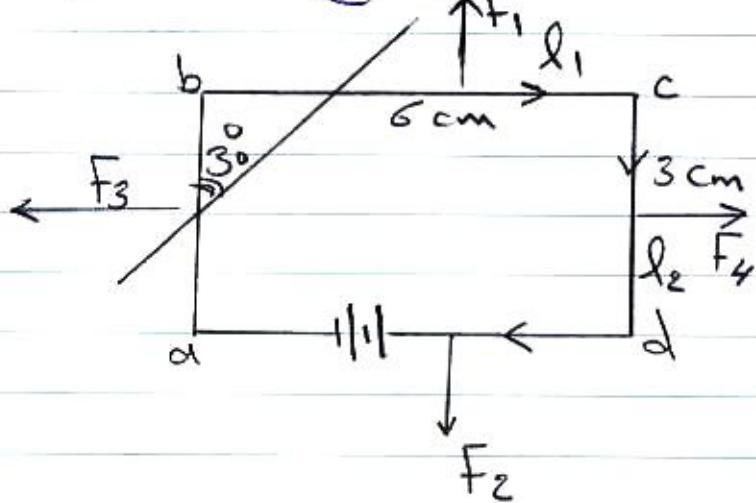
$$\therefore R_m = \frac{V_{ab} - I_G R_G}{I_G}$$

multi resistance  
میلٹری ریزنسنے

## JUJU JIALL problems chapter -3-

- Q-1 :- The rectangular loop as in figure . carries a current of (2A) in the direction indicated . find the magnitude of the force at every side of loop if the loop is a uniform magnetic field of magnitude (0.5 T) ?
- at direction perpendicular to the loop ?
  - at direction parallel to the loop and parallel to the ab ?
  - find the Torque ?
  - if the magnetic field effected parallel to loop but make an angle  $30^\circ$  with ab & find the force at every side ?

لهم لك كل حمد

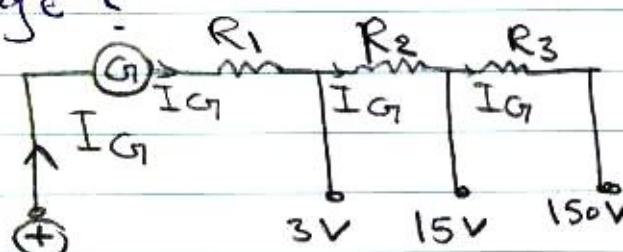


- Q-2:- The resistance of galvanometer coil is (25 ohms) and the current required for full scale deflection is (0.02 amp)
- Show in figure how to convert the galvanometer to an ammeter reading (5 amp) full scale and compute the shunt resistance
  - Show how to convert the galvanometer to voltmeter reading (150) Volts full scale?

-40-

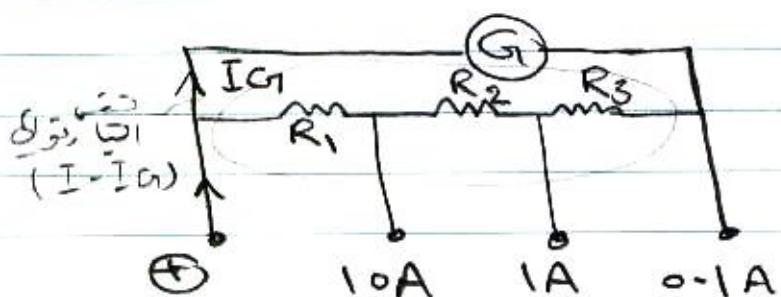
Q.3:- The resistance of coil of a pivoted coil galvanometer is  $(10\Omega)$  and a current of  $(0.02 \text{ amp})$  causes it to deflect full scale. It is desired to convert this galvanometer to an ammeter reading  $(1 \text{ amp})$  full scale. The only shunt available has resistance of  $(0.03) \Omega$ . What resistance  $(R)$  must be connected in series with the coil?

Q.4:- <sup>دالة</sup> Figure shows the internal wiring of three scale voltmeter whose binding posts are marked in the figure. The resistance of the moving coil  $(R_G)$  is  $(15)\Omega$  and a current of  $(1 \text{ mA})$  in the coil causes it to deflect full scale.   
 @ Find the resistance  $R_1$ ,  $R_2$  &  $R_3$  and   
 (b) overall resistance of the meter on each of its range?



المرجع الموصى  
بالكتاب

Q.5:- The resistance of the moving coil at the galvanometer  $G$  as in figure is  $(25\Omega)$  and it deflects full scale with current of  $(0.01 \text{ amp})$ . Find the magnitude of the resistance  $R_1$ ,  $R_2$  &  $R_3$  to convert the galvanometer to a multi-range ammeter deflecting full scale with the current of  $(10 \text{ amp})$ ,  $(1 \text{ amp})$  &  $(0.1 \text{ amp})$ ?



### Chapter Four-

الفصل الرابع

الحالات المغناطيسية للتيار الكهربائي والشحنات المتحرّكة

Magnetic field of the current and a moving charge:-

(Biot and Savart law) قانون بيوارت - سوارت

Let wire of length ( $l$ ) which is current passing in it ( $i$ ), how to find the magnetic field ( $B$ ) at point ( $P$ ) at distance ( $R$ ) from the wire?



The wire is to be divided into short elements of ( $dl$ ) each element setup a field ( $dB$ ) of all point of space and the field of the entire circuit at any point is the resultant of the fields of all the elements of the circuit.

The magnetic field ( $dB$ ) at point ( $P$ ) is:-

$$dB \propto \frac{idl \sin \theta}{R^2} \quad (\theta = \overrightarrow{dl} \times \overrightarrow{R})$$

( $R$ ) :- is distance between ( $dl$ ) and the point ( $P$ ).  
( $dB$ ) :- is perpendicular to the ( $dl$ ) and ( $R$ ).

$$dB \perp (\overrightarrow{dl} \times \overrightarrow{R})$$

$$\text{عواد} (dB) \propto \frac{idl \sin\theta}{R^2} \rightarrow K \frac{idl \sin\theta}{R^2}$$

$$\text{عواد} d\vec{B} = k_i \frac{d\vec{l} \times \vec{R}}{R^3}$$

(K) :- is proportionality constant ثابت النسبة

In the (mks) system equal (K = 10<sup>-7</sup> Weber amp. meter)  
 (SI) system international units

$$K = \frac{\mu}{4\pi} = 10^{-7} \frac{\text{Weber}}{\text{amp. meter}}$$

$$\therefore \mu_0 = 4\pi \times 10^{-7} \frac{\text{Weber}}{\text{amp. meter}}$$

ملا  
 $(\text{Tesla} = \frac{\text{Weber}}{\text{m}^2})$

Hence the Biot law then becomes

$$\boxed{d\vec{B} = \frac{\mu_0}{4\pi} \frac{idl \sin\theta}{R^2}}$$

$$(\mu_0 = 4\pi \times 10^{-7})$$

$$\theta = (\vec{dl} \times \vec{R})$$

$$\therefore \vec{B} = \int d\vec{B} = \frac{\mu_0}{4\pi} \int \frac{idl \sin\theta}{R^2}$$

$$\vec{dB} \perp (\vec{dl} \times \vec{R})$$

ويعتبر كل بعث الموجة المائية ينبع من الملا

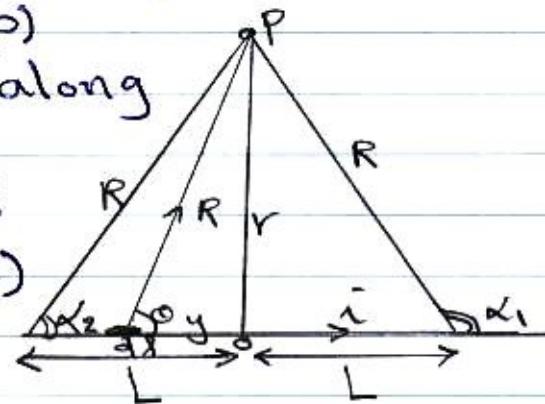
تَطْبِيقَاتٌ عَلَى قَادِرَتِي مَاجِيُوت - افَارِت

### Application of Biot Law

#### 1- Magnetic field of along straight Biot law:-

الحاله للتعاليه في المنهج (جعفر) مختصر طوبول

Let us use the Biot law to compute the magnetic field ( $B$ ) at point ( $P$ ) as shown in the figure. Due to along straight conductor carrying a current ( $i$ ). We consider a conductor of total length ( $2L$ ) with its midpoint at the origin.



We divided a conductor to an element. The direction of the field ( $dB$ ) set up at point ( $P$ ) by an element of length ( $dy$ ) which at distance ( $y$ ) from the origin.

$$dB = \frac{\mu_0 i dl \sin\theta}{R^2} \quad (\text{Biot Law})$$

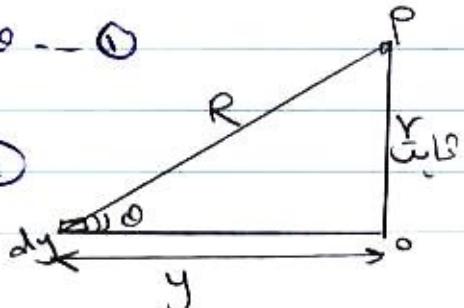
$$\therefore dB = \frac{\mu_0 i dl \sin\theta}{R^2}$$

$R$  &  $\theta$  are variable we see that

وَكَانَتْ سَعْيَ

$$\therefore \tan\theta = \frac{r}{y} \Rightarrow y = \frac{r}{\tan\theta} = r \cot\theta \quad \text{--- ①}$$

$$\therefore y = r \cot\theta \Rightarrow dy = -r \csc^2\theta d\theta \quad \text{--- ②}$$



$$\therefore \sin\theta = \frac{r}{R} \Rightarrow \therefore R = \frac{r}{\sin\theta} = r \cdot \csc\theta$$

$$\therefore R^2 = r^2 \csc^2\theta \dots \textcircled{3}$$

sub \textcircled{3} & \textcircled{2} in \textcircled{1} :-

$$dB = \frac{\mu_0}{4\pi} \frac{i(-r \csc\theta d\theta) \sin\theta}{(r^2 \csc^2\theta)}$$

$$dB = \frac{\mu_0 i}{4\pi r} \frac{i \sin\theta}{r} d\theta$$

$$\therefore B = \int dB = \frac{\mu_0 i}{4\pi r} \left[ \sin\theta \right]_{\alpha_1}^{\alpha_2}$$

$$\therefore B = -\frac{\mu_0 i}{4\pi r} (-\cos\theta) \left|_{\alpha_1}^{\alpha_2} \right. \Rightarrow \frac{\mu_0 i}{4\pi r} (\cos\alpha_2 - \cos\alpha_1)$$

If the conductor is very long compared with the distance (r) then  $\{\alpha_1 = \pi \wedge \alpha_2 = 0\}$

