

# Electrical Engineering

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$$K \rightarrow 10^3$$

$$m \rightarrow 10^{-3}$$

$$M \rightarrow 10^6$$

$$\mu \rightarrow 10^{-6}$$

$$G \rightarrow 10^9$$

$$n \rightarrow 10^{-9}$$

$$T \rightarrow 10^{12}$$

$$P \rightarrow 10^{-12}$$

$$F \rightarrow 10^{-5}$$

\* أكثر التي نحتاجه من ي فوقه :-

$K, M, m, \mu, n, P$

\* وحدات التيار وفوق الجهد  
والقارمة معكن تكون حيعلم  
كبيرة أومغيرة .

\* أغلب التيارات تقاس بـ  $mA$

وأغلب الفواصات تقاس بـ  $PF$  أو  $FF$

\* الشكات نوعين موجبة وسالبة .

\* أصل شحنة هي شحنة الإلكترون

$$-1.6 \times 10^{-19}$$

charge  $\rightarrow Q$  or  $q$  or  $q(t)$

current  $\rightarrow I$  or  $i$  or  $i(t)$

voltage  $\rightarrow V$  or  $v$  or  $v(t)$

power  $\rightarrow P$  or  $p$  or  $p(t)$

\* متى بنستخدم كل

شكل من هذه ؟

### # convention :-

1- Use capital letter For Dc (For constant or independent on time quantites).  
يكتبنا حرفا كبير لما تكون القيمة بي عندي ثابتة .  
مع الزمن زي مثلا بطارية فرق الجهد فيها  $12V$  وبعد ساعة جنل ثابت .  
 $Q = 5C$

2- Use small letter for Dc or Ac quantites .

$q = 5C$  Alternative current .

هاي حالة عامة يعني معكن على قول نستعمل حرفا صغير

3- Function of  $(t)$  when it is written on expression

$$q(t) = 5e^{-t}$$

$$[Q = 5 \cos t]$$

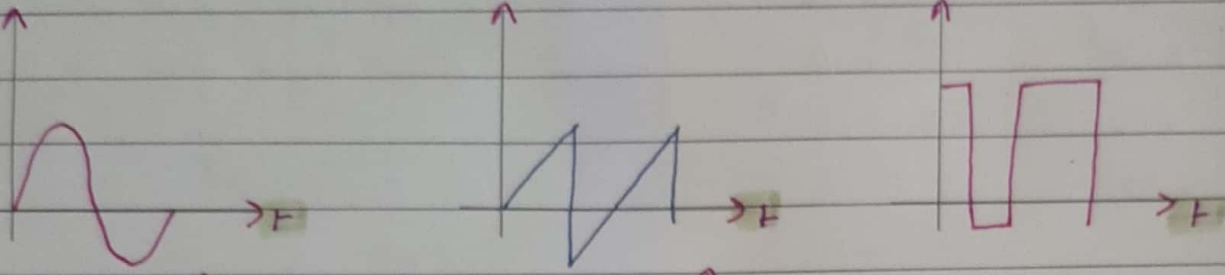
Function of  $t$

ask :: believe & recieve

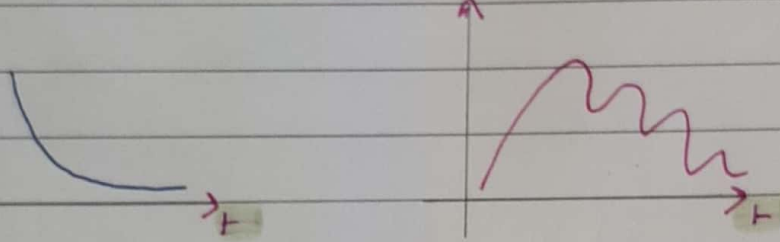


Subject : .....

## # AC → تتغير مع الزمن

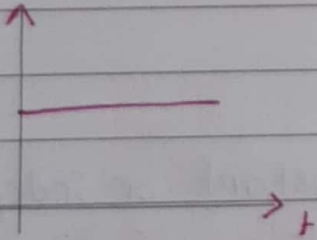


محور y معك  
يكون أي +  
(q, i, v, p)  
أما محور x يكون



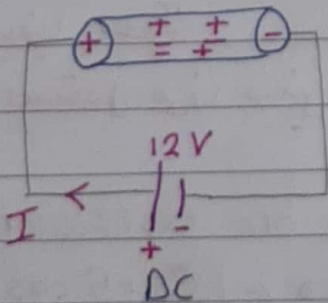
\* أول 3 رسعات بنسبهم (periodic) متكررات مع الزمن. للزمن (t)  
\* الرسعتين يلي تحت (non-periodic) وما يكون العلم رموز.

## # DC → ثابتة مع الزمن

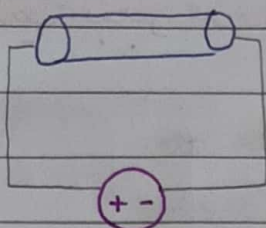


## # Current : I or i or i(t)

I →



\* في الوضع الطبيعي راج يكون هذا  
اكتفيل متعادل كهربائياً ( $q_{total} = 0$ ) عدد  
الشحنات ايجابية يساوي عدد الشحنات  
السالبة ، إذا وصلوا بفارق جهد راج  
يجري التيار من الشحنة ايجابية للسالبة .



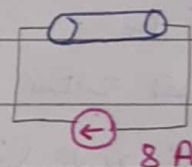
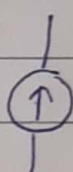
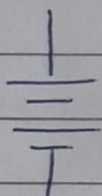
DC → متغير ثابتة للجهود  
مثلاً 12V , 15V دهمكزا .

AC → متغيرة مثل  $3\sin 5t$   
أو  $15\cos 10t$  دهمكزا .

برضو هاي  
طريقة ثانية عشان  
نغير عن مصدر فرق  
الجهود لما يكون DC

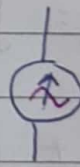
DC voltage source

DC current source



AC voltage source

AC current source



\* دافعاً الفولتية بدها (+ -)

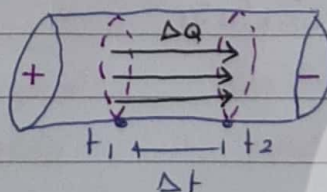
لما يكون تغير منتظم

أما التيار بده اتجاه .

$$i = \frac{\Delta Q}{\Delta t} \rightarrow \text{unit } C/s \text{ or } A$$

تغير غير منتظم

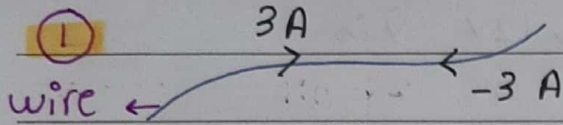
$$i = \frac{dQ}{dt}$$



مجموع الشحنات  
لي تتركز خلال زمن  
 $\Delta t$  نقل التيار اكار  
بها السلك

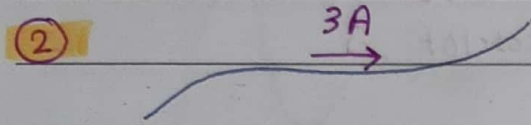


\* كيف يتغير عن التيار :-



\* على نفس السلك

مفتوح يمر تيارين مختلفين  
بنفس الاتجاه



\* Example :-

Find the total positive charge that has passed during

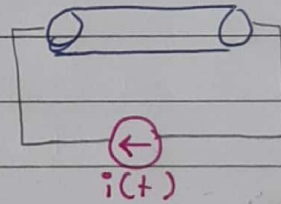
$[-0.25, 0.25] \text{ s} \rightarrow i(t) = 5e^{4t} \text{ (A)} \quad t < 0$

$i(t) = 5e^{-4t} \text{ (A)} \quad t > 0$

ما في زمن

سالب المكثرو جنبها

في الزبح ثانية الأحيوة



$$\int dq = \int i dt \rightarrow q = \int i dt$$

$$q = \int_{-0.25}^0 5e^{4t} dt + \int_0^{0.25} 5e^{-4t} dt = 1.58 \text{ C}$$

هنا السلك خلال

هاي الفترة من الزمن موت حبة

شحنات حبيتها 1.58 C

$$\# \text{ No of } = \frac{1.58 \text{ C}}{1.6 \times 10^{-19} \text{ C}} = 10^{19}$$

protons

الشحنة  
الإلكترونات

عدد البروتونات

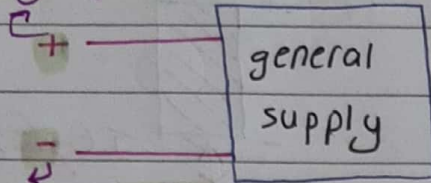
لي موت خلال

هاي الفترة



# voltage :-  $V$  or  $v$  or  $v(t)$

high potential



low potential  
or ground

التيار يفلج  
من القطب الموجب لـ  
supply

voltage =  $\frac{\text{work}}{\text{charge}}$   $\rightarrow$  unit (V) or (J/C)

عشان أحذر  $1V = 1J/C \rightarrow$   
أُنقل شحنة مقدارها 1C  
1C وبتل عليها شغل  
مقداره 1J بالتالي يكون  
محصلة على جهد مقداره 1V

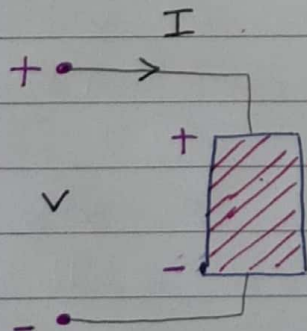
# Power :-  $P$  or  $p$  or  $p(t)$

$P = \frac{\text{work (w)}}{\text{time (t)}}$   $\rightarrow$  unit (watt) or (w)

$$P = \frac{\Delta W}{\Delta t} = \frac{dW}{dt} * \frac{dq}{dt} \rightarrow I$$

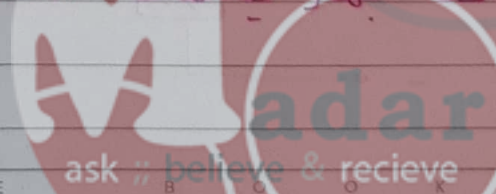
$$P = V * I \text{ or } v * i$$

\* power could be generated (supplied or delivered) or consumed (absorbed).  
أو power لا بتعني لا بتأخذ

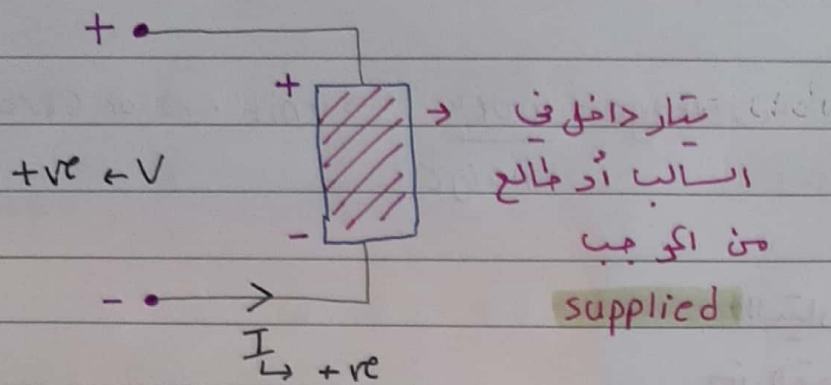


التيار داخل في  
الموجب بالتالي  
absorbed

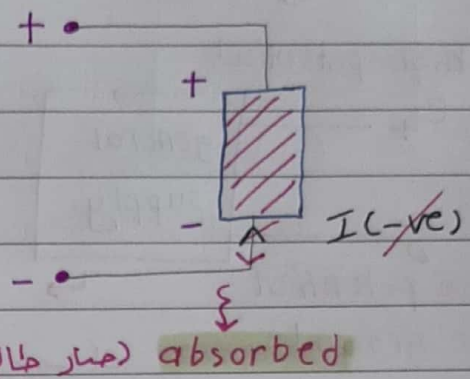
\* عشان أتحف النوع بتفوج على  
المسئوق إذا تيار موجب دخل  
بالقطب الموجب لـ positive supply  
يكون الجهاز يستهلك power







تيار داخل في  
السالب أو طالع  
من الكوجب  
supplied



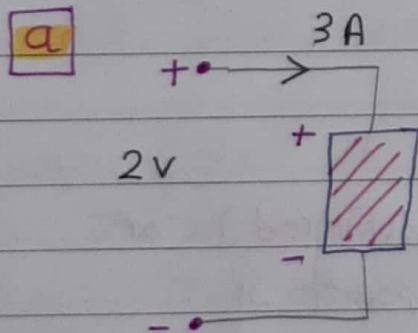
absorbed (تيار طالع من  
الكوجب لأن التيار سالب)

عشان أحدد النوع بستوف  
اتجاه التيار الكوجب

### \* Example :-

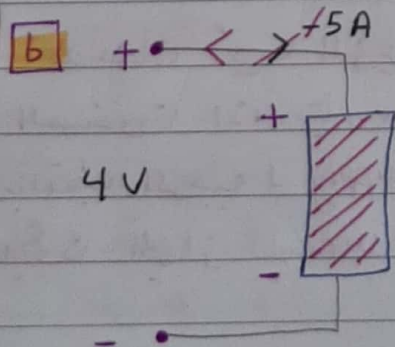
Find the absorbed power by each of the following elements :-

$$P = V * I$$



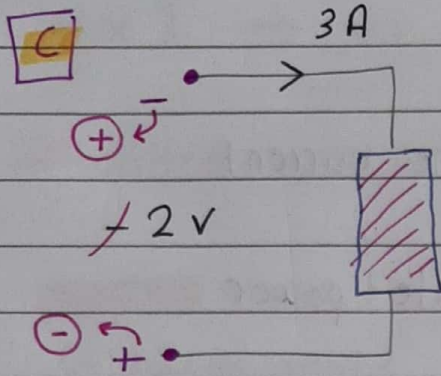
$$P_{abs} = 3 * 2 = 6 \text{ AW}$$

$$P_{gen} = -6 \text{ W}$$

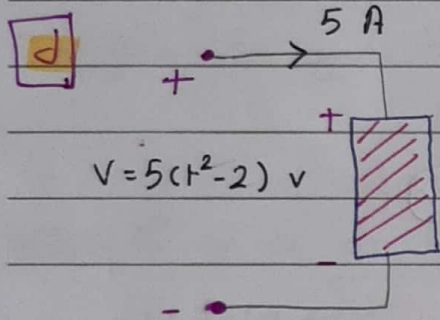


$$P_{abs} = -20 \text{ W}$$



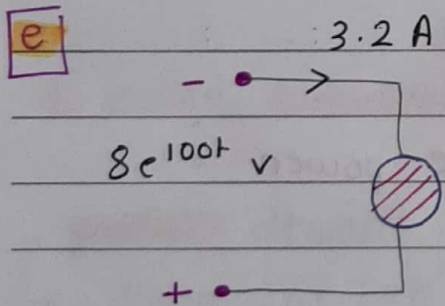


$$P_{abs} = 6 \text{ W}$$



$$P_{abs} = 25(t^2 - 2) \text{ W}$$

لو أعطاني زمني يا  
معين بعوض



$$P_{abs} = -25.6 e^{100t} \text{ W}$$

$I \rightarrow$  يحتاج إلى direction

$V \rightarrow$  يحتاج إلى زوج من الشحنتين  
لوجبة والسالبة .

$P \rightarrow$  يحتاج التنتين  $\nabla$

\* الشحنة هي الأ شح لأتو لو غش  
حركة غش تيار بالتالي ما عنا جهد  
ولا power





## # voltage & current relationships :-

1- if the voltage is independent on the current

↳ independent voltage source

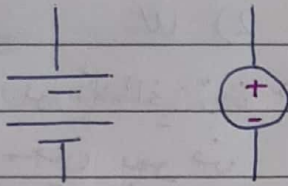
↳ active → generate power

بغير حثية  $V$

مع بقاء حثية  $I$

ثابتة .

DC →



AC →



2- if the current is ind. on the voltage

↳ independent current source

↳ active → generate power

تغير حثية  $I$

مع بقاء حثية  $V$

ثابتة .

DC →



AC →

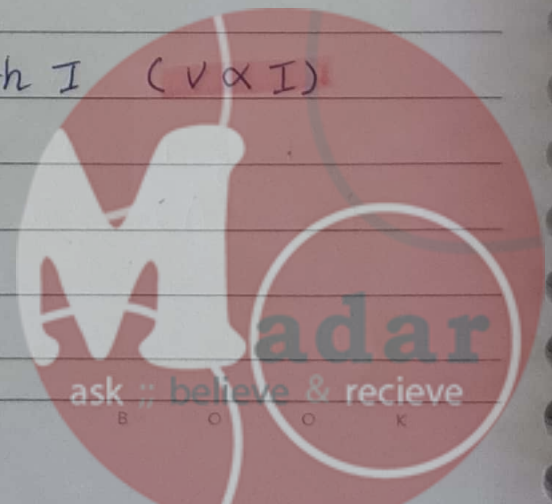


3- if  $V$  is linearly proportional with  $I$  ( $V \propto I$ )

↳

لما أغير الجهد التيار يتغير

بشكل خطي .



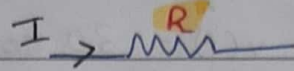
$$V \propto I \rightarrow [V = RI] \rightarrow \text{ohm's law}$$

$R$  called resistance



passive element

(عنصر مستهلك)



تُسمى المقاومة

تقاوم التيار الكار فيها

(تقلل سرعة)

↳ dissipated as a heat

الطاقة يتميخ على شكل حرارة

$$R = \frac{V}{I}, \text{ unit } \frac{V}{A}, \text{ ohm, } \Omega$$

$$4- \text{ if } V \propto \frac{di}{dt} \rightarrow V = L \frac{di}{dt}$$

التيار معدل تغير

التيار

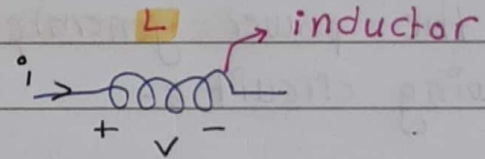
$L$  called Inductance or coil



passive element

↳ dissipated as stored inside the inductor as a magnetic energy

تخزن الطاقة جمانة على شكل طاقة مغناطيسية



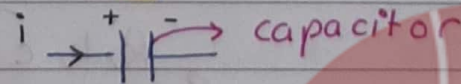
$$5- \text{ if } i \propto \frac{dV}{dt} \text{ (or } V = \int i dt) \rightarrow i = C \frac{dV}{dt}$$

$C$  called capacitance



passive element

↳ dissipated as stored inside the capacitor as a electrical energy (battery).

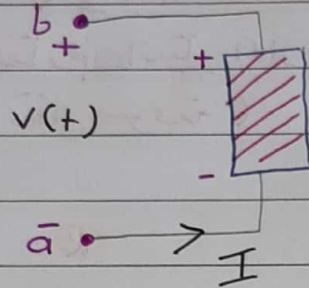




**\* Example :-**

What is the energy required to move  $3C$  from point  $a$  to  $b$  during  $6s$ , if  $v(t) = 30 \cos(10t) V$  :-

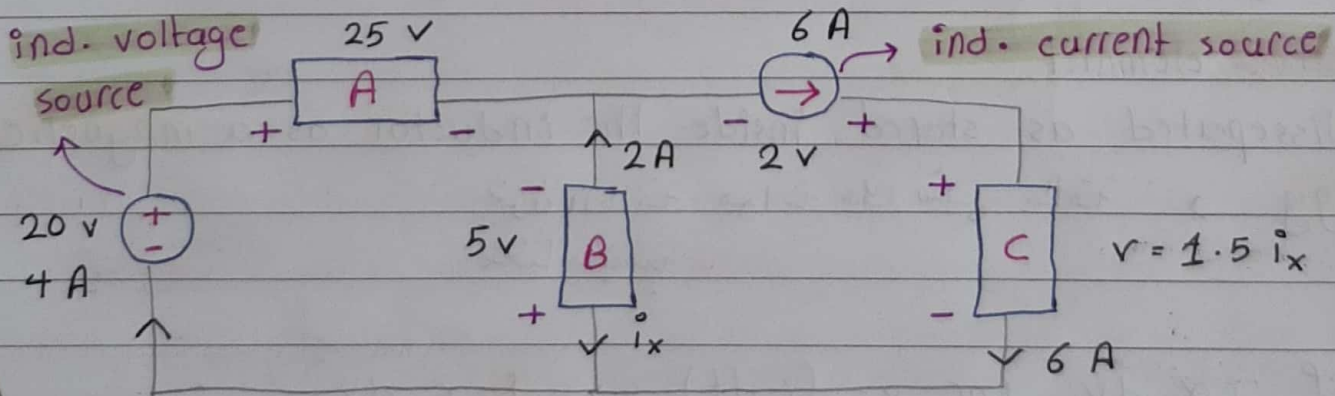
مطلوب بهاء السؤال  
حسب الشغل



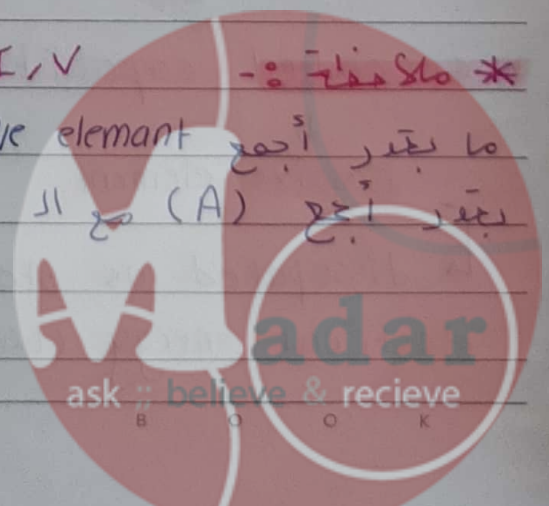
voltage =  $\frac{\text{work}}{\text{charge}}$   $\Rightarrow W = VQ = 90 \cos 10t \big|_{t=6} = 45 J$

**\* Example :-**

Find the power generated by each element in the following circuit :-



**\* ملاحظة :-**  
ما يتغير أجمع active element مع  $R, L, C$  positive element مع  $I, V$   
بغير أجمع (A) مع ال 20V إذا كانت A voltage source



$A, B, C \rightarrow$  unknown element.

$$P_{20V} = 80 \text{ W}$$

$$P(A) = 25 \times 4 = -100 \text{ W}$$

$$P(B) = -10 \text{ W} \quad I_x = -2 \text{ A} \rightarrow$$

لأنه ما

بغير تيارين الهم نفس

التيمة يكون اتجاههم مختلف بنفس السلك

$$P_{6A} = 12 \text{ W}$$

$$P(C) = - (1.5 \times (-2)) \times (6) = 18 \text{ W}$$

$\Rightarrow$  عشان أتاكد اذا الكلى مع

$$\sum P = 0$$

\* بنستنتج من هاد السؤال ان

active element  $\leftarrow C, 20V, 6A$

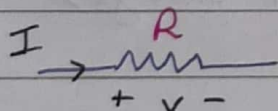
$$\sum P_{gen} = \sum P_{abs} \leftarrow \text{هاد من}$$

هاي مو  $(R, L, C)$

مبدأ حفظ الطاقة

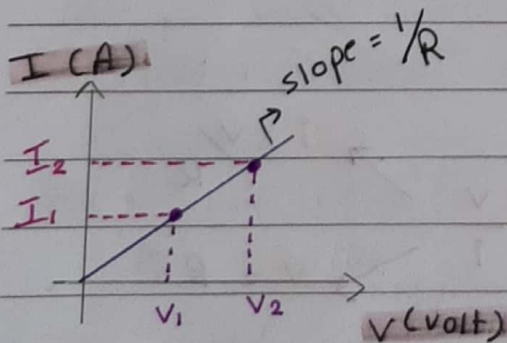
دها يتكون  $(V \text{ او } I)$

# Ohm's law :-



$$V \propto I \rightarrow V = R I$$

$\hookrightarrow$  Resistor in ohm ( $\Omega$ )



$$\rightarrow \text{slope} = \frac{I_2 - I_1}{V_2 - V_1} = \frac{1}{R} = G$$

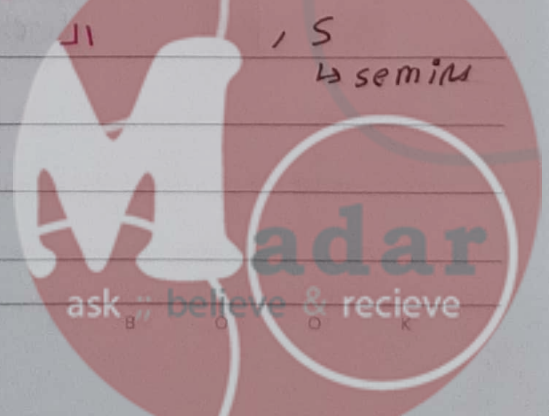
$\hookrightarrow$  conductance

unit  $\Omega^{-1}$ , mho

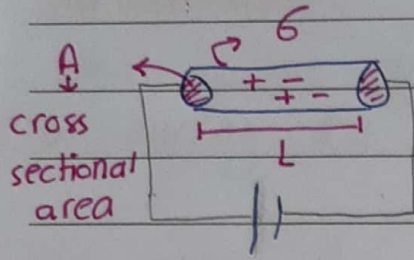
Resistance

$\hookrightarrow$  semis

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







\* parameter يعني السلك :-

- ① cross sectional area (A)
- ② length of wire (L)
- ③ type of wire (sigma)

$\sigma = \text{conductivity} = \frac{1}{\rho}$   
 فاجية S/m  
 اوجلية

$\rho \rightarrow \text{Resistivity}$   
 فاجية  $\Omega / m$   
 المقاومة

$\sigma(\text{cu}) = 5.8 \cdot 10^7 \text{ S/m}$

من اقل

اكواد

علاقة خردية مع R

\*  $R = \frac{\rho L}{A}$   
 مع R  
 علاقة عكسية

هنا القانون كيف

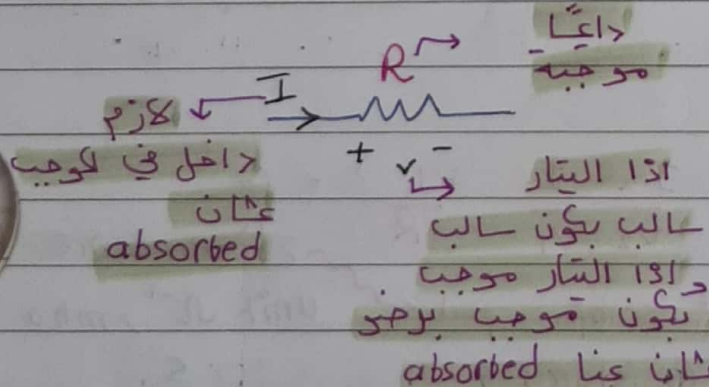
احسب R بناءً على الشكل

يعني ان (A, L, sigma) كاجابات عشان

اعرف قيمة المقاومة

## # Power on the resistor :- (absorbed power always)

عشان R تستهلك power وبتعنيها على شكل heat



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



$$P = V * i \rightarrow \left[ P = \frac{V^2}{R} \right]$$

$$P = I^2 R$$

$$P = G V^2$$

$$P = \frac{i^2}{G}$$

Real power (w)

Doule's law

(absorbed power)

← طاقة مُتَاحِة

الطاقة الفعلية تقبل الـ  
power ← طاقة مُتَاحِة كجارية

\* Example :-

if  $V = 2 \sin(100t)$  &  $R = 10 \Omega$

∴  $i = \frac{V}{R} = 0.2 \sin(100t) \text{ A} \rightarrow 200 \sin(100t) \text{ (mA)}$   
← أغلب تقاملنا يكون مع الـ  
mA

\* Example :-

(a) Find R if  $i = -1.6 \text{ mA}$  &  $V = -6.3 \text{ V}$  :-

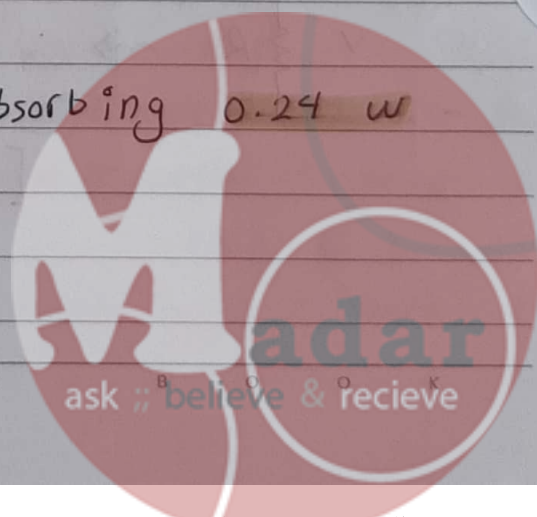
$$R = \frac{-6.3}{-1.6 \times 10^{-3}} = 3.94 \text{ K}\Omega$$

(b) Find absorbed power if  $V = -6.3 \text{ V}$  &  $R = 21 \Omega$  :-

$$P = \frac{V^2}{R} = \frac{(-6.3)^2}{21} = 1.89 \text{ W}$$

(c) Find i if  $V = -8 \text{ V}$  & R is absorbing 0.24 w

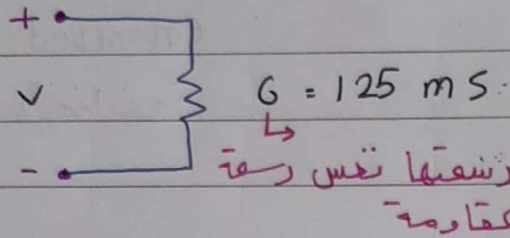
$$i = \frac{P}{V} = \frac{0.24}{-8} = -30 \text{ mA}$$





**\* Example :**

Find  $V$  if  $P_{abs} = 200 \text{ mW}$



$$P = GV^2 \rightarrow V = \sqrt{\frac{P}{G}} = \sqrt{\frac{200 \times 10^{-3}}{125 \times 10^{-3}}} = \pm 1.26 \text{ volt}$$

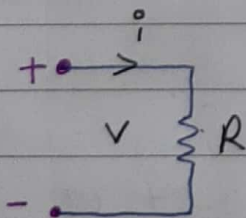
$\Rightarrow$  both answer are correct but for  $(+1.26 \text{ V})$  the current must be positive & for  $(-1.26 \text{ V})$  the current must be negative.

$$i = \pm \sqrt{PG} = \pm \sqrt{200 \times 125} \times 10^{-3} \text{ A}$$

**\* التيار هو إيجابي**  
إشارة الجهد (لازم  $V$  نفس الإشارة).

**# short circuit & open circuit :** (الدوائر المغلقة والمفتوحة)

1- short circuit :- (S.C)  $\rightarrow$  الجهاز مش شغال (الخرق)



$$V = 0$$

$$R = 0$$

$$P_{abs} = 0$$

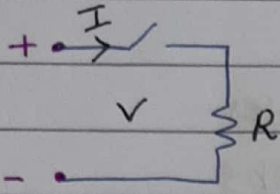
$$[i \text{ is max}]$$

**\* إذا  $V$  و  $i$  مش**  
بتكون طاقة ممتصة مش فيها

active element

ask believe & recieve

2- open circuit :- (O.C) → ما في منها خوف بس ما راح  
استفيد من الجهاز (مش واصله كهرباء)



$$I = 0$$

مقاومة كبيرة بحيث تقنع التيار يعني  $R = \infty$

$$P_{abs} = 0$$

\* ال S.C أخف

[V is max]

من ال O.C

## # Voltage & current laws :-

⇒ Analysis of Electrical circuit :-

أكثر شي يعني ال

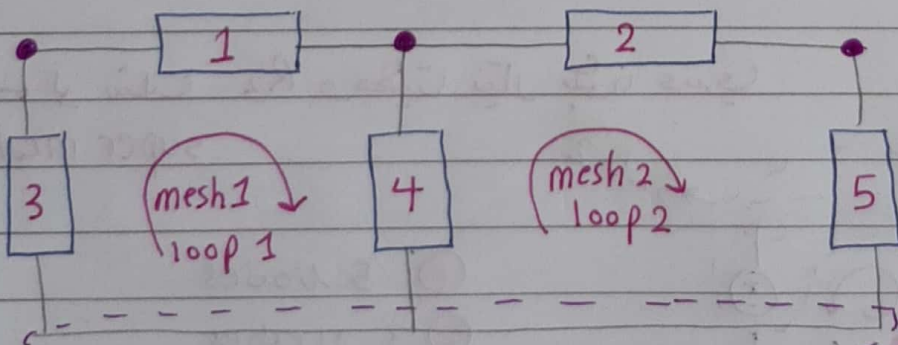
mesh & node

Node , Path , branch , loop , mesh

loop ما في لا أي سلك مسار نقطة التقاء

جواها loop يعني فية الأقل فية 2 element أو أكثر

الأقل one 2 branch وبالغالب ما بنستخدم  
component (عدد عدد ال comp.)



