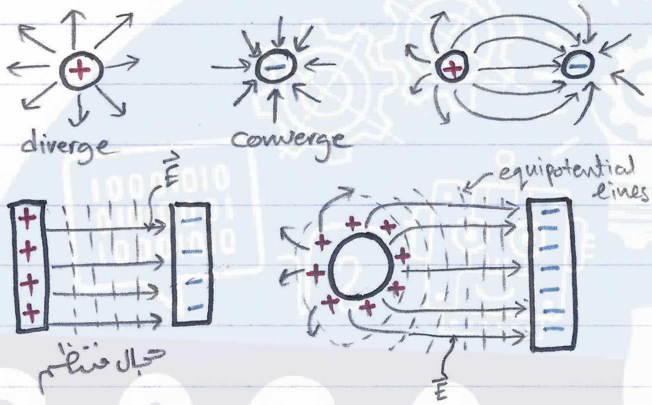
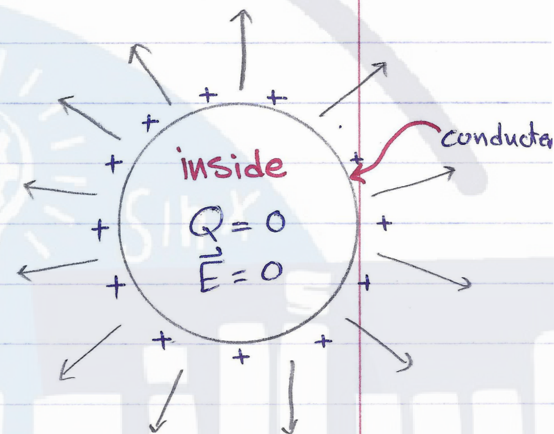
Experiment #1: Electric field mapping:

• **Back ground:**

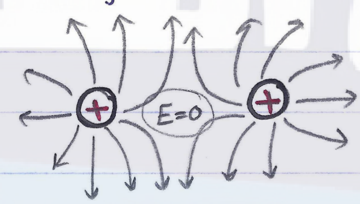
* سطح الموصل هو سطح تساوي جهد!

- Electric field lines





* Electric field lines $\perp$ equipotential lines.
* " " " should never intersect each other
* " " strength is greatest where the lines are closest together & weakest where lines are furthest a part.



* Work needed to move a charge through an equipotential line = 0 since $\Delta V = 0$ & $\Delta W = q\Delta V$

but $\Delta W = Fd\cos\theta$

$0 = Fd\cos\theta$

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

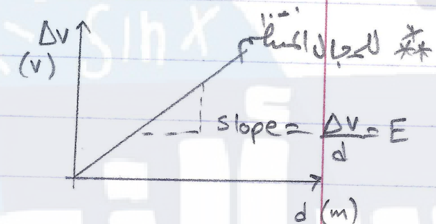
$F \perp d$

$E \perp V$

- $\vec{F_e} = \frac{k q_1 q_2}{r^2} \equiv \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$ ... Electric Force [N]

- $\vec{E} = \frac{\vec{F_e}}{q} \equiv \frac{kQ}{r^2}$ مصدر المجال ... Electric Field [N/C] ≡ [V/m]

↳ $\vec{E} = \frac{\Delta V}{d}$ (للمجال المنتظم)



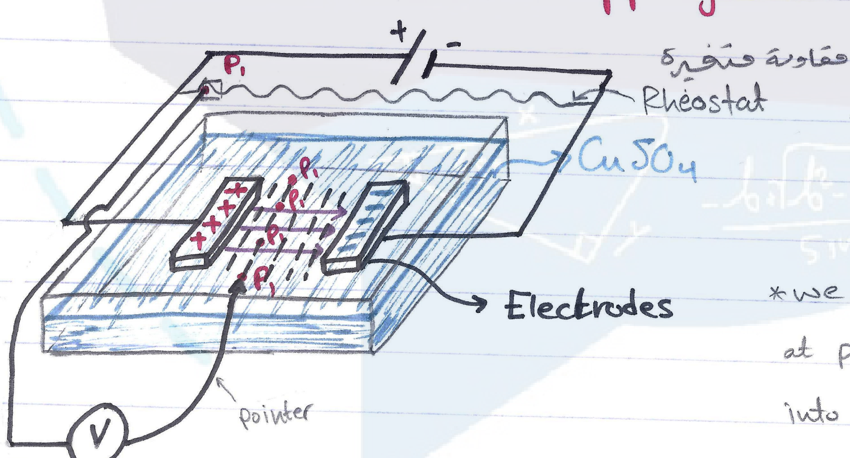
- in general $\Delta V = \int \vec{F} \cdot \hat{n}\, dA$