Therefore

$$B = \frac{\mu_0 i}{4\pi r} (\cos 0 - \cos \pi)$$

$$B = \frac{\mu_0 i}{4\pi r}$$

$$B = \frac{\mu_0 i}{2\pi r}$$

النتائج ملخص  
(مدى) طول جهاز

الحال للفيزياء والتكنولوجيا - دارسي - الفصل

## 2- Magnetic field of a circular loop :-

A circular loop of wire of radius ( $a$ )

carrying a current ( $i$ ) we discuss

may use Biot Savart law to

calculate the magnetic

field ( $d\mathbf{B}$ ) at a point ( $P$ )

along a line perpendicular

to the plane of the loop a distance

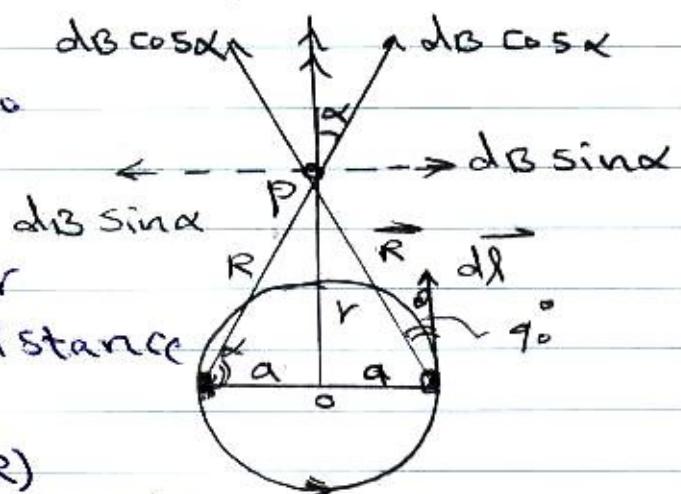
( $r$ ) from its center as the

figure shown ( $dl$ ) and ( $R$ )

perpendicular and the direction  $\hat{i}$

of field ( $d\mathbf{B}$ ) caused by element also.

$$(\phi = 90^\circ : R \neq dl).$$



$$\therefore d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{idl \sin\phi}{R^2} \quad (1)$$

$$\therefore d\mathbf{B} = \frac{\mu_0 i}{4\pi} \frac{dl}{(r^2 + a^2)}$$

$$d\mathbf{B}_{\parallel} = d\mathbf{B} \sin\alpha = 0 \quad \text{حيث المدار متوازي الدائري}$$

الخط  
الموازي

$$d\mathbf{B}_{\perp} = d\mathbf{B} \cos\alpha$$

فقط

$$d\mathbf{B}_{\perp} = d\mathbf{B} \cos\alpha \quad (\text{only})$$

$$\therefore d\mathbf{B} = d\mathbf{B}_{\perp} = \frac{\mu_0 i dl}{4\pi R^2} \cos\alpha \quad \phi = 90^\circ \quad \sin 90^\circ = 1$$

$$\therefore B = \int d\mathbf{B} = \frac{\mu_0 i \cos\alpha}{4\pi R^2} \int dl$$

$$\therefore B = \frac{\mu_0 i \cos\alpha}{4\pi R^2} (2\pi a)$$

$$B = \frac{Mo i \cos \alpha}{2R^2} (a)$$

$$\cos \alpha = \frac{a}{R}$$

$$= \frac{Mo i a}{2R^2} - \left(\frac{a}{R}\right) = \frac{Mo i a^2}{2R^3}$$

$$\therefore B = \frac{Mo i a^2}{2(a^2 + r^2)^{3/2}}$$

$$R = \sqrt{a^2 + r^2}$$

for case (N) loop & Hence

$$B = \frac{N Mo i a^2}{2(a^2 + r^2)^{3/2}}$$

الناتج  
لكل طرف

$$R = (a^2 + r^2)^{1/2}$$

• حالة خاصة إذا كانت بـ تقع في حرجـ الدائرة.

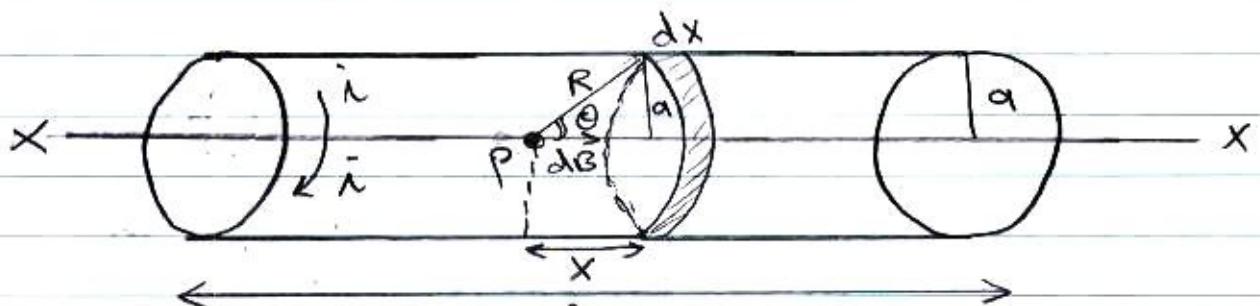
At the center of the loop  $r=0$  and the above equation reduces to:-

$$B = \frac{N Mo i a^2}{2 a^3} = \frac{N Mo i}{2 a}$$

### - 4x -

### الكتل المغناطيسية

### 3- Magnetic field of solenoid coil



A solenoid coil of length ( $l$ ) radius ( $a$ ). the number of turns ( $N$ ), carrying current ( $i$ ) as shown in figure, we may use the Biot law to calculate the magnetic field ( $B$ ) at point ( $P$ ) on the axis ( $x$ ) of the Solenoid.

استدلال

consider an elementary length ( $dx$ ) of the Solenoid at an axis distance ( $x$ ) from ( $P$ ). The number of turns per unit length is then ( $n = \frac{N}{l}$ ) and the number of turns is the length ( $dx$ ) is ( $ndx$ )  $\Rightarrow$  ( $N = ndx$ ).

The magnetic field ( $dB$ ) caused by element  $dx$ .

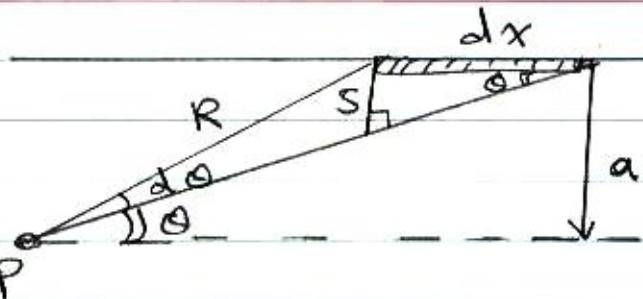
$$\therefore B = \frac{N Mo i a^2}{2(a^2 + x^2)^{3/2}} \quad \text{الكتل المغناطيسية}$$

$$\therefore B = \frac{N Mo i a^2}{2R^3} \quad N = ndx$$

$$\therefore dB = \frac{(ndx) Mo i a^2}{2(a^2 + x^2)^{3/2}}$$

$$\therefore dB = \frac{Mo i n a^2}{2R^3} dx \quad \text{--- (1)}$$

العنوان  $S = R d\theta$  ناتج  
المحور من  
كتلتين (أوتومات).



$$\therefore \sin\theta = \frac{S}{dx} \Rightarrow dx = \frac{S}{\sin\theta}$$

$$\therefore dx = \frac{(R d\theta)}{\sin\theta} \quad \text{--- (2)}$$

sub eq. (2) in (1) :-

$$\therefore dB = \frac{M_0 I n a^2}{2 R^2} \left( \frac{R d\theta}{\sin\theta} \right)$$

$$= \frac{M_0 I n (R^2 \sin^2\theta)}{2 R^2} \left( \frac{d\theta}{\sin\theta} \right)$$

$$\therefore dB = \frac{M_0 I n}{2} \sin\theta d\theta \Rightarrow \therefore B = \int dB$$

$$\therefore B = \frac{M_0 I n}{2} \int_{\alpha_1}^{\alpha_2} \sin\theta d\theta$$

$$\therefore B = \frac{M_0 I n}{2} \left[ -\cos\theta \right]_{\alpha_1}^{\alpha_2}$$

$$\therefore B = -\frac{M_0 I n}{2} (\cos\alpha_2 - \cos\alpha_1)$$

العلاقة العامة لبعض  
القطاط المأهولة على  
المحور متساوية

The equation to any axial point and not restricted to point within Solenoid.

$P =$  موقع النقطة

$$\sin\theta = \frac{a}{R}$$

ناتج المليمات

$$\therefore a = R \sin\theta$$

$$\alpha^2 = R^2 \sin^2\theta$$

(ج)

At any axial point within along solenoid coil  
 $(\alpha_1 = 0 \quad \alpha_2 = \pi) \rightarrow$  داخل الملف

$$\therefore B = \frac{-M_{o\text{in}}}{2} (\cos \pi - \cos 0)$$

$$= -\frac{M_{o\text{in}}}{2} (-1 - 1) = M_{o\text{in}}$$

$$\left. \begin{aligned} \therefore B &= M_{o\text{in}} \end{aligned} \right\} \text{ داخل حلقة مفتوحة}$$

At an axial point at one end along solenoid:

$$(\alpha_1 = 0 \quad \alpha_2 = \frac{\pi}{2})$$

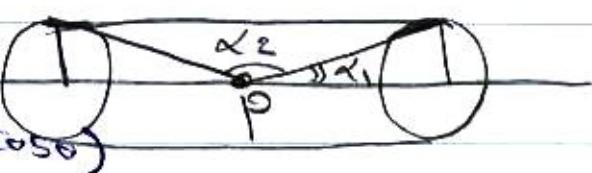
$$\therefore B = -\frac{M_{o\text{in}}}{2} (\cos \frac{\pi}{2} - \cos 0)$$

$$= -\frac{M_{o\text{in}}}{2} (0 - 1) = \frac{M_{o\text{in}}}{2}$$

$$\left. \begin{aligned} B &= \frac{M_{o\text{in}}}{2} \end{aligned} \right\}$$

outside points  
 جنبة الملف

$\therefore$  The flux density at either end is  
 one-half its magnitude at the center.



#### 4- Field of moving point charge

اکٹ ایکٹ  
لختہ کھوائے تحریک

The magnetic induction at point around a current element is given by :-

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{idl}{r^2} \sin\theta \quad \dots \textcircled{1}$$

The current in a conductor may be written:-

$$[i = nqVA] \quad \dots \textcircled{2}$$

$n$  :- The number of moving charge in the element

$v$  :- Velocity

$q$  :- charge

Sub eq (2) in (1) :-

$$\therefore dB = \frac{\mu_0}{4\pi} \cdot \left( \frac{nqVA}{r^2} \right) dl \sin\theta$$

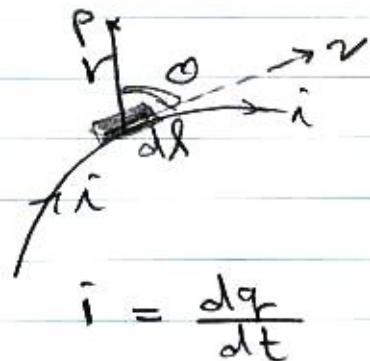
$$\therefore dB = \frac{\mu_0 V}{4\pi r^2} (nqA dl) \sin\theta$$

للتدار (nqA dl) سے مل جائے الممکن  
الممکنہ للتدار فی آخری (dl)

$dq$  ملکے

$$\therefore dB = \frac{\mu_0 V}{4\pi r^2} \frac{d\theta}{dl} \sin\theta$$

$\theta$  :- between ( $V$ ) and ( $r$ )



$$\begin{aligned} dq &= idt \\ &= (nqVA) dt \\ &= nq \frac{dl}{dt} A dt \end{aligned}$$

$$\therefore dq = nqA dl$$

If ( $A$ ) is very small and also ( $dl$ ). Therefore the charge ( $dQ$ ) become very small as charge point ( $Q$ ).

$$\therefore B = \frac{\mu_0 QN}{4\pi r^2} \sin\theta \quad \begin{array}{l} \text{أى المساهمة في الناتج} \\ \text{هي التي تدور في اتجاه ممتد} \\ \text{من مسافة } r \text{ تتركه في اتجاه ممتد} \\ \text{مواردة} \end{array}$$

if number of charges contribution to the field

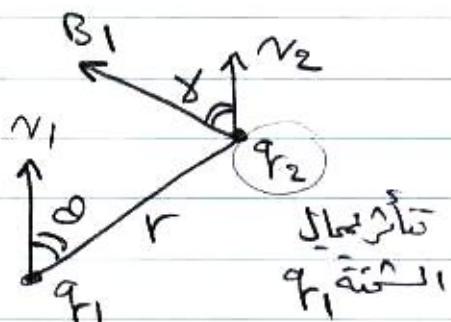
$$B = \frac{\mu_0}{4\pi} \sum \frac{Qv \sin\theta}{r^2}$$

consider now two charges  $q_1, q_2$  moving with velocities  $v_1, v_2$  and separated by distance ( $r$ ).