→ 5 components  
معنى active or passive

① 4 nodes

② 5 branch

③ 3 loops كل mesh

④ 2 mesh هي loop

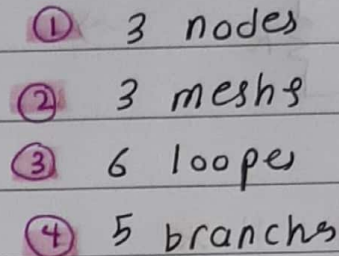
بين مش على loop

في mesh

node وحدة لأن لا  
3 comp. يلتقوا بنقطة واحدة.



Count nodes, mesh, branch, ... :-



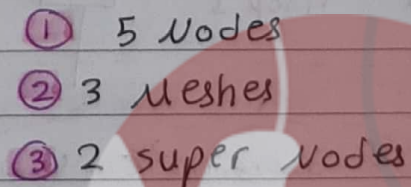
is any two nodes that contains a voltage source between them. لازم يكون بينهم مصدر فرق جهد كذا

لازم يكون بينهم محسّر فوق جهر كاله  
يون اي شاي .

any two meshes that contains a current source between them.   
 تعریف کیا آنا   
 current   
 بیرون آئی گئی

برضو مهر پيار لاله  
ليون اي شافي

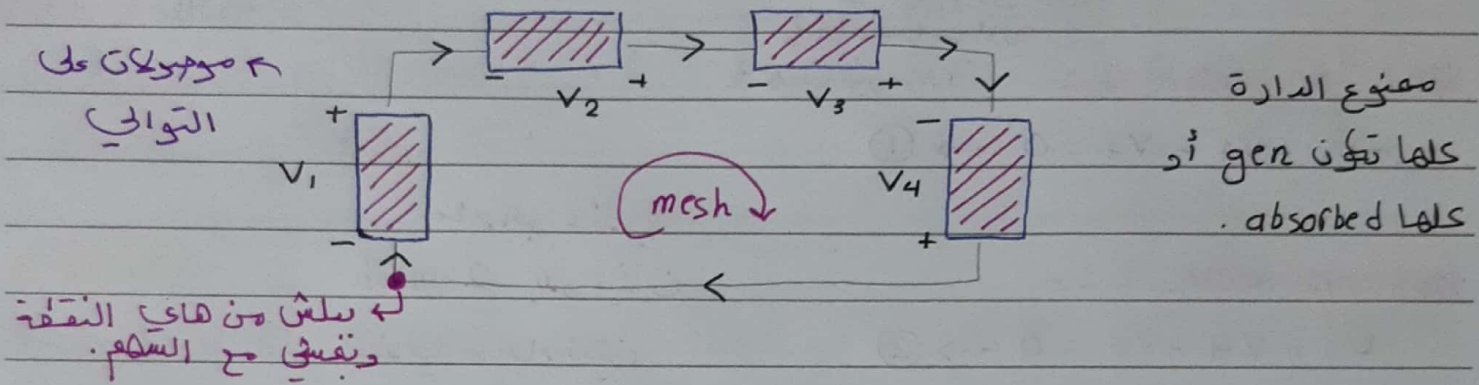
→ لو شلت  $R_2$  و هجيت بيار بتون عدي  
super mesh



① دو قسم  
نسايي ال voltage source  
نسف

# # Kirchoff's laws :-

- 1- Kirchoff's voltage law (KVL)
- 2- Kirchoff's current law (KCL)

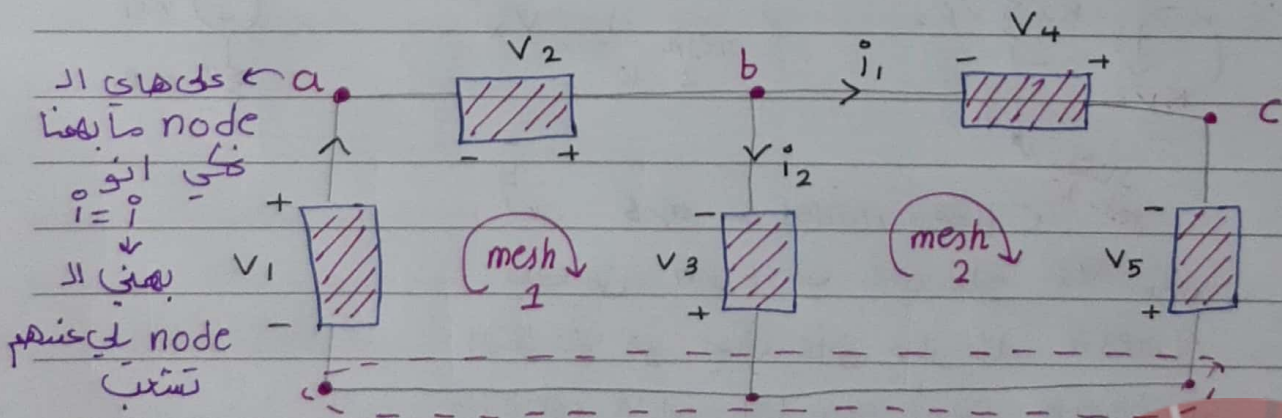


$\Rightarrow KVL \rightarrow \sum_{n=1}^N V = 0 \rightarrow$  مجموع الجهد على أي مسار مغلق يساوي صفر

↓  
بهذا الـ mesh

↓  
closed loop

$= -V_1 - V_2 - V_3 - V_4 = 0$



$\Rightarrow KCL \rightarrow \sum i = 0$  on each node مجموع التيارات عند أي node يساوي صفر

↓  
بهذا الـ node

↓  
entering or leaving

$\sum i_{\text{entering a node}} = \sum i_{\text{leaving a node}}$



# node b  $\Rightarrow$ 

$$i = i_1 + i_2 \rightarrow i - i_1 - i_2 = 0$$

# node d  $\Rightarrow$ 

$$i_1 + i_2 = i$$

علاقة ما  
نكتبها KCL  
لا node في تحت  
لأنها نفس معادلة

معنى اكتسابها بالشكل  
يا كل التيارات داخلية يا كلها  
طالعة

KVL on mesh 1 :-

$$-V_1 - V_2 - V_3 = 0 \rightarrow (1)$$

KVL on mesh 2 :-

$$V_3 - V_4 - V_5 = 0 \rightarrow (2)$$

ما حرام عندي

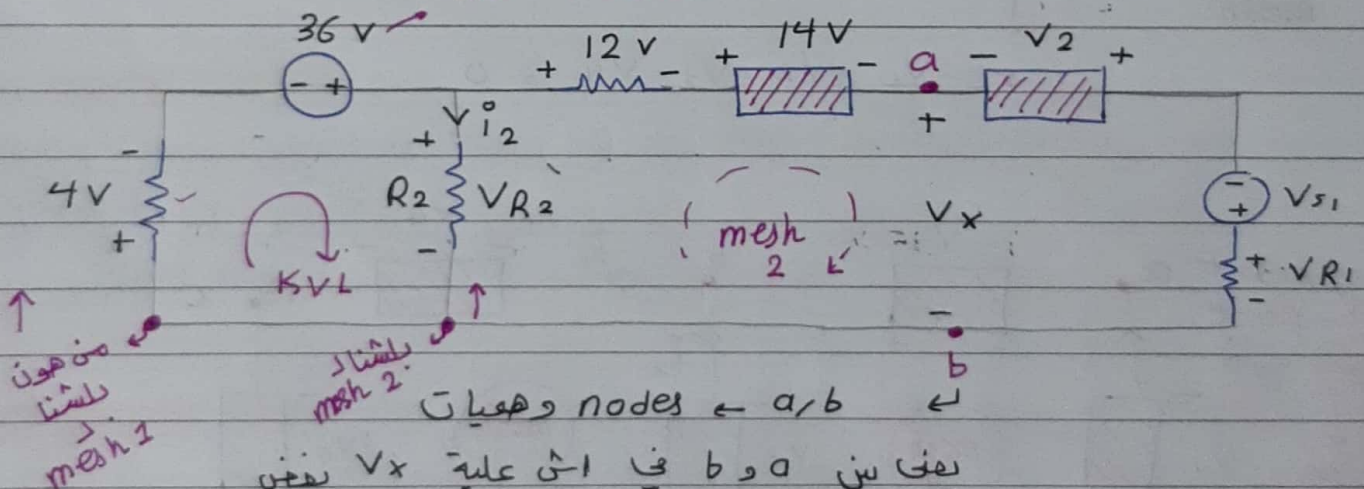
2 mesh بدويكون

عندي معادلتين

# Example :-

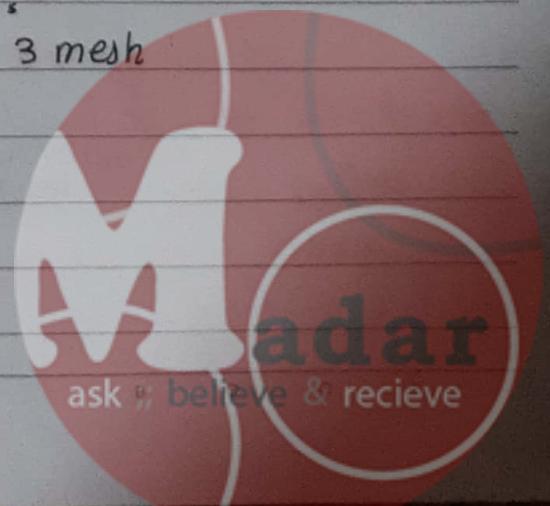
Find  $V_x$  &  $V_{R_2}$  :-

ind. v-source



يفني بين a و b في اشي عليه  $V_x$  يفني  
النظر هو هو يفني كأنو حمارنا 4 mesh  
وأننا ابي الخيار انا بدوي اعتبر 2 mesh أو

3 mesh



KVL at mesh 1:-

$$4 - 36 + V_{R2} = 0$$

$$V_{R2} = 32 \text{ V}$$

Find  $R_2 = ?$

KVL at mesh 2:-

$$-32 + 12 + 14 + V_x = 0$$

$$V_x = 6 \text{ V}$$

$$R_2 = \frac{V_{R2}}{I_2}$$

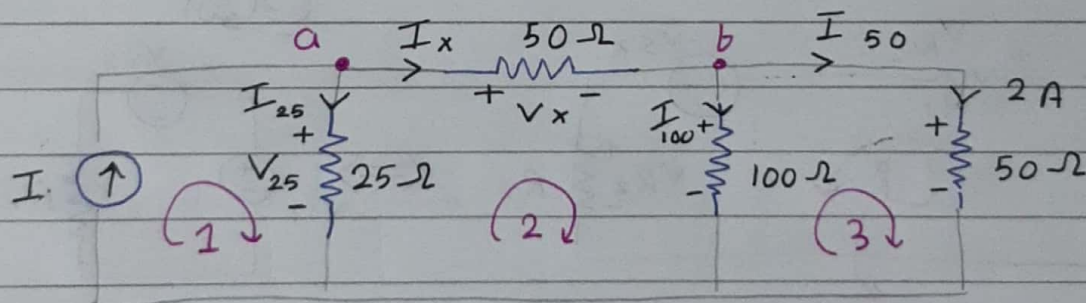
لو أعطاني  
قيمة التيار

⇒ Note:-

The parallel element's must have the same voltage, series elements must have the same current.

# Example:-

Find  $V_x$  &  $I$  :-

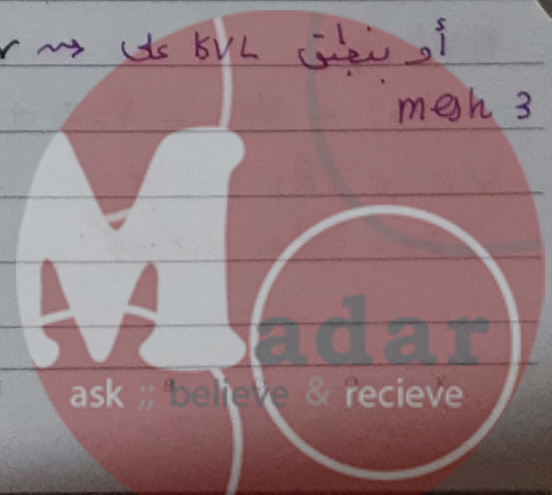


يجب أبلش بـ KVL أو KCL متباعدة  
بدنا نبلش بـ Ohm's

Ohm's law at  $R = 50 \Omega$  :-

$$V_{50} = 2 \times 50 = 100 \text{ V}$$

$50 \Omega // 100 \Omega \rightarrow \therefore V_{100} = V_{50} = 100 \text{ V} \rightarrow$  أو بنطبق KVL على mesh 3





KCL at Node b :-

$$I_x = 2 + 1 = 3 \text{ A}$$

$$V_x = 3 \times 50 = 150 \text{ V}$$

KVL at mesh 2 :-

$$-V_{25} + 150 + 100 = 0$$

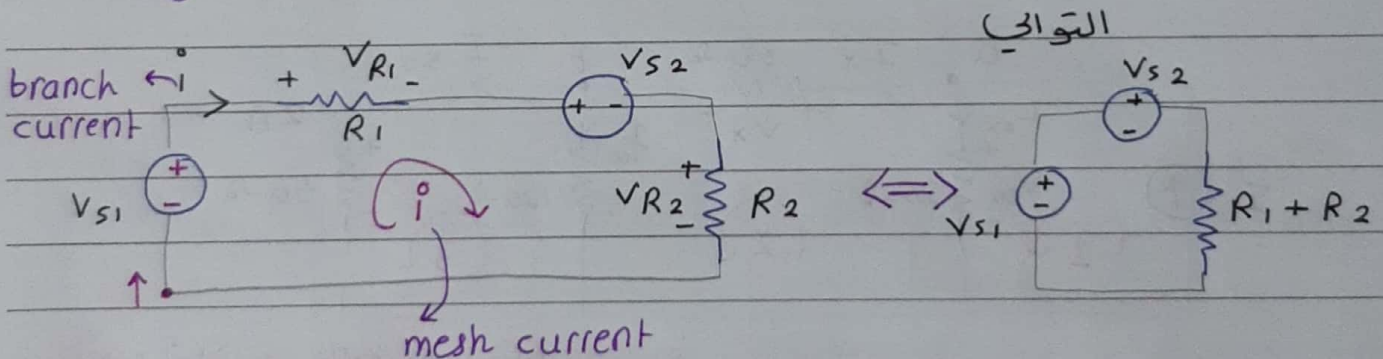
$$V_{25} = 250 \text{ V}$$

$$I_{25} = \frac{250}{25} = 10 \text{ A}$$

KCL at Node a :-

$$I = 3 + 10 = 13 \text{ A}$$

# single loop circuit :- كل العناصر موصولة على التوالي



branch current = mesh current  $\Rightarrow$  في حالة ان branch ما انشبت مع آخر ثاني

KVL  $\Rightarrow$

$$-V_{S1} + V_{R1} + V_{S2} + V_{R2} = 0$$

$$V_{R1} = i R_1$$

$$V_{R2} = i R_2$$

بعضتي



$$-V_{s1} + V_{s2} + iR_1 + iR_2 = 0$$

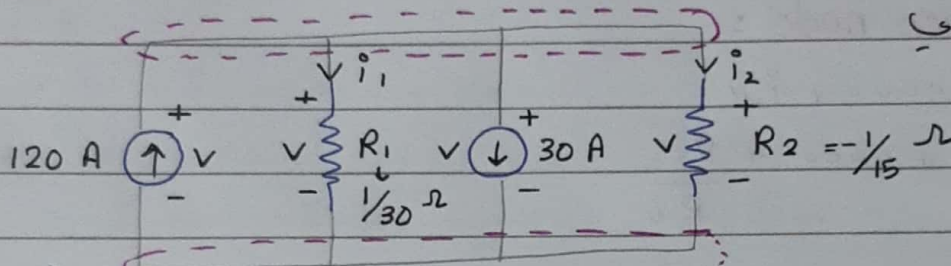
$$i = \frac{V_{s1} - V_{s2}}{R_1 + R_2}$$

\* المقارنات الكهربية على التوالي بقدر أجمعها  
جمع عادي ← شأن أهل يعمل KVL بدين بغير  
عن المقارنات بدلالة التيار.

### # single node pair circuit :-

كل العناصر موصولة

على التوازي



بكونا عندي  
زوج من ال node  
مقال يعني

### KCL at the upper node :-

$$120 = i_1 + 30 + i_2 \rightarrow \textcircled{1}$$

$$i_1 = \frac{V}{R} = 30 \times V = 60 \text{ A}$$

$$120 - 30 = 45 \times V$$

$$i_2 = \frac{V}{R} = 15 \times V = 30 \text{ A}$$

$$[V = 2 \text{ V}]$$

### => Power generate by each elements :-

$$P_{(120 \text{ A})} = 240 \text{ W (gen)}$$

$$P_{(30)} = -60 \text{ W (abs)}$$

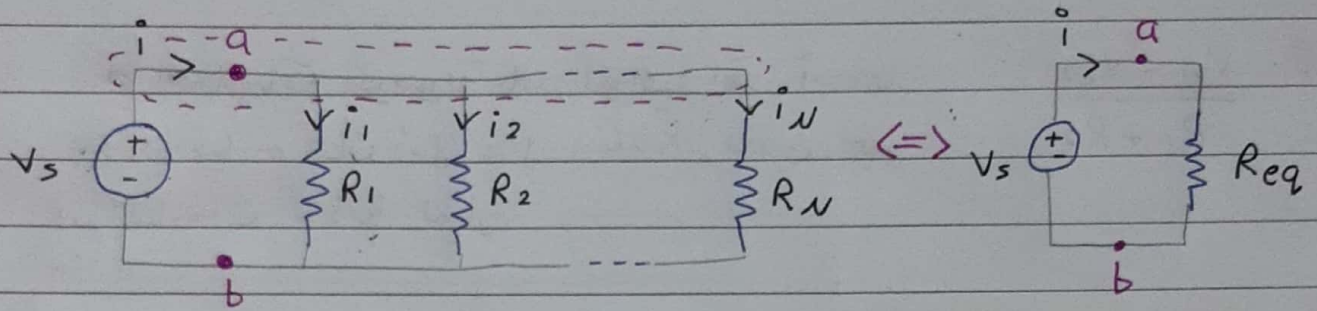
$$P_{(1/30)} = -120 \text{ W (abs)}$$

$$P_{(1/15)} = -60 \text{ W (abs)}$$

$$\sum P = 0$$



## # Resistors in parallel :-



### KCL at the upper node :-

$$i = i_1 + i_2 + \dots + i_N$$

$$i = \frac{V_s}{R_1} + \frac{V_s}{R_2} + \dots + \frac{V_s}{R_N}$$

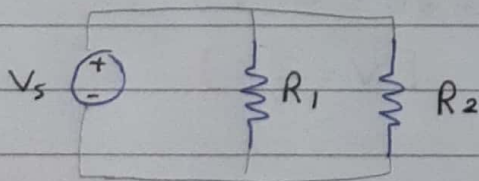
$$i = V_s \left( \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N} \right) = \frac{V_s}{R_{eq}}$$

$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N}}$$

\* يفضل ما يكون عنا أكثر من مقاومتين  
مربولات على التوازي نستعمل كن مقاوميش  
مع بعض أسهل

### → special case :-

For two resistors in parallel

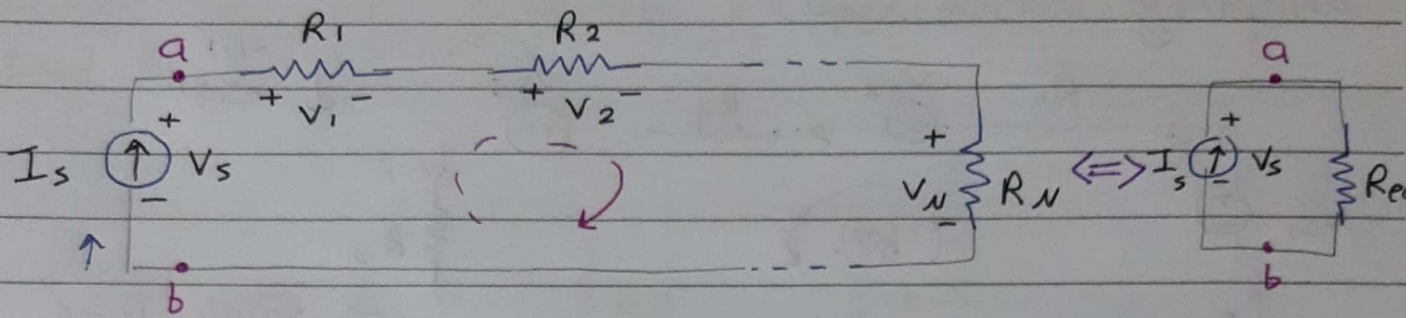


$$R_{eq} = \frac{1}{\frac{R_2 \times 1}{R_2 R_1} + \frac{1 \times R_1}{R_2 R_1}}$$

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

$$\therefore R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

# Resistors in series :-



## KVL :-

$$-V_s + V_1 + V_2 + \dots + V_N = 0$$

$$V_s = V_1 + V_2 + \dots + V_N$$

$$= I_s R_1 + I_s R_2 + \dots + I_s R_N$$

$$V_s = I_s (R_1 + R_2 + \dots + R_N)$$

$$V_s = I_s R_{eq}$$

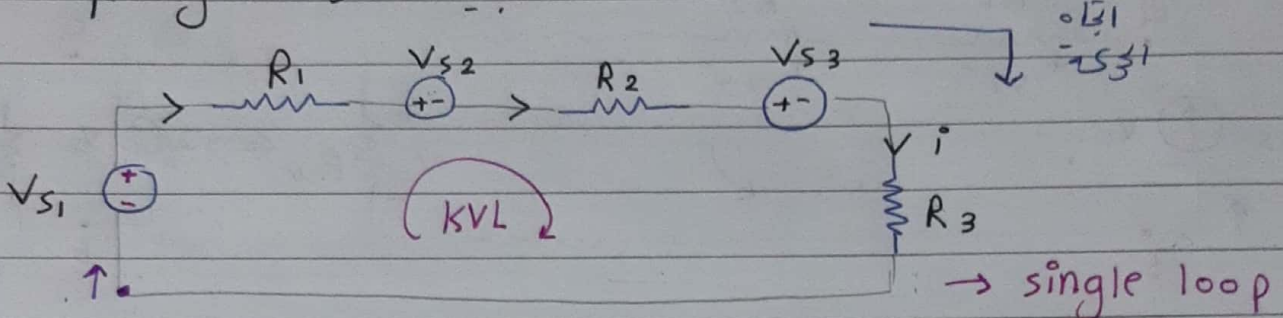
$$R_{eq} = R_1 + R_2 + \dots + R_N$$





### # Example :-

Simplify (تبسيط الدارة)



$$R_{eq} = R_1 + R_2 + R_3$$

$$V_{seq} = V_{s1} - V_{s2} - V_{s3}$$

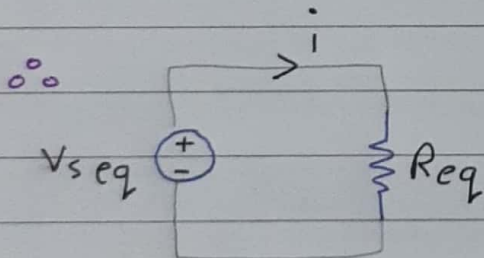
اتجاه  
الحركة  
مقابلة  
من فوق

KVL :-

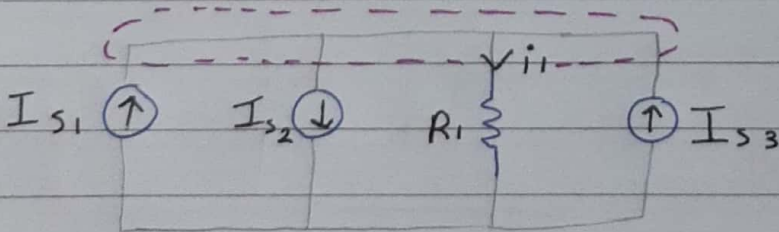
$$-V_{s1} + V_{s2} + V_{s3} + iR_1 + iR_2 + iR_3$$

$$V_{s1} - V_{s2} - V_{s3} = i(R_1 + R_2 + R_3)$$

$$V_{seq} = iR_{eq}$$



في حال التوازي يكون نفس  
هناك الجهد لكن التيار مختلف

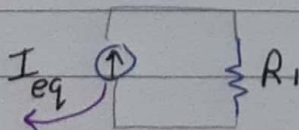


single node circuite

لما يكون عنا بروج على

KCL

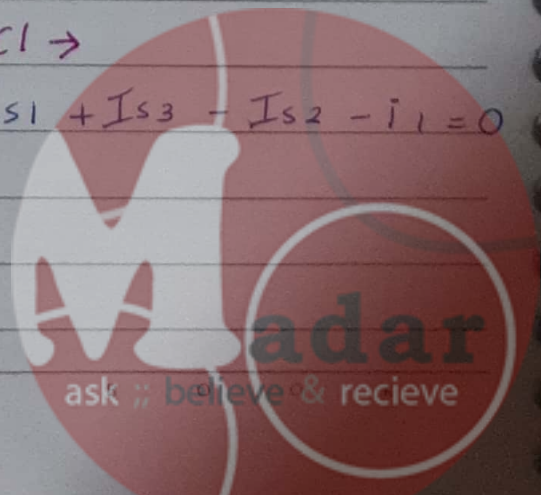
اتجاه السهم يحدد  
مب الدارة



$$I_{eq} = I_{s1} + I_{s3} - I_{s2}$$

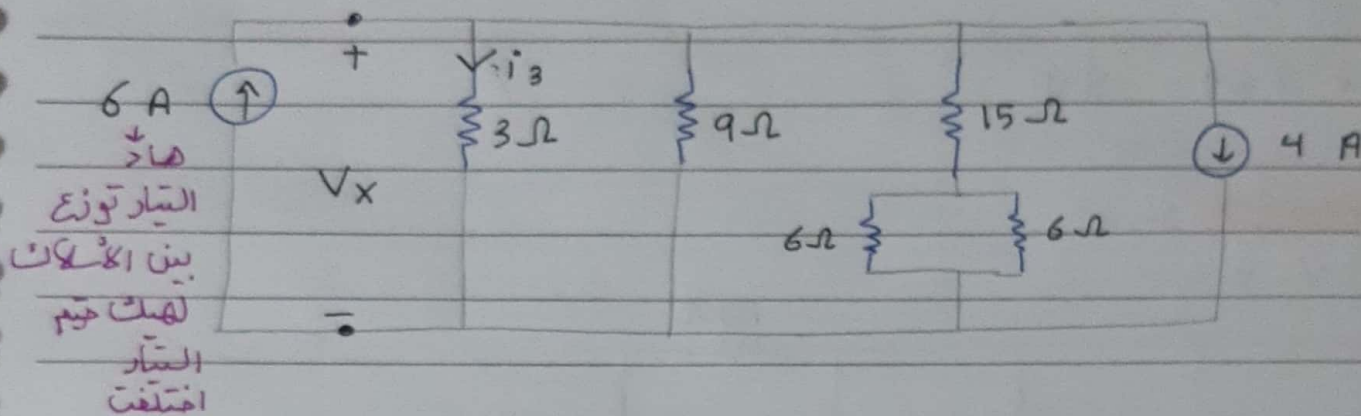
KCL →

$$I_{s1} + I_{s3} - I_{s2} - i_1 = 0$$



### # Example :-

Calculate the power generated by the two current sources & find  $i_3$  :-



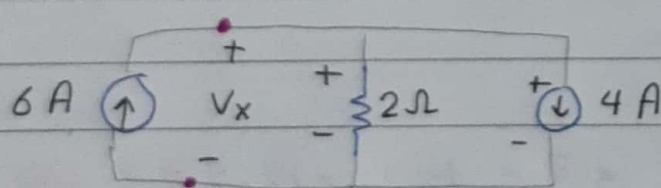
$$6\Omega // 6\Omega \rightarrow \frac{6 \times 6}{6 + 6} = 3\Omega$$

