Electric Circuits

7-1

* Electric current

In a such a substance electric charge can be transferred from one point to another by a general drift of the charged particles within it. such a movement of electric charge is called an "electric current"

Current in solids

a* Materials through which an electric current will pass are known as ((Conductors))
these materials have free electrons

b* Those substance in which there are no charged particles that are free to move are known as ((non-conductors)) or ((insulators.)) , there are no free electrons

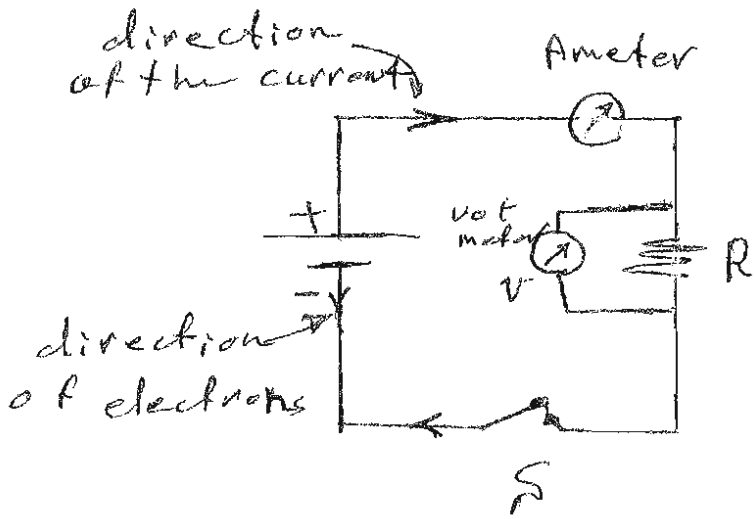
c* Semi conductors - in the semiconductors only avery small proportion of the (Valance - electrons) are free to move through materials.

CH-7-

* Elements of electric circuits

1. Power supply (Dynamo, cell)
2. wirs
3. Loads
4. switches

* The direction of the current



when there is an electric current in a circuit, two physical effects are observed:

1. A heating effect.
2. A magnetic effect

ان شدة التيار الكهربائي تعرف بكمية الشحنات الكهربائية التي تمر في وحدة الزمن خلال مقطع من جهاز تمر به

لذا فعند مرور عدد (N) من الجسيمات المشحونة في زمن قدره t ويحمل كل منها شحنة مقدارها (q) من خلال جزء من وسط موصل فان مجموع الشحنات المارة ستكون

$$Q = qN$$

وان شدة التيار تكون

$$I = \frac{Q}{t}$$

هذه المعادلة تعطي معدل التيار المار في زمن مقداره t ثانية بينما التيار الآني (Instantaneous current) هو

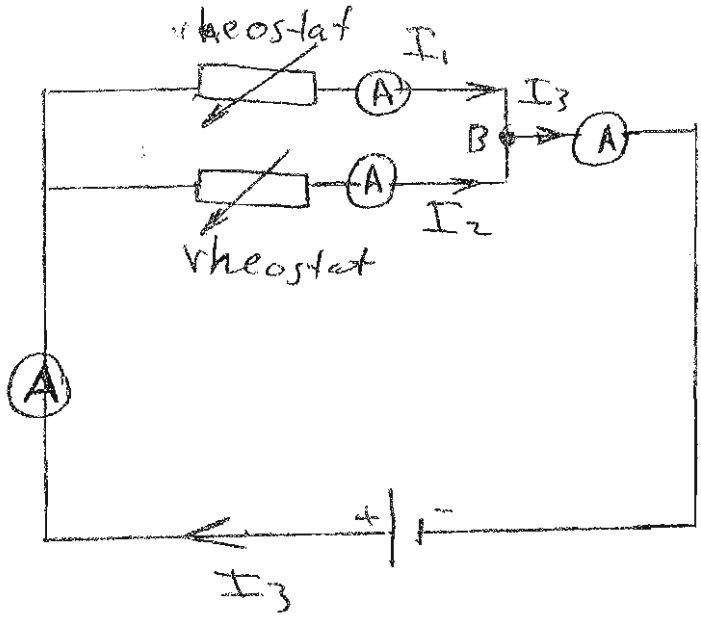
$$I = \frac{dQ}{dt}$$

$$= \frac{[\text{Coulomb}]}{[\text{sec}]} = \text{Ampere}$$

الامبير: هو شدة التيار الكهربائي الناتج عن مرور شحنة كهربائية مقدارها كولوم واحد خلال مقطع من مادة في الثانية الواحدة