The magnetic field setup by charge ( $q_1$ ) at the point of space occupied by ( $q_2$ ) is form

$$B_1 = \frac{\mu_0}{4\pi} q_1 v_1 \sin\theta$$

and the force  $F_2 = q_2 v_2 B_1 \sin\gamma$  on the charge ( $q_2$ ) is



where ( $\gamma$ ): - angle between  $v_2$  &  $B_1$ ,  
and  $F$ : - perpendicular to the plane of  $v_2$  and  $B_1$ .

combining  $\text{eq}$  these equation we find.

$$F_2 = q_{r_2} v_2 \left( \frac{\mu_0}{4\pi r^2} q_1 v_1 \sin\theta \right) \sin\gamma$$

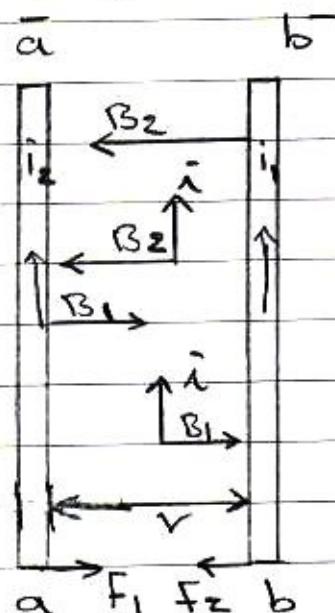
$$\boxed{\therefore F_2 = \frac{\mu_0}{4\pi r^2} q_1 q_{r_2} v_1 v_2 \sin\theta \sin\gamma}$$

Also there is a force ( $F_1$ ) on the charge ( $q_1$ ) by effect of ( $B_2$ ) equal and opposite to the ( $F_2$ )

$$\boxed{\therefore F_1 = \frac{\mu_0}{4\pi r^2} q_1 q_{r_2} v_1 v_2 \sin\theta \sin\gamma}$$

**- 53 -**  
 المفهوم كله متسان متسان في كل متسان  
**Force between parallel straight conductor:**

Let there is two long straight parallel conductors separated by distance ( $r$ ) and carrying current ( $i_1$ ) and ( $i_2$ ) in the same direction since each conductor lies in the magnetic field of the other, each will exert an exoteric force exerted on it by the magnetic field setup by the current in the other conductor



$$\therefore B = \frac{\mu_0 i}{2\pi r} \quad [\text{For long straight conductor}].$$

$$\therefore F = i l B \sin\theta \quad [\text{from chapter-3}]$$

$$\therefore B_1 = \frac{\mu_0 i_1}{2\pi r}$$

$$\sin\theta = 1$$

$$\theta = 90^\circ$$

$$\therefore F_2 = i_2 l B_1 \sin 90^\circ$$

$$\therefore F_2 = i_2 l B_1 \sin 90^\circ$$

$$\therefore F_2 = \frac{\mu_0 i_1 i_2 l}{2\pi r}$$

القوة بين مسلكين متوازيين  
 طولهما يمتد في كل دهنا  
 تيار كهربائي

Force per unit length

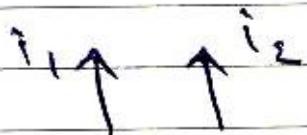
$$\left\{ \frac{F}{l} = \frac{\mu_0 i_1 i_2}{2\pi r} \right\}$$

القوة لوحدة الطول  
 في المدى

There is an equal and opposite force per unit length on both conductor, hence the conductors attract  $\rightarrow$  on other.

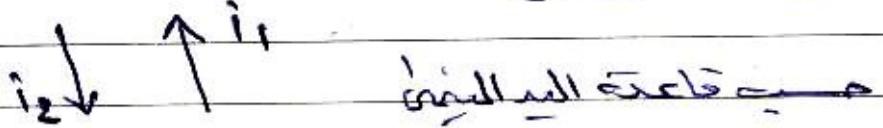
\* If the direction of either current is reversed the forces reverse also.

النتيجة : إذا كانت التيارات  $i_1$  ،  $i_2$  في أحدي導體 متقابلة فـ قـوـة جـمـاـزـيـة بـيـنـهـمـ



اما اذا كانت التيارات  $i_1$  ،  $i_2$  في أحدي導體 مـعـاـكـيـدـ

فـ هـنـاكـ قـوـة تـنـافـرـ بـيـنـهـمـ



### The ampere :-

Is that unvarying current which is present in each of two parallel conductors of infinite length and one meter apart empty space causes each conductor to experience a force of exactly ( $2 \times 10^{-7} \text{ Nt/m}$ ) Newton per meter of length ( $F/l$ )

$$\frac{F}{l} = \frac{M_0 i_1 i_2}{2\pi r} = \frac{4\pi \times 10^{-7} (i)(i)}{2\pi (r)} = 2 \times 10^{-7} \text{ Nt/m}$$

### Ampere's Law:

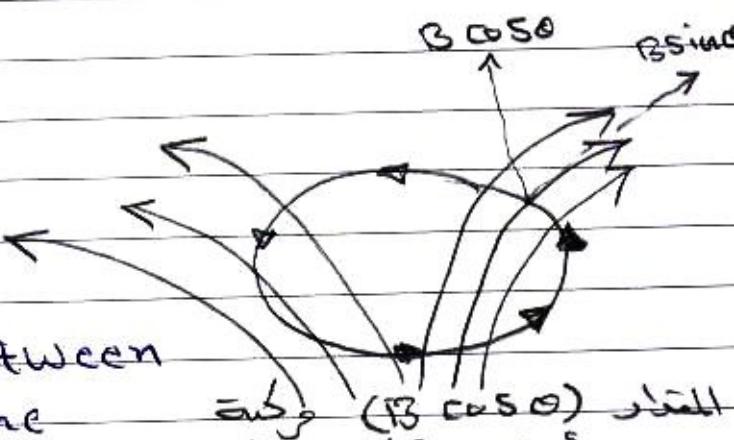
القانون

The line integral of the magnetic induction ( $B$ ) around any closed path is equal to  $M_0$  times the net current across the area bounded by the path.

$$\oint B \cos \theta dL = M_0 I$$

$$\oint \vec{B} \cdot d\vec{L} = M_0 I$$

where  $\theta$  :- IS the angle between any element ( $dL$ ) and the direction of ( $\vec{B}$ ) at the element.

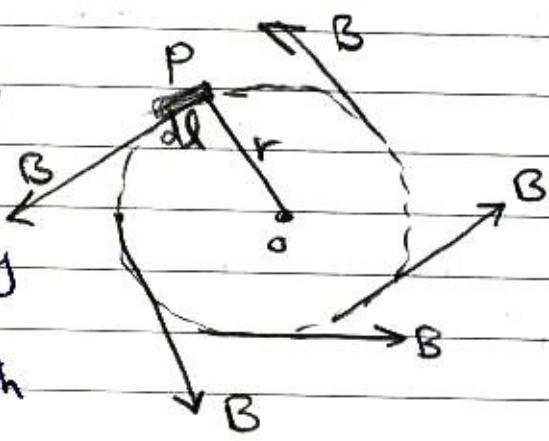


## Application of Ampere's Law تطبيقاً على قانون أمبير

الداير

### 1- The field of along straight conductor

consider the closed curve by full circle طبقة كاملة، a circle of radius ( $r$ ) concentric with conductor - كل المحيط



معلمات المحيط

The direction of field at every point is tangent to circle, hence ( $B$ ) equal to every point.

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I \Rightarrow \oint B dl \cos 90^\circ = \mu_0 I$$

$$\therefore \oint B dl \cos 90^\circ = \mu_0 I$$

$$B \cdot l = \mu_0 I$$

$$l = 2\pi r$$

حيط المحيط

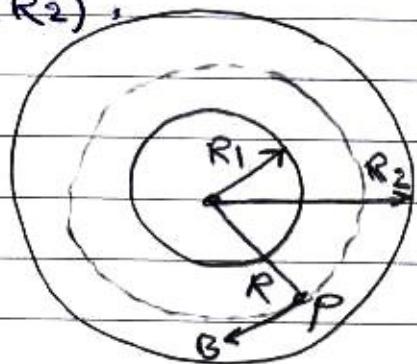
$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 I}{2\pi r}$$

صيغة لقانون  
باديوت

## 2- The field ( $B$ ) inside toroid coil

Toroid coil of center in ( $O$ ) and the inner radius ( $R_1$ ) and the outer radius ( $R_2$ ), its turns ( $N$ ) and the current in the coil is ( $I$ ), the field ( $B$ ) at point ( $P$ )



$$\int B dl \cos 90^\circ = \mu_0 I$$

The total current through the area is ( $NI$ ), ( $B$ ) is equal in every point  $r$  and the direction of ( $B$ ) tangent to the circle.

$$0 = \theta \quad \therefore \cos 90^\circ = 1$$

$$\int B dl = \mu_0 NI$$

$$\int B dl = \mu_0 NI$$

$$\therefore B(2\pi R) = \mu_0 NI \Rightarrow \therefore B = \frac{\mu_0 NI}{2\pi R} \Rightarrow \therefore B \propto \frac{1}{R}$$

$$\therefore B_{\max} = \frac{\mu_0 NI}{2\pi R_1} \quad \& \quad B_{\min} = \frac{\mu_0 NI}{2\pi R_2}$$

$$\text{If } R_1 \text{ near } R_2 \Rightarrow \text{Hence } B_{\max} = \frac{\mu_0 NI}{2\pi R}$$

## The problems of chapter four

E&I final

Q.1 :- An over head transmission line (5)m above the ground carries a current of 400 A in a direction from south to north. Find the magnitude and direction field of the conductor?

Q.2:- A magnetic field of magnitude ( $5.0 \times 10^{-4}$  T) is to be produced at a distance of (5 cm) from along straight wire?

- (a) What current is required to produce this field
- (b) With the current found in (a) what is the magnitude of the field at a distance of 10 cm from the wire at 20 cm?

Q.3:- Two long straight horizontal parallel wires one above the other are separated by distance  
(2a) if the wire carry equal current in opposite direction what is the field magnitude in the plane of the wires at point?

- a) Mid way between them and
  - b) at the distance above the upper wire?
- (2) (c) If the wire carry equal current in the same direction what is the field magnitude in the plane of the wires at point?
- d) mid way between them and?
  - e) at a distance above the upper wire?

Q.4: The long straight wire AB in figure carries a current of  $(20)$  A. The rectangular loop whose long edges are parallel to the wire carries a current of  $(10)$  A. Find the magnitude and direction of the resultant force exerted on the loop by the magnetic field of the wire?