ما يكون عندي مقارميتين  
إلهم نفس القيمة بتكون المقادير  
المكافئة فيها

$$15\Omega + 3\Omega = 18\Omega \text{ series}$$

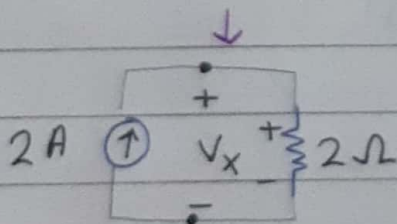
$$18 // 9 = \frac{18 \times 9}{18 + 9} = 6\Omega$$

$$6 // 3 = 2\Omega$$



نقر بـ  $3\Omega \rightarrow i_3$

لهذا شلناها ما بسعنا



$$\rightsquigarrow V_x = 2 \times 2 = 4V$$





$$P_{gen(6A)} = 6 \times 4 = 24 \text{ W} \quad \left. \begin{array}{l} \rightarrow 24 - 16 = 8 \text{ W} \\ \leftarrow \text{power يبدى} \end{array} \right\}$$

$$P_{gen(4A)} = -16 \text{ W}$$

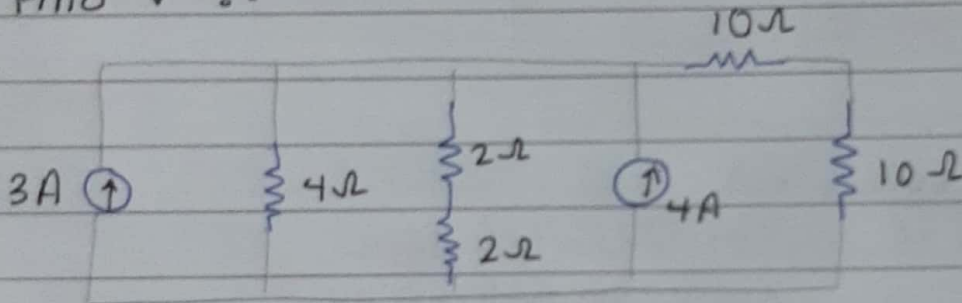
ضاعت بين العقول

$$I_3 = \frac{4}{3} \text{ A}$$

$$P_{2\Omega} = 2 \times 4 = -8 \text{ W}$$

**Example :-**

Find  $V$  :-



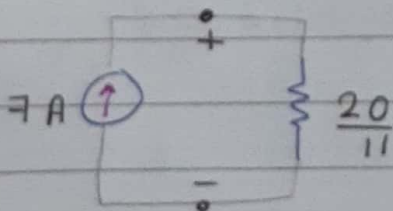
$$10\Omega + 10\Omega = 20\Omega \quad (\text{series})$$

$$2\Omega + 2\Omega = 4\Omega \quad (\text{series})$$

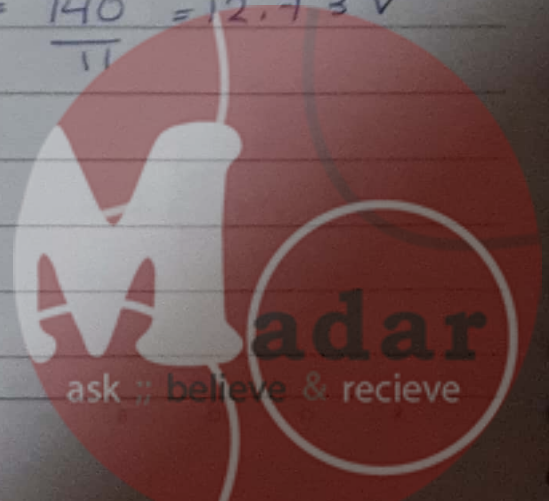
$$R_{eq} = 4 \parallel (2+2) \parallel (10+10)$$

$$4 \parallel 4 \parallel 20$$

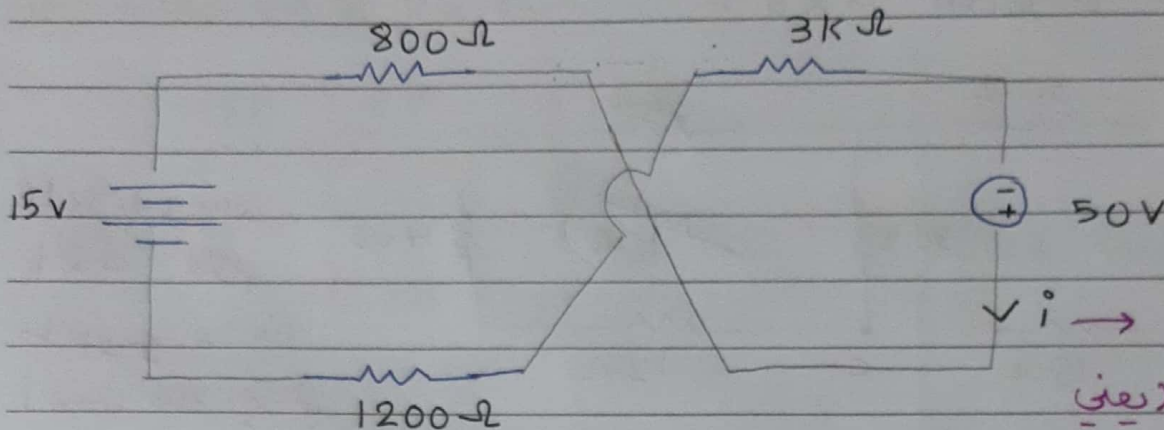
$$2 \parallel 20 = \frac{40}{22} = \frac{20}{11} \Omega$$



$$V = \frac{20}{11} \times 7 = \frac{140}{11} = 12.73 \text{ V}$$

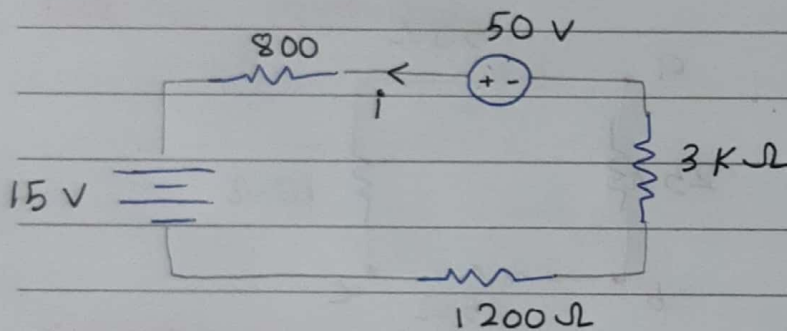


# # Example :-

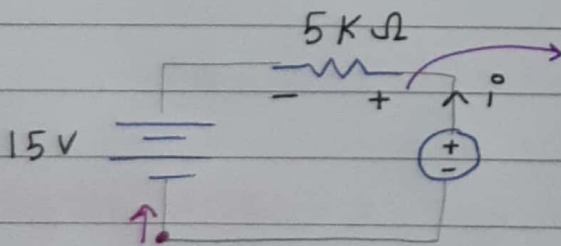


التيار نفسه  
صار بكل الدارة (يعني)  
توالي (لوفيت الأسلاك)  
بتبين توالي

بشكل ثاني ><



$$R_{eq} = 1200 + 800 + 3000 = 5 \text{ k}\Omega$$

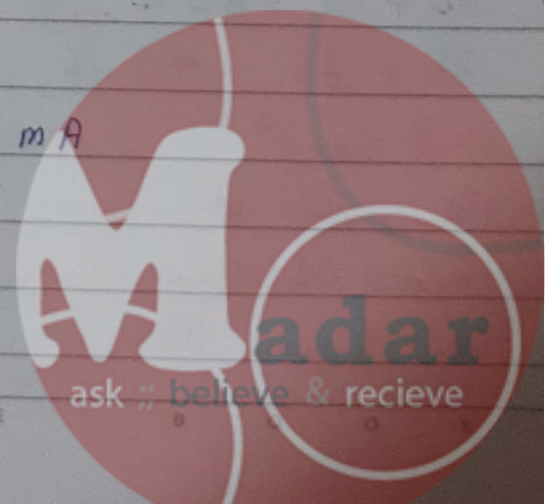


الإشارات  
بغير منظر بناداً  
على اتجاه  
التيار (من لوجب  
للسالب)

KVL =>

$$-15 - 5000 i + 50 = 0$$

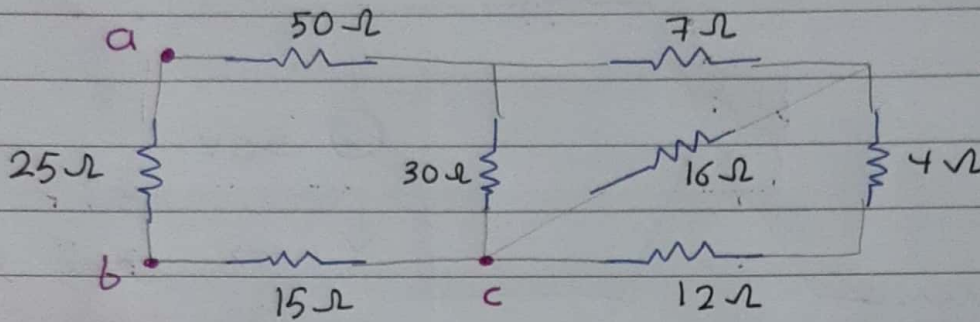
$$35 = 5000 i \rightarrow i = \frac{35}{5000} = 7 \text{ mA}$$





# Example :-

Find  $R_{eq}$  between a & b :-



ما بيني بين  
a & b لازم

ما يروحو عن

أصغر هاد الإشي

بلس من أبعد نقطة عن

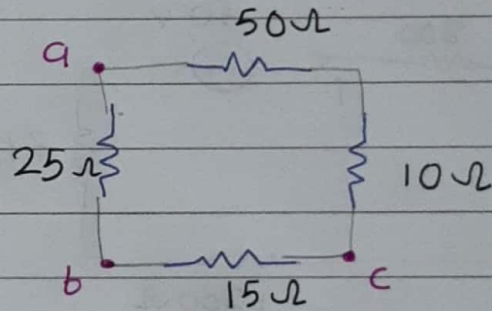
القطب

$$4 + 12 = 16\Omega$$

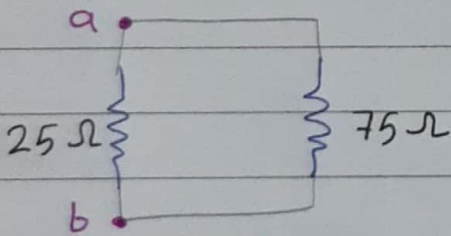
$$16\Omega // 16\Omega = 8\Omega$$

$$8 + 7 = 15\Omega$$

$$15 // 30 = \frac{450}{45} = 10\Omega$$



$$50 + 10 + 15 = 75\Omega$$



$$R_{eq} = 25 // 75 = 18.75\Omega$$

between a & c =>

$$50 + 10 = 60\Omega$$

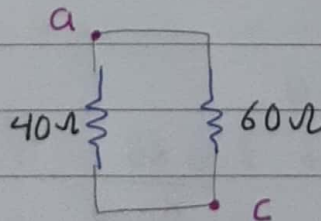
$$25 + 75 = 100\Omega$$

↓ رجعت للدارة

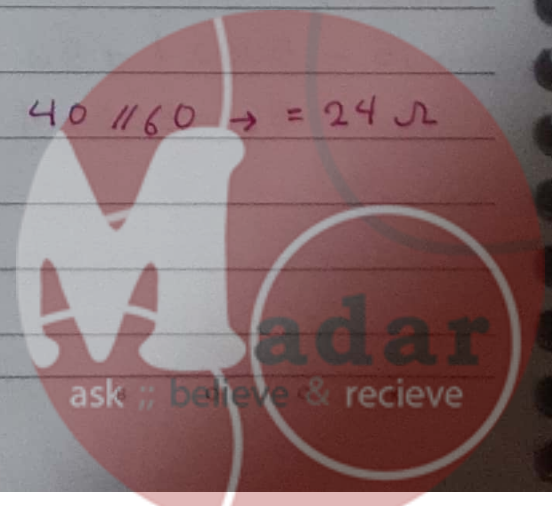
في فوق وبناءاً

عليها علت ( بديش

a & c يعني )

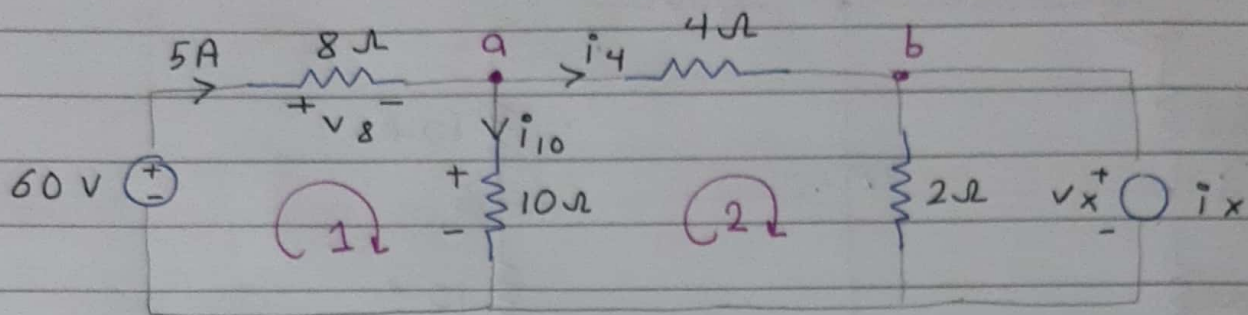


$$40 // 60 \rightarrow = 24\Omega$$



Solve the following questions:-

1 - Find  $i_x$  &  $V_x$  :-



$$V_8 = 5 \times 8 = 40 \text{ V}$$

KVL at mesh 1 :-

$$-60 + 40 + V_{10} = 0$$

$$V_{10} = 20 \text{ V}$$

$$i_{10} = \frac{20}{10} = 2 \text{ A}$$

KCL at node a :-

$$5 = 2 + i_4$$

$$i_4 = 3 \text{ A}$$

$$V_4 = 3 \times 4 = 12 \text{ V}$$

KVL at mesh 2 :-

$$-V_{10} + V_4 + V_x = 0$$

$$V_x = 20 - 12 = 8 \text{ V} \quad \text{وهو نفس جهد الـ } 2\Omega \text{ (توازي)}$$

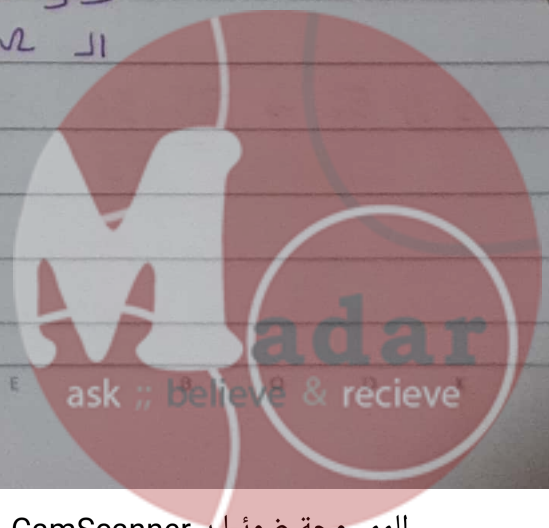
KCL at node b :-

$$i_x + i_4 = i_2$$

$$i_x = 4 - 3 = 1 \text{ A}$$

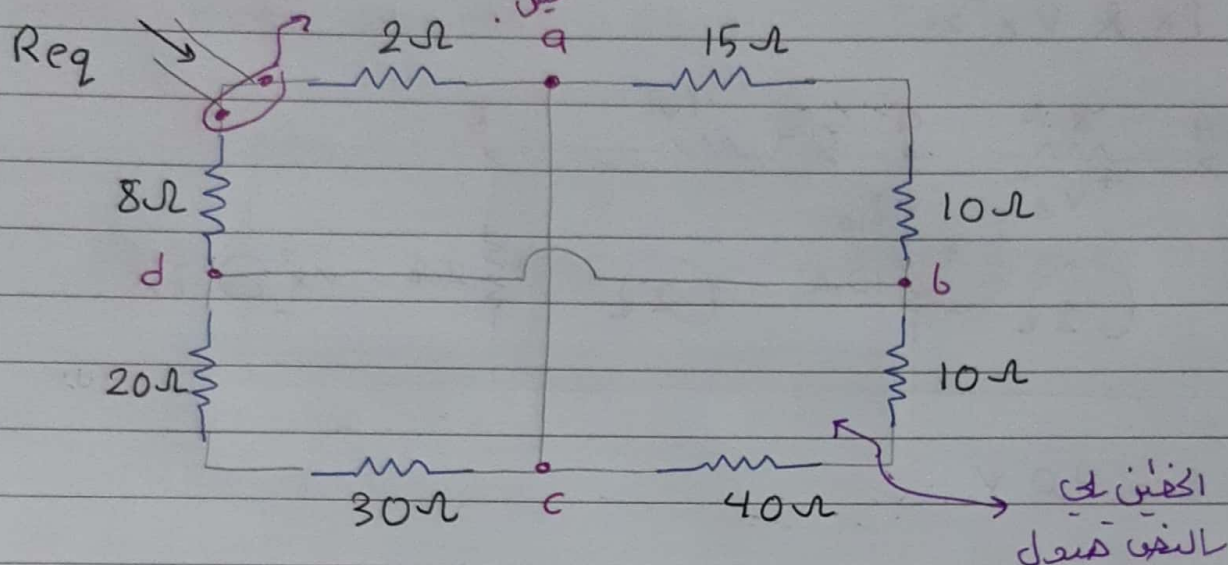
$$\downarrow$$

$$\frac{4x}{2}$$





2 - find  $i$  :-  $R_{eq}$  بين  $a$  والنقطتين  $d$  و  $c$

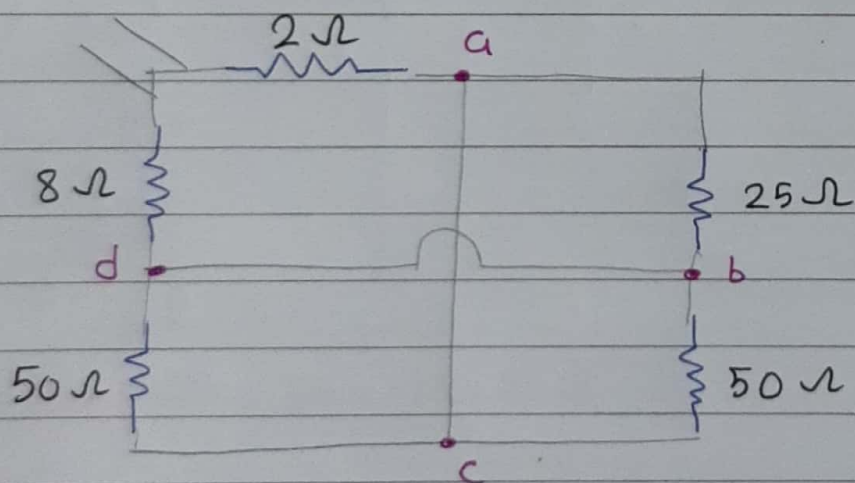


$$15 + 10 = 25 \Omega$$

$$10 + 40 = 50 \Omega$$

$$20 + 30 = 50 \Omega$$

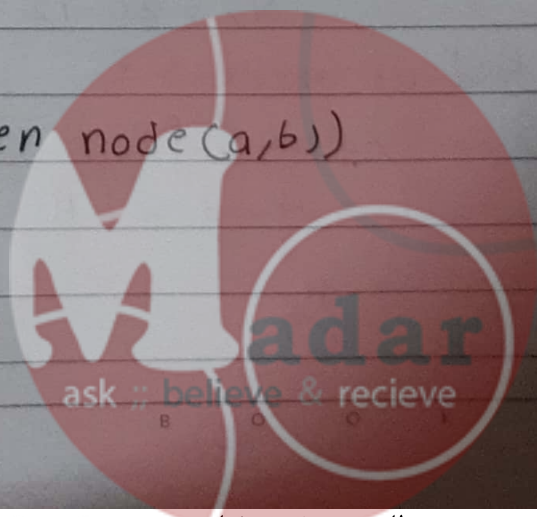
$a, c$  short circuited  
نفس ال node

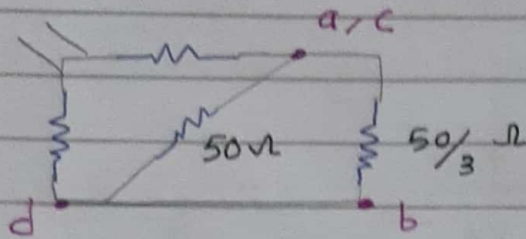


Node  $a$  = Node  $c$

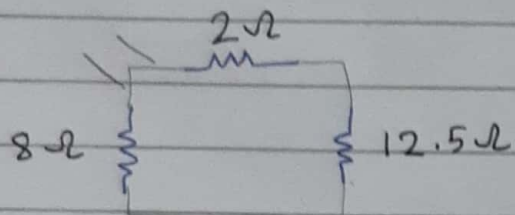
Node  $d$  = Node  $b$

$$25 // 50 \rightarrow \frac{25 \cdot 50}{75} = \frac{50}{3} \Omega \text{ (between node (a,b))}$$





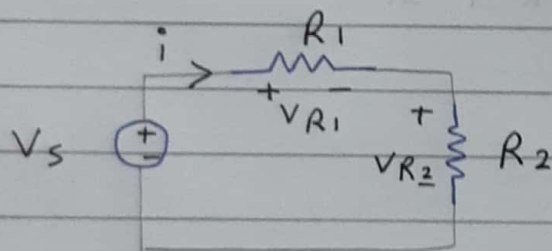
$$50 \parallel \frac{50}{3} \rightarrow 12.5 \Omega$$



$$\therefore R_{eq} = 22.5 \Omega$$

### \* voltage & current division :-

1- voltage divider rule (VDR) :- قانون حصة الجهد



KVL  $\rightarrow$

$$-V_s + V_{R1} + V_{R2} = 0$$

$$V_s = V_{R1} + V_{R2} \rightarrow \textcircled{1}$$

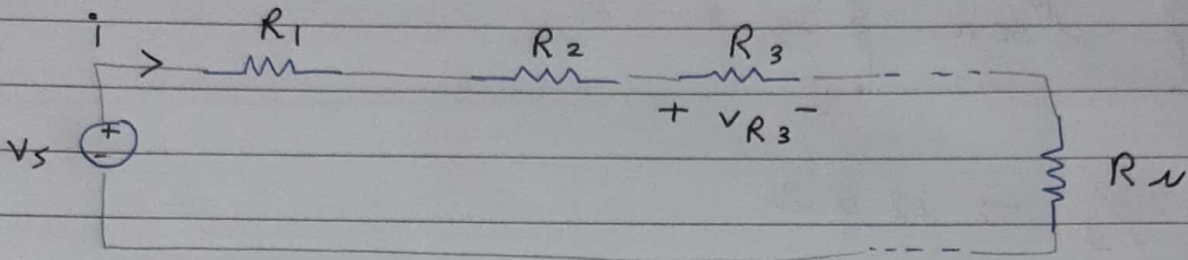
$$V_{R1} = iR_1, \quad V_{R2} = iR_2$$

$$V_s = i(R_1 + R_2) \rightarrow i = \frac{V_s}{R_1 + R_2}$$

$$\left[ \begin{aligned} V_{R1} &= \frac{V_s}{R_1 + R_2} R_1 \\ V_{R2} &= \frac{V_s}{R_1 + R_2} R_2 \end{aligned} \right] \rightarrow \text{(VDR)}$$



$$V_{R_N} = \frac{V_s R_N}{R_1 + R_2 + \dots + R_N}$$

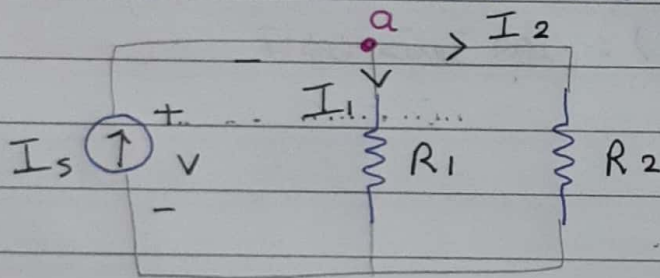


$$V_{R_3} = \frac{V_s R_3}{R_1 + R_2 + \dots + R_N}$$

#

$(R_1 + R_2 + \dots + R_N)$   
 $\rightarrow R_{eq} \rightarrow$  المقاومة الكلية

## 2- Current Divider rule (CDR) :-



جاي هن  
 KCL

KCL at (a) :-

$$I_s = I_1 + I_2 \rightarrow \textcircled{1}$$

$$I_1 = \frac{V}{R_1} \quad I_2 = \frac{V}{R_2}$$

$$I_s = V \left( \frac{1}{R_1} + \frac{1}{R_2} \right)$$

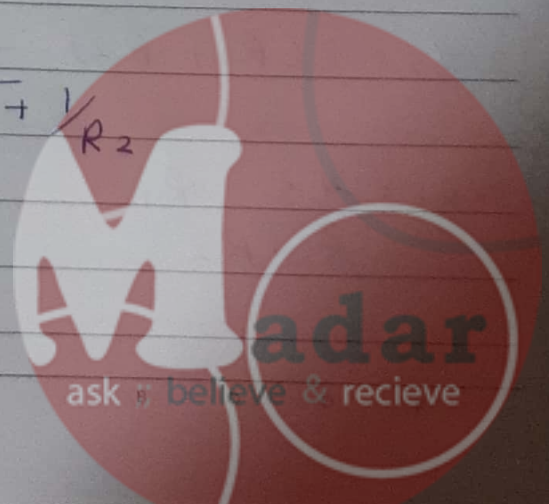
$$V = I_s \left( \frac{1}{\left( \frac{1}{R_1} + \frac{1}{R_2} \right)} \right)$$

$\downarrow$   
 $R_{eq}$

$$V = I_s R_{eq}$$

$\rightarrow$  ohm's law

$$\text{or } V_s = I_s \left( \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \right)$$



$$V = I_s (R_1 R_2) \quad (\text{نصفنا الكهارة في})$$

$$(R_2 + R_1) \quad (\text{جمل دوحنا مقامان})$$

$$I_1 = I_s \frac{R_1 R_2}{R_1 + R_2} \cdot \frac{1}{R_1} \rightarrow I_1 = \frac{I_s R_2}{R_1 + R_2}$$

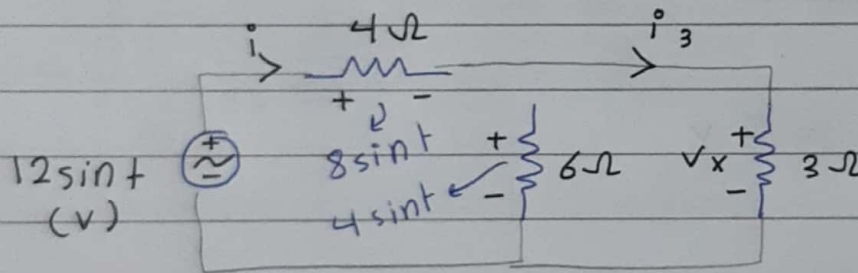
$$I_2 = I_s \frac{R_1 R_2}{R_1 + R_2} \cdot \frac{1}{R_2} \rightarrow I_2 = \frac{I_s R_1}{R_1 + R_2}$$

→ CDR

← المقاومة الأكبر تقاوم التيار بالتالي التيار فيها يقل .  
 ←  $I \propto V$  (علاقة طردية) أي مقاومة أكبر يأخذ جهد أكثر .