Kirchhoff's First Law

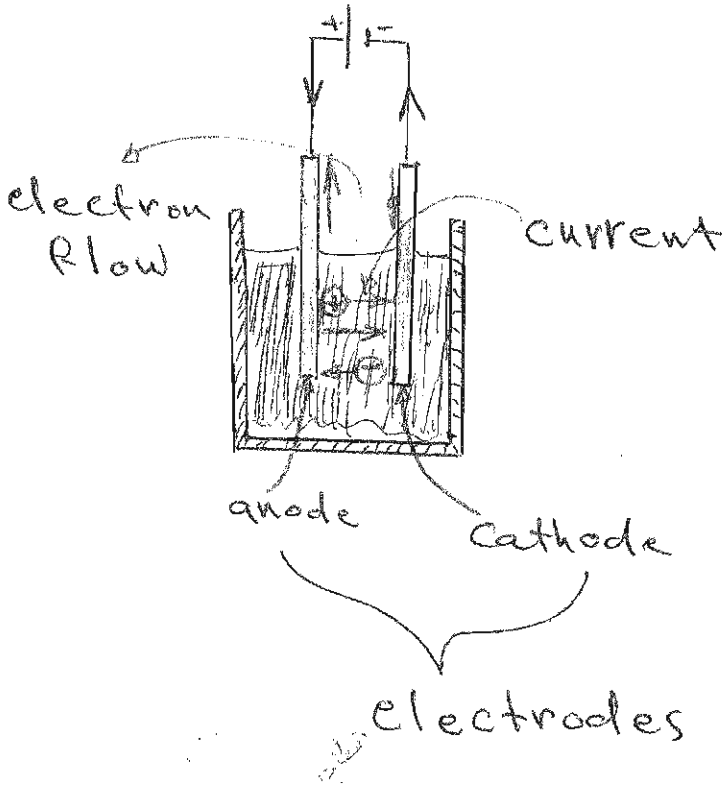
At any junction-point in a circuit (such as B in figure) the rate at which charge enters the junction ($I_1 + I_2$) is equal to the rate at which charge leaves it (I_3).

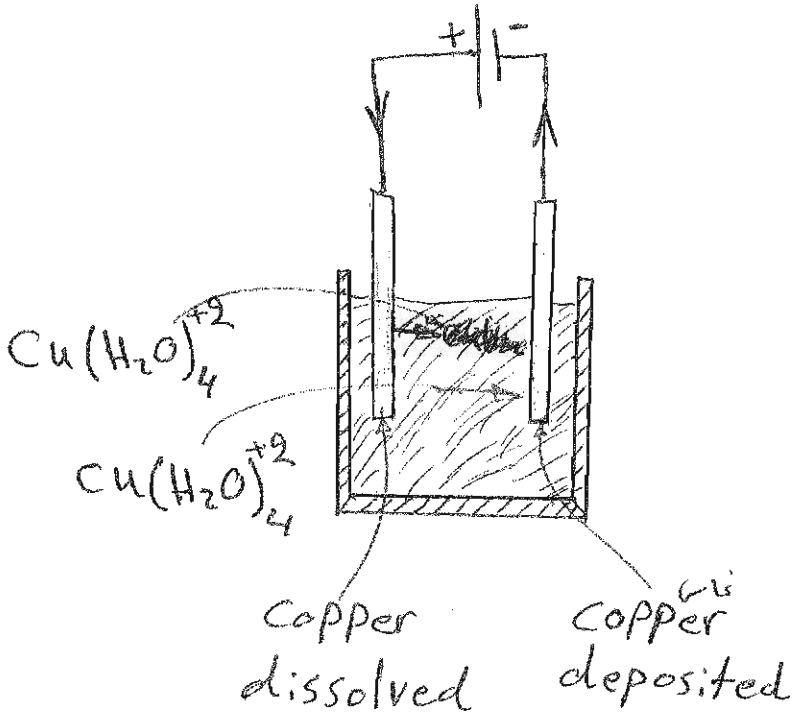


This result is sometimes known as ((Kirchhoff's first law of electric ~~cuit~~ circuits))

7-2

Currents in liquids





النوعية

Specific Charge.

Each ion carries a definite charge and has a definite mass, so that the mass ~~liberar~~ liberated or deposited at the surface of an electrode is proportional to the total charge passed.

This is called ((Faraday's first law of electrolysis))

$$\text{specific charge} = \frac{Q_i}{m_i} = \frac{\text{total charge passed}}{\text{total mass deposited}}$$

$$\boxed{Q = \frac{I}{t}} \Rightarrow \qquad = \frac{It}{M}$$

[illegible]

7-4 Electrical Energy

الطاقة الجهد الكهربائية المنجز

If the charge separated is (Q) and the electrical potential energy produced is W, then we define the e.m.f (E) by

$$e.m.f = E = \frac{W}{Q}$$

e.m.f القوة الدافعة الكهربائية

وهي الشغل المنجز في تحريك وحدة الشحنة

ex: A small electric cell in a torch can maintain a current of (0.2 A) for about 2 hours. Estimate the total energy converted in the torch in this time, when the e.m.f = 1.5 J/C

$$Q = It$$
$$= 0.2 * (2 * 3600)$$
$$= 1440\ C$$

$$W = EQ$$
$$= 1.5\ \frac{J}{C} * 1440\ C$$
$$= 2.16 \times 10^3\ J = 2.16\ kJ$$

Potential difference فرق الجهد

ثانياً

The potential difference (P.d.) between two points in a circuit is an indication of the strength of the electric field acting to drive electric charge from one point to other.