Q.5: A closely wound coil has a diameter of  $40$  cm and carries a current of  $(2.5)$  A. How many turns does it have if the magnetic field at the center of the coil is  $(1.26 \times 10^{-4}$  Tesla)?

Q.6: A solenoid is  $(30)$  cm long and is wound with two layers of wire. The inner layer consists of  $(300)$  turns the other layer of  $250$  turns. The current is  $3$  A in the same direction in both layers. What is the magnetic field at point near the center of the solenoid?

Q.7: A wooden ring whose mean diameter  $10$  cm is wound with closely spaced toroidal winding of  $500$  turns. Compute the field of a point on the mean circumference of the ring when the current in the winding is  $\sim 3$  A?

Q.8: A closely wound coil of  $100$  turns  $(5)$  cm in radius, carries a current of  $2$  amp. Compute the magnetic flux density of points on the axis of the coil at the following distances from its center  $0, 2$  cm,  $5$  cm,  $8$  cm,  $10$  cm?

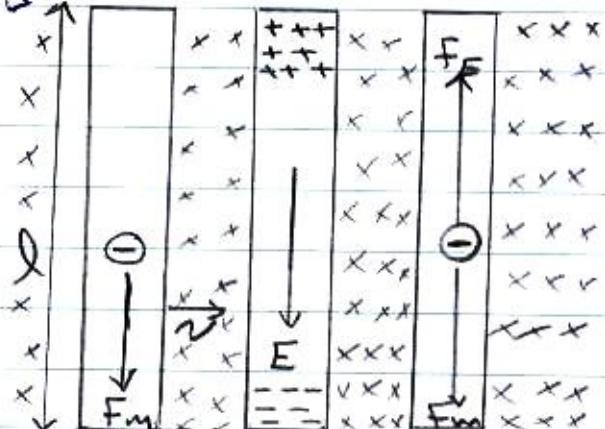
## chapter five

الفصل الخامس

### Induced electromotive force المفهوم المترافق

#### 1- Motional electromotive force المفهوم المترافق

Let a conductor of length ( $l$ ) in a uniform magnetic field perpendicular to the plane of the diagram (B) and directed away from the reader.



If the conductor is set in motion towards the right the velocity ( $v$ ), every charged particle ( $q$ ) within it experiences a force ( $F_m$ ) equal  $\Rightarrow (F_m = qvB)$  divided along the length ( $l$ ) of the conductor.

The direction of the force on negative charge is from  $a$  to  $b$  while the force on positive charge is from  $b$  to  $a$ . The moving charges to the ends of conductor causing to produce current in conductor and also produced electrostatic field ( $E$ ) at the same direction of the force, also there is electric force ( $Ee$ ) producing to the upper end.

Therefore the electron effected by two force [ $F_m$  &  $F_E$ ] the current is continuous to moving until the two force equal, it mean the resultant ~~other~~ force on every charge within the conductor is (zero). The moving of electrons is stoping the charge are then in equilibrium الناتج and the current also stopping :  $[F_m = F_E]$ . موجة تيار ملائمة

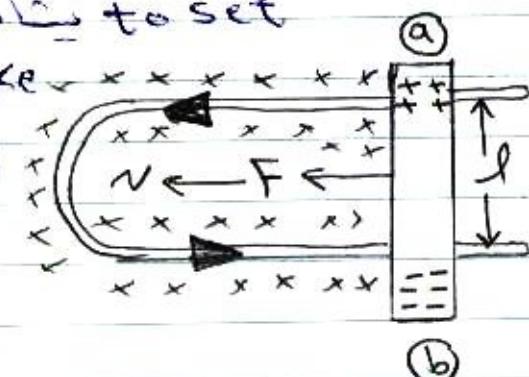
$F_m$ , is caused by magnetic field ( $B$ ).  
 $F_E$ , is caused by electric field ( $E$ ).

But we have to find out the current is continue for a long period.

فیض  
Suppose now, that the moving conductor slides along a stationary V-shaped conductor.

The current continuous moving for long time

The moving conductor corresponds to a set of electromotive force(emf) By making the previous conductor is moving on a closed track made of conductor materials in this case -



The electron will complete movement from ⑥ to ⑤ on the track, therefore will obtain the continuous current called (induced current) and the induced (emf) will be generated توليد.

The definition of the (emf) :- تعریف القوی لذاعنہ الکھم طبیعی :-

Is the ratio of the work done of the circulating charge to the quantity of charged displaced past a point of the circuit.

کوئی کار انجام دادنے والے طبقے کا طبقے

The magnitude of (emf) can be found as follows:-

Let suppose a conductor of length ( $l$ ) carries a current ( $i$ ) with a magnetic field ( $B$ ) thus there is a magnetic force ( $F$ ) ( $F = Bli$ ).

Therefore an external force provided by some working agent لڑکا is needed to keep it move with constant velocity the work done on the charge with distance ( $ds$ ) in time ( $dt$ )

$$\therefore ds = v dt$$

and the work done is:-

$$dw = F \cdot dx = F(v dt)$$

$$dw = (Bl i)(v dt)$$

$$dw = Bl v \cdot i dt$$

But  $(idt)$  is the charge ( $dq$ ) displaced in this time  $(dt)$ , Hence:-

$$\therefore dw = Blv(dq)$$

and the (emf) : The work per unit charges so:-

$$\therefore E = \frac{dw}{dq} .$$

$$E = \frac{dw}{dq}$$

$$\therefore \frac{dw}{dq} = Blv \left( \frac{dq}{dq} \right)$$

$dq$  is unit

$$\therefore E = \frac{dw}{dq} = Blv$$

$$emf = E$$

above equation was deduced given for special case (where the magnetic field was uniform & the velocity and the magnetic field mutually perpendicular).

$$dq = (\vec{B} \times \vec{dl}) - (\vec{v})$$

$$dq = Bl \sin\theta \cdot \cos\phi .$$

where  $\theta$  :- is the angle between  $(B)$  &  $(dl)$

$\phi$  :- The angle between  $(v)$  & normal to the plane determined by  $(dl)$  and  $(B)$ .

$E$  ... is scalar quantity

$$E = Bl \sin\theta \cdot \cos\phi$$

ذالك  $B$  &  $N$  تزيدان  
وتحادثان بعض أحراز المعمل



وعدد الدفعات يجب تأمينه  
أكبر الممكن.

## 2- Faraday's Law قانون فارادی

The induced (emf) in the circuit is numerically equal to the negative rate of change of the magnetic flux through the circuit.

$$\boxed{E = -\frac{d\phi}{dt}}$$

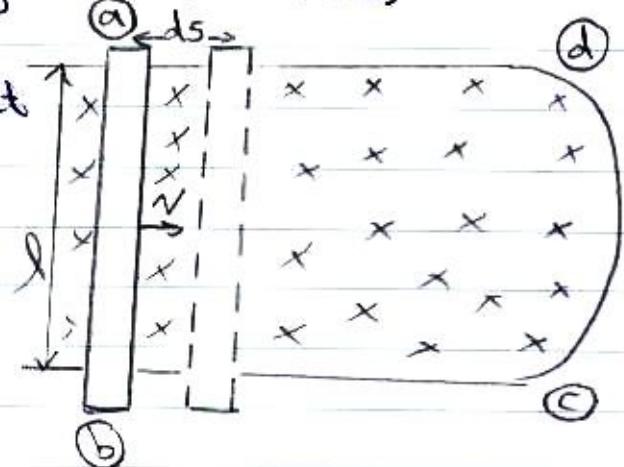
السؤال Q:- prove that  $E = -\frac{d\phi}{dt}$  ?

Let there is a conductor of length ( $l$ ) moving by uniform velocity in uniform magnetic field ( $B$ ) in closed loop (abcd), if the conductor moves towards to right a distance ( $ds$ ), the area enclosed by the circuit (abcd) shown by :-

$$\therefore dA = l ds$$

$$\phi = ABC \cos \theta$$

$$\cos \theta = 1$$



and the change in magnetic flux through the circuit :-

$$\therefore d\phi = -B dA$$

$$\therefore d\phi = -B(l ds)$$

When both sides are divided by (dt) get:-

$$\frac{d\phi}{dt} = - \frac{ds}{dt} \cdot Bl$$

$$\therefore \frac{d\phi}{dt} = -v \cdot Bl$$

But ( $Blv$ ) equal to induced emf so, the above equation become.

$$\therefore \boxed{\mathcal{E} = - \frac{d\phi}{dt} = -Blv} \quad \text{Faraday's Law}$$

To produced emf due to the Faraday's law there is change in magnetic flux through the loop -

There is two case:-

① Varying of ( $B$ ) and both ( $A$ ) & ( $\phi$ ) are constant.

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

$$\therefore \phi = AB \cos \theta$$

$$\therefore \mathcal{E} = - \frac{d}{dt} (AB \cos \theta)$$

$$\therefore \mathcal{E} = -A \cos \theta \left( \frac{dB}{dt} \right).$$

② Varying of ( $\phi$ ) and ( $B$ ) & ( $A$ ) are constant.

$$\therefore \mathcal{E} = - \frac{d\phi}{dt} = - \frac{d}{dt} (BA \cos \theta)$$

$$\mathcal{E} = - BA \frac{d \cos \theta}{dt}$$

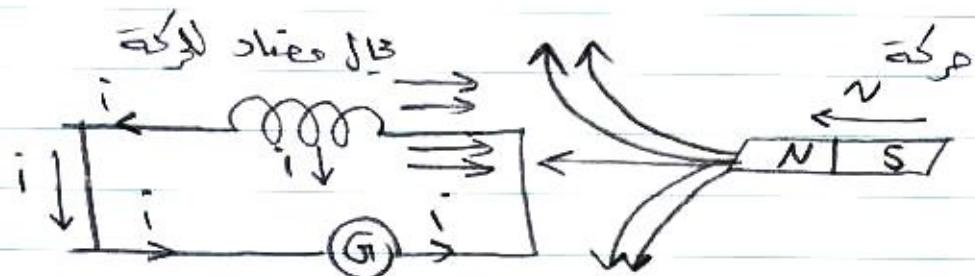
If there is  $N$  (turns) then the induced (emf) is

$$\boxed{\mathcal{E} = - N \frac{d\phi}{dt}}$$

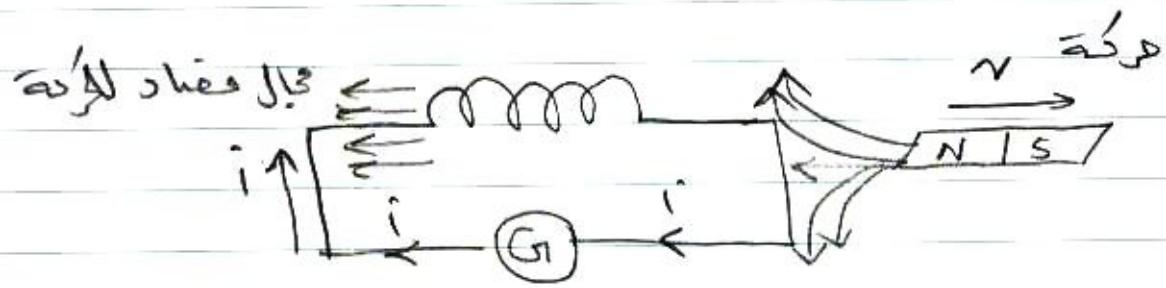
Henz's Law :- قانون لامبرت

The direction of an induced (emf) is such as to oppose the cause producing

① If the magnetic is moved near to coil : there is change in the flux (increase) the an (emf) is generated and an induced current ( $i$ ) also generated, when the direction opposite the cause producing it.