- $W = \vec{F} \cdot \vec{d}$ ... Work [J] ≡ [N.m] ≡ [C.V]

$= q\vec{E} \cdot \vec{d}$ $\Rightarrow \vec{E} = \left[\frac{J}{C.m}\right]$

$= q\,\Delta V$

- **Electric Field mapping:**

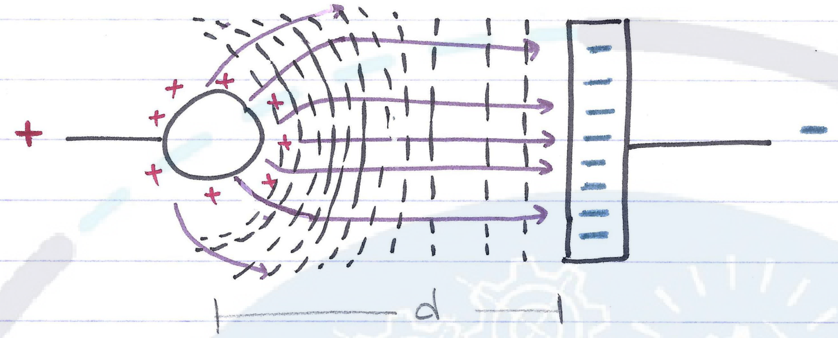


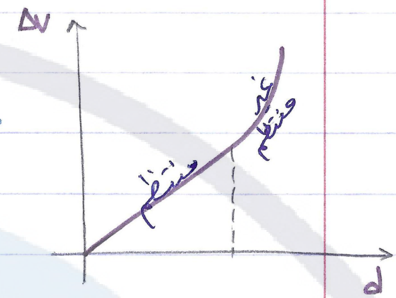
$V=0$ @ P_1

---- equipotential lines

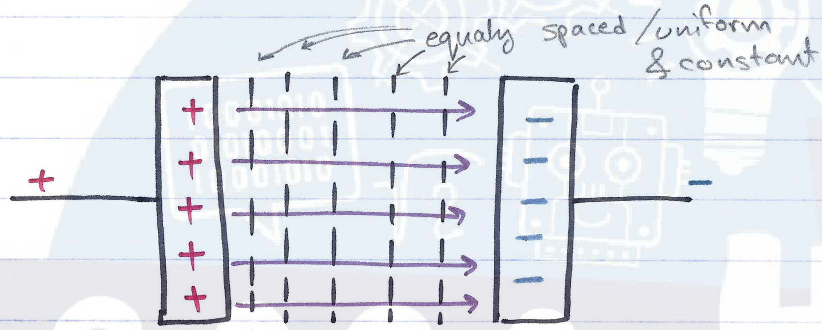
⟶ Electric field lines

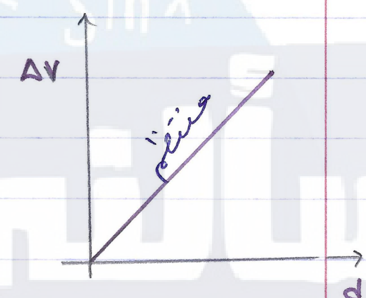
* we set the slide of the Rheostat at point P_1, and Dip the pointer into the liquid to find the points where $V=0$ (all these points form an equipotential line). then, we repeat the same Procedure for another point P_2... and so on.