فرق الجهد الكهربائي: كمية الشغل المصروف من قبل المجال الكهربائي لتحريك شحنة كهربائية ذات وحدة واحدة من نقطة الى اخرى.

$$V = E/q$$

$$= \frac{[J]}{[C]} \quad \text{جول / كولوم}$$

$$= \text{Volte}$$

V: الجهد الكهربائي

E: الطاقة الكامنة

q: الشحنة

$$\therefore \quad E = q \cdot V$$

اولاً

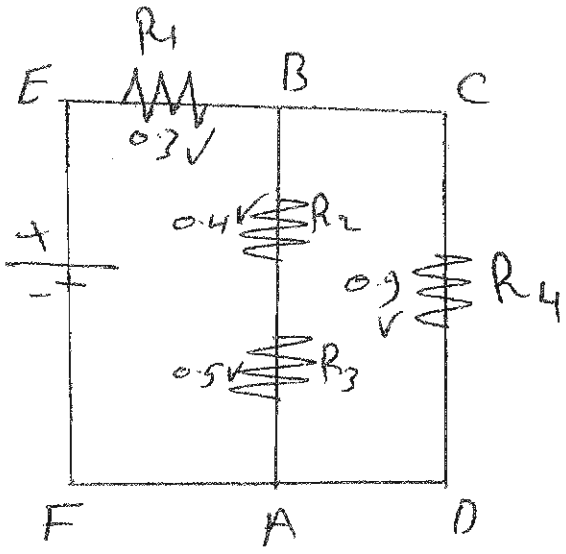
فالجهد الكهربائي هو الطاقة الكامنة لوحدة الشحنات.

$$W = E_{p_1} - E_{p_2} = q\,(V_1 - V_2)$$

اذا كانت هناك شحنة (q) تنتقل من نقطة P_1 الى P_2 فان الشغل المنجز من قبل المجال الكهربائي هو (W)

Kirchhoff's second law of Electric circuits:

The sum of the p.d.s round any closed loop must always be zero.



ABCDA

P.d between B and A		0.5 V
		+0.4 V
P.d between D and C		−0.9 V
sum		zero

Similarly for the loop ABEFA

P.d between B and A		0.9 V
" "	E and B	+0.3 V
" "	F and E	−1.2 V
Sum		zero

Electric field Strength:

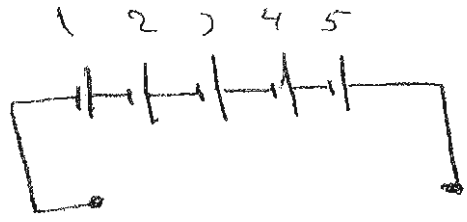
If we have a current in an conductor of constant cross-section, the potential decreases uniformly (متساوية) along its length frome its positive end to its negative end.

If the p.d. between the ends of the conductor is V and its length l we have

$$\text{Potential gradient} = E = \frac{V}{l} = \frac{[V]}{[m]} = V\,m^{-1}$$

7-5 Electric Cells (Batteries)

total energy produced = ~~energy~~



$$E_1Q + E_2Q + E_3Q$$

Q = متساوية

$$\text{the total e.m.f} = \frac{\text{total energy}}{Q}$$

$$= \frac{E_1Q + E_2Q + E_3Q}{Q} = \frac{\cancel{Q}(E_1 + E_2 + E_3)}{\cancel{Q}}$$

$$= E_1 + E_2 + E_3$$

Thermocouples

If we form a circuit of two different metals A and B, a small e.m.f. E is found to act in it when the junctions of the metals are at different temperatures.

$$e.m.f = E = E_1 - E_2$$

A thermocouple is a form of heat engine converting internal energy to electrical energy.

7-6 Electrical Power

The rate at which energy is converted from one form to another in some mechanical or electrical device is called its "power"

$W = Pt$, the unit of power is the

$J s^{-1}$ = watt (w) $\left(P = \frac{W}{t}\right)$

معدل الطاقة التي تتحول، أو حرارة في الموصل

أي مقدار القدرة في وحدة الزمن

$P = V I$

current : I

p.d : V

$P = E I$

e.m.f : E

(P: القدرة) القدرة اللازمة لاستمرار

سريان التيار في الموصل.

مثال

I

7-3

من قانون كرشوف الاول

~~مع اعتبار ان قيم المقاومة~~

$$I_1 = I_2 + I_3$$

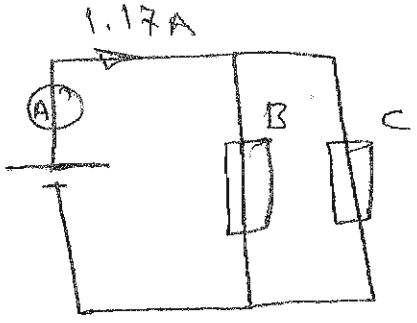
$$1.17 = 2I' + I''$$

$$1.17 = 3I'$$

$$\therefore I' = 0.39$$

$$2I'' = 0.39$$

$$\therefore I'' = 2 \times 0.39 = 0.78$$



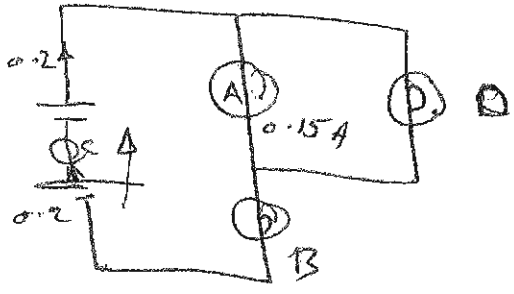
7-4

من قانون كرشوف

$0.2 - 0.15 = 0.5$ A in D

B , C is full brightness

B current in B and C = 0.2A



7-6

$$I = \frac{Q}{t} \Longrightarrow Q = It$$

$$= 0.25 * (12 * 60)$$

$$= 180\ C$$

the total of charge Pass

$$N = \frac{Q}{e} = \frac{180}{1.6 \times 10^{-19}} = 1.1 * 10^{21}$$

no. of electrons

7-8

$$I = 1.5\ mA$$

$$= 1.5 \times 10^{-3}\ A$$

$$N = \frac{I}{e} = \frac{1.5 \times 10^{-3}}{1.6 \times 10^{-19}} = 0.93 \times 10^{16}$$

$$= 0.93 \times 10^{16} - 6 \times 10^{15}$$

$$= 9.3 \times 10^{15} - 6 \times 10^{15}$$

$$= 3.3 \times 10^{15}\ s^{-1}$$

no. of hydrogen ions.