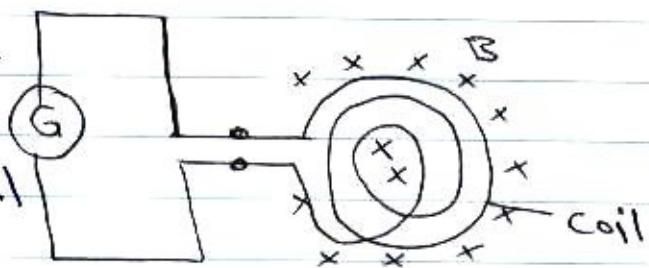
② If the magnet is away from (faraway) the coil - there is change in the flux (decreases).



مقدار میدان مغناطیسی بوسیله:

#### 4- Search coil method of measuring magnetic field

The apparatus consists of  
electromagnetic galvanometer  
connected to the search coil  
(a coil with  $N$  turns and small  
area  $A$ ) ..



The search coil is placed with its plane perpendicular to magnetic field of flux density ( $B$ )  
 $\{\phi = BA\}$ .

If coil is quickly given a quarter turn about one of its diameters, so that its plane becomes parallel to the field or if it is quickly moving from its position to another where the field is known to be zero.

The flux it decrease rapidly from ( $AB$ ) to zero

During the time that the flux is decreasing and (emf) is induced in the coil check by the Ballistic (G)

The maximum deflection of galvanometer is noted.

The galvanometer current at any instant is:

$$\therefore \{ i = \frac{\mathcal{E}}{R} \} \quad \text{--- ①} \quad \text{امتداد قانون أمبير}$$

where  $(R)$  is the combined resistance of galvanometer and search coil:-

$$\mathcal{E} = -N \frac{d\phi}{dt} \quad \text{--- ②}$$

$$\therefore i = -\frac{N}{R} \frac{d\phi}{dt}$$

$$\therefore idt = -\frac{N}{R} d\phi$$

$$\text{Hence } \int idt = -\frac{N}{R} \int_{\phi_1}^{\phi_2} d\phi \quad \therefore dq = idt$$

$$\therefore \int dq = -\frac{N}{R} [\phi_2 - \phi_1] \quad \begin{bmatrix} \phi_2 = 0 \\ \phi_1 = AB \end{bmatrix}$$

$$\therefore q_r = -\frac{N}{R} (0 - AB)$$

$$\therefore q_r = +\frac{N}{R} AB \quad \phi = BA$$

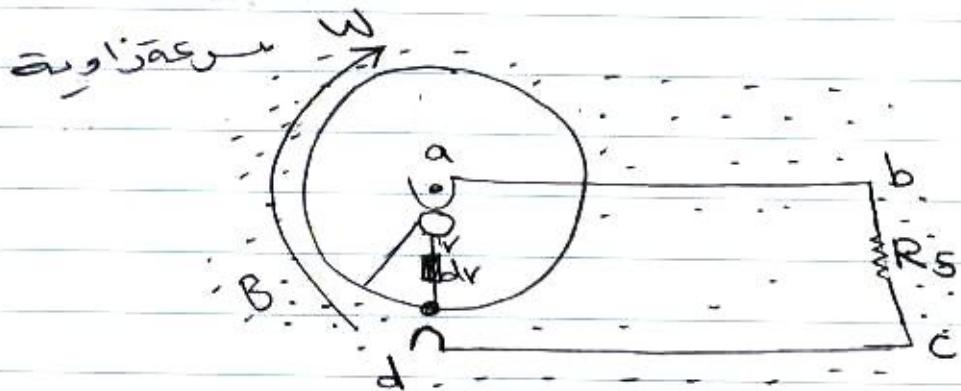
$$\therefore q_r = \frac{N}{R} (AB)$$

$$\left\{ \therefore B = \frac{q_r R}{NA} \right\}$$

$\therefore q_r = q$   
 $\therefore N = \text{عدد لفات الملفت}$   
 $\therefore R = \text{مقاومة مركبة لفات الملفت}$   
 $\therefore A = \text{مساحة الملفت}$

## 5- The Faraday Disk Dynamic

مهمة



It is used to obtain electric energy by mechanical method.

The apparatus itself consists of a metal disk of radius  $(R)$  rotating about an axis through its center. The disk is in a uniform magnetic field perpendicular to the plane of the diagram. The circuit (abcd) is electric circuit and (a) contact the center of the disk and (d) contact with rim of the disk.

consider the disk moving with angular velocity  $(\omega)$ , the magnetic flux changes hence an (emf) induced.

we can divided (ad) to elements the segment  
of length ( $dr$ ) is moving to the field with  
velocity:

~~angular~~  $\omega r$   
~~solid~~

and hence an (emf) is induced init of  
magnitude.

$$\therefore \mathcal{E} = B v l$$

$$\therefore d\mathcal{E} = B v dr$$

$$d\mathcal{E} = B \underset{R}{(wr)} dr$$

$$\therefore \mathcal{E} = B w \int_0^R r dr \Rightarrow$$

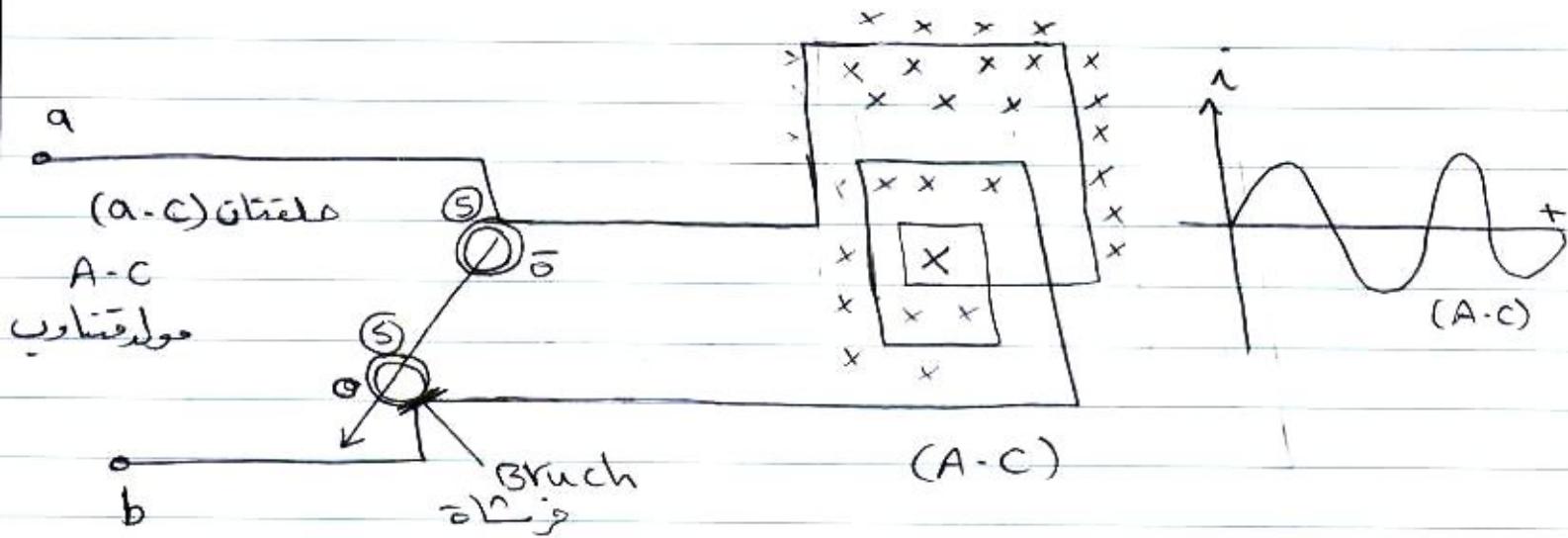
$$\mathcal{E} = B w \left[ \frac{r^2}{2} \right]_0^R$$

$$\boxed{\mathcal{E} = \frac{1}{2} B w R^2}$$

$R$  :- is the radius of the disk.

## 6- Alternating current generator:-

لولہ الکٹریکی مارکیٹ



It is used to obtain electric energy by mechanical method.

It is consist of rectangular coil of ( $N$ ) turn rotates about axis ( $oo'$ ) which is perpendicular to a uniform magnetic field of flux density ( $B$ ).

The ends of coil are connected to (slip-rings) ( $S-S'$ ) are rotating with the coil.

Brushes  $\odot \odot$  bearing poles against مقابلہ the rings connect the coil to the external circuit.

The magnetic field is provided by an electromagnet and the coil is wound on an iron cylinder.

The magnitude (emf) induced in the coil may be computed either from the rate of change of flux through the coil or from the velocity  $w$  (angular velocity).

When the coil rotated and make an angle ( $\theta$ ).- If the area of one turn is ( $A$ ) and the coil is rotated by angular velocity ( $w$ ). the flux through the coil

$$\phi = BA \cos \theta \\ (\text{where } \theta = wt)$$

$$\therefore \phi = BA \cos(wt) \quad \textcircled{1}$$

then  $\phi \propto$  with  $\cos(wt)$ .

The change of flux is varying therefore (emf) is generated.

$$\therefore \mathcal{E} = -N \frac{d\phi}{dt} \quad \textcircled{2}$$

$$\therefore \mathcal{E} = -N \frac{d(BA \cos wt)}{dt}$$

$$\therefore \mathcal{E} = -NAB (-w \sin wt)$$

$$\boxed{\therefore \mathcal{E} = NAB w \sin wt}$$

Jumlah 2 pks

-74-

$$\therefore \mathcal{E} = \mathcal{E}_{\max} - \sin \omega t$$

$$\therefore \mathcal{E}_{\max} = NABW$$

$$\mathcal{E}_{\min} = 0$$

$$\therefore \mathcal{E} = \mathcal{E}_{\max} \sin(2\pi f t)$$

$$\mathcal{E} = \mathcal{E}_{\max} \sin \omega t$$

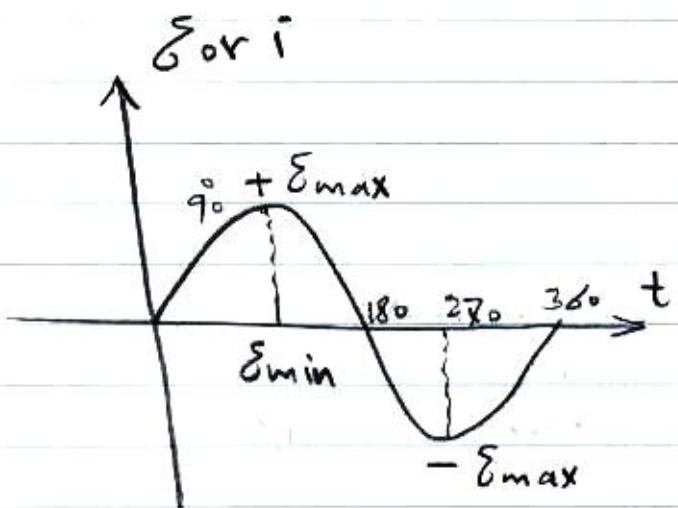
- When ( $\omega t$ ) equal ( $90^\circ$ )