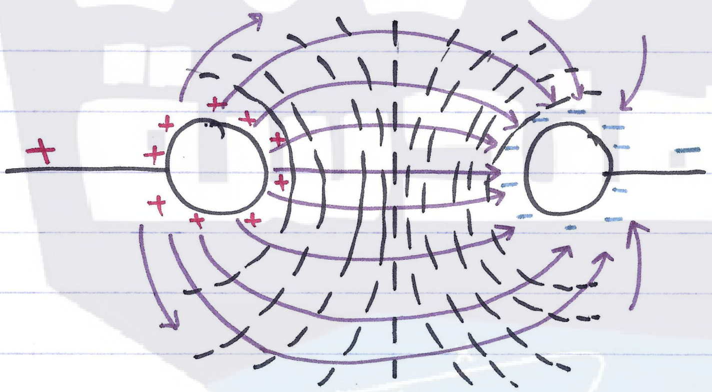


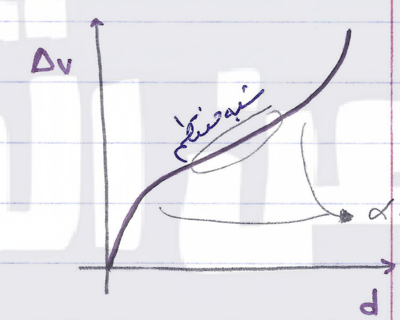


taken from the -ve electrode







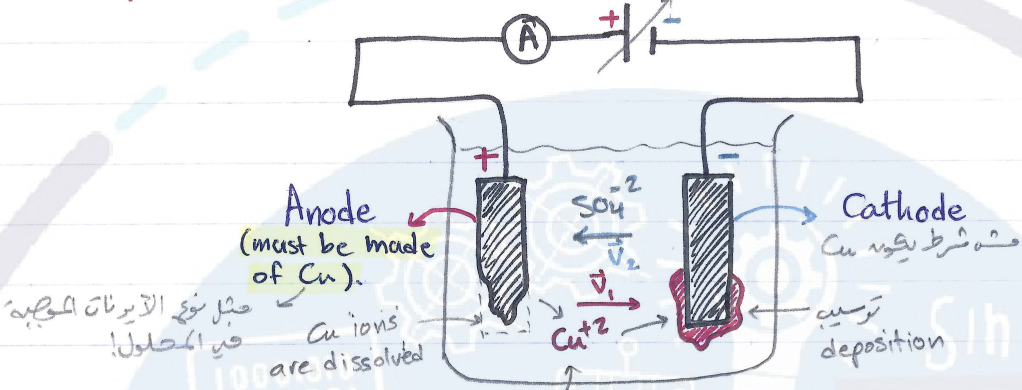


$\propto \frac{1}{d^2}$

* we can't detect Electric field lines from a direct experiment, so we take an indirect way; by Plotting equipotential lines first.

* $CuSO_4$ can be replaced by any conducting solution.

Experiment #2: Specific Charge of Copper Ions:-



$CuSO_4 \longrightarrow Cu^{+2} + SO_4^{-2}$ "electolyte Solution"

↳ "Electrolysis" التحليل الكهربائي

- $\vec{J} = \vec{J}_1 + \vec{J}_2$; $\vec{J}$: current density $[A/m^2]$

$= n_1 q_1 \vec{V}_1 + n_2 q_2 \vec{V}_2$; n: density of charge $[1/m^3]$

$\vec{v}$: velocity of charge carrier $[m/s]$

$n_1 = n_2$

$q_1 = -q_2 = |q|$

$\vec{V}_1 = -\vec{V}_2 = \vec{V}$

$[\vec{J}] = \frac{1}{m^{3}} \cdot C \cdot \frac{m}{s} = \frac{C}{s} \cdot \frac{1}{m^2} = \frac{A}{m^2}$

$\therefore \vec{J} = 2n|q|\vec{V}$

- $i(t) = \frac{dQ(t)}{dt}$

when i is constant:

$\Delta Q = I \Delta t$

$[C] = [A].[sec]$

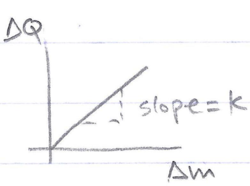
فرق الكتلة قبل وبعد ترسيب Cu

- $\Delta m \propto \Delta Q \equiv M_{Cu} \propto It$ (directly proportional & linear relation).