CH-7-

7-9

$$v = \frac{s}{t} \Rightarrow t = \frac{s}{v} = \frac{0.5}{8\times10^{7}}$$
$$= 0.062\times10^{-7}$$

$$I = \frac{Q}{t} \Rightarrow Q = It = 2\times10^{-3}\times0.062\times10^{-7}$$
$$= 0.12\times10^{-10}$$

$$N = \frac{Q}{t} = \frac{0.12\times10^{-10}}{\cancel{0.062\times10^{-7}}\ 1.6\times10^{-19}} = 0.075\times10^{9}$$

7.10 no. of drops $= 10\times60\times12$
$= 7200$

a) $V = 7200\times3\times10^{-8}$
$= 216\times10^{-6}$ the volum of the water

b) $Q = 4\times10^{-15}\times7200 = 2.88\times10^{-13}$ C
total charge

c) $I = \frac{Q}{t} = \frac{2.88\times10^{-13}}{10\times60} = 0.48\times10^{-13}$

7-11

$$v = \frac{I}{enA} = \frac{I}{eA} - \frac{I}{en}$$

$$= 1.2\times10^{6} - \frac{1}{1.6\times10^{-19}\times10^{29}}$$

عدد الالكترونات الحرة

$$= 0.75\times10^{-3}\ m.s^{-1}$$

7-13

$$V = \frac{I}{enA} \Rightarrow n = \frac{I}{eVA}$$

$$= \frac{12\times10^{-3}\ A}{1.6\times10^{-19}\times40\times2\times10^{-6}}$$

$$= 0.07\times10^{21}$$

عدد الالكترونات الحرة في المادة

شبه الموصل

CH-8-

Electrical Resistance

8-1 Ohm's Law

An electric current I is produced in a conductor by applying a potential difference V across it. The relationship between the two quantities for metal conductors is "Ohm's Law" when all these were kept constant

The quantity V/I is a constant for a given metallic conductor under steady physical condition's. It is known as it's resistance R. Thus

$$R = \frac{V}{I}$$

The unit of R is therefore VA^{-1} (Ω)

* Fixed resistors مقاومات ثابتة

a- wire-wound type

b- Carbon composition type

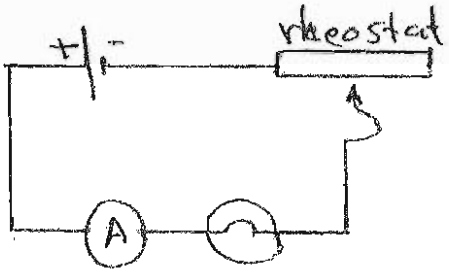
c- Carbon film type

* Variable resistors مقاومات متغيرة

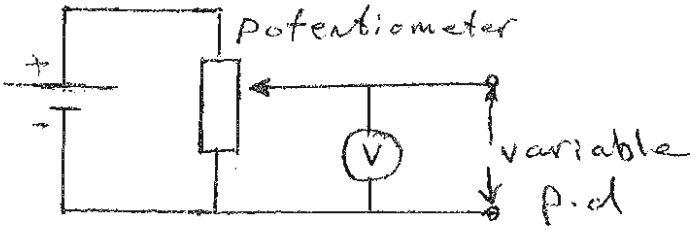
a- As a rheostat - for controlling the current in a low resistance device

b- As a potentiometer - for controlling the p.d across some device

a



b



Energy Conversion in resistors.

The electrical power P converted in a resistor is given by

$$\boxed{P = VI}$$

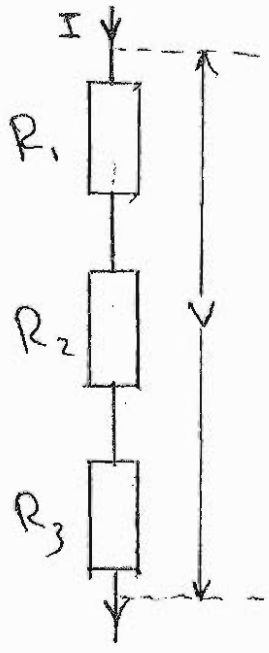
but $R = \frac{V}{I} \Rightarrow V = IR$