then  $\sin \omega t = 1$

$$\therefore \mathcal{E}_{\max} = NABW$$

When ( $\omega t$ ) = 0  $\Rightarrow \sin \omega t = 0$

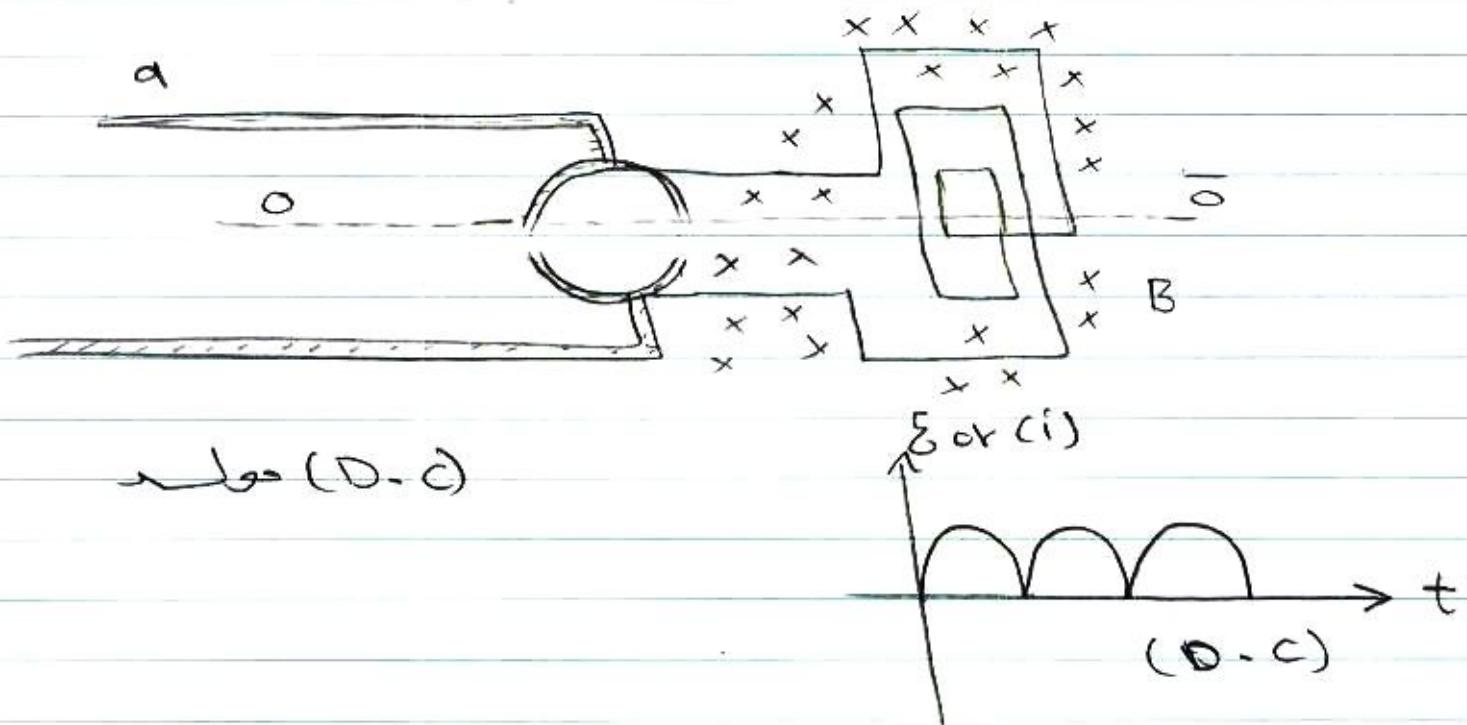
$$\therefore \mathcal{E}_{\min} = 0$$



(A - C)

Now: A coil of rotating in magnetic field developed to unidirectional (متجه واحد) (emf) may be obtained by connecting each terminals coil to one side of a slipping

D-C in one  
A-C in two

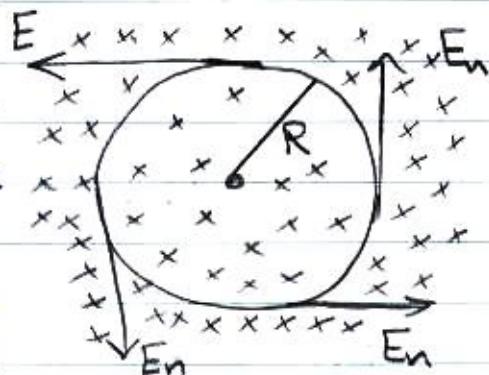


سؤال / قارن بين جولدن D-C و A-C / يمثل رسم الامبيره للقوعين والرسم المباعي واتجاه المترار.

## X- Induced electric field:-

المجال الكهرومagnetic

Suppose there is circular toroid of radius ( $R$ ) in annular form magnetic field ( $B$ ) perpendicular to the its face. If the magnetic induction changing there is causing to change in magnetic flux passes through the toroid and its causing to produced induced current and induced current passing in the toroid



عوّض كهرومائي تيار طاقة حافظة

$$B \rightarrow \phi \rightarrow \mathcal{E} \rightarrow i \rightarrow E \rightarrow F$$

Because of the axial symmetry, the non-electrostatic field ( $E_n$ ) has the same magnitude at all points on the toroid, and it is tangent to this on the toroid.

The work done to the electron through one period is equal

- قبط الماء

$$\text{الجهد المبذول} \quad W = F \cdot S = (E_n \cdot e) \cdot (2\pi R) \quad \text{--- (1)}$$

$$\therefore \mathcal{E} = \frac{\omega}{e} \Rightarrow \omega = \mathcal{E}e \quad \textcircled{2}$$

$$\therefore \mathcal{E}\phi = (E_n \cdot \phi) - 2\pi R$$

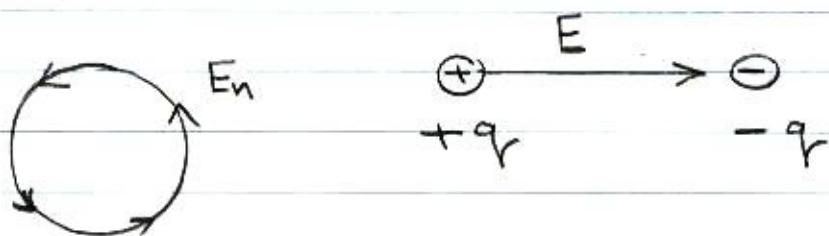
$$\therefore E_n = \frac{\mathcal{E}}{2\pi R}$$

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

$$\boxed{\therefore E_n = - \frac{d\phi/dt}{2\pi R}}$$

الحالات الكهرومagnetique التي

The lines of the induced electric field is closed circles and is different with the electric field between two charges which is straight lines.



## problems of chapter five

مسائل�اتیفیل

Q-1 :- As in figure, the length ( $l$ ) equal (0.1 m) & the velocity (0.1 m/sec). The resistance of the loop be (0.01 Ω) and the magnetic field (1 Tesla) calculate:  
a) induced (emf). the current the force in the loop?  
b) the mechanical power necessary to move the loop against Jiles this force? c) The rate of energy conversion?

Q-2:- A certain coil of wire consists of (500) circular loops of radius (4 cm) it is placed between the poles of a large electromagnet. Where the magnetic field is uniform perpendicular to the plane of the coil, and increasing at a rate of (0.2 T/sec)  
a) what is the magnitude of the resulting induced (emf)?  
b) If the coil is tilted like so that a line perpendicular to its plane makes an angle of ( $30^\circ$ ) with ( $B$ ) - find the induced (emf)?

مهم

Q-3: - Suppose the long solenoids wound with (1000) turns per meter and the current in its winding ends is increasing at the rate of ( $100 \text{ A} \cdot \text{s}^{-1}$ ). The cross sectional area of the solenoid is  $4 \text{ cm}^2$ , what is the magnitude of (emf) in the solenoid?

Q-4 :- A conducting rod (AB) as in figure, The apparatus is in a uniform magnetic field ( $0.5\text{ T}$ ) perpendicular to the plane of the diagram

a) Find the magnitude of the (emf) induced in the rod when it is moving towards the right with a speed ( $4\text{ m/s}$ ), b) if the resistance of the circuit (ABCD) is ( $0.2\Omega$ ) find the force required to maintain the rod in motion? c) compare the rate at which mechanical work is done by the force ( $FN$ ) with the rate of development of heat in the circuit ( $i^2R$ )?

Q-5 :- Figure show that is a side view of the same rod and metal rails as in (Q-4) except that the magnetic induction makes an angle of ( $60^\circ$ ) with the plane of the loop (ABCD), find the induced (emf) the flux density is ( $500$ ) million weber/ $\text{m}^2$  and the velocity of the rod is ( $4 \frac{\text{m}}{\text{sec}}$ ) toward the right?

Q-6 :- A coil ( $4\text{cm}$ ) in radius containing ( $500$ ) turns with constant angular velocity about an axis along a diameter perpendicular to the earth's magnetic field, which may be taken as ( $0.5 \times 10^{-4}\text{ Tesla}$ ). What angular velocity must it have for the induced (emf) have a maximum value of ( $1 \times 10^{-3}\text{ volt}$ )?

Q-7:- The cross-section area of closely wound search coil having ( $20$ ) turns is ( $1.5 \text{ cm}^2$ ) and its resistance is ( $4\Omega$ ). The coil is connected through leads of negligible resistance to a ballistic galvanometer of resistance ( $16\Omega$ ). Find the quantity of charge displaced through the galvanometer when the coil is pulled quickly out of a region where ( $B = 1.8 \text{ Wb/m}^2$ ) to a point where the magnetic field is zero. The plane of the coil when in the field make an angle of  $60^\circ$  with magnetic induction?

Q-8:- A solenoid coil ( $2.2 \text{ m}$ ) long and the cross-section area ( $24 \text{ cm}^2$ ) is wound with ( $8800$ ) turns. A closely wound coil of ( $200$ ) turns surrounds the solenoid. If the current passing through the solenoid changing by rate ( $0.2 \text{ amp/sec}$ ), find the induced ( $\text{emf}$ ) produced in the short coil?

Q-9:- A generator coil of (200) turns and area ( $400 \text{ cm}^2$ ) rotating about its radius by uniform frequency in magnetic field (0.2 Tesla). Compute the coil frequency when the maximum of induced (emf) equal (220 volt)?

Q-10:- A coil of (1000) turns and resistance ( $50\text{-}\omega$ ) passing through it magnetic flux ( $\phi$ ) where ( $\phi = 4 \times 10^{-5} \sin 120\pi t$ ). Find (emf) and the current and the maximum value for every one?

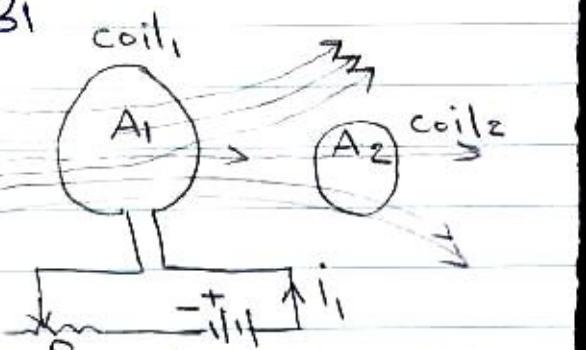
chapter - 6 -  
الجاء الماء

Inductance:-

: الماء

Mutual inductance:-

Now we study in this chapter the induced (emf) in terms of the varying currents suppose that there are two circuit closely wound coils of wire with ( $N_1$ ,  $N_2$ ) turns and ( $A_1$ ) and ( $A_2$ ) cross-section area of the coils, if the current of coil (1) is ( $i_1$ ). Some of magnetic field lines pass through coil (2).