**Example :-**

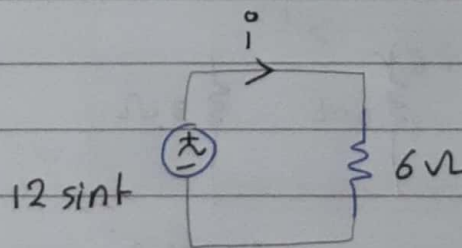
Determin  $V_x$  :-



$$6 \parallel 3 = 2 \Omega$$

$$2 + 4 = 6 \Omega (R_{eq})$$

$$i = \frac{12 \sin t}{6} = 2 \sin t$$



$$V_x = 4 \sin t$$

KVL →

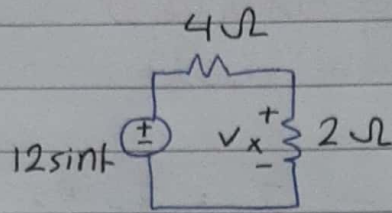
$$-12 \sin 8 + 8 \sin t + V_6 \rightarrow V_6 = 4 \sin t$$





VDR →

$$3 // 6 \rightarrow 2\Omega$$

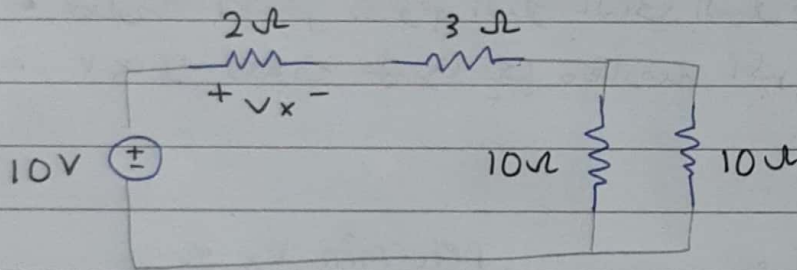


← حلينا اكمال بهوا يقين  
أول مرة حل عادي وثاني  
مرة على الـ (VDR)

$$V_x = V_s \left( \frac{2}{2+4} \right)$$

$$= 12 \sin t \cdot \frac{2}{6} = 4 \sin t$$

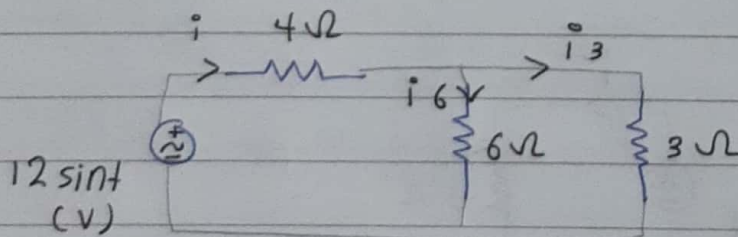
# Example :-



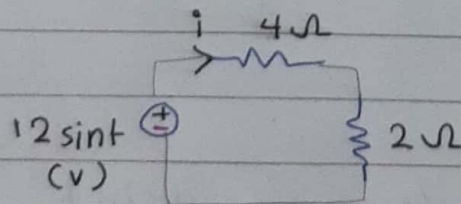
$$V_x = 10 \times \frac{2}{2+3+(10//10)} = 2 \text{ V}$$

↓  
5

# Example :-



$$3 // 6 \rightarrow 2\Omega$$



$$i = \frac{12 \sin t}{4 + 2} = 2 \sin t$$

by CDR  $\Rightarrow$

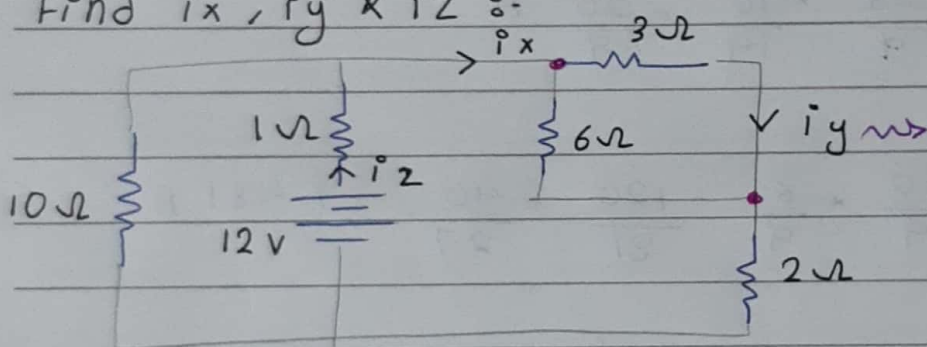
$$i_3 = 2 \sin t \times \frac{6}{6+3} = \frac{12}{9} \sin t = \frac{4}{3} \sin 3 \text{ (A)}$$

$$i_6 = 2 \sin t \times \frac{3}{9} = \frac{2}{3} \sin t \text{ (A)}$$

\* CDR  $\leftarrow$  يَفْعَلُ تَجَنُّبًا  
على 2 (branches)

# Example :-

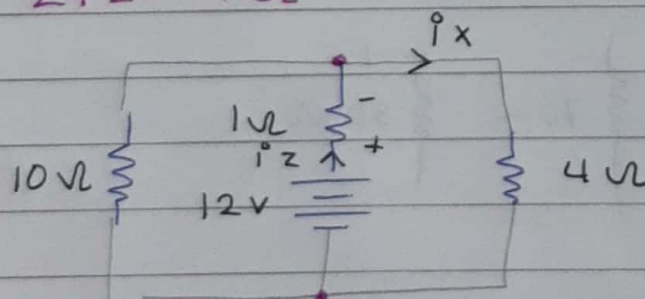
Find  $i_x$ ,  $i_y$  &  $i_z$  :-



هنا التيار مار  
يس بال 3Ω  
لهيك يهنيغ ما  
أعمل توازي

3 // 6  $\rightarrow$  2Ω (we lose  $i_y$ )

$$2 + 2 = 4 \Omega$$

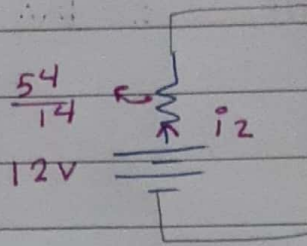


$$4 // 10 \rightarrow \frac{40}{14} \Omega \text{ (we lose } i_x \text{)}$$





$$R_{eq} = \frac{40}{14} + 1 = \frac{54}{14} \Omega$$



$$i_2 = \frac{12}{\frac{54}{14}} = \frac{28}{9} A$$

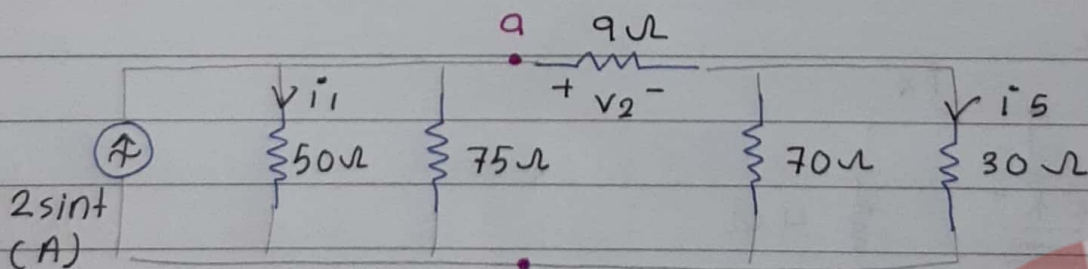
$i_2$  + جهد البطارية  $\rightarrow$  هذا هو الجهد على نفسه بار 4 و 10

$$i_x = i_2 * \frac{10}{10+4} = \frac{28}{9} * \frac{10}{14} = \frac{20}{9} A$$

$$i_y = i_x * \frac{6}{3+6} = \frac{20}{9} * \frac{6}{9} = \frac{120}{81} = \frac{40}{27} = 1.481 A$$

### # Example :-

Find  $i_1$ ,  $v_2$ ,  $i_5$  :-

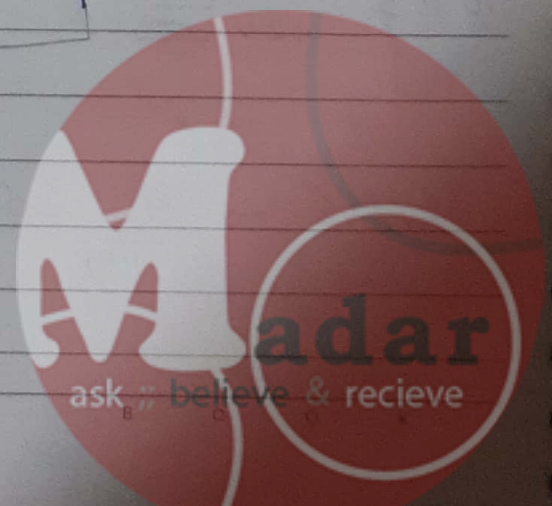


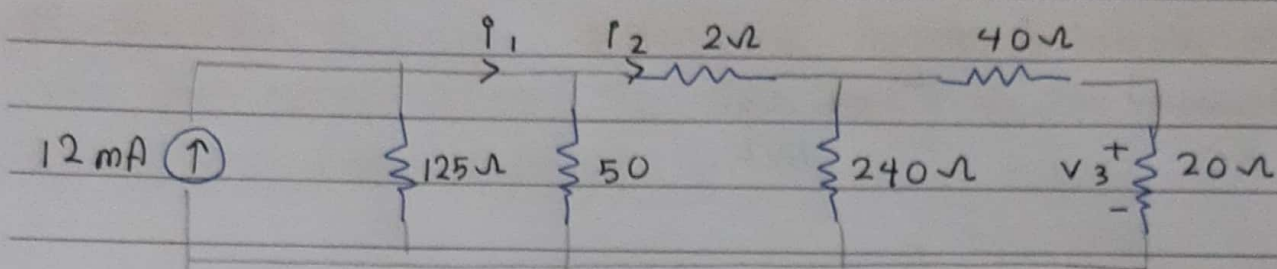
أب هدف ما بالهم هدف في الزا

$$i_1 = 0.6 \sin t (A)$$

$$v_2 = 9 \sin t (V)$$

$$i_5 = 0.7 \sin t (A)$$





$$i_1 = 100 \text{ mA (CDR)}$$

$$i_2 = 50 \text{ mA (CDR)}$$

$$v_3 = 0.8 \text{ V (VDR)}$$





## # Basic Nodal & mesh analysis :-

← عقدة ← KCL      → عقدة → KVL

### 1- Nodal Analysis :-

#### \* procedure :-

1- Assume the circuit has  $N$ -nodes, chose one of them as a reference node, then write  $(N-1)$  the node voltage  $v_1, v_2, \dots, v_{N-1}$ .  
أول خطوة بعد ال node وتبنا وحدة منهم تكون مرجع وبسيفها (Ref) أو  $(\frac{1}{\circ})$  وبسيف باقي ال node  $(v_1, v_2)$  وهكذا.

2- write  $(N-1)$  KCL equation one for each node.

راح أكتب معادلات KCL بكل node عدد المعادلات يكون على عدد ال node ناقص واحد لأنني node كانت مرجع.

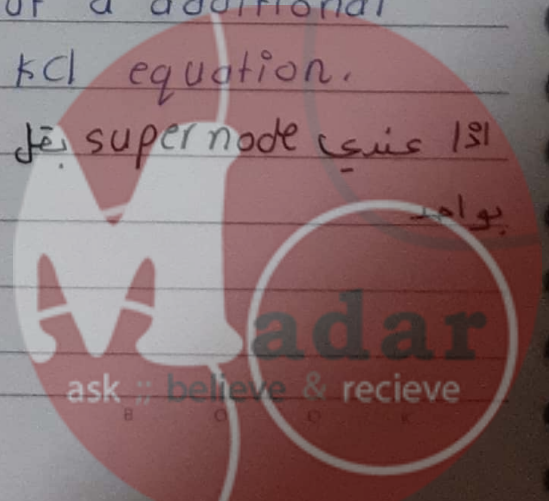
3- solve the resulting equations to find the  $(N-1)$  unknowns.

بدي أوجد ال unknown في سيتم في البداية ال  $(v_1, v_2, \dots)$ .

4- If there exist a super-node, the number of equation will reduce by the no. of supernodes, but a additional equation will be written instead of KCL equation.

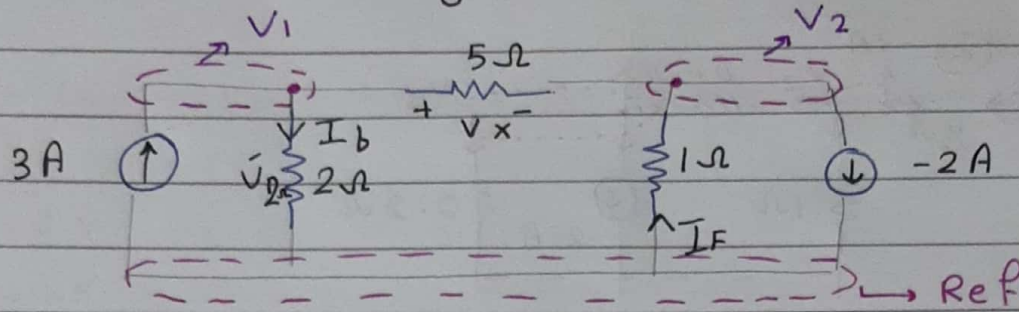
إذا عندي super node يقل عدد المعادلات  $(\frac{1}{\circ})$

المهدف من هاي الطريقة  
يوجد voltage ونكفل  
الحل.



### # Example :-

Find the value of  $V_x$ ,  $I_b$ ,  $I_F$  using nodal analysis  
(Find the nodal voltages) :-



لـ بقدر أختار أي node تكون ref. بس أفضل نختار  
ad node لي كت لواد لي طالع منها branches أكثر  
ومرات بعمينا ad ref من السؤال :-

KCL at node 1 :-

\*\*\* ما نكتب KCL

$$\frac{V_1}{2} + \frac{V_1 - V_2}{5} - 3 = 0$$

بعتبر كل التيارات طالعة من  
ad node

$$\frac{V_1}{2} + \frac{V_1}{5} - \frac{V_2}{5} - 3 = 0 \rightarrow 0.7V_1 - 0.2V_2 = 3 \rightarrow \textcircled{1}$$

KCL at node 2 :-

كل ص  
يعتبر تيار

$$\frac{V_2 - 0}{1} + \frac{V_2 - V_1}{5} - 2 = 0$$

بنحل المعادلتين  
① و ②

$$\Rightarrow -0.2V_1 + 1.2V_2 = 2 \rightarrow \textcircled{2}$$

$$\therefore V_1 = 5V$$

$$V_2 = 2.5V$$

$$I_b = \frac{V_1}{2} = 2.5A$$

$$I_F = \frac{0 - V_2}{1} = -2.5A$$

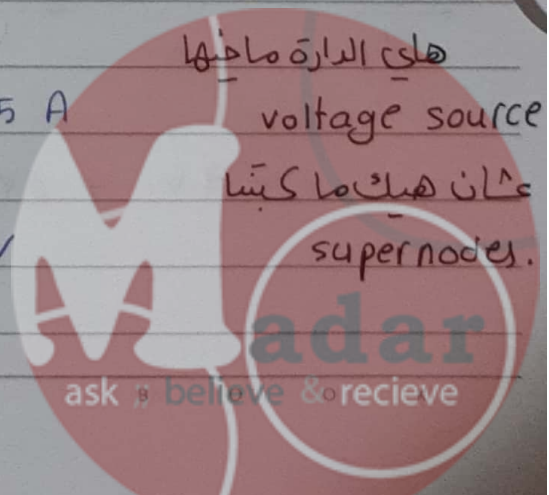
$$V_x = V_1 - V_2 = 2.5V$$

هنا الدارة ما فيها

voltage source

عشان هيك ما كتبنا

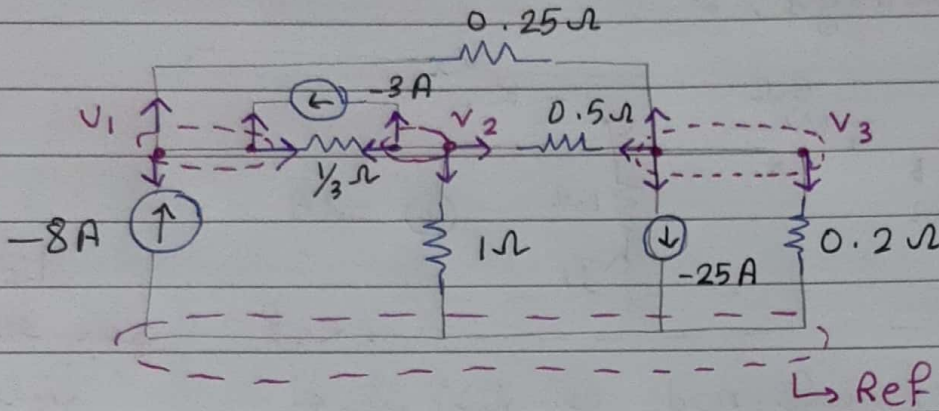
supernodes.





### # Example :-

Find the nodal voltages :-



Kcl at node 1 :-

ما اكتب الكل ل node 1 ل  $V_1$

طالع من

بتكون موجبة وباقي الكود سالبة

هنا ال node

4 تيارات

$$8 + \frac{V_1 - V_3}{1/4} + 3 + \frac{V_1 - V_2}{1/3} = 0 \rightarrow (1)$$

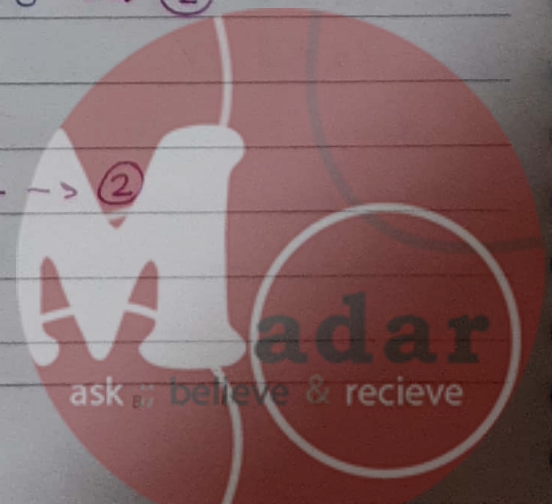
$$7V_1 - 3V_2 - 4V_3 = -11 \rightarrow (1)$$

ل اخطانا  
موجبة لان  
اتجاه التيار  
في ختمه  
اتجاه التيار الاصلي

Kcl at node 2 :-

$$\frac{V_2 - V_1}{1/3} - 3 + \frac{V_2 - 0}{1} + \frac{V_2 - V_3}{1/2} = 0 \rightarrow (2)$$

$$-3V_1 + 6V_2 - 2V_3 = 3 \rightarrow (2)$$



KCL at node 3 :-

$$\frac{-25}{1/5} + \frac{V_3 - 0}{1/4} + \frac{V_3 - V_1}{1/4} + \frac{V_3 - V_2}{1/2} = 0 \rightarrow (3)$$

بندل 3 معادلات

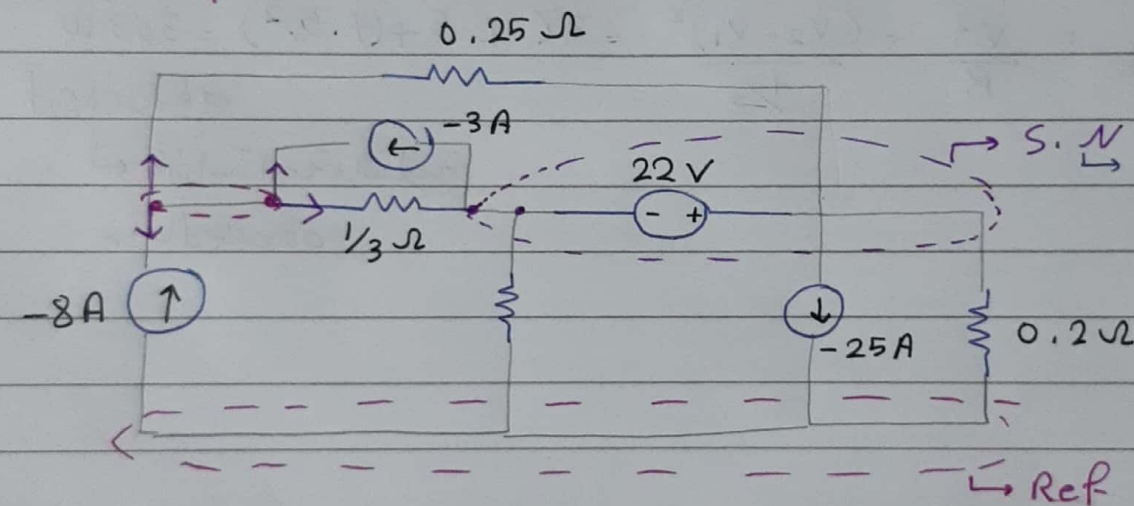
$$-4V_1 - 2V_2 + 11V_3 = 25 \rightarrow (3)$$

$$V_1 = 1V$$

$$V_2 = 2V$$

$$V_3 = 3V$$

**Example :-**



عني  
S.N و 3 node  
يعني عدد المعادلات  
لي بي ايها  
معادلات

KCL at S.N :-

$$\frac{V_2 - V_1}{1/3} - 3 + \frac{V_2 - 0}{1} - 25 + \frac{V_3 - V_1}{1/4} + \frac{V_3 - 0}{1/5} = 0$$

$$-7V_1 + 4V_2 + 9V_3 = -28 \rightarrow (1)$$

KCL at node 1 :-

$$8 + \frac{V_1 - V_3}{1/4} + \frac{V_1 - V_2}{1/3} + 3 = 0$$





$$7V_1 - 3V_2 - 4V_3 = -11 \rightarrow (2)$$

$$V_3 - V_2 = 2 \rightarrow (3) \text{ معادلة فرق جهد جيناها}$$

من ال S.N شغرت وين لوجب

وحدد  $V_3$  و  $V_2$  + فرقهم يساوي ال  
voltage source  $-V_2$

$$V_1 = -4.5V$$

$$V_2 = -15.5V$$

$$V_3 = 6.5V$$

$$\text{Power at } \frac{1}{3} = \frac{V^2}{R} = \frac{(V_2 - V_1)^2}{\frac{1}{3}} = 3(-15.5 + 4.5)^2 = 363W$$

absorbed

لأنها مقارمة وللقارمة  
absorbed



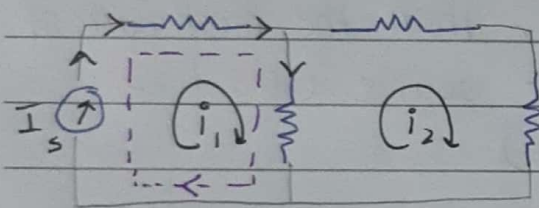
# # Mesh analysis :-

mesh

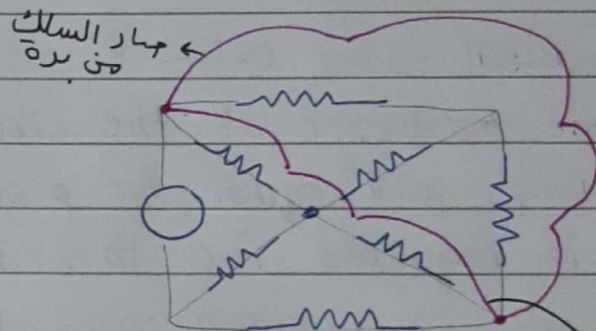
بجانبها ما يكون عندي

planar circuite

يعني الدارة مرسومة على  
نقطة أو plane ما في عناصر فوق  
فها ما بقدر أخلص منه .



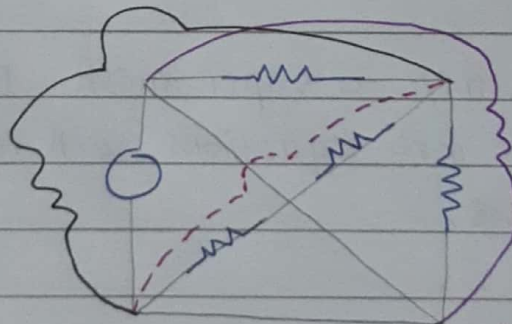
planar



planar

هنا السلك

بقدر أسحب وأجيبه  
من برة



non-planar ( ما ينطبق )

عليها الـ mesh analysis

## # procedure to apply mesh analysis :-

1- Assume the circuit has  $M$  - meshes assign a clockwise mesh current in each mesh with names  $i_1, i_2, \dots, i_M$

بشوف عدد الـ mesh وكل mesh

بقر من بينها بيار مع عقارب الساعة وبسببه

$i_1, i_2, \dots, i_M$



2- Apply KVL equation around each mesh & write the equations in terms of  $i_1, i_2, \dots, i_m$ .  
 بنكتب المعادلات بدلالة  $i_1, i_2, \dots, i_m$ .  
 اتجاه يكون عدد المعادلات بعد ال mesh

3- solve the resulting equation to find  $i_1, i_2, \dots, i_m$ .

4- if a current source exists :-

(a) on the perimeter of the circuit, then the mesh current in that loop will equal the current source (No KVL equation is required for this mesh)

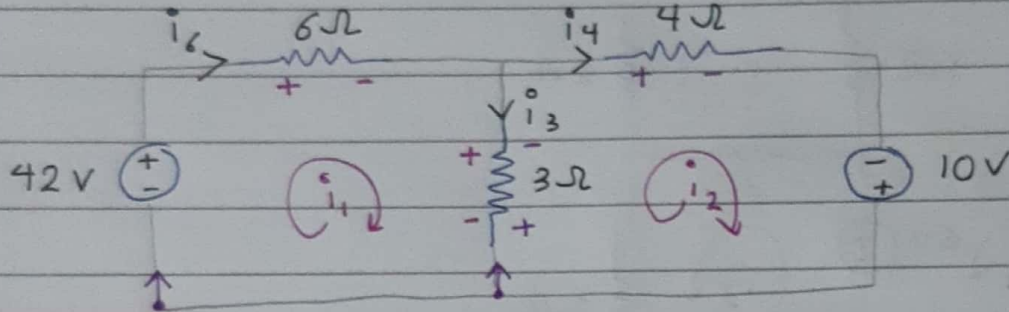
عدد المعادلات را حقل بواحد مقابل كل current source موجود  
 في هاي الحالة  $[i_1 = I_s]$  يعني حش اتي اقل KVL

(b) between two meshes, then a super mesh between these two meshes & hence the KVL equations will reduce by the number of current sources.