$$\therefore \boxed{P = I^2 R}$$

ربط المقاومات

8-2 Combinations of resistors

a- Resistors in series



$$R_{ser} = \frac{V}{I}$$

$$I_t = I_1 = I_2 = I_3$$

$$V_t = V_1 + V_2 + V_3$$

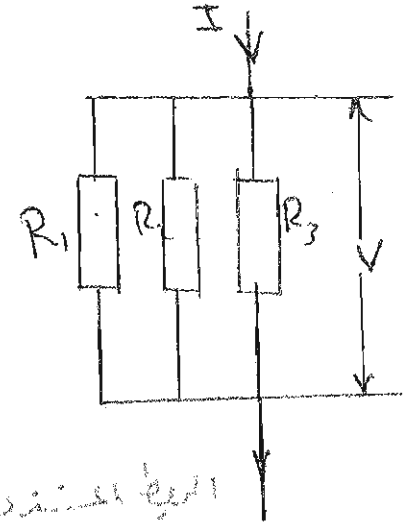
$$R_t = R_1 + R_2 + R_3$$

b- Resistor in parallel

$$V_t = V_1 = V_2 = V_3$$

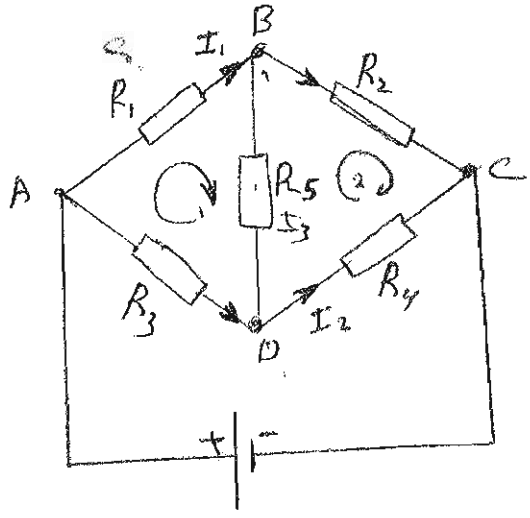
$$I_t = I_1 + I_2 + I_3$$

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



* The Wheatstone bridge.

$$\boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$



when the bridge is balanced

- No current in R_5
- there is the same current in R_1 and R_2 (I_1)

Also " " " " " R_3 and R_3 (I_2)

B and D the must be same potential, so that p.d R_1 and R_3 are the same ($I_1 R_1 = I_2 R_3$)

p.d in R_2 and R_4 are the same

and so $I_1 R_2 = I_2 R_4 \Longrightarrow \frac{R_1}{R_2} = \frac{R_3}{R_4}$

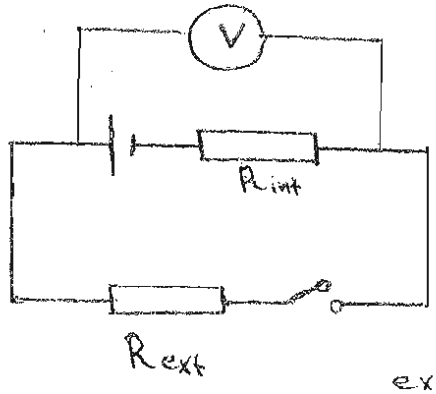
8-3 Battery resistance

When a current is taken from a cell (or any other source of e.m.f), it is found that the p.d. across it falls.

$$R_{int} = \frac{(E - V)}{I}$$

Internal , external

$$R_{ext} = \frac{V}{I}$$

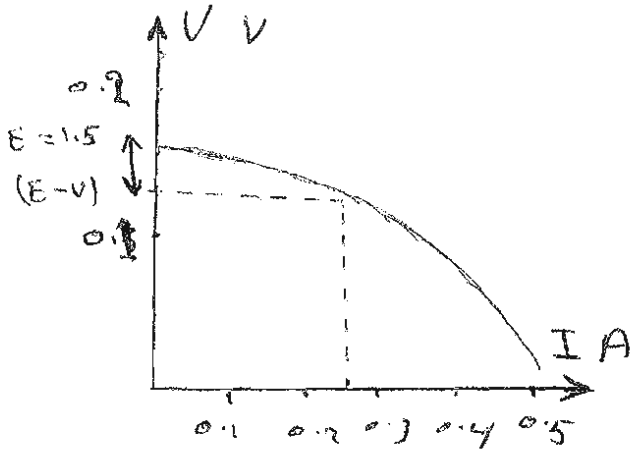


internal

external

$$\underbrace{(R_{ext} + R_{int})}_{R_{tot}} = \frac{E}{I}$$

$$R_{tot} = \frac{E}{I}$$



8-4 Resistivity

The resistance of a conductor at given temperature depends on its length and cross-sectional area and material.

$$R = \frac{\rho l}{A}$$

$$\therefore \rho = \frac{RA}{l} = \frac{[\Omega][m^2]}{[m]} = \Omega . m$$

The reciprocal of the resistivity of a material is known as its "Conductivity"

$$\sigma = \frac{1}{\rho}$$

$$\sigma = \frac{l}{RA} \quad . \quad [\Omega^{-1} . m^{-1}]$$

8-4 p.d. = ? , $R = 10\ M\Omega$, $I = 5\ \mu A$

$$R = \frac{V}{I} \quad , \quad V = RI$$

$$\therefore V = 10 \times 10^{6} \times 5 \times 10^{-6}$$

$$= 50 \text{ volt} \quad \text{p.d.}$$

8-6

$$V_t = V_1 + V_2$$

$$6 = 3 + V_2 \Longrightarrow V_2 = 3 \text{ Volt}$$ (b1)

الفولتيج في المقاومة

$$R = \frac{V}{I} \quad , \quad 20 = \frac{3}{I} \quad \therefore I = 0.15\ mA$$ (b2)