Let the resulting flux through coil (2) be ( $\phi_2$ ) & the magnetic field is proportional to ( $i_1$ ). So ( $\phi_2$ ) is also proportional to ( $i_1$ ). When ( $i_1$ ) changes  $\phi_2$  is changing

$$\phi_2 \propto i_1 \Rightarrow \phi_2 = K i_1$$

where ( $K$ ) is the constant of proportionality

$$E_2 = -N_2 \frac{d\phi_2}{dt} \quad (\text{Faraday Law})$$

$$E_2 = -N_2 \frac{d(Ki_1)}{dt}$$

$$E_2 = -N_2 K \frac{di_1}{dt}$$

Let us represent the product ( $N_2 K$ ) by a single constant (M) then:-

$$E_2 = -M \left( \frac{di_1}{dt} \right) \Rightarrow M = -\frac{E_2}{\left( \frac{di_1}{dt} \right)}$$

The factor (M) is called the coefficient of mutual inductance or the mutual inductance of the two circuit.

نوريت معامل امبير

We may be defined the mutual inductance (M):-

The ratio of the induced (emf) in one circuit to the rate of change of current in the other the unit of (M) is (henry).

$$\boxed{\text{Henry} = \frac{\text{Volt-Sec}}{\text{amp}}}$$

تعريف الهنري

And the definition of (henry)-

Is the mutual inductance of two circuit is one henry (emf) of one volt is induced in one of the circuits when the current in the other is changing of the rate of the amper per second.

$$\therefore \mathcal{E}_2 = -M \left( \frac{di_1}{dt} \right)$$

$$\therefore -N_2 \left( \frac{d\phi_2}{dt} \right) = -M \left( \frac{di_1}{dt} \right)$$

$$\therefore N_2 \left\{ d\phi_2 = M \right\} di_1$$

$$\therefore N_2 \phi_2 = Mi_1 + C$$

C ثابت

$$\text{if } i_1 = 0 \text{ , } \phi_2 = 0 \Rightarrow C = 0$$

$$\therefore N_2 \phi_2 = Mi_1$$

$$M = \frac{N_2 \phi_2}{i_1}$$

M ( $\frac{\text{weber.turn}}{\text{amp}}$ )

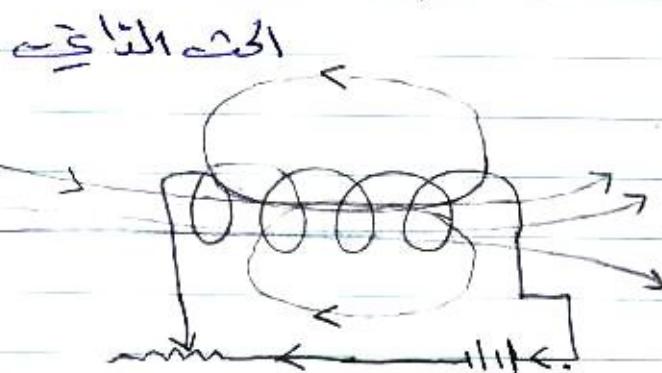
Also we can written the mutual inductance is:-

$$M = \frac{N_1 \phi_1}{i_2}$$

Self inductance

Suppose that the circuit has (N) turn of wire and that flux ( $\phi$ ) passes through each turn. When (i) changes, ( $\phi$ ) changes this changing flux induces an emf ( $\mathcal{E}$ ) in the coil we can write:-

$$\phi \propto i \Rightarrow \therefore \phi = ki$$



$$\therefore \mathcal{E} = -N \frac{d\phi}{dt}$$

$$\therefore \mathcal{E} = -N \frac{d(Nki)}{dt}$$

$$\therefore \mathcal{E} = -NK \left( \frac{di}{dt} \right).$$

Let us represent the product ( $NK$ ) by using a single constant ( $L$ ), then:

$$\therefore \mathcal{E} = -L \left( \frac{di}{dt} \right) \Rightarrow L = \boxed{\frac{\mathcal{E}}{\frac{di}{dt}}}$$

The factor ( $L$ ) is called self inductance of the circuit  
تُعرف بـ عوامل الذات

We can define the self inductance ( $L$ )

Is the ratio of the induced (emf) in the circuit to the rate of change of current, the unit of ( $L$ ) is (henry).

الهنري

Henry = Is the self inductance of the circuit is  
one henry if an (emf) of one Volt  
induced in the circuit - when the current is  
changing at the rate of amper per second.

$$\mathcal{E} = -N \frac{d\phi}{dt} = -L \frac{di}{dt}$$

$$\therefore N \int d\phi = L \int di$$

$$\therefore N\phi = Li + C$$

If  $i = 0 \Rightarrow \phi = 0 \Rightarrow C = 0$

$$N\phi = Li \rightarrow \boxed{L = \frac{N\phi}{i}}$$

مُعْلَمَةُ الْمَوْسِعَةِ الْأَنْتَارِيَّةِ

Self-inductance of toroidal solenoid coil :-

Let solenoid coil of cross-section area (A) is closely wound with (N) turns of wire length (l) which passing current (i) in it:-

$$\therefore L = \frac{N\phi}{i}$$

$$\phi = BA$$

$$B = \mu_0 i n = \mu_0 i \frac{N}{l}$$

$$\therefore \phi = \mu_0 i \frac{N}{l} A$$

$$\therefore \phi = (\mu_0 i \frac{N}{l}) A$$

$$\therefore L = \frac{\mu_0 N i}{l} A$$

$$\therefore \boxed{L = \frac{\mu_0 N^2 A}{l}}$$

The stored energy in inductor: الطاقة المخزنة في المكثف

There is an energy stored in magnetic field we can find this energy. Let an inductor of self inductance ( $L$ ) and ( $N$ ) turns carries current ( $i$ ) which changing at the rate ( $\frac{di}{dt}$ ). The induced (emf) is equal ( $E = L \cdot \frac{di}{dt}$ ) and the power ( $P$ ) supplied to the inductor is:-

$$\therefore E = -L \frac{di}{dt}$$

$$\therefore P = EI = -LI\left(\frac{di}{dt}\right)$$

القدرة المزودة للملف

الإيجي

$$\therefore P \cdot dt = -LIdi$$

$$\therefore dw = -L \int idi$$

$$dw = P dt \rightarrow w = \int pdt$$

المطاقة

$$\boxed{\therefore w = -\frac{1}{2} Li^2}$$

الاستدراة الالكترونية  
على ان الطاقة في المكثف

المزودة للملف

خزن

The energy supplied to the inductor is stored as a form of potential energy as long as the current continuous passing. When the current is reduced to (zero), this energy is returned to the circuit which supplied it.

Magnetic energy density ( $u$ ):-

كثافة الطاقة  
المغناطيسية

Is defined as a magnetic energy per unit volume of magnetic field.

$$u = \frac{w}{v} \quad , \quad u = \frac{\text{الطاقة}}{\text{الحجم}}$$

Let that is solenoid coil of length ( $l$ ), across section area ( $A$ ) and ( $N$ ) turns carrying current the self inductance ( $L$ )

$$\therefore L = \frac{\mu_0 N^2 A}{l}$$

$$w = \frac{1}{2} L i^2$$

$$\left\{ w = \frac{1}{2} \left( \frac{\mu_0 N^2 A}{l} \right) i^2 \right\} * \frac{\mu_0 l}{\mu_0 l}$$

$$w = \frac{1}{2} \left( \frac{\mu_0^2 N^2 i^2}{l^2} \right) \frac{Al}{\mu_0}$$

$$\therefore w = \frac{1}{2} (B)^2 \frac{Al}{\mu_0}$$

الطاقة  
 $u = \frac{w}{v}$  كثافة الطاقة

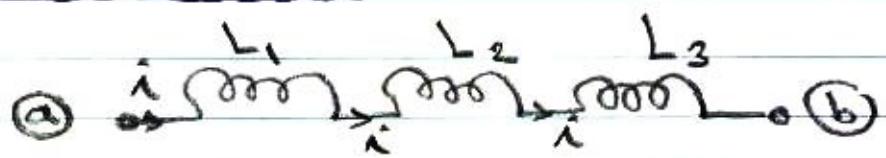
$v = Al$   
الحجم

$$\therefore u = \frac{1}{2} \left( \frac{B^2 A l}{\mu_0} \right) \frac{1}{Al}$$

$$u = \frac{1}{2} \frac{B^2}{\mu_0}$$

The unit of ( $u$ ) is ( $\frac{\text{Joule}}{\text{m}^3}$ )

# 1- Inductors in series ربط المكواني في سلسلة



There are three coils of self inductance  $L_1, L_2, L_3$   
let there is No mutual inductance

The induced (emf) in every coils is:-

$$\mathcal{E}_1 = -L_1 \frac{di}{dt} \quad , \quad \mathcal{E}_2 = -L_2 \frac{di}{dt} \quad , \quad \mathcal{E}_3 = -L_3 \frac{di}{dt}$$

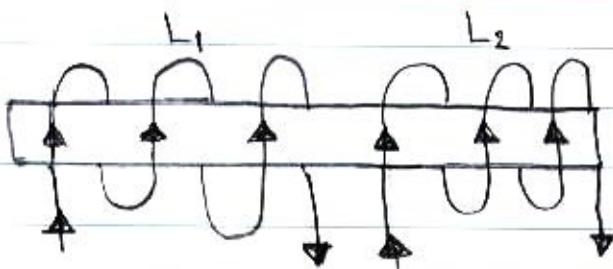
$$\mathcal{E}_{\text{ad}} = \mathcal{E}_1 + \mathcal{E}_2 + \mathcal{E}_3$$

$$\mathcal{E}_{\text{ad}} = -(L_1 + L_2 + L_3) \frac{di}{dt}$$

$$\mathcal{E}_{\text{ad}} = -L_T \left( \frac{di}{dt} \right)$$

$$L_T = L_1 + L_2 + L_3$$

Now there are two coils having self inductances ( $L_1, L_2$ ) and between them mutual inductance is ( $M$ ), Let the coils be placed when the flux linking each coil, due to the current in other is the same direction as the flux due to



Then if the current varying and induced (emf) both self flux and mutual flux will be in the same direction.

$$\mathcal{E}_1 = -L_1 \left( \frac{di}{dt} \right) - M \left( \frac{di}{dt} \right)$$

$$\therefore \mathcal{E}_1 = -(L_1 + M) \left( \frac{di}{dt} \right) \quad \text{للكتف الأول} \quad \textcircled{1}$$

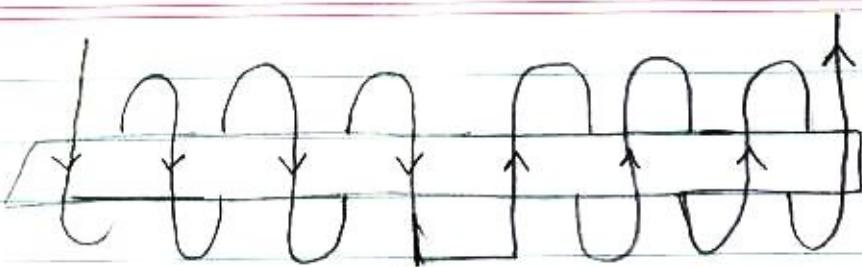
$$\therefore \mathcal{E}_2 = -(L_2 + M) \left( \frac{di}{dt} \right) \quad \text{للكتف الآخر} \quad \textcircled{2}$$

$$\therefore \mathcal{E} = \mathcal{E}_1 + \mathcal{E}_2$$

$$= -(L_1 + L_2 + 2M) \left( \frac{di}{dt} \right).$$

$$\therefore \mathcal{E} = -(L_T) \left( \frac{di}{dt} \right)$$

$$\therefore L_T = (L_1 + L_2 + 2M).$$



if one of the coils is reversed: so that the flux linking each coil due to the current in the other is opposite in direction to the coil, the self flux and mutual flux and induced (emf) in each coil will be in opposite.