$\equiv M_{Cu}$: mass of the deposited Cu

$\Delta Q = k \Delta m \equiv k M_{Cu}$

$[k] = \frac{C}{kg} \equiv$ slope



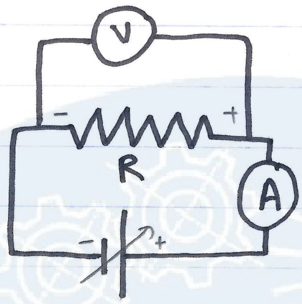
- $|\text{charge of electron}| = \dfrac{\text{charge of } Cu^{+2}}{2}$

$$= \frac{\overset{\Delta m}{M_{Cu}}\,\overset{\text{slope}}{K}}{2}$$

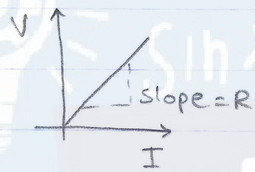
- charge of Cu ion $= M_{Cu} K$

** Cu is deposited on the -ve electrode (cathode)
** The diposited Cu comes from the solution in the cel
** Through the electrolysis, concentration of copper i
in solution remains constant

Experiment#3:- Ohm's law:



- $R = \frac{V}{I} \equiv$ Slope $[\Omega] \equiv [V/A]$

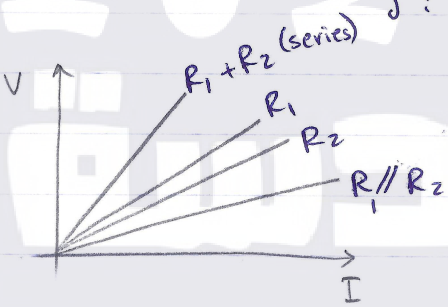


@constant temperature

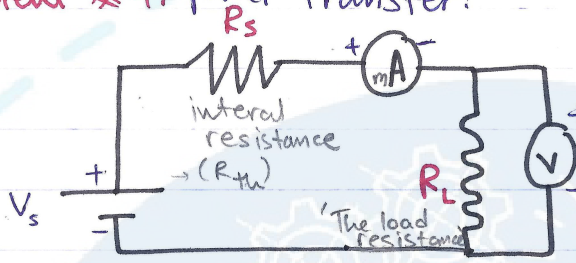
- $R = \frac{\rho L}{A}$; L: Length of R [m]

  A: cross sectional area of wire $[m^2]$

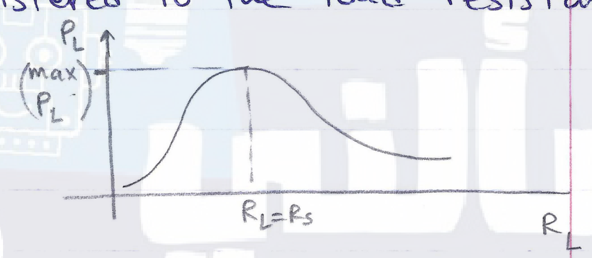
  ρ: resistivity $[\Omega . m]$



Experiment ※4: Power transfer:



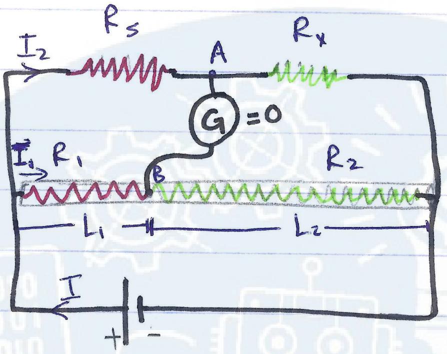
Maximum power is transfered to the load resistance R_L when $\boxed{R_L = R_s}$



- $P_L = V_L I$
- $P_L = I^2 R_L = V_L^2 / R_L$ & $P_s = I^2 R_s = V_s^2 / R_s$
- if $R_s > R_L$
  $\rightarrow P_s > P_L$

Experiment ※5: The Wheatstone Bridge:

هي طريقة لإيجاد قيمة مقاومة مجهولة من خلال وصلها بمقاومات معلومة.