التيار في المقاومة

(a) $$\therefore R_v = \frac{V}{I} = \frac{3}{0.15 \times 10^{-3}} = 20\ k\Omega$$

(c)

$$V_t = V_1 + V_2$$

$$6 = V_1 + 2$$

$$\therefore V_1 = 4 \text{ Volt}$$

فولتيج (V) التاني

(d) $$R_1 = \frac{V}{I} \quad , \quad 20\ k\Omega = \frac{4}{I}$$

$$\therefore I = 0.2\ mA$$

$$R_2 = \frac{V}{I} \quad ,$$

ت.ب

CH-8-

d)

$$20\,k\Omega = \frac{2}{I} \qquad \therefore I = 0.1\ mA$$

$$I_t = I_1 + I_2$$

$$0.2 = 0.1 + I_2 \qquad \therefore I_2 = 0.1\ mA$$

تيار ⑦ الثاني

e)

$$\boxed{R_{par} = \frac{R_1 R_2}{R_1 + R_2}}$$

ثنائيات

8-17

$$R_{par} = \frac{R}{n}$$

$$40 = \frac{240}{n} \qquad \therefore n = 6$$

عدد الثنائيات

8-18

a) $R_t = 5 + 8 + 10$
$= 23\ \Omega$

b) $R_x = 5 + 5 = 10\ \Omega$

$R_x = 5 + 5 = 10\ \Omega$

$$\frac{1}{R_t} = \frac{1}{R_x} + \frac{1}{R_x}$$

$R_t = 5\ \Omega$

c) $$\frac{1}{R_t} = \frac{1}{4} + \frac{1}{6}$$

$R_{t_{p\times}} = 2.4\ \Omega$

$R_t = 2.4 + 5$
$= 7.4\ \Omega$

d) $R = 4 + 4 = 8\ \Omega$

R

$$\frac{1}{R_t} = \frac{1}{8} + \frac{1}{12}$$

$= 4.8\ \Omega$

CH-8

8-51 $R = \frac{\rho l}{A} = \frac{4.8 \times 10^{-7} \times 4}{1 \times 10^{-6}}$

$= 1.92\ \Omega$

$P.g = \frac{V}{l} = \frac{0.96}{4} = 0.24\ V.m^{-1}$

$R = \frac{V}{I}$, $1.92 = \frac{V}{0.5} \Rightarrow V = 0.96$ volt

8-37

$E = 1.5\ V$

$V = 1.3\ V$

$I = 0.4\ A$

$R_{int} = \frac{(E - V)}{I} = \frac{1.5 - 1.3}{0.4}$

$= 0.5\ \Omega$

CH-14- Storing electric charge

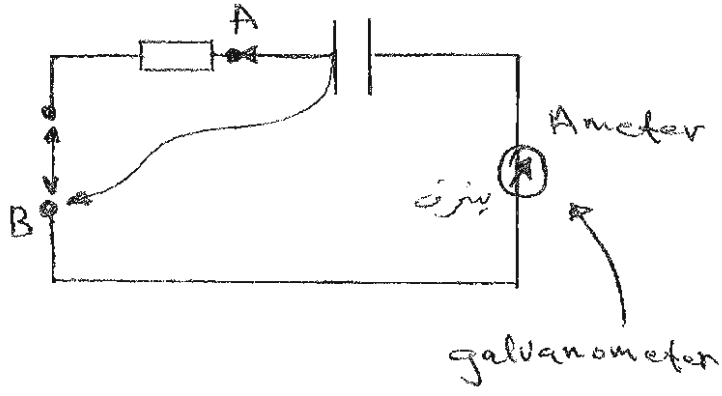
المتسعات

Capacitors:

An arrangement of two conductors close together, but insulated from one an

المتسعة: جهاز يخزن الشحنة

في النقطة A يحدث شحن المتسعة.
في النقطة B يحدث تفريغ للمتسعة.



العوامل التي تعتمد عليها سعة المتسعة

1. مساحة اللوحين
2. المسافة بين اللوحين
3. طبيعة الوسط بين المتسعة
4. نوع العازل

شحنة

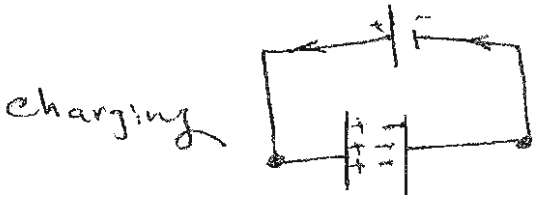
$Q \propto \ominus$

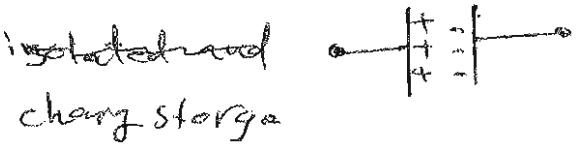
$Q = b\,\ominus$ Calibration Constant

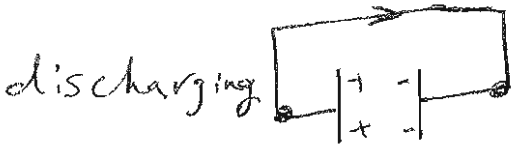
$Q \propto A$ السعة تزداد بزيادة المساحة