### Example :-

Determine the current through each resistor using mesh analysis :-



\* الإشارات

عند كل مقاومة

حسب اتجاه آبي

فوضته بكل mesh

(اتجاه التيار من الموجب

إلى السالب)

KVL at mesh 1 :-

$$-42 + 6i_1 + 3(i_1 - i_2) = 0$$

لأنه الـ 3 مشتركة

من الجهتين ولذا يكتب لأول

mesh  $i_1$  بالأسفل و  $i_2$  يتكون عكسه

$$9i_1 - 3i_2 = 42 \rightarrow \textcircled{1}$$

KVL at mesh 2 :-

$$3(i_2 - i_1) + 4i_2 - 10 = 0$$

$$-3i_1 + 7i_2 = 10 \rightarrow \textcircled{2}$$

$$i_1 = 6 \text{ A}$$

$$i_2 = 4 \text{ A}$$

mesh current

ما هو خلاصة باد Branch

$$i_6 = i_1 = 6 \text{ A}$$

$$i_3 = i_1 - i_2 = 2 \text{ A}$$

$$i_4 = i_2 = 4 \text{ A}$$

$$P_{3\Omega} = i_3^2 R = (2)^2 \times 3 = 12 \text{ W (absorbed)}$$

\* لو واحد بالذوال

الخريفية في المستطيل

فشار الأسفل (في بتقطين)

معادلات أقل يعني المثال ما هو

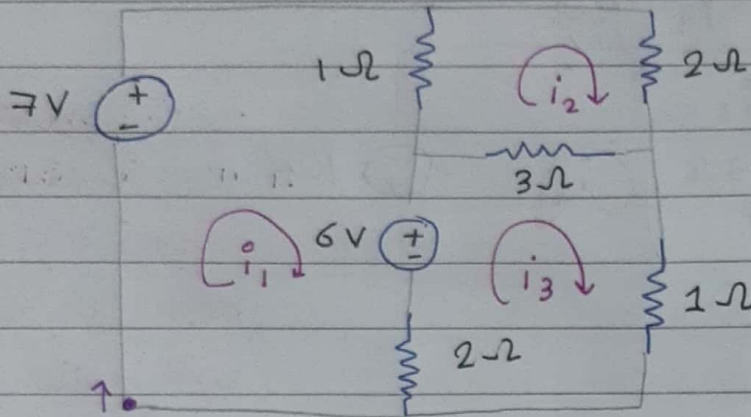
nodal method لأننا زاح أكتب معادلة واحدة.

ask // believe & recieve



### Example :-

Find the mesh current :-



KVL at mesh 1 :-

$$-7 + 1(i_1 - i_2) + 6 + 2(i_1 - i_3) = 0$$

$$3i_1 - i_2 - 2i_3 = 1 \rightarrow \textcircled{1}$$

KVL at mesh 2 :-

$$(i_2 - i_1) + 2i_2 + 3(i_2 - i_3) = 0$$

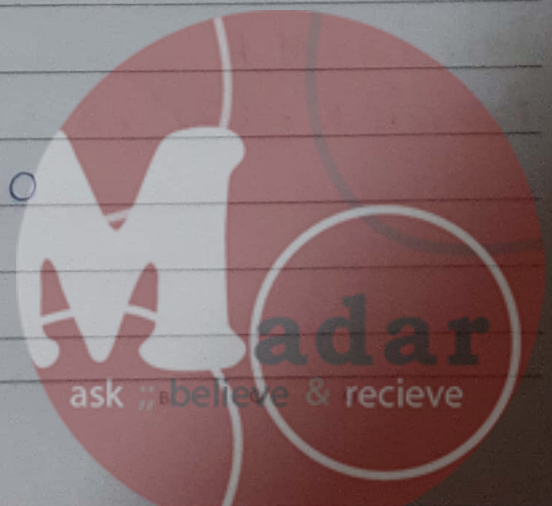
$$-i_1 + 6i_2 - 3i_3 = 0 \rightarrow \textcircled{2}$$

مشتري ح 1
مشتري ح 2 + 3 + 1
مشتري ح 3

KVL at mesh 3 :-

$$2(i_3 - i_1) - 6 + 3(i_3 - i_2) + i_3 = 0$$

$$-2i_1 - 3i_2 + 6i_3 = 6 \rightarrow \textcircled{3}$$



$$i_1 = 3 \text{ A}$$

$$i_2 = 2 \text{ A}$$

$$i_3 = 3 \text{ A}$$

لو حلينا الكثال على nodal

$$V_1 = 7 \text{ V} \leftarrow \text{جهد البطارية لانها}$$

$$\text{supernode } V_2 = 6 \text{ V}$$

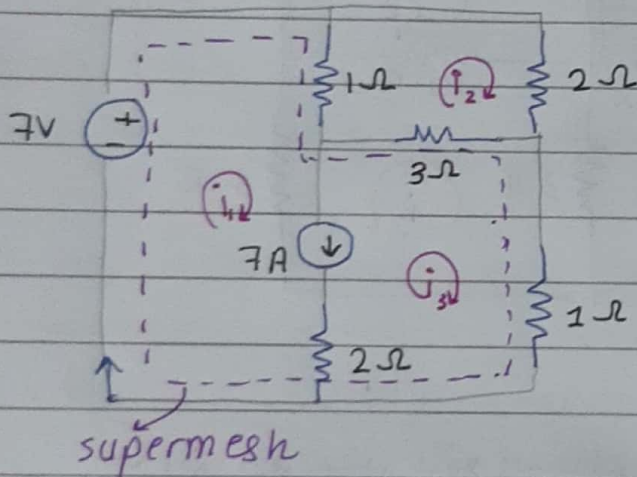
$$V_3 = 3 \text{ V}$$

$$V_4 = 0 \text{ V} \rightarrow \text{الـ } 2 \Omega \text{ ما راجيعو}$$

منها يتار بالتالي ما عليها

power و voltage

### Example :-

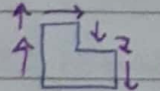


\* عادي لما يكون

عنا supermesh يكون

فيه مقاومة مع التيار بنفخ

السلك

KVL at mesh 1 :-  مسيت مولين  
هاي

$$-7 + 1(i_1 - i_2) + 3(i_3 - i_2) + i_3$$

$$i_1 - 4i_2 + 4i_3 = 7 \rightarrow \textcircled{1}$$

KVL at mesh 2 :-

$$(i_2 - i_1) + 2i_2 + 3(i_2 - i_3) = 0$$

$$-i_1 + 6i_2 - 3i_3 = 0 \rightarrow \textcircled{2}$$





$$i_1 - i_3 = 7 \rightarrow (3)$$

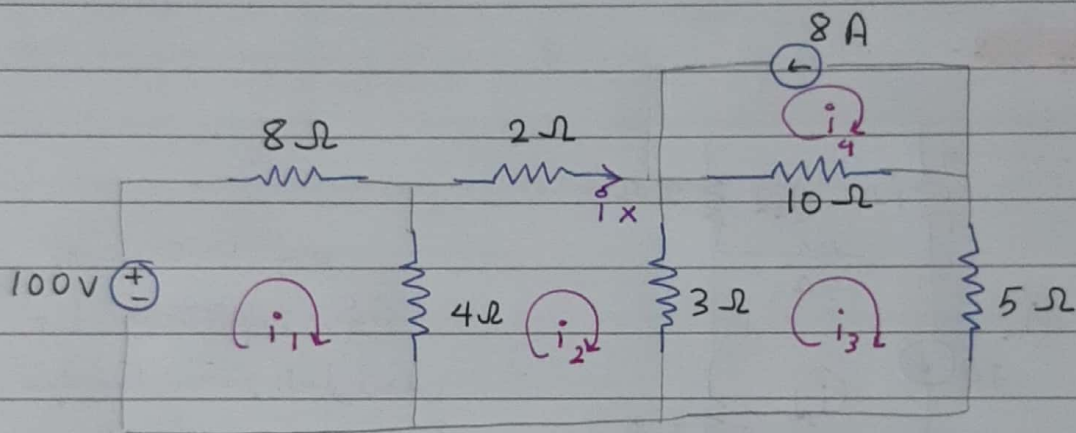
مينا من ال

supermesh

نقطة  
حبة  
لا نو  
بالجدة 7A

### Example :-

find  $i_x$  in the following circuit :-



Nodal

5 node

3 KCL

↓  
لو بدي اصل  
عليها

$$i_x = \frac{V_2 - V_3}{2}$$

mesh

4 mesh

3 KVL

$$\downarrow$$

$$i_2 = i_x$$

بعا انو الفرق بين بنفع استعمل

هسا يرجع للعطوب في السؤال

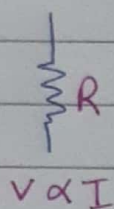
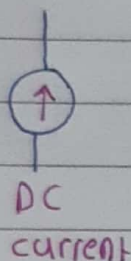
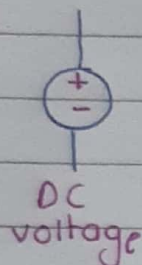
بعا انو مطلوب تيار اذا الأسهل

أعمل على ال mesh



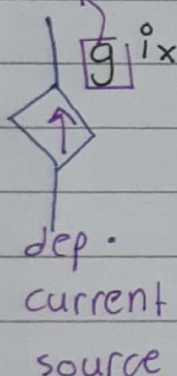
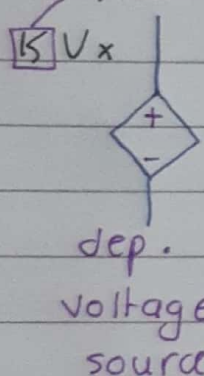
# # Superposition & linearity :-

↳ circuit must be a linear circuit.



linear element  
(independent sources)

unit less

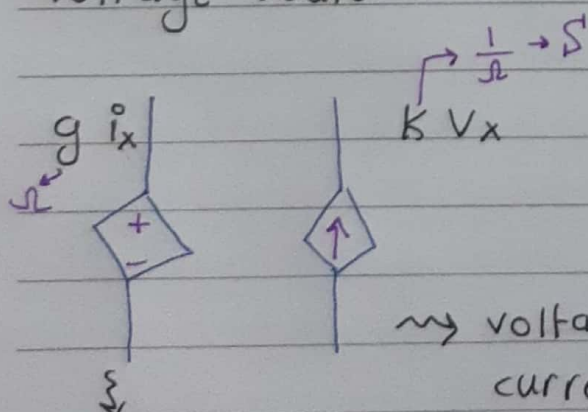


dependent sources

يختلفون عن الـ ind. انهم  
مربطون مع ثنائي  
(يعتمد على ثنائي)

voltage controlled  
voltage source.

current controlled  
current sources.



voltage controlled current source

current controlled →  
voltage source

الـ indep. linear أم لا  
depend linear أو non-linear

non-linear ما ينطبق  
superposition

$$V = Ri$$

$$P = iV = \frac{V^2}{R} = i^2 R$$

non-linear  
power

ask :: believe & recieve

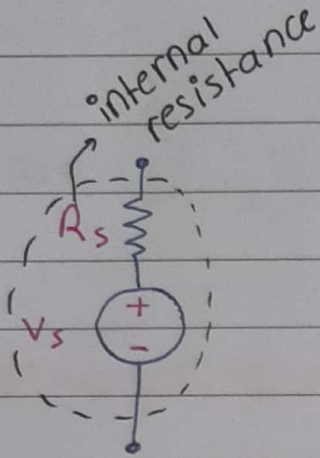


## # source transformation (S.T) :-

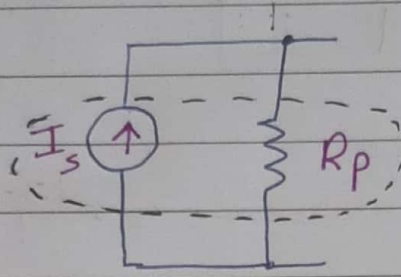
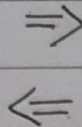
↳ بي أحول ال source

$$I \rightarrow V$$

$$V \rightarrow I$$



practical voltage source



practical current source

بي أحول voltage  
series مع مقاومة  
الى current يكون  
parallel مع  
مقاومة والعكس.

$$R_s = R_p$$

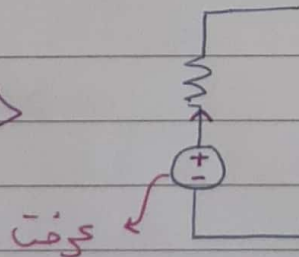
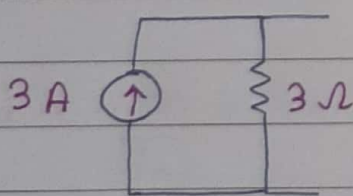
$$I_s = \frac{V_s}{R_s}$$

$$R_p = R_s$$

$$V_s = I_s R_p$$

ما في مقاومة مفر  
اي voltage source  
أقل اشي يكون فيه  
مقاومة مقدارها  $50\Omega$

## # Example :-



$$R = 3\Omega$$

$$V = 3 \times 3 = 9V$$

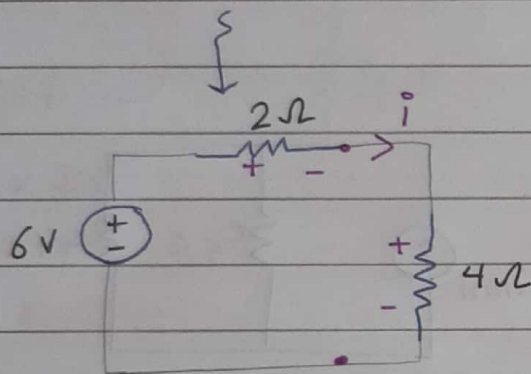
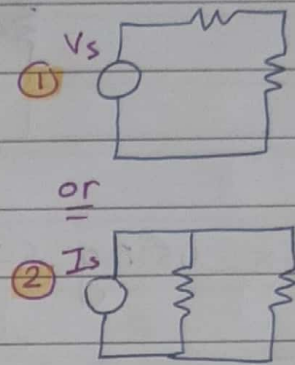
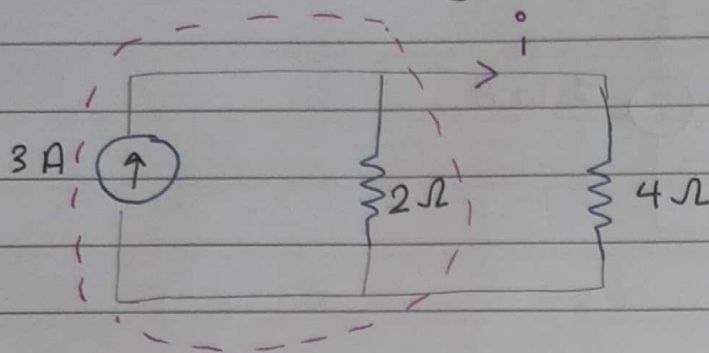
الإشارات بنادًا على اتجاه التيار



### # Example :-

Find  $P(4\Omega)$  using S.T :-

\* لا دقة :-  
يدي أفضل أبسط بالكل لفافة  
↓  
لا يصح عني



VDR :-

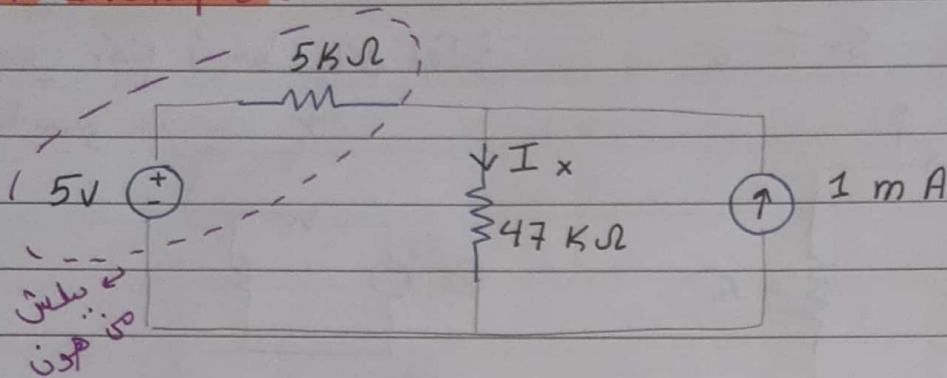
$$V(4\Omega) = \frac{6 \times 4}{6} = 4V \quad P = \frac{V^2}{R} = \frac{16}{4} = 4W \text{ absorbed}$$

$$I = \frac{V}{R} = 1A$$

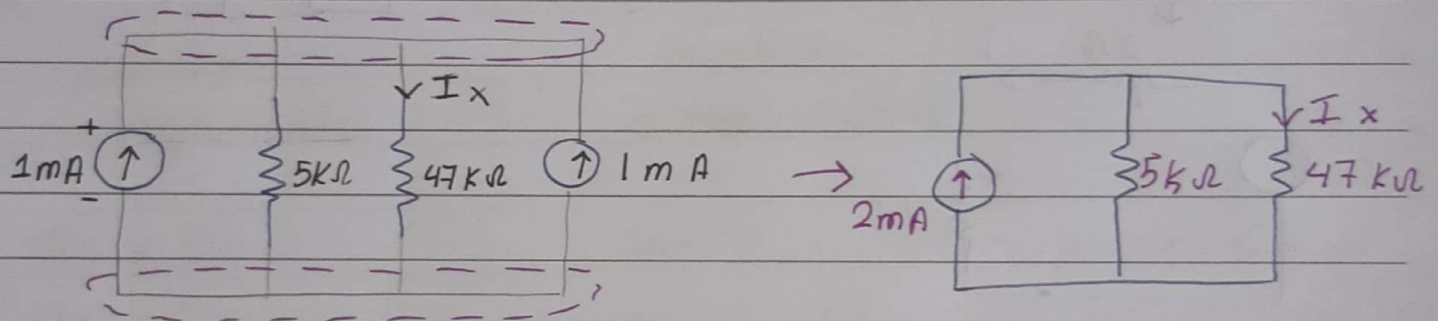




### # Example :-



Find  $I_x$  using S.T :-

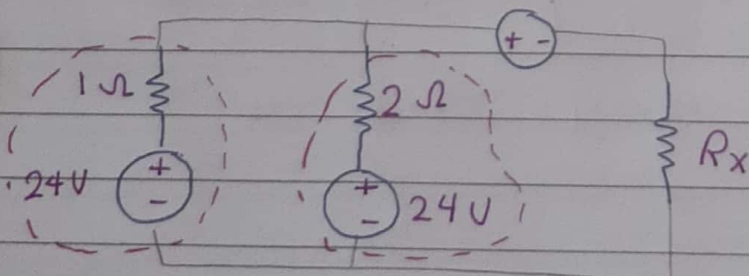


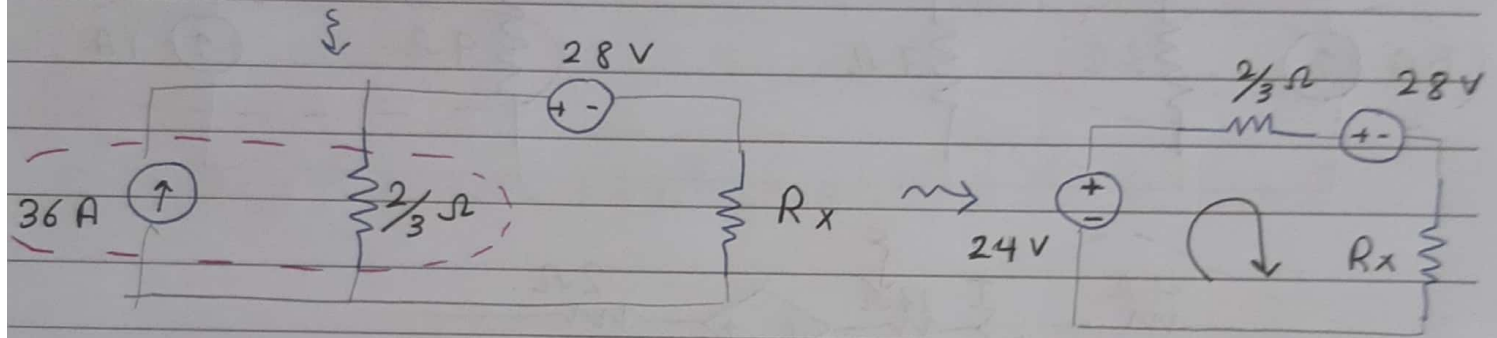
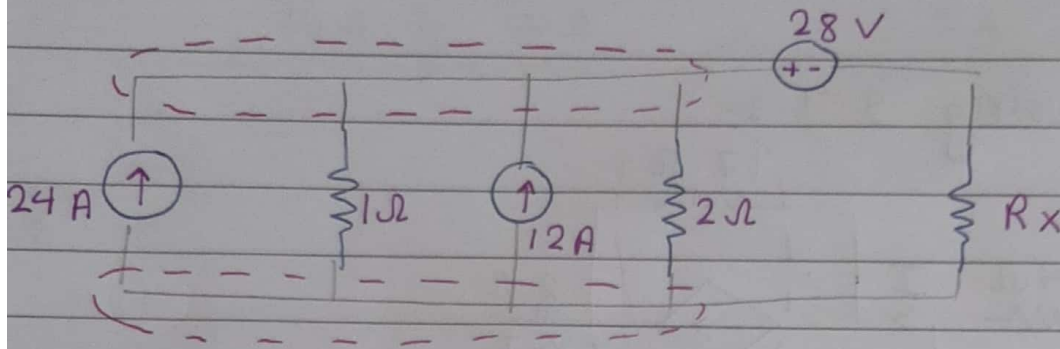
CDR :-

$$I_x = \frac{2 \times 10^{-3} \times 5 \times 10^3}{52 \times 10^3} = 0.192 \text{ mA}$$

### # Example :-

What is the value of  $R_x$  to absorb 5W ?!





KVL :-

$$-24 + \frac{2}{3}i + 28 + R_x i = 0 \rightarrow (1)$$

$$P^2 R_x = 5 \rightarrow (2)$$

لـ من التـوالـد

$$R_x = 0.28 \Omega \rightarrow$$

$$R_x = 1.587 \Omega$$

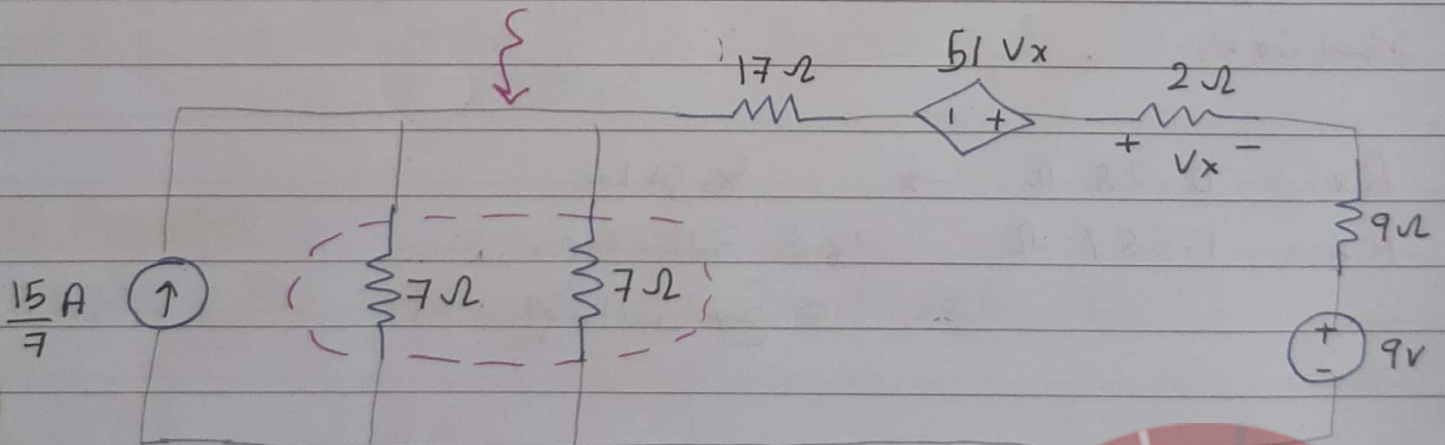
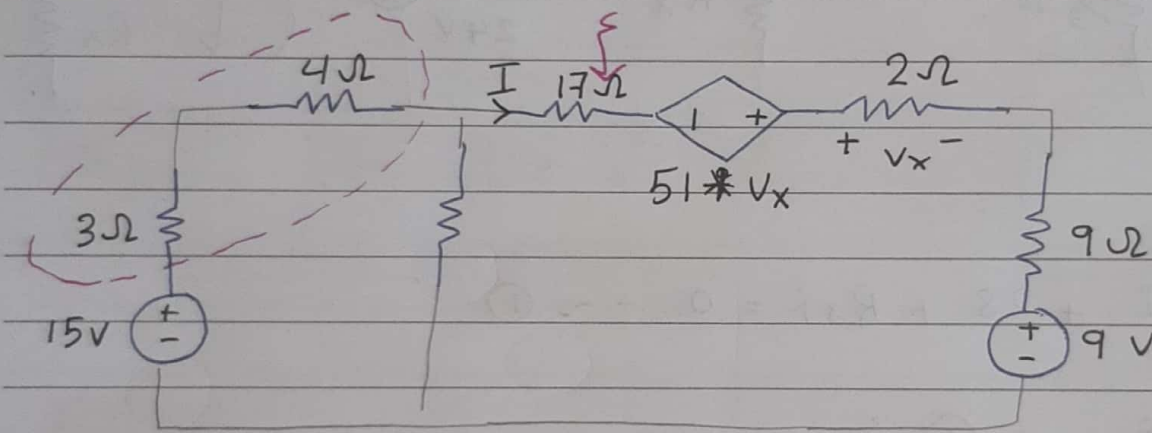
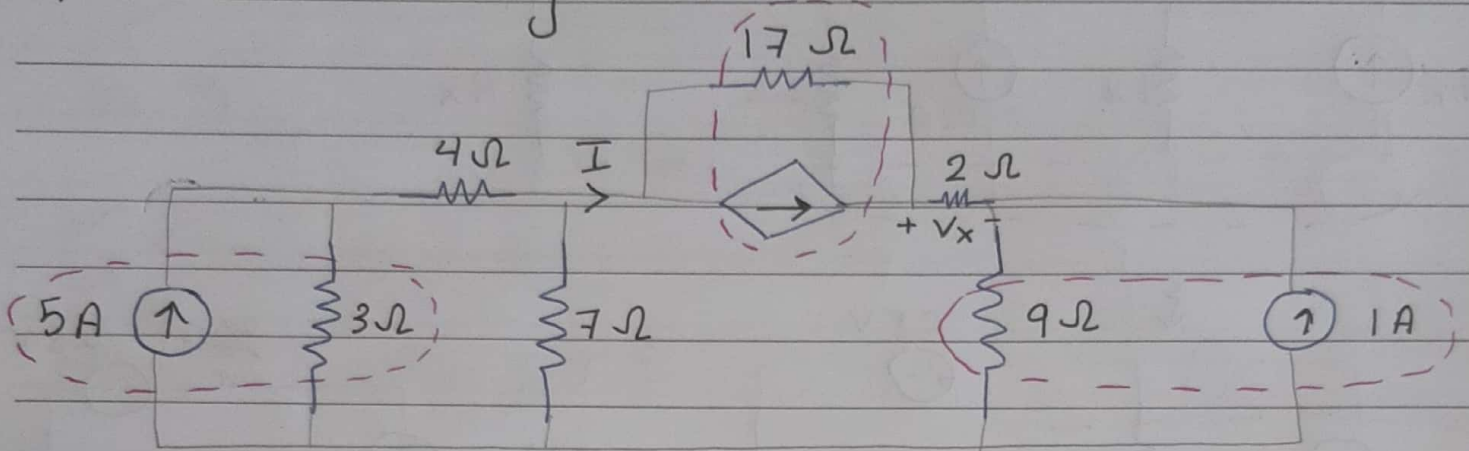
بـا التـوالـد  
وـحـدة سـالـة بـكـونـوا  
الـمـا بـتـن مـن

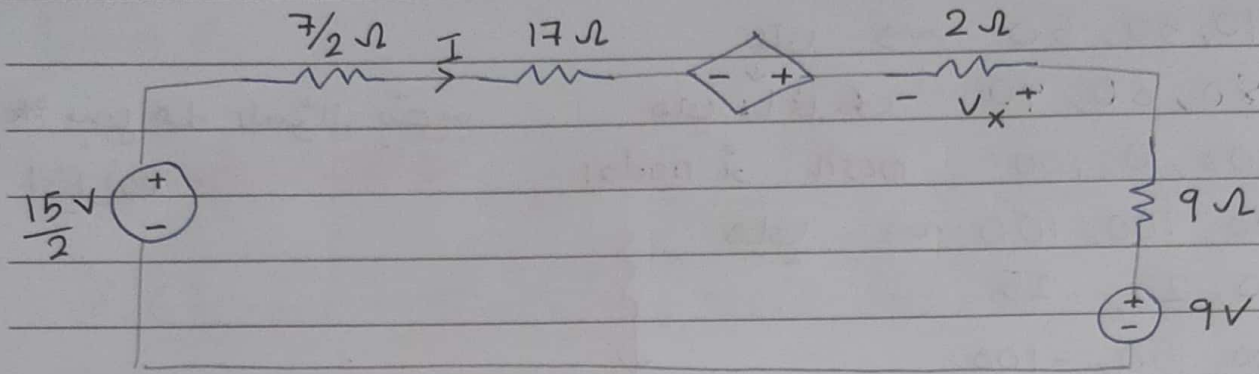




# # Example :-

find  $V_x$  &  $I$  using S.T :-





KVL :-

$$-\frac{15}{2} + I \left( \frac{7}{2} + 17 + 2 + 9 \right) - 51 V_x + 9 = 0 \rightarrow (1)$$