B is the Balance Point where Ⓖ reads 0

when Ⓖ reads zero $\longrightarrow I_{AB} = 0$

$$\therefore V_{R_s} = V_{R_1} \dots (1) \quad \& \quad V_{R_x} = V_{R_2} \dots (2)$$

* I_1, I_2, I, Bridge's Resis values does not affect the value of R_x

$$I_2 R_s = I_1 (R_1)$$
$$I_2 R_s = I_1 \left(\frac{\rho L_1}{A}\right) \dots (1)'$$

$$I_2 R_x = I_1 (R_2)$$
$$I_2 R_x = I_1 \left(\frac{\rho L_2}{A}\right) \dots (2)'$$

$$\frac{(1)'}{(2)'} \Rightarrow \frac{R_s}{R_x} = \frac{L_1}{L_2}$$

$$\boxed{R_x = \frac{R_s L_2}{L_1}}$$

$$\Delta R_x = R_x \sqrt{\left(\frac{\Delta L_2}{L_2}\right)^2 + \left(\frac{\Delta L_1}{L_1}\right)^2} \qquad \Delta L_1 = \Delta L_2 = \pm 0.5 \text{ mm}$$

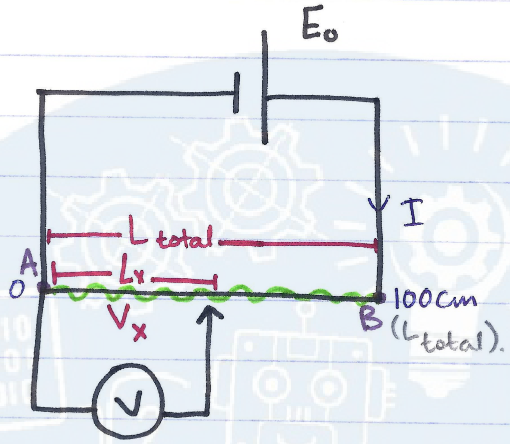
* we don't need a specific constant current since our calculations doesn't depend on current Ⓖ reads 0

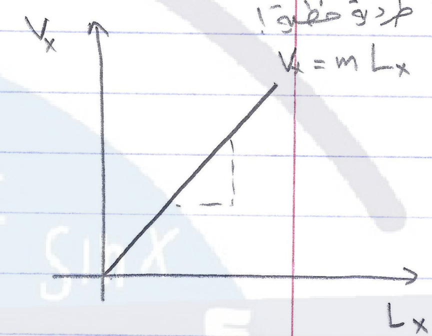
$$\boxed{R_x = \frac{R_s L_2}{L_1}}$$

$\frac{\Delta R_x}{R_x}$ is minimum when $L_1 \cong L_2$! و $\boxed{R_x = R_s}$

Experiment # 6: The Potentiometer :

- **Step 1:**





علاقة طردية مطلقاً

$V_x = m\,L_x$

$\rightarrow I = \frac{V}{R} = \frac{E_o}{\left(\frac{\rho L_{total}}{A}\right)}$

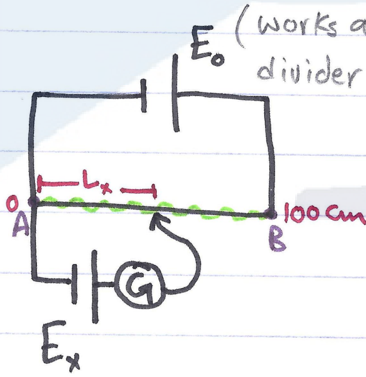
$\rightarrow V_x = I R_x$

$= \frac{E_o}{\left(\frac{\cancel{\rho} L_{total}}{\cancel{A}}\right)} \times \left(\frac{\cancel{\rho} L_x}{\cancel{A}}\right) = E_o \frac{L_x}{L_{total}}$

$$\boxed{V_x = \frac{E_o}{L_{total}} L_x}$$

$\hookrightarrow$ slope $= \frac{E_o}{L_{total}} = \frac{E_o}{(1)\,\text{meter}} = E_o$ ← المعطيات

- **step 2:**



(works as a voltage divider for the potentiometer wire, when (G) reads 0)

* when (G) reads $0 \Rightarrow V_x = E_x$

$\therefore m L_x = E_x$

صفر وصلت مقاومة E_x

$V_x = E_x + IR$

$I = 0$ ((G) $= 0$)

$\therefore \boxed{V_x = E_x}$

the unknown Emf

$$\boxed{E_x = \underline{\underline{m}}\, L_x}$$

↳ slope (measured from (V_x-L_x) relation for a known emf). $m = \frac{\Delta V_x}{\Delta L_x}$ → المحور الصادي

$$\boxed{m = \frac{E_o}{L_{total}}}$$ → total length of potentiometer wire.