$Q \propto \frac{1}{d}$ كلما قلت المسافة بين اللوحين

$Q \propto V$ تزداد بزيادة الجهد





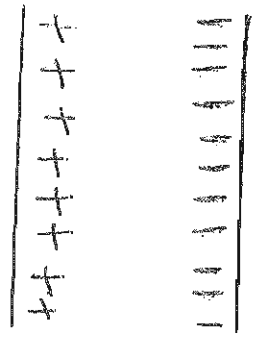


CH - 14 -

Capacitance

$$Q \propto V$$

$$Q = C V$$



$$\therefore C = \frac{Q}{V} = [C \cdot V^{-1}] = [\text{Farad}]$$

$$\mu F = 10^{-6} F$$

$$pF = 10^{-12} F$$

The charging Current

$$I = \frac{dQ}{dt}$$

~~(I) Is the current in the wires joined to Pair of Capacitor Plates.~~

$$\because Q = C.V$$

$$\therefore I = C \frac{dV}{dt}$$

(لماذا dQ, dV)

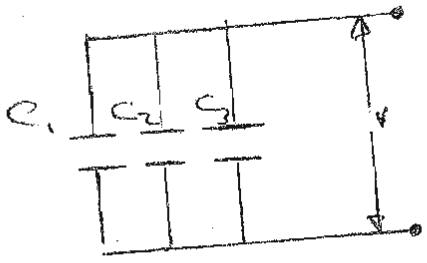
لأنه عندنا ~~[illegible]~~ V ابتدائية و
V نهائية وكذلك t ازاي

CH - 14 -

Capacitors in Parallel

ربط المتسعات على التوازي

where Q is the total charge ~~on~~ the capacitors, the sum of their separate charges.



$$Q_t = Q_1 + Q_2 + Q_3 + \dots + Q_n$$

$$\because Q = CV \quad , \quad C = \frac{Q}{V}$$

V متساوية

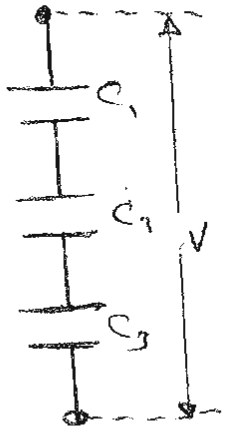
$$Q_t = C_1 V_1 + C_2 V_2 + C_3 V_3$$

$$Q = V(C_1 + C_2 + C_3)$$

$$\boxed{C_t = C_1 + C_2 + C_3} + \dots C_n$$

- فرق الجهد متساوية عند كل متسعة

Capacitors in Series



$$V_t = V_1 + V_2 + V_3$$

$$Q = CV$$

$$\therefore V = \frac{Q}{C}$$

$$V = \frac{Q}{C_t} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) \div Q$$

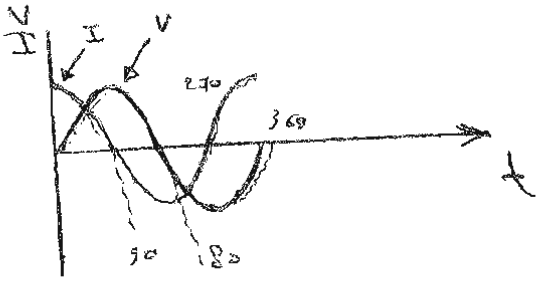
$$\frac{V}{Q} = \frac{1}{C}$$

$$\therefore \frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$$

CH-14

التيار المتناوب
في المكثفات

Alternating Current in capacitors



If an alternating current supply is joined to the plates of a capacitor charge flows onto and then off the plates as the potential difference between them oscillates; and there may be a large alternating current in the connecting wires.

The magnitude of the alternating current ~~of the~~ in capacitor of capacitance (c) may be calculated as follows:

$$\boxed{I = c\,\frac{dV}{dt}}$$

If a sinusoidal alternating p.d. of peak value (V_0) and frequency f is joined to the capacitor we have

$$\boxed{V = V_0 \sin 2\pi f t}$$

CH-14-

The maximum current occurs at the moments when the p.d. V is zero, when the p.d. is changing at the maximum rate. The peak value I_0 of the current is therefore ~~giving~~ given by

$$I_0 = C \cdot \frac{dV}{dt}$$

$$V = V_0 \underbrace{\sin 2\pi f t}_{\text{مقدار}}$$

$$V = V_0 \, 2\pi f t$$

$$\frac{dV}{dt} = V_0 \, 2\pi f$$

$$I = C(2\pi f V_0)$$

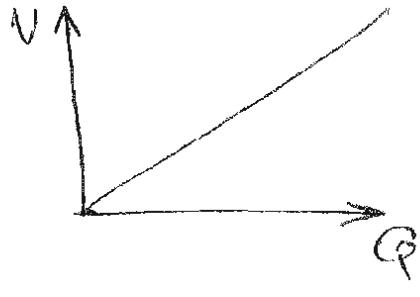
* Charging and discharging

Energy storage

The total energy W_E stored in the capacitor is.