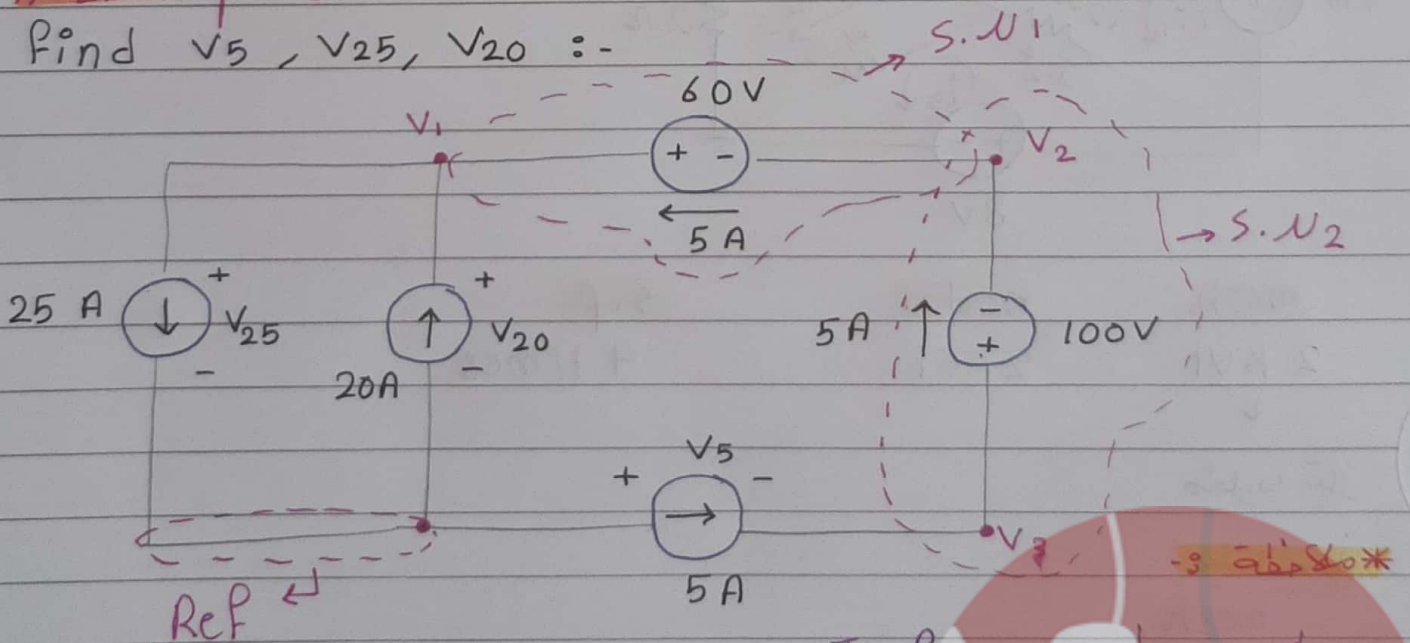
$$V_x = 2I \rightarrow (2)$$

$$\therefore I = 21.28 \text{ A}$$

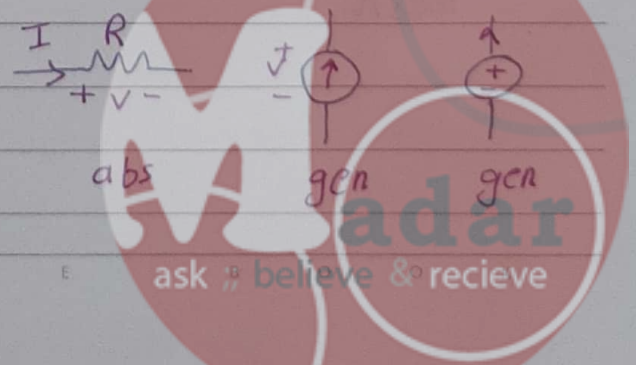
$$V_x = 42.56 \text{ V}$$

# Example :-

Find  $V_5$ ,  $V_{25}$ ,  $V_{20}$  :-



$$V_{25} = V_{20} \rightarrow \text{توازي}$$





► Subject : Chapter 5

4 / 8 / 2022

A - -90, 50, 50 → هاي

B - -80, 60, 40 هاي با غل على

C - -200, 10, 100 mesh أو nodal

D - 200, 100, 100 → هاي

E - 50, 25, -25

F - 300, 150, -100

\* بنحل هاد السؤال بترتيب

الكميات

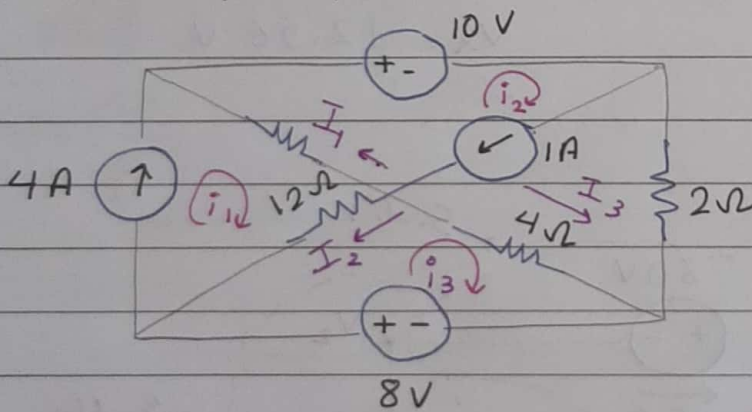
$$-5 V_{20} - 5 V_5 - 500 + 300 = 0$$

$$V_{20} + V_5 = -40$$

← بعوض القيم ونبشوف المخرج

### # Example :-

Find  $I_1, I_2, I_3$  2!



mesh

nodal

s.p

2 KVL

2 KCL

4 times



مطلوب تيار

لهيك بنحل

mesh



$$i_1 = 4 \text{ A}$$

KVL at S.N :-

$$6(i_2 - i_1) + 10 + 2i_3 + 4(i_3 - i_4) = 0 \rightarrow \textcircled{1}$$

KVL at mesh 4 :-

$$12(i_4 - i_1) + 4(i_4 - i_3) - 8 = 0 \rightarrow \textcircled{2}$$

$$i_2 - i_3 = 1 \rightarrow \textcircled{3}$$

$$\therefore I_1 = i_2 - i_1$$

$$I_2 = i_1 - i_4$$

$$I_3 = i_4 - i_3$$

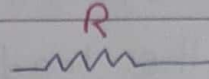
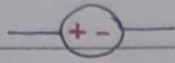




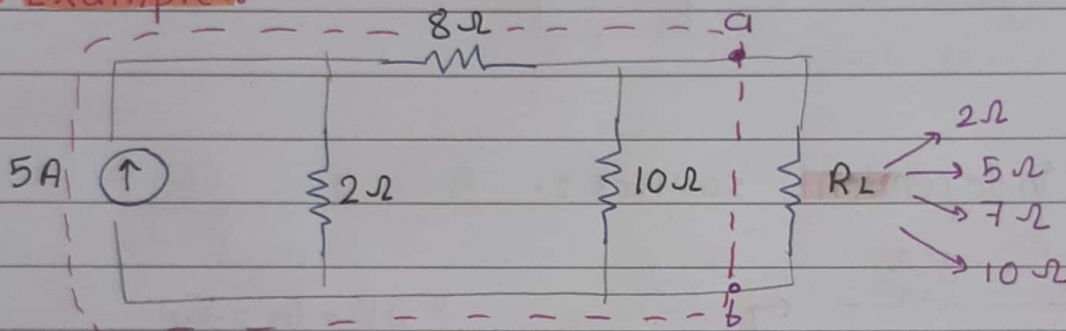
## # Thevenin's & Norton's equivalent circuits :-

لما كان لى

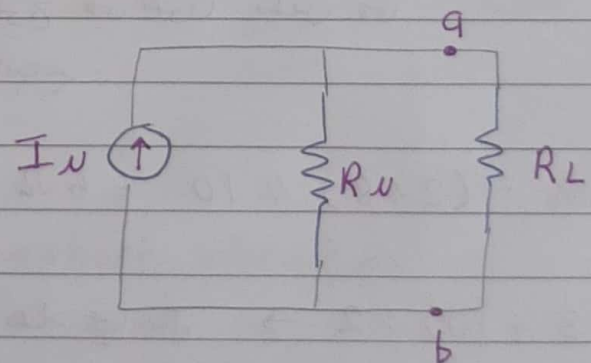
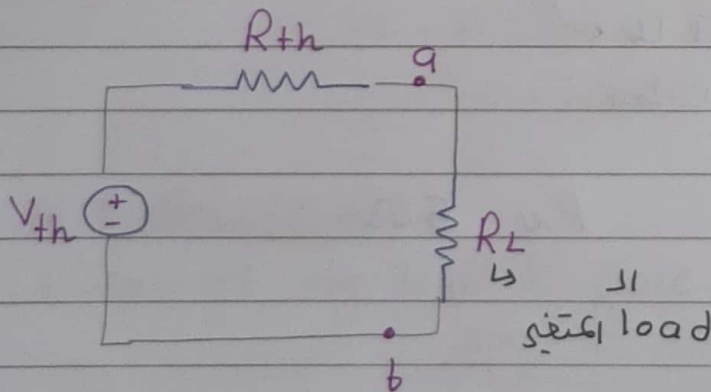
مقاومة متغيرة



## # Example :-



Find Thevenin's equivalent or Norton's equivalent :-



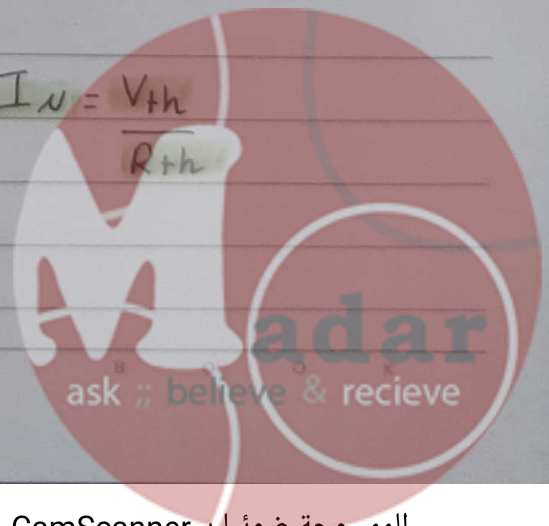
$$R_{th} = R_N$$

لازم نحل  
الدارة لها  
الشكل

$$R_N = R_{th}$$

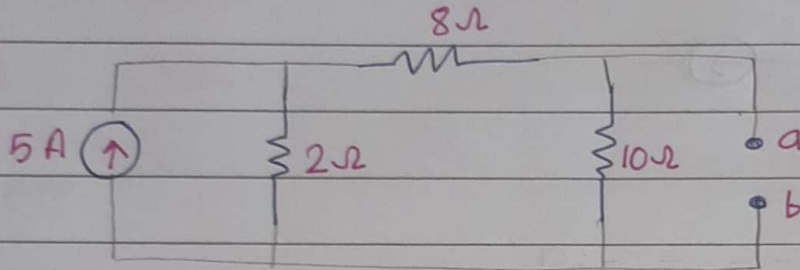
$$V_{th} = I_N R_N$$

$$I_N = \frac{V_{th}}{R_{th}}$$

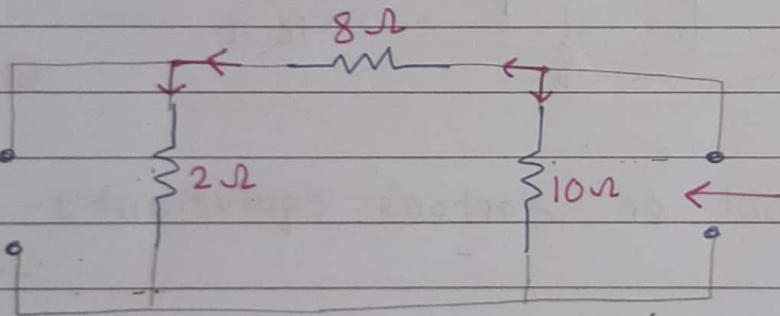


\* To find  $R_{th}$  or  $R_N$  :-

1- Disconnect the load  $\Rightarrow$



2- Kill all independent sources :-



بتفحص من مكان ال  
 $R_{eq} = R_{th}$  load  
 (دائرة مفتوحة)

ما أنفوخ من هون يلعش من  
 الطرف البعيد

$$R_{th} = (2 + 8) \parallel 10 = 5 \Omega$$

$$R_N = 5 \Omega$$

ها في حال  $\rightarrow (8 + 10) \parallel 2$

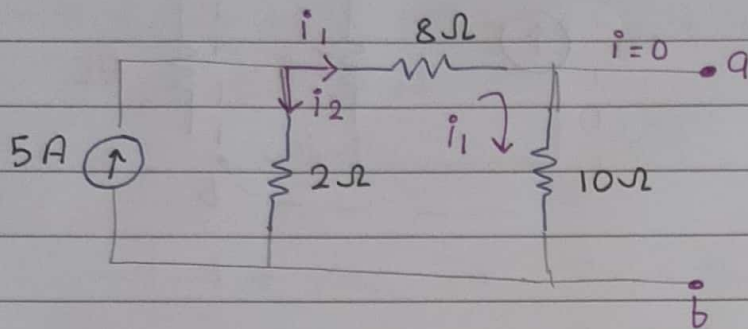
تفحصت من الجهة الثانية





\* To find  $V_{th}$  :-

Disconnect the load & place  $V_{o.c}$  :-



$$V_{o.c} = V_{th}$$

↳ voltage open circuit

وهو نفس voltage الـ

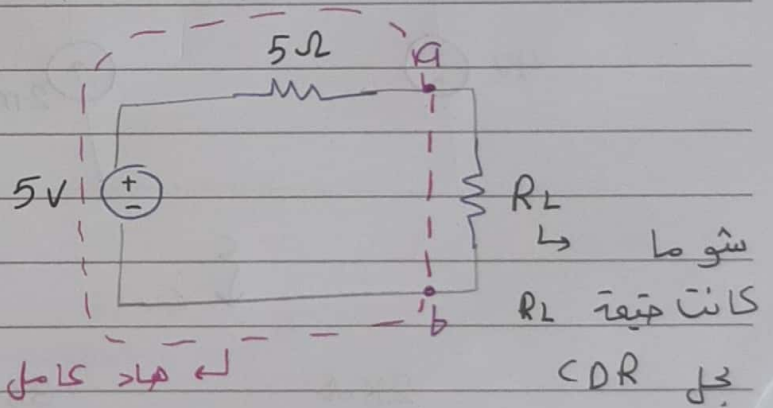
الـ 10Ω ما ابى دخل بالتيار

لأنه مفتوح

CDR :-

$$i_1 = \frac{5(2)}{2+8} = 0.5 \text{ A}$$

$$V_{o.c} = i_1 (10) = 5 \text{ V}$$



شوا

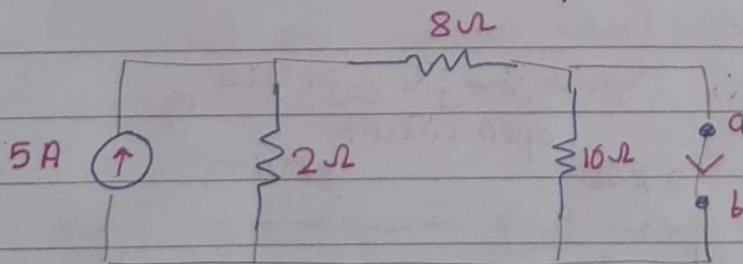
كانت قيمة  $R_L$

جلى CDR

لـ هاد كامل مكافئ للتدري  
بالدارة الأصلية

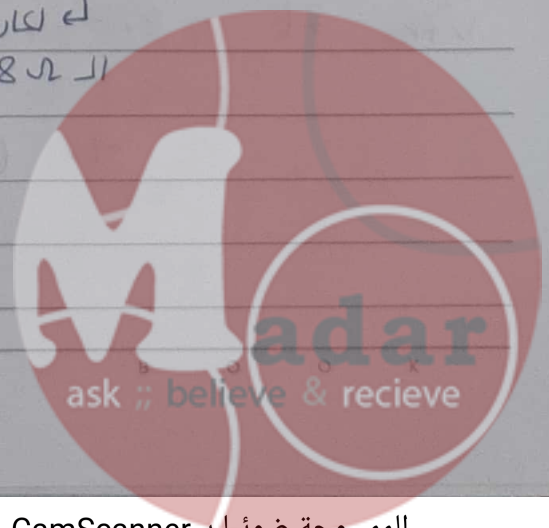
\* To find  $I_N$  :-

Disconnect the load & place a short circuit =>



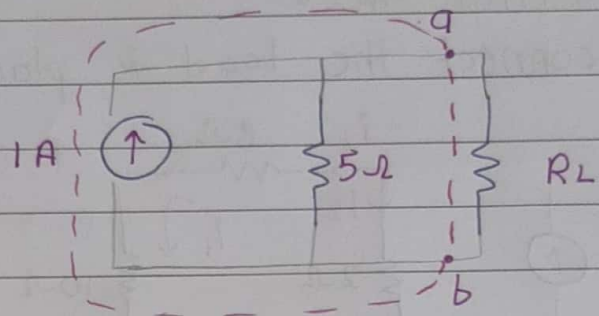
$$I_{s.c} = I_N$$

لـ تيارى  
الـ 8Ω



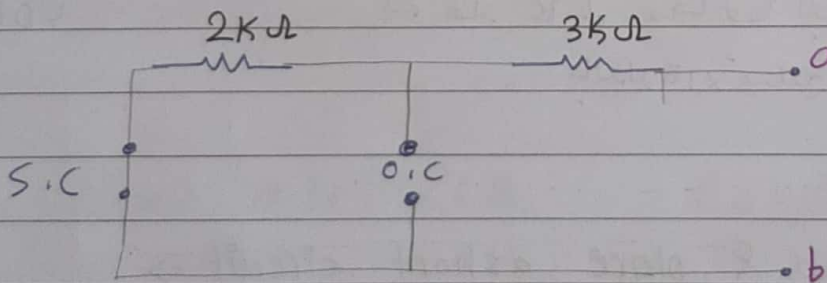
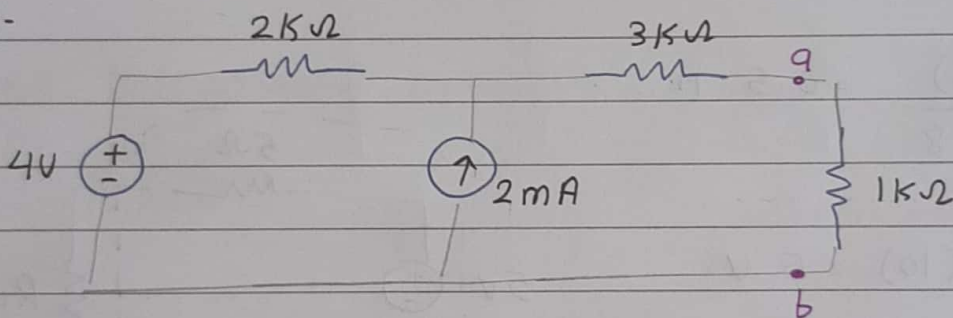
CDR :-

$$I_{s.c} = I_N = 5 \times \frac{2}{10} = 1A$$



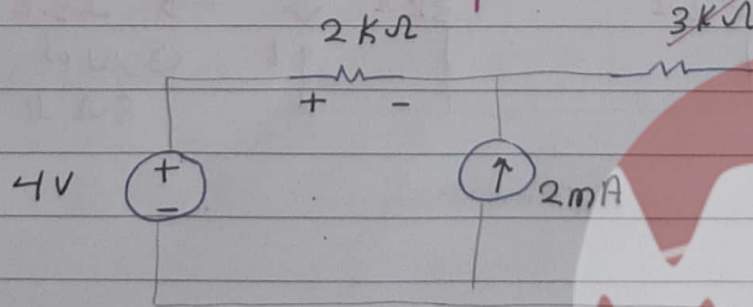
# Example :-

Find thevenin/Norton equivalent circuit between a & b :-



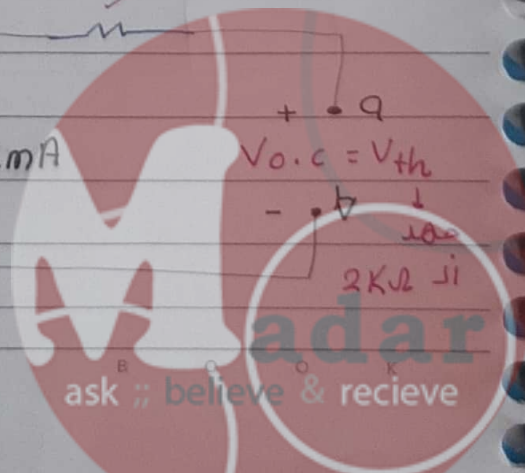
$$R_{th} = R_N = 5k\Omega$$

$V_{th}$  ?!



هائي بترج لا تفرغ عندى  
open circuit

$$V_{o.c} = V_{th}$$



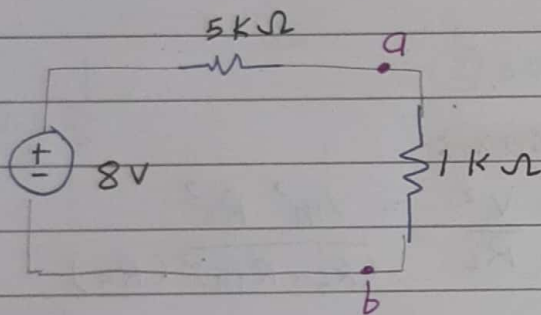


KVL :-

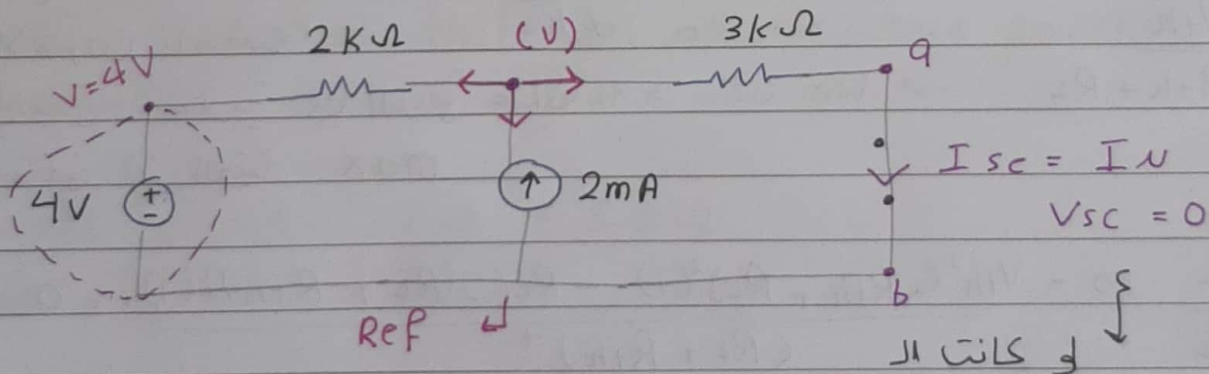
$$-4 + 2 \times 10^3 (-2 \times 10^{-3}) + V_{oc} = 0$$

لأن التيار داخل  
السلك

$$-4 - 4 + V_{oc} \rightarrow V_{oc} = V_{th} = 8V$$



$I_N$  ?!



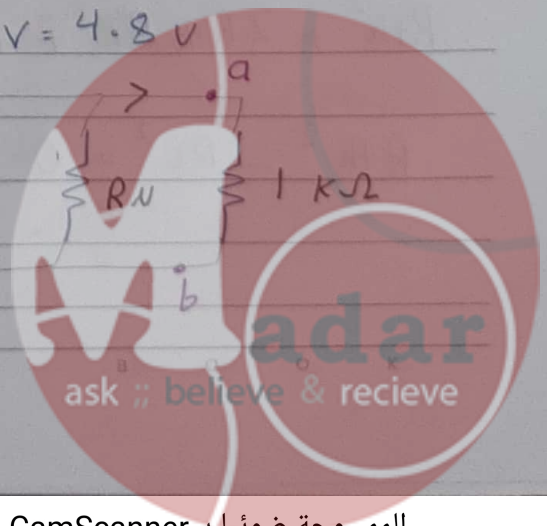
3kΩ موازية short circuit بنفذهما لأن الجهد  
عليها zero

$$\frac{V-4}{2k} - 2mA + \frac{V-0}{3k} = 0$$

$$V = 4.8V$$

$$I_N = \frac{V}{3k\Omega} = 1.6mA$$

$$I_N = 1.6mA$$

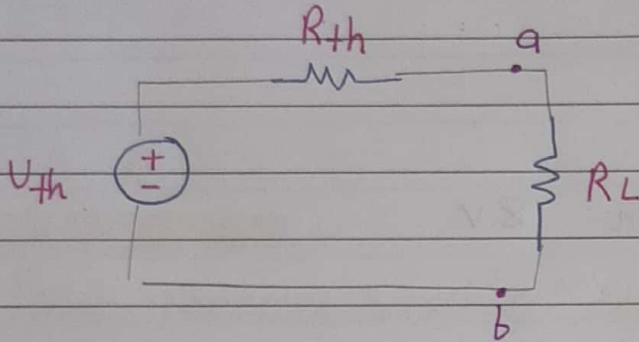


# # Maximum Power transfer (M.P.T) :-

له هاد اكو صوع مربوط بال

Nortone و Therinex

$$P_{L \max} = I_L V_L = \frac{V_L^2}{R_L} = I_L^2 R_L$$



VDR :-

$$V_L = \frac{V_{th} R_L}{R_L + R_{th}}$$

PL max :-

$$P_L = \frac{V^2}{R_L} = \frac{V_{th}^2 R_L^2}{(R_L + R_{th})^2 (R_L)}$$

Ohm's law :-

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

بيني استق  
الاختزان المشية  
للمتغير وأسوية في الميز عان  
أمنفن انو العيفة max

$$\frac{dP_L}{dR_L} = 0 = \frac{V_{th}^2 (R_{th} + R_L)^2 (1) - R_L (2(R_L + R_{th})) (1)}{(R_L + R_{th})^4} = 0$$

$$(R_{th} + R_L)^2 - 2R_L^2 - 2R_L R_{th} = 0$$

$$R_{th}^2 + 2R_{th}R_L + R_L^2 - 2R_L^2 - 2R_L R_{th} = 0$$

$$R_{th}^2 - R_L^2 = 0 \Rightarrow R_L^2 = R_{th}^2$$

$$[R_L = R_{th}] \rightarrow \text{a condition}$$

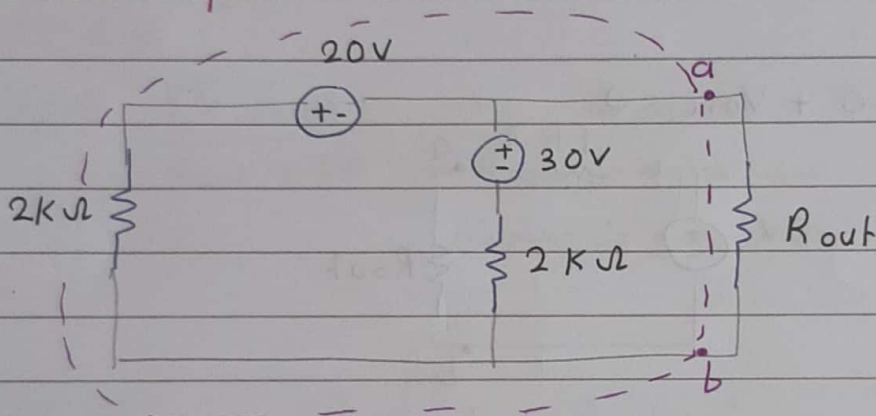
ask believe & recieve



$$P_{L \max} = \frac{V_{th}^2 R_L}{(R_L + R_{th})^2} = \frac{V_{th}^2 R_{th}}{4 R_{th}^2} = \frac{V_{th}^2}{4 R_{th}}$$