* When Ⓖ reads zero, no current is draw by the unknown voltage & so the reading is independant of the source's internal resistance.

Calculating error & uncertainty :-

1. Percent error.

* يُحسب percent error في التجارب التي تهدف لحساب قيمة متعارف عليها مثل g ، π .

* $\text{Percent error} = \dfrac{|E - A|}{|A|} * 100\%$

E: experimental value (قد تكون معدل) القيمة المحسوبة من التجربة

A: accepted value . القيمة المتعارف عليها.

* when A (accepted value) is not known we calculate :-

2. percent differance.

two measurements.

$$\text{percent diff.} = \frac{|E_2 - E_1|}{(E_2 + E_1)/2} * 100\%$$

Avg

* for 3 or more measurements:

الفرق بين أكبر وأصغر قيمة

$$\text{Percent diff} = \frac{\text{absolute differance } \cancel{\text{betw}} \text{ of the extreme values}}{\text{avg}}$$

* Average or (mean) value ($\bar{x}$) :-

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \dots + x_n}{n} = \frac{1}{n} \sum_{i=1}^{N} x_i$$

* لحساب تشتت القيم المقاسة عن المعدل $\bar{x}$ نستخدم الانحراف المعياري

(d) standard daviation

المعدل

$$d_i = \underbrace{x_i}_{\text{القيمة المقاسة}} - \bar{x}$$

⟸ لحساب الانحراف المعياري لقيمة واحدة من القيم المقاسة

$$\delta = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \dots - (x_n - \bar{x})^2}{n}}$$

لحساب الانحراف المعياري لمجموعة من القيم المقاسة.

$$= \sqrt{\frac{d_1 + d_2 + \dots + d_n}{n}}$$

* when we have a Small number of measurements it's better to use:-

$$\delta = \sqrt{\frac{d_1+d_2+\dots+d_n}{n-1}}$$

⇝ we can use standard daviation δ to calculate the precisior or error in the mean of a ~~gro~~ set of measured values.

$$\Delta\bar{x} = \frac{\delta}{\sqrt{n}} = \sqrt{\frac{(x_1-\bar{x})^2+(x_2-\bar{x})^2+\dots+(x_n-\bar{x})^2}{n(n-1)}}$$

error in x

عدد القيم المقاسة ← n

* هذا القانون يستخدم لحساب الـ error لقيمة قمنا بقياسها مثل الإزاحة أو ~~...~~ الزاوية ... ،

* بعض القيم مثل الكتلة تقاس بأدوات تكون نسبة أخطائها محددة وتساوي نصف أصغر قراءة يستطيع الجهاز قراءتها.

مثلاً: في الميزان أصغر قراءة = $(0.01)g$

$\therefore$ error = $\Delta m = \pm 0.005\,g$

* بعض القيم الأخرى نقوم بحسابها من خلال عدة قيم مقاسة مثلاً:

$V = \frac{\pi D^2 H}{4}$

* Rules ⇝ قواعد حساب الخطأ

1. $R = x+y$ or $R = x-y$ — x و y are measured values

$$\Delta R = \sqrt{(\Delta x)^2+(\Delta y)^2}$$

2. $R = x * y$ or $R = x/y$

$$\Delta R = \bar{R}\sqrt{\left(\frac{\Delta x}{\bar{x}}\right)^2+\left(\frac{\Delta y}{\bar{y}}\right)^2}$$

$\frac{\Delta R}{R}$ ≡ fractional error

3. $R = x^n$

$$\frac{\Delta R}{R} = n\left(\frac{\Delta x}{\bar{x}}\right) \rightsquigarrow \Delta R = nR\left(\frac{\Delta x}{\bar{x}}\right)$$