$$W_E = \frac{1}{2} Q V$$

since $Q = CV$



$$W_E = \frac{1}{2} C V^2 = \frac{1}{2} \frac{Q^2}{C}$$

14-6

$b = 1.3 \times 10^{-8}$ C / div

e.m.f = 6 volt

$\theta = 22$

$C = ?$

$\therefore Q = b\theta = 1.3 \times 10^{-8} \times 22$

$= 28.6 \times 10^{-8}$

$C = \frac{Q}{V} = \frac{28.6 \times 10^{-8}}{6}$

$= 4.7 \times 10^{-8}$ F

14-7

$C = 100\ \mu F$

$V = 200$ V

$t = 4$ s

$Q = CV = 100 \times 10^{-6} \times 200$

$= 2 \times 10^{-2}$ C

$I = \frac{Q}{t} = \frac{2 \times 10^{-2}}{4} = 0.5 \times 10^{-2}$

$= 5$ mA

14-8

$C = 33\,\mu F$

$V = 4\ V$

$t = 60\ s$

$I = ?$

$$I = C\frac{dv}{dt} = 33\times10^{-6}\ \frac{6}{60}$$

$$= 22\times10^{-6}\ \text{Amp.}$$

14-9

$I = 50\,\mu A$

$V = 5\ V$

$t = 20\ s$

$C = ?$

$$I = C\frac{dv}{dt}$$

$$50\times10^{-6} = C\ \frac{5}{20} \Rightarrow C = 200\times10^{-6}\ F$$

$$= 200\ \mu F$$

14-14

$C = 180\ pF$

$V = 12\ V$

$f = 250 \rightarrow t = \frac{1}{250}$

$I = ?$

$$I = C\frac{dV}{dt} = 180 \times 10^{-12} \frac{12}{1/250}$$

$$= 54 \times 10^{-8}\ Amp.$$

14-17

$C_1 = 2\ \mu F$

$C_2 = 3\ \mu F$

$C_3 = 6\ \mu F$

a. in parallel

$$C_t = C_1 + C_2 + C_3$$
$$= 2 + 3 + 6$$
$$= 11\ \mu F$$

b. in series

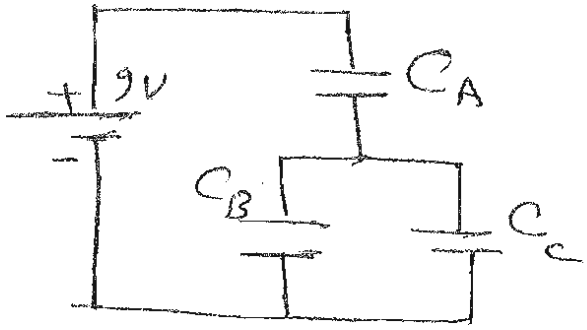
$$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$
$$= \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$$
$$\frac{1}{C_t} = 0.996$$
$$\therefore C_t = 1\ \mu F$$

14-18

$C_A = 3\ \mu F$

$C_B = 1.5\ \mu F$

$C_C = 4.5\ \mu F$



$C_{CB} = C_B + C_C = 1.5 + 4.5$

$= 6\ \mu F$ ← السعة المكافئة للمتسعتين (C+B) توازي

$$\frac{1}{C} = \frac{1}{C_{CB}} + \frac{1}{C_A} = \frac{1}{6} + \frac{1}{3}$$

$$\frac{1}{C} = 0.496$$

$C = 2\ \mu F$ ← السعة المكافئة للمجموعة ككل

$Q = CV = 2 \times 10^{-6} \times 9$

$= 18 \times 10^{-6}\ C$ ← شحنة المتسعة A وهي نفسها شحنة (C+B) لأنها توالي مع A

$Q = CV$, $V = \frac{Q}{C} = \frac{18 \times 10^{-6}}{6 \times 10^{-6}}$

$= 3V$ ← فرق الجهد بين B و C

$V_A = 9 - 3 = 6V$ ← فرق الجهد عند A

$Q_C = 3 \times 4.5 \times 10^{-6} = 13.5 \times 10^{-6}\ C$

$Q_B = 3 \times 1.5 \times 10^{-6} = 4.5 \times 10^{-6}\ C$

14-33

$C_1 = 16\ \mu F$	$C_2 = 8\ \mu F$
$V = 150\ V$	$V = ?$
$Q = ?$	$W_E = ?$
$W_E = ?$	

$$Q = CV = 16 \times 10^{-6} \times 150$$
$$= 2400 \times 10^{-6}\ C$$ ← شحنة المتسعة الأولى C_1

$$W_E = \frac{1}{2} Q V = \frac{1}{2} \times 2400 \times 10^{-6} \times 150$$
$$= 18 \times 10^{-2}\ \text{Joul}$$ ← الطاقة المخزونة في المتسعة الأولى

$$C_t = C_1 + C_2 = 16 + 8$$
$$= 24\ \mu F$$ ← السعة المكافئة بعد ربط C_1 مع C_2 توازي

$$V = \frac{Q}{C} = \frac{2400 \times 10^{-6}}{24 \times 10^{-6}} = 100\ V$$ ← الفولتية الكلية

$$W_E = \frac{1}{2} C V^2 = \frac{1}{2} \times 24 \times 10^{-6} \times (100)^2$$
$$= 12 \times 10^{-2}\ \text{Joul}$$ ← الطاقة المخزونة بعد ربط C_1 مع C_2

$$18 \times 10^{-2} - 12 \times 10^{-2} = 6 \times 10^{-2}$$ ← الفرق بين الطاقتين في الحالتين وهي تمثل الطاقة المهدورة والتي تتحول الى حرارة في السلك