→ top ←

**Example :-**

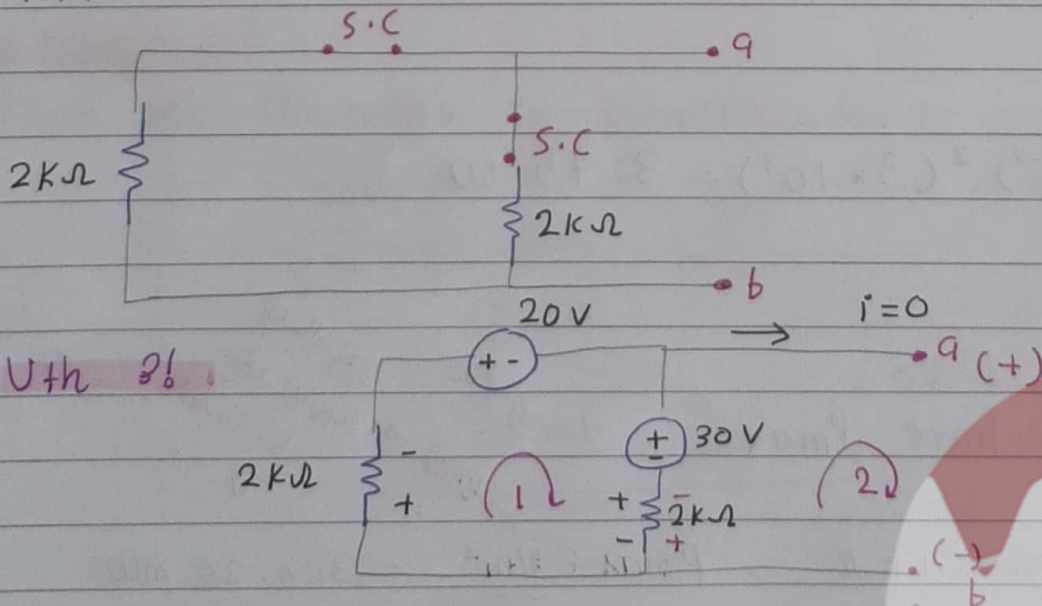


(a) Find  $P_{out}$  if  $R_{out} = 3k\Omega$  :-

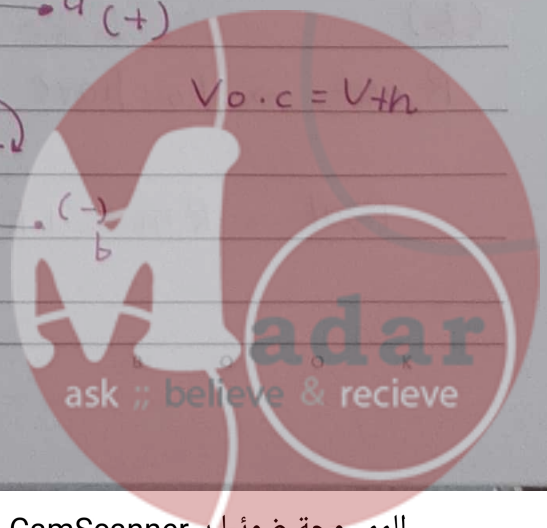
(b) Find  $R_{out}$  that will absorb max power :-

(c) Find  $R_{out}$  if  $P_{out} = 20 \text{ mW}$  :-

$$R_{th} = 2k\Omega // 2k\Omega = 1k\Omega$$



$$V_{o.c} = V_{th}$$



KVL :- (1)

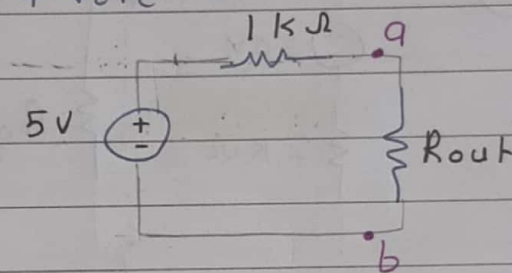
$$2000 i + 20 + 30 + 2000 i = 0$$

$$i = \frac{-50}{4000} = -12.5 \text{ mA}$$

KVL :- (2)

$$2000 (12.5 \text{ mA}) - 30 + V_{o.c} = 0$$

$$V_{o.c} = 5 \text{ V}$$



(a)

$$P_{out} = i^2 R = \frac{V^2}{R}$$

$$i = \frac{5}{1+3} = 1.25 \text{ mA}$$

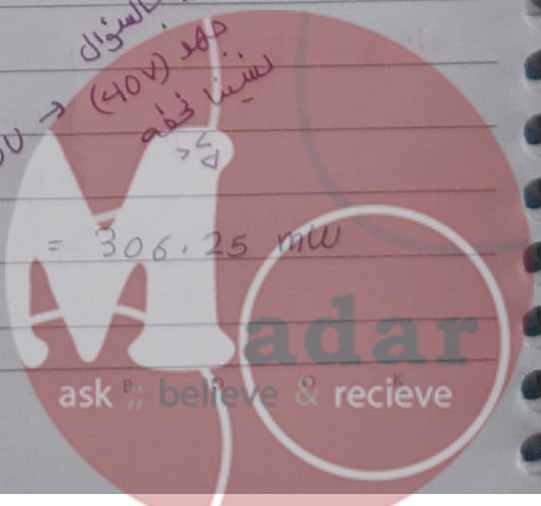
$$P = (1.25 \times 10^{-3})^2 (3 \times 10^3) = 3.75 \text{ W}$$

(b)

$R_{out} \rightarrow$  to have  $P_{max}$

$$R_{out} = R_{th} = 1 \text{ k}\Omega, \quad P_{max} = \frac{V_{th}^2}{4 R_{th}} = 306.25 \text{ mW}$$

في السؤال  
هذا (40V)  
لستين فيهم  
35V →





(c)

$$P_{out} = i^2 R_{out} = 20 \times 10^{-3} \rightarrow (1)$$

$$i = \frac{35}{1k + R_{out}} \rightarrow (2)$$

VDR :

$$V_{out} = \frac{35 R_{out}}{R_{out} + 1k} \rightarrow \text{سواء أخذت هـاي الكهـادله أو معادله التيار بفـضل عنـا معادلـتين}$$

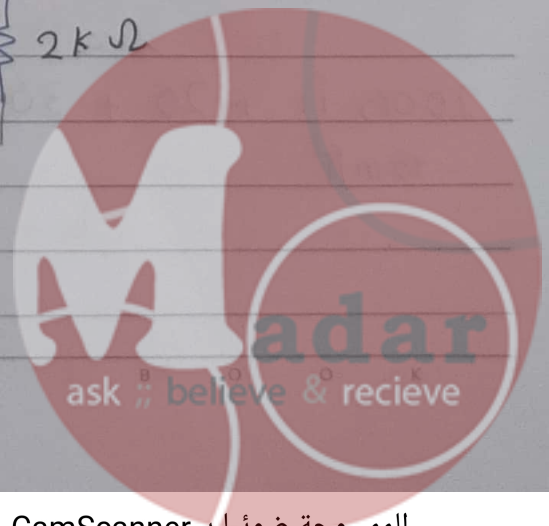
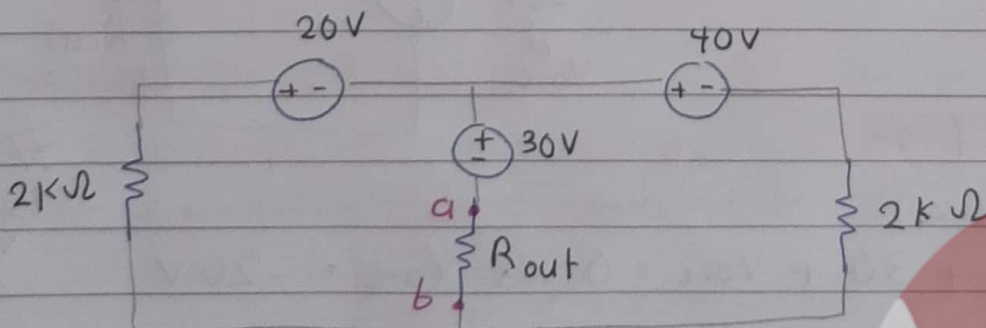
$$\left( \frac{35}{1k + R_{out}} \right)^2 R_{out} = 2 \times 10^{-3}$$

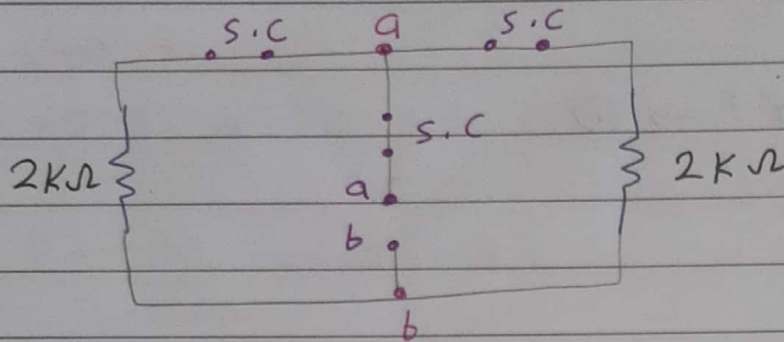
$$R_{out} = 59.2 \text{ k}\Omega$$

$$R_{out} = 16.88 \Omega$$

# Example :-

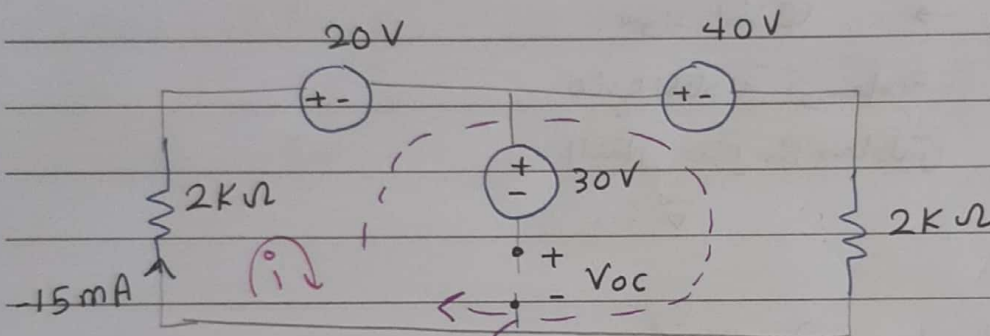
Find the Thevenin's eq. between a & b :-





S.C.  
كلها عبارة  
عن 1 node

$$(2k\Omega // 2k\Omega) \rightarrow R_{th} = 1k\Omega$$

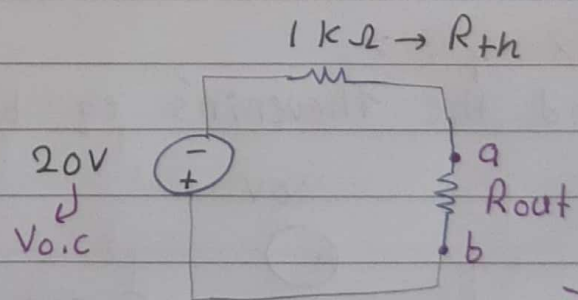


هنا الفرع مازح يعر حيه  
تيار

KVL on outer loop :-

$$2000i + 20 + 4 + 2000i = 0$$

$$i = \frac{-60}{4000} = -15mA$$



KVL on mesh i :-

$$2000i_1 + 20 + 30 + V_{O.C} = 0 \rightarrow V_{O.C} = -20V$$

-15mA



# # Delta - wye conversion :-

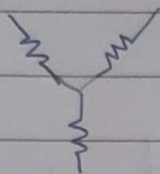
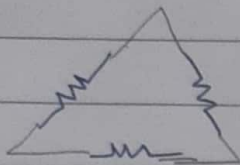
$\Delta \rightarrow Y, Y$

$\rightarrow$

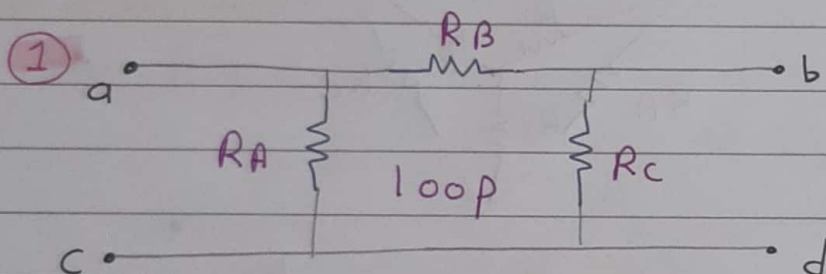
تحويل دلتا إلى نجمة

تحويل نجمة إلى دلتا

توازي وتوالي

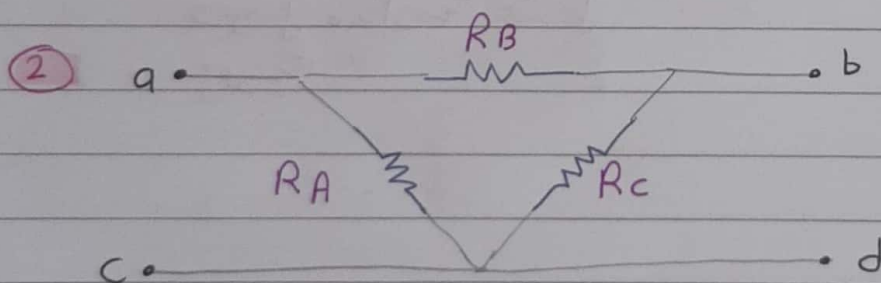


## Delta connection :-

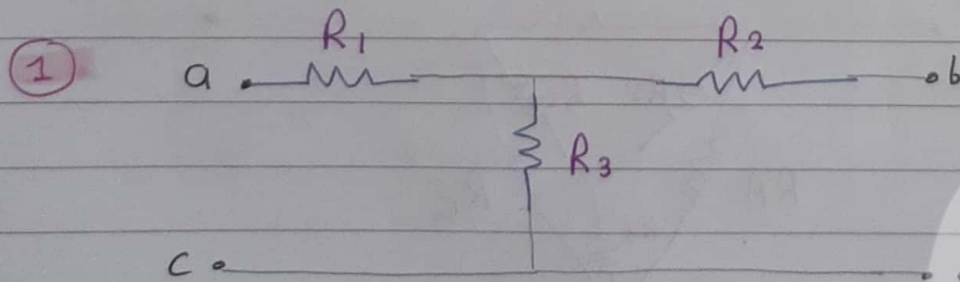


\* في الدلتا لنا

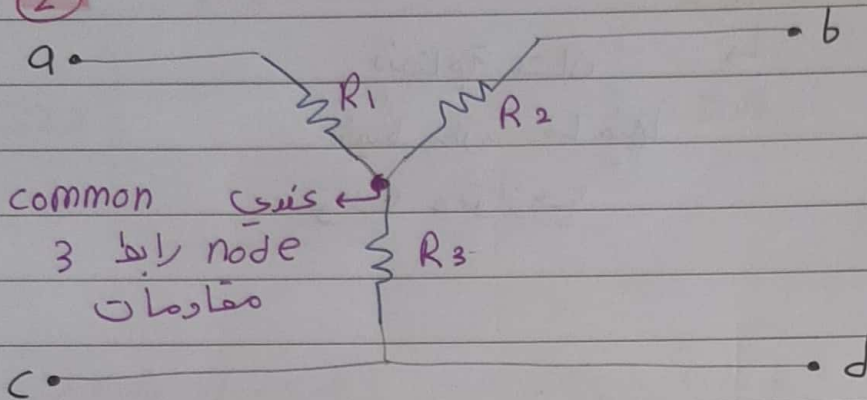
loop



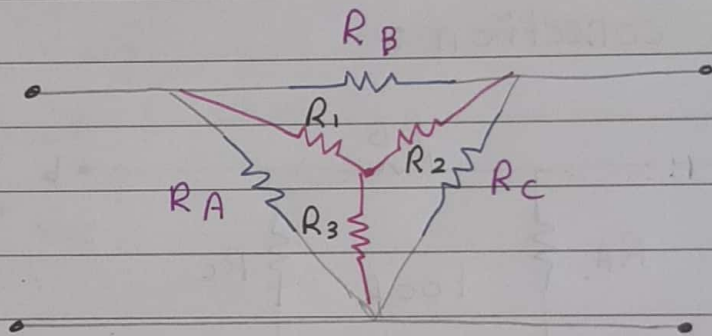
## Wye connection :-



(2)



#  $\Delta \rightarrow Y$  :-

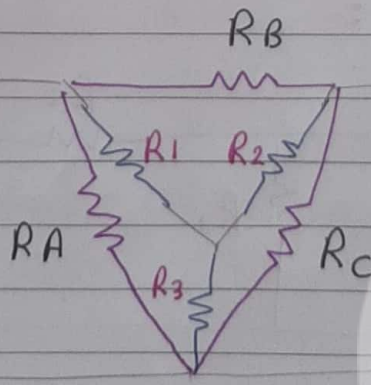


$$R_1 = \frac{R_A R_B}{R_A + R_B + R_C}$$

$$R_2 = \frac{R_B R_C}{R_A + R_B + R_C}$$

$$R_3 = \frac{R_A R_C}{R_A + R_B + R_C}$$

#  $Y \rightarrow \Delta$  :-





Subject :

## chapter 5

9 / 8 / 2022

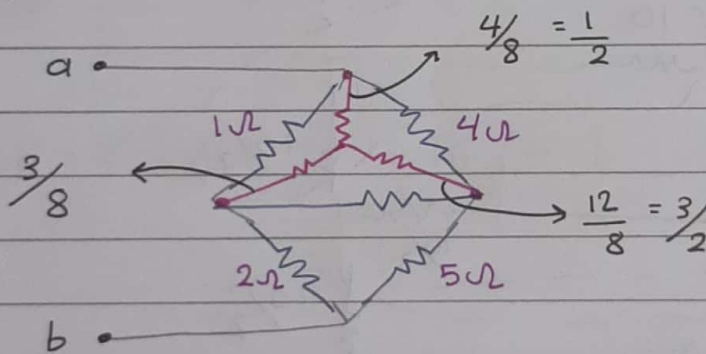
$$R_A = \frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_2}$$

$$R_B = \frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_3}$$

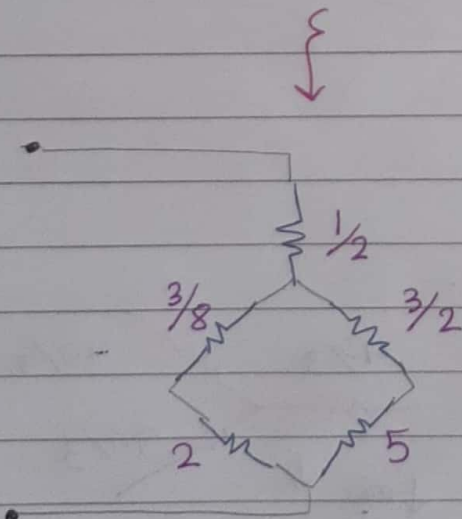
$$R_C = \frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_1}$$

# Example :-

find  $R_{eq}$  :-

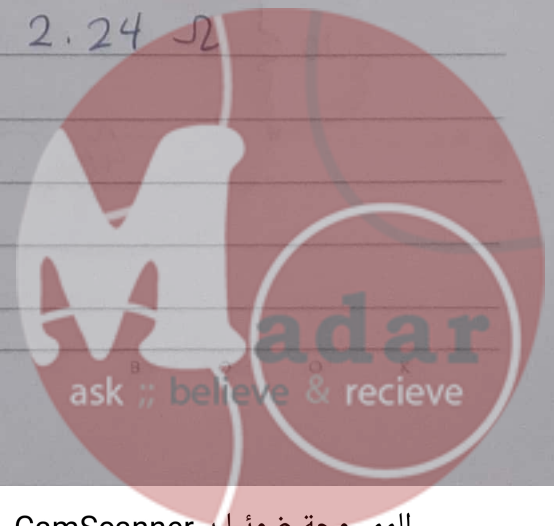


هذا الشكل كان  
Y ← مدارم 3  
مقاومات مرتبطات  
note

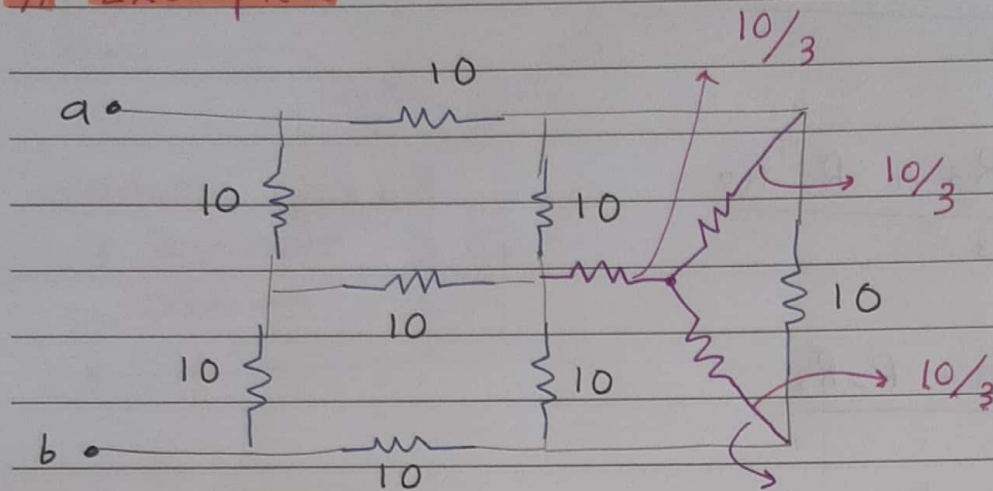


$$R_{eq} = \frac{1}{2} + \left[ \left( \frac{3}{8} + 5 \right) \parallel \left( \frac{3}{8} + 2 \right) \right]$$

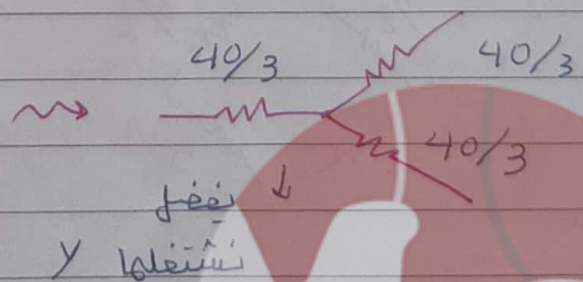
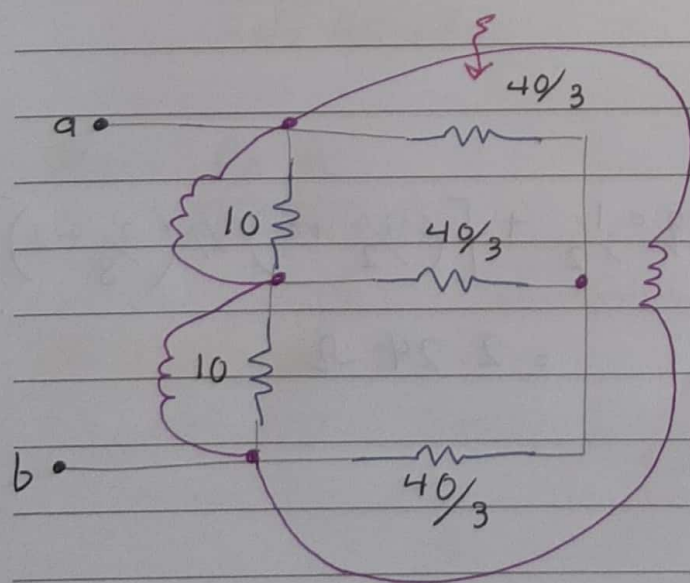
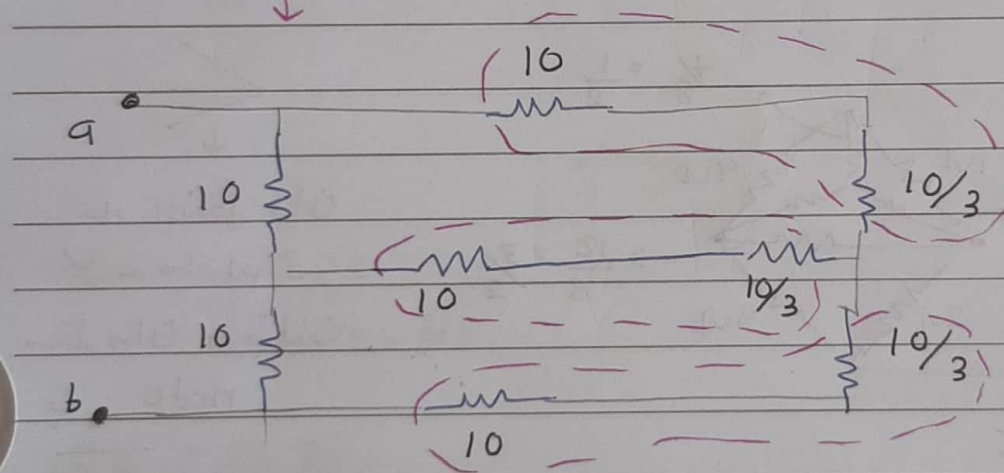
$$= 2.24 \Omega$$



# # Example :



بيننا من هون  
عشان بدنا نضع a & b

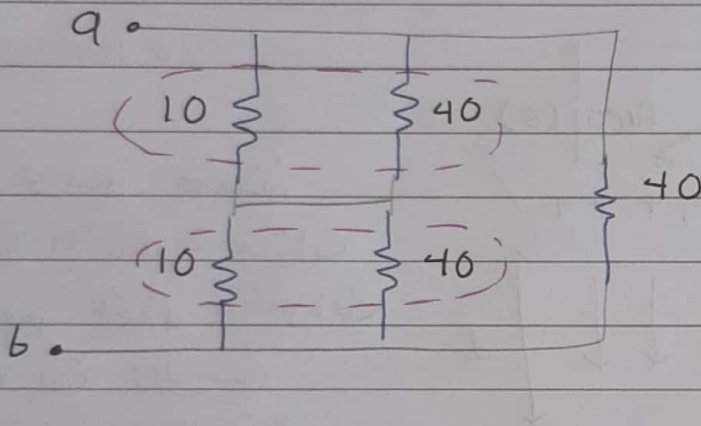


بفضل  
نستعملها



$$R_1 = \left( \frac{40}{3} \right)^2 + \left( \frac{40}{3} \right)^2 + \left( \frac{40}{3} \right)^2 \bigg/ \left( \frac{40}{3} \right)$$

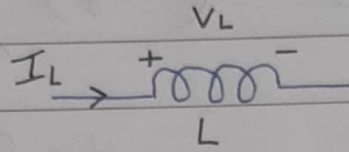
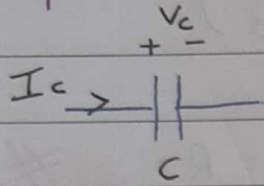
$$= 3 \left( \frac{40}{3} \right)^2 \bigg/ \frac{40}{3} = 40 \, \Omega = R_2 = R_3 \quad \#$$



$$R_{eq} = (8 + 8) \parallel 40 = \frac{16(40)}{56} = 11.43 \, \Omega$$



## # Capacitors & Inductors :-



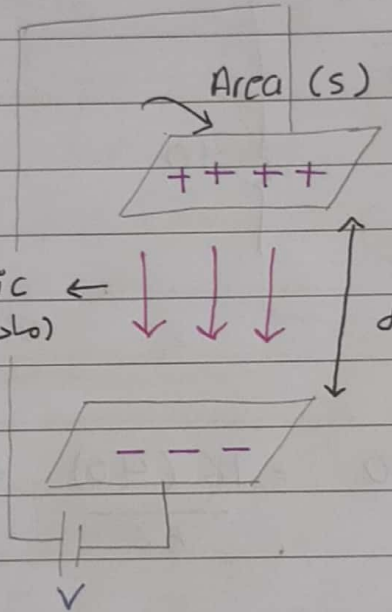
passive elements

### => Capacitors :-

$$i \propto \frac{dV}{dt}$$

$$i = C \frac{dV}{dt}$$

dielectric (مادة عازلة)  $\leftarrow$   
 $\epsilon_r$  ← السماحية النسبية للمادة  
 $\epsilon_0$  ← سماحية الهواء  
 $\epsilon = \epsilon_0 \epsilon_r$



\* لوحين متقابلين  
 في الإشارة عشان  
 أجبر المجال الكهربائي  
 يهرب بين اللوحين  
 وتتوزع الطاقة في  
 المادة العازلة

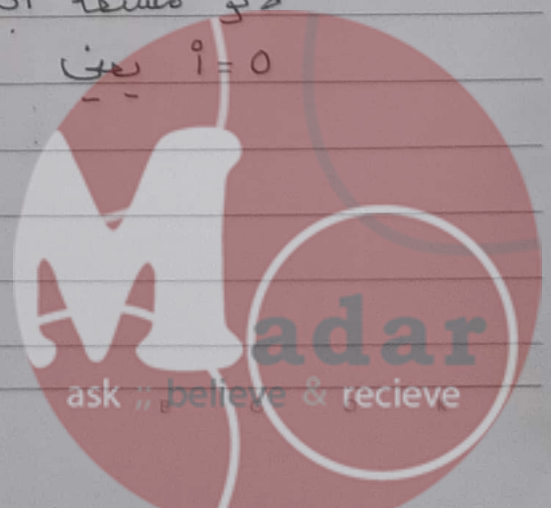
كلما كانت  
مساحة  
اللوحين  
(اللوحين هم  
نفس المساحة)  
 $C = \epsilon \frac{S}{d}$   
 كلما كبرت  
مساحة  
اللوحين  
كلما كانت  
مساحة  
اللوحين  
نفس المساحة

in Farad (F) و

أغلب الجوانح  
 تقاس بالـ (μF, nF)