$$\therefore \mathcal{E}_1 = -L_1 \left( \frac{di}{dt} \right) + M \left( \frac{di}{dt} \right)$$

$$\therefore \mathcal{E}_1 = -(L_1 - M) \frac{di}{dt} \quad \text{--- ①}$$

$$\therefore \mathcal{E}_2 = -(L_2 - M) \frac{di}{dt} \quad \text{--- ②}$$

مفتاح ①

مفتاح ②

$$\therefore \mathcal{E} = \mathcal{E}_1 + \mathcal{E}_2$$

$$\therefore \mathcal{E} = -(L_1 + L_2 - 2M) \left( \frac{di}{dt} \right)$$

$$\therefore \mathcal{E} = -L_T \left( \frac{di}{dt} \right)$$

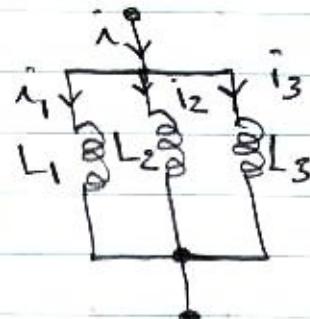
$$\boxed{\therefore L_T = (L_1 + L_2 - 2M)}$$

in general ( $L_T$ ):

$$\boxed{L_T = (L_1 + L_2 \mp 2M)} \rightarrow (L_T \text{ مع})$$

## 2- Inductors in parallel :-

Suppose there are three coil of self inductances  $L_1, L_2, L_3$   
let there is no mutual inductance



$$\text{الإشارات} \quad \frac{di}{dt} = \frac{di_1}{dt} + \frac{di_2}{dt} + \frac{di_3}{dt} \quad \text{--- ①}$$

الرئيسي  
الثانوي

The induced (emf) in every coil is:-

$$\mathcal{E}_1 = -L_1 \left( \frac{di_1}{dt} \right) \Rightarrow \frac{\mathcal{E}_1}{L_1} = -\left( \frac{di_1}{dt} \right) \quad \text{--- ②}$$

$$\mathcal{E}_2 = -L_2 \left( \frac{di_2}{dt} \right) \Rightarrow \frac{\mathcal{E}_2}{L_2} = -\left( \frac{di_2}{dt} \right) \quad \text{--- ③}$$

$$\mathcal{E}_3 = -L_3 \left( \frac{di_3}{dt} \right) \Rightarrow \frac{\mathcal{E}_3}{L_3} = -\left( \frac{di_3}{dt} \right) \quad \text{--- ④}$$

Sub. eq. (2) & (3) & (4) in eq (1):-

$$\therefore -\left( \frac{di}{dt} \right) = \frac{\mathcal{E}_1}{L_1} + \frac{\mathcal{E}_2}{L_2} + \frac{\mathcal{E}_3}{L_3}$$

$$\therefore \mathcal{E}_1 = \mathcal{E}_2 = \mathcal{E}_3 = \mathcal{E} \quad (\text{متساوية})$$

$$\therefore -\left( \frac{di}{dt} \right) = \mathcal{E} \left( \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \right).$$

$$\therefore -\left( \frac{di}{dt} \right) = \mathcal{E} \left( \frac{1}{L_T} \right)$$

$$\boxed{\therefore \frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}}$$

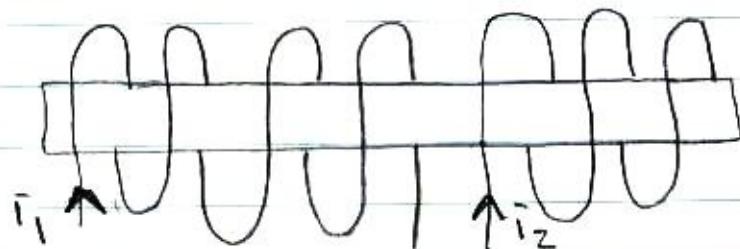
If there are two coils having self inductance ( $L_1, L_2$ ) and between which the mutual inductance is ( $M$ ). Find ( $M$ )?

$$M = \sqrt{L_1 L_2}$$

$$\therefore \phi_1 = \phi_{21}$$

$$\phi_2 = \phi_{12}$$

معامل التبادل بين الملفتين



$$M = \frac{N_1 \phi_{12}}{i_2}$$

$$M = \frac{N_1 \phi_2}{i_2}$$

$$M = \frac{N_2 \phi_{21}}{i_1}$$

$$M = \frac{N_2 \phi_1}{i_1}$$

$$M \times M = \left( \frac{N_1 \phi_2}{i_2} \right) \times \left( \frac{N_2 \phi_1}{i_1} \right)$$

$$M^2 = \left( \frac{N_1 \phi_1}{i_1} \right) \left( \frac{N_2 \phi_2}{i_2} \right)$$

$$L_1 = \frac{N_1 \phi_1}{i_1} \quad , \quad L_2 = \frac{N_2 \phi_2}{i_2}$$

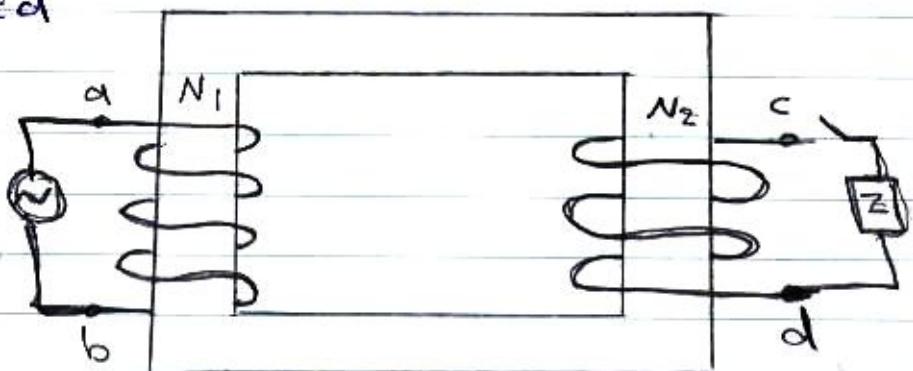
وكلات

$$M^2 = L_1 L_2$$

$$M = \sqrt{L_1 L_2}$$

## Transformer

used to - transformed electrical power at high voltage and small one circuit to another.



It is consist of two coils wound on the same iron core.

An alternating current in one winding set up an alternating magnetic flux in the core. most of this flux links with the other winding and induce in it, an alternating (emf) power thus transferred from one winding called primary which is supplied to other called secondary which power reached.

The power output of transformer is less than power input because:-

1- Some losses in form of heat ( $i^2 R$ ) in primary and secondary winding.

2- Hysteresis

3- Eddy current losses in the core.

All flux which producing the primary in the core. The same flux links both primary and secondary the induced (emf) per turn is the same in each.

The ratio of primary to secondary induced (emf) is therefore equal to the ratio of primary to secondary turns.

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{N_1}{N_2}$$

Since the windings are assumed to have zero resistance, the induced (emf)  $\mathcal{E}_1$  and  $\mathcal{E}_2$  are numerically equal to the corresponding terminals voltage ( $V_1$ ) and ( $V_2$ )

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

If  $N_2 > N_1$  or  $V_2 > V_1$  (step-up) transformer.  
If  $N_2 < N_1$  or  $V_2 < V_1$  (step-down) transformer.

## 7- Eddy current      التيارات المعاوقة

Some of apparatus have a pieces of metal.  
if an alternating current passing through  
the apparatus an induced current passing  
through it with circulatory nature these  
current are called eddy current.

We can defined the eddy current:-

It is induced current with closed circuit  
is like circulatory nature in it is movement.

Problems of chapter six (6):  
أمثلة الفصل السادس

Q.1:- An air core toroidal - solenoid cross-section area ( $10 \text{ cm}^2$ ) and mean radius ( $10 \text{ cm}$ ) is closely wound with ( $100$ ) turns of wire. Find the self inductance if the current in the coil increase uniformly from (zero) to ( $1 \text{ amp}$ ) in ( $0.1 \text{ sec}$ )? Find the magnitude and direction of the self inductance (emf)?

Q.2:- Along solenoid of length ( $50 \text{ cm}$ ) and cross-sectional area ( $10 \text{ cm}^2$ ) is closely wound with ( $1000$ ) turns surrounds it at its center. What is the mutual inductance of two coils?

Q.3:- A circular coil (A) of ( $50$ ) turns of fine wire  $4 \text{ cm}^2$  in cross-sectional area, is placed at the center of circular coil (B) ( $20 \text{ cm}$ ) in radius and having ( $100$ ) turns. the axes of the coils coincide?

- What is the mutual inductance of the coil
- What is the induced (emf) in coil (A) when the current in coil (B) is decreasing at the rate of ( $50$ ) amp / sec ??
- What is the rate of change of flux through coil (A) at this instant?

Q.4:- An inductor used in a (d-c) power supply has an inductance of ( $20\text{H.}$ ) and resistance of ( $200\text{-}\Omega$ ) and carries a current of ( $0.1\text{A}$ )

- What is the energy stored in the magnetic field
- At what rate is energy dissipated in the resistor.

Q.5:- An inductor with ( $L = 40\text{H}$ ) carries a current ( $i$ ) that varies with time according to the equation [ $i = 0.1\text{A} \sin(120\pi t)$ ]

Q.6:- A toroidal solenoid has a mean radius of ( $0.12\text{m}$ ) and a cross-sectional area of ( $20 * 10^{-4}\text{m}^2$ ) it is found that when the current is ( $20\text{A}$ ), the energy stored is ( $0.1\text{J}$ ). How many turns does the winding have?

Q.7:- The resistance of a (1ohenry) inductor is ( $200\text{-}\Omega$ ) - The inductor is suddenly connected across potential difference ( $10\text{Volts}$ )

- What is the final steady current in the inductor?
- What is the initial rate of increase of current?
- At what rate is the current increasing when its value is one-half the final current?

Q.8/ Along solenoid of (1m) cross section ( $10\text{cm}^2$ ) having (1000) turns has wound about its center a small coil of (20) turns,

a) compute the mutual inductance of two circuit

b) what is the induced (emf) in circuit ② when the current in circuit ① changes at the rate of 10 amp/sec  
 Let the resistance of coil 2 be (10 ohms), if the terminals of this coil are connected to a ballistic galvanometer of resistance (20 ohms)

How many columbs are displaced past a point in the galvanometer current when the current in the solenoid is suddenly increase from (Zero) to (5 amp)?

Q.9 :- A certain toroidal solenoid has a rectangular cross-section as shown in figure. It has (N) uniformly spaced turns with air inside. The magnetic field at point inside the toroid is given. Do not assume the field to be uniform over the cross section  
 a) Show that magnetic flux through a cross-section of the toroid is

$$\phi = \frac{M_0 N i h}{2\pi} \ln \frac{b}{a}$$

b) find the self-inductance of the toroidal solenoid due to this magnetic flux?