\* Capacitor is an open circuit to Dc voltage or zero voltage. لأن مشتقة الجهد راج تكون صفر بالتالي

open circuit  $i = 0$  يعني

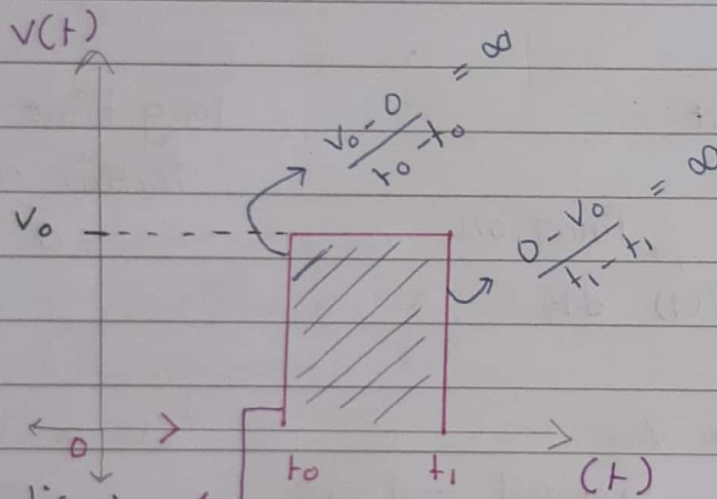




$$i = C \frac{dv}{dt} \rightarrow \int \frac{dv}{dt} = \int \frac{i}{C}$$

$$V = \frac{1}{C} \int_{t_0}^t i(t) dt \rightarrow \text{علاقة غير خطية (اشتقاق وتكامل)}$$

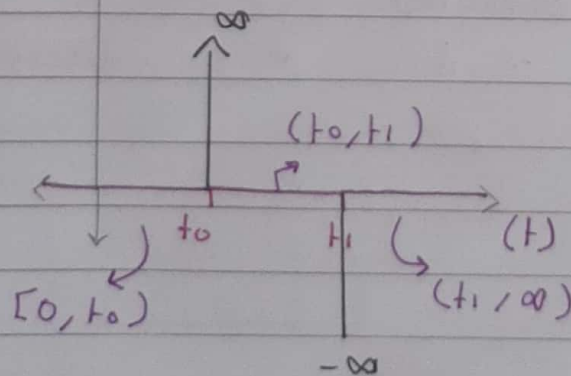
لهيك خلعت  
برة التكامل

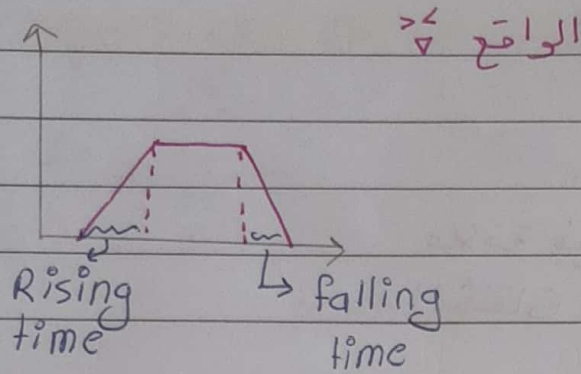


حمار عنا تغير  
voltage بار  
شغلت البطارية عند  
t0 وخلصتها عند t1

\* إذا كان في تغير مفاجئ  
بار voltage التيار يكون  
∞ (كان 0 ونفاة حمار V0)  
وال P = ∞ وهما الحكي من على

\* The voltage shouldn't  
change suddenly  
across a capacitor





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

$$V(t_0) = V_0$$

↳ initial condition (I.C)

$$\int_{V_0}^{V(t)} \frac{dV}{dt} = \int_{t_0}^t i(t) dt$$

long time ago  
initial condition

$$= 0 \quad \nabla$$

$$V(t) - V(t_0) = \frac{1}{C} \int_{t_0}^t i(t) dt$$

Function

$$* V(t) = \frac{1}{C} \int i(t) dt + V_0$$

↳ stored voltage

$$* V(t) = \frac{1}{C} \int_{-\infty}^{\infty} i(t) dt = \frac{1}{C} \int_{-\infty}^{t_0} i(t) dt + \frac{1}{C} \int_{t_0}^t i(t) dt$$

لهای هي ال  
(initial condition)

# Power :-

$$P = IV, \quad i = C \frac{dv}{dt}$$





energy stored in the capacitor  $\Rightarrow$

$$W_C(t) = \int_{-\infty}^t p(t) dt$$

$$W_C(t) = \int_{-\infty}^t \left( \underbrace{C}_{\text{constant}} v \frac{dv}{dt} \right) dt$$

$$= \underbrace{C}_{\rightarrow I \cdot C} \int_{-\infty}^t v dv + C \int_{t_0}^t v dv$$

(مفصلنا هو  
التكامل)

$$= \boxed{\frac{1}{2} C v^2(t_0)} + C \int_{t_0}^t v dv$$

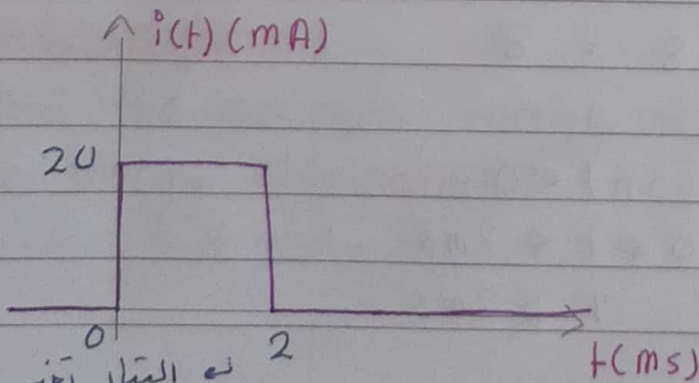
initial energy  $\leftarrow W_0$

$$\rightarrow \frac{1}{2} C v^2(t)$$

\* if  $v(t_0) = 0$  then :-  $W_C(t) = \frac{1}{2} C v^2(t)$

# Example :-

Find  $v_C(t)$  if  $C = 5 \mu F$  &  $i(t) = \begin{cases} 0 & t \leq 0 \\ 20 \text{ mA} & 0 \leq t \leq 2 \text{ ms} \\ 0 & t \geq 2 \text{ ms} \end{cases}$



في المسألة  
نحتاج أن نعرف ما  
هو التيار تغير

أعطاني الفترة كاملة يعني  
أنا لازم أعرف الـ  
initial condition

ask :: believe & recieve

$$V = \frac{1}{C} \int_{-\infty}^t i(t) dt$$

$$① -\infty < t < 0$$

$$V = \frac{1}{5 \times 10^{-6}} \int_{-\infty}^t 0 dt = 0$$

\* لما تكامل كل خترة بدنا نفوض بنهاية الفترة لأنها راح تكون I.C للفترة يلي بعدها .

$$V(0) = 0$$

$$② 0 \leq t \leq 2 \text{ ms}$$

$$V = \frac{1}{5 \times 10^{-6}} \int_0^t 20 \times 10^{-3} dt + 0$$

$$= \frac{20 \times 10^{-3}}{5 \times 10^{-6}} (t - 0) = 4000t \quad V$$

$$V(2 \text{ ms}) = 4000(2 \times 10^{-3}) = 8 \text{ V}$$

$$③ 2 \text{ ms} \leq t \leq \infty$$

$$V = \frac{1}{5 \times 10^{-6}} \int_2^t 0 dt + 8 = 8$$

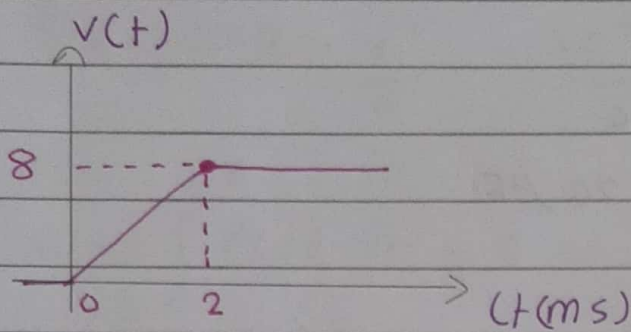
$$V(t) = \begin{cases} 4000t & 0 \leq t \leq 2 \text{ ms} \\ 8 & t \geq 2 \text{ ms} \end{cases}$$

slope ←

$$\begin{aligned} t &\leq 0 \\ 0 &\leq t \leq 2 \text{ ms} \\ t &\geq 2 \text{ ms} \end{aligned}$$







$$W_C(t) = \frac{1}{2} C v^2(t) + W_C(t_0)$$

$$\rightarrow W_C(t) = 0 \quad t \leq 0 \rightarrow W_C(0) = 0 = \frac{1}{2} C V_0^2$$

$$= \frac{1}{2} (5 \times 10^{-6}) (16 \times 10^6 t^2)$$

$$= 40 t^2 + 0$$

$$t \leq t \leq 2 \text{ ms}$$

$$W_C(t) = \frac{1}{2} (5 \times 10^{-6}) (64) = 0.16 \text{ mJ} \quad 2 \text{ ms} \leq t$$

الـ capacitor

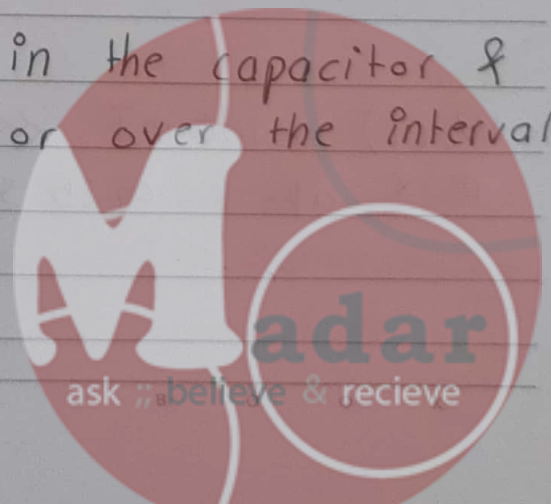
64 اشتغل 2ms خزن طاقة

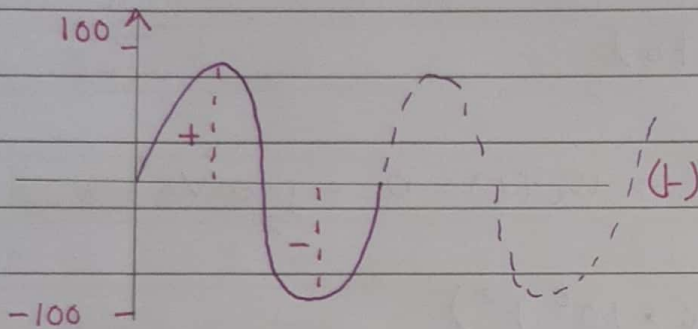
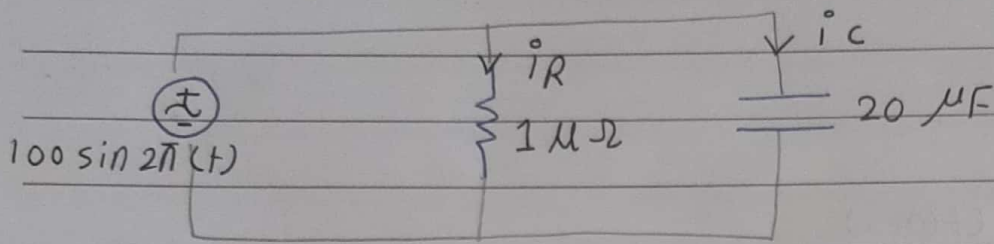
مقدارها 0.16 mJ

$$P = \frac{W}{t} = \frac{0.16 \times 10^{-3}}{2 \times 10^{-3}} = 0.08 \text{ W}$$

### Example :-

Find the maximum energy stored in the capacitor & the energy dissipated in the resistor over the interval  $0 < t < 0.5 \text{ s}$  :-





$$\omega = 2\pi f = 2\pi \text{ rad/s}$$

↓  
Frequency (Hz or s<sup>-1</sup>)

radian  
Frequency  
(rad/s) [f = 1 Hz]

$$W_C(t) = \frac{1}{2} C V^2(t)$$

$$= \frac{1}{2} (20 \times 10^{-6}) (100 \sin(2\pi t))^2 = 0.1 \sin^2 2\pi t \text{ J}$$

$$= 100 \sin^2 2\pi t \text{ mJ}$$

$$W_C(t)_{\text{max}} = 100 \sin^2 2\pi t$$

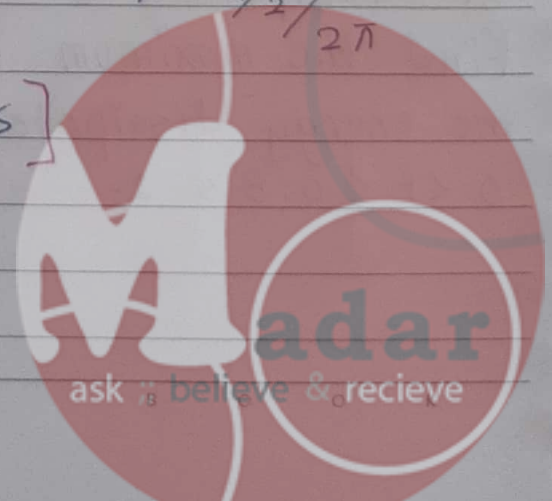
$$\sin^2 \pi(t) = 1$$

$$\sin^{-1}(\sin 2\pi t) = \sin^{-1}(1)$$

$$2\pi t = \frac{\pi}{2} \rightarrow t = \frac{\pi/2}{2\pi}$$

$$W_C(t)_{\text{max}} = 100 \text{ mJ} \text{ at } t = 0.25 \text{ s}$$

$$[t = \frac{1}{4} \text{ s}]$$





$$P_R = i^2 R = \frac{v^2}{R} = \frac{10^4 \sin^2 2\pi t}{10^6} 10^{-2} (w)$$

$$W = \int_0^{0.5} P(t) dt = 0.01 \int_0^{0.5} \sin^2 2\pi t dt$$

$$= 0.01 \int_0^{0.5} \frac{1}{2} (1 - \cos 4\pi t) dt$$

$$= 0.01 \left[ \frac{1}{2} \frac{1}{2} - \frac{\sin 4\pi t}{4\pi} \right]_0^{0.5}$$

$$= 0.01 \left( \frac{1}{4} \right) = 2.5 mJ$$

الطاقة الضائعة

2.5 %

\*  
\*\*

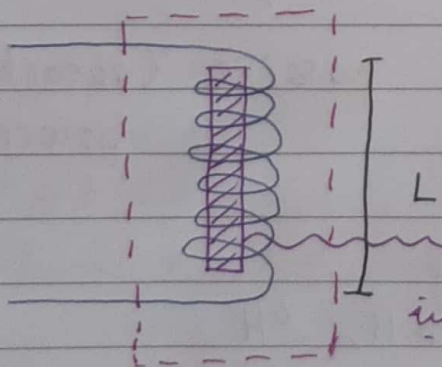
$$i_c = C \frac{dv_c}{dt}$$

$$v_c = \frac{1}{C} \int_{-\infty}^t i_c(t) dt$$

لذا إذا عطيناها فنش داي

$$v_o \text{ بحسب الـ } \rightarrow \frac{1}{C} \int_{t_0}^t i_c(t) dt + v_o$$

=> Inductor :-



مادة لها  
مغناطيسية

السماحية المغناطيسية  
(μ) → Permeability

$$= \mu_0 \mu_r$$

ask " believe & recieve

$$L = \frac{\mu A N^2}{l}, \quad A = \pi a^2$$

$$V \propto \frac{di}{dt} \rightarrow V_L = L \frac{di_L}{dt} \rightarrow \text{إذا كان } i = 0 \text{ يعني } V = 0 \text{ short circuit}$$

### Duality (التقايق) $\Rightarrow$

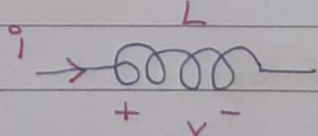
- ①  $V \leftrightarrow i$
- ②  $L \leftrightarrow C$
- ③  $R \leftrightarrow 1/R = G \rightarrow (\text{conductance})$
- ④ series  $\leftrightarrow$  parallel

\* Inductor is a short circuit for DC (constant current or zero current).

\* The current shouldn't change suddenly across an inductor.  
معنوع التيار يتغير فجأة

$$W_L(t) = \frac{1}{2} L i^2(t)$$

energy



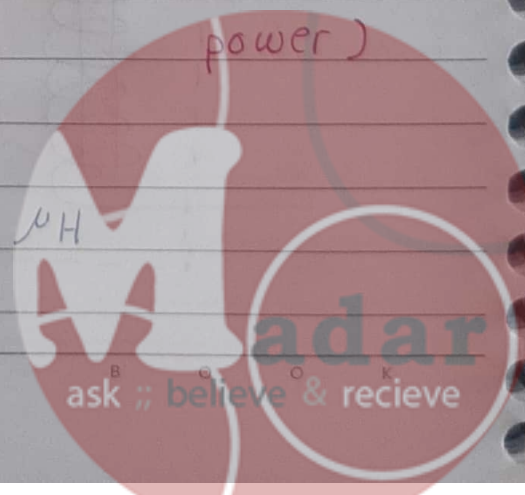
passive (absorbed power)

unit of  $L \Rightarrow$

$$V = L \frac{di}{dt} \rightarrow L \rightarrow \frac{V \cdot s}{A} \rightarrow (H) \text{ Henry}$$

A/s

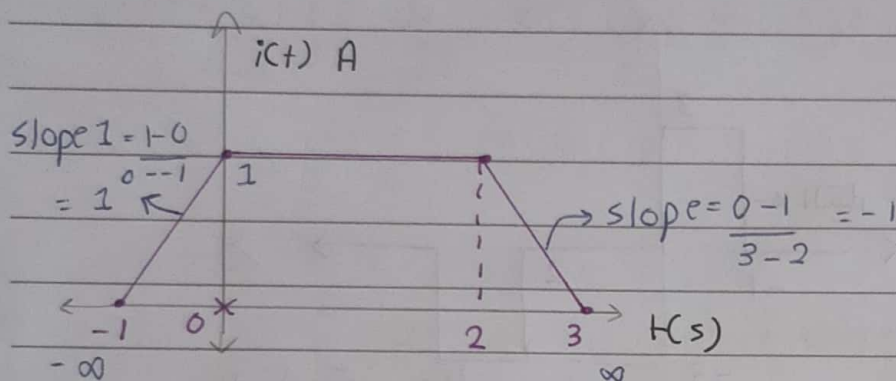
$\rightarrow mH, \mu H$





## # Example 8-

Given the waveform of the current in a 3H inductor, Determine the inductor voltage :-



$$i(t) = \begin{cases} 0 & t \leq -1 \\ t+1 & -1 \leq t \leq 0 \\ 1 & 0 \leq t \leq 2 \\ 3-t & 2 \leq t \leq 3 \\ 0 & t \geq 3 \end{cases}$$

\* معادلة الخط

المستقيم  $y = mx + c$ 

$$y - y_0 = \text{slope}(x - x_0)$$

$$V_L(t) = L \frac{di}{dt}$$

$$\textcircled{1} \quad t \leq -1$$

$$i = 0 \quad V = 0$$

$$\textcircled{2} \quad -1 \leq t \leq 0$$

$$i = t+1 \rightarrow V = L \frac{di}{dt} = 3(1) = 3V$$

3)  $0 \leq t \leq 2$

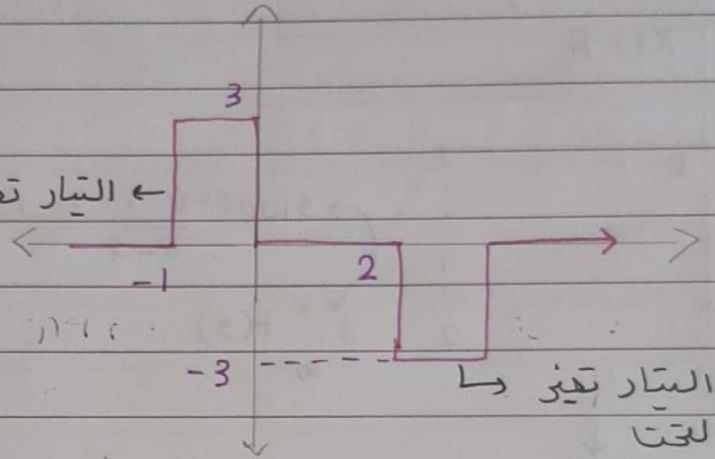
$i = 1$      $v = 0$     ( $i \rightarrow \text{constant}$ )

4)  $i = 3 - t$      $v = L \frac{di}{dt} = 3(-1) = -3V$     ( $2 \leq t \leq 3$ )

5)  $t \geq 3$

$i = 0$      $v = 0$

التيار تغيره لوقت



$v = L \frac{di}{dt}$

$i(t_0) = i_0$

$L \rightarrow I \cdot C$

$i$

$t$

$\int_{i_0}^i \frac{di}{L} = \int_{-\infty}^t \frac{1}{L} v dt \rightarrow i - i_0 = \frac{1}{L} \int_{t_0}^t v(t) dt$

$i_0$   
 $\downarrow$   
 $I \cdot C$

$i = \frac{1}{L} \int_{t_0}^t v(t) dt + i_0$

or

$t$

$i = \frac{1}{L} \int_{-\infty}^t v(t) dt$

لما محتاج أخط

هأ لأنني راح أحييها





$$W_L(t) = \int_{-\infty}^t p(t) dt$$

$$W_L(t) = L \int_{-\infty}^t i \frac{di}{dt} dt \rightarrow W_L(t) = \frac{1}{2} L i^2(t) \quad \#$$

or

$$W_L(t) = \frac{1}{2} L i^2(t) + W_0(t)$$

↓ if there is an I.C

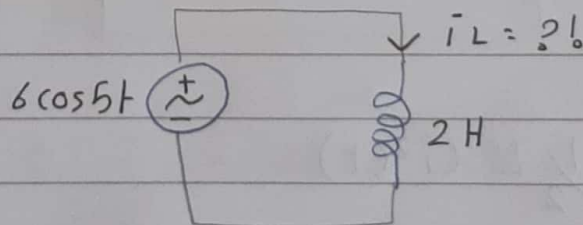
$$\int_{t_0}^t$$

$$\int_{-\infty}^{t_0}$$

### # Example :-

The voltage across a 2H inductor is known to be  $6 \cos 5t$  (v), Determine the resulting inductor current  $i_L(t - \pi/2) = 1A$  :-

→ I.C



$$i = \frac{1}{L} \int_{-\infty}^t v(t) dt$$

$$= \frac{1}{L} \int_{-\pi/2}^t v(t) dt + i(-\pi/2)$$

$$i = \frac{1}{2} \int_{-\pi/2}^t 6 \cos 5t dt + 1$$

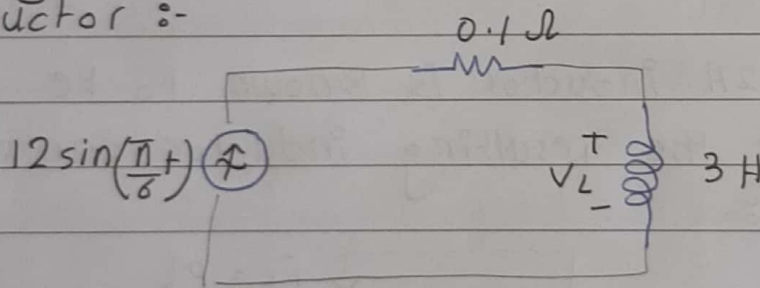
$$i = \frac{3 \sin 5t}{5} \Big|_{-\pi/2}^t + 1$$

$$= 0.6 [\sin 5t - \sin(-5\pi/2)] + 1$$

$$= 0.6 (\sin 5t + 1) + 1 = 0.6 \sin 5t + 1.6 \text{ (A)}$$

### Example 8 -

Find the maximum energy stored in the inductor shown & how much energy is dissipated in the resistor in the time during which the energy being stored in & then recovered from the inductor :-



$$W_L(t) = \frac{1}{2} L (i^2(t))$$

$$= \frac{1}{2} (3) (144) \sin^2(\frac{\pi}{6}t)$$

$$= \underline{216} \sin^2(\frac{\pi}{6}t) \text{ J}$$

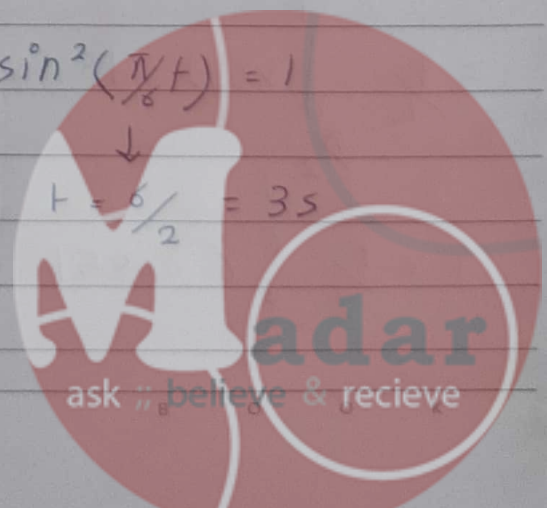
$$W_L \text{ max} = 216 \text{ J}$$

at  $t = 3 \text{ s}$

$$\sin^2(\frac{\pi}{6}t) = 1$$

$$\downarrow$$

$$t = \frac{6}{2} = 3 \text{ s}$$





interval  $\rightarrow [0, 6]$ 

$$\begin{array}{c} \swarrow \quad \searrow \\ 0 \rightarrow 3 \quad \quad 3 \rightarrow 6 \end{array}$$
inductor  $\rightarrow$  شحنinductor  $\rightarrow$  خرج

$$W_R(t) = \int_0^6 P_R(t) dt \quad , \quad P_R(t) = i^2 R$$

$$= \int_0^6 14.4 \sin^2\left(\frac{\pi}{6}t\right) dt$$

$$= 14.4 \int_0^6 \frac{1}{2} \left[ 1 - \cos\left(\frac{2\pi t}{6}\right) \right] dt$$

$$= 14.4 \left[ 3 - \frac{\sin \pi t / 3}{3/\pi} \right]_0^6$$

$$W_R(t) = 43.2 \text{ J} \rightarrow \frac{43.2}{216} \times 100\% = 20\%$$

كفاءة الطاقة الضائعة

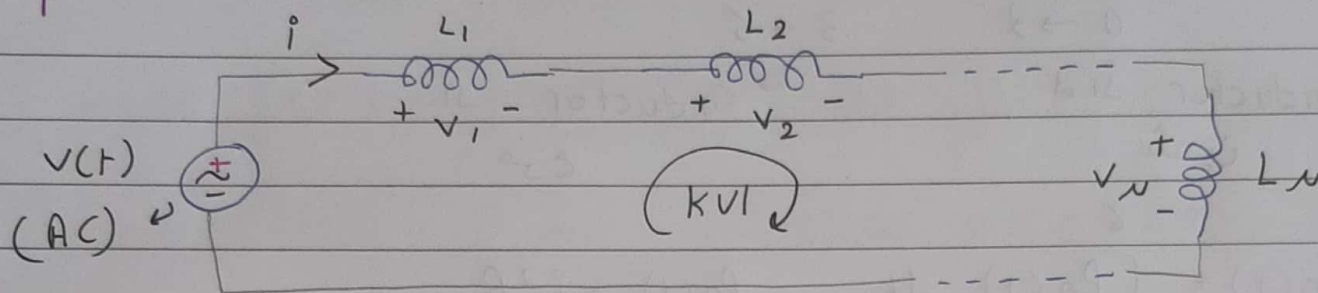
و أنا بشحن ال Inductor

 $\rightarrow$  which is very

hard

الطبيعي 1% (2-3)

**# series & parallel combinations of inductors & capacitors :-**



**KVL →**

$$V_1 + V_2 + \dots + V_N$$

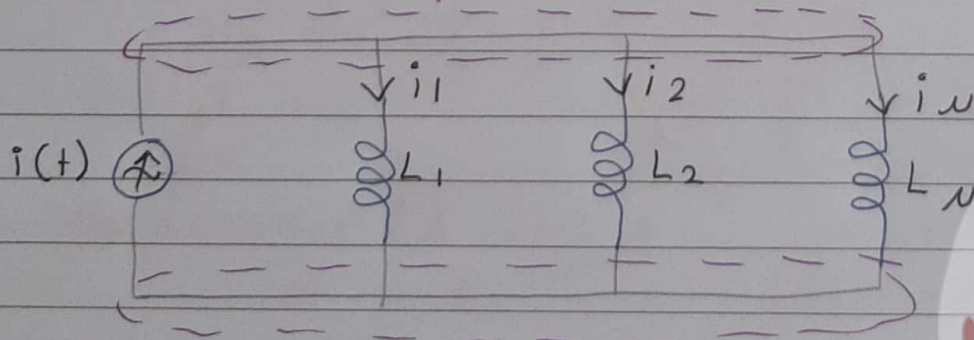
$$= L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + \dots + L_N \frac{di}{dt}$$

$$\frac{di}{dt} (L_1 + L_2 + \dots + L_N) \rightarrow L_{eq}$$

$$V = L_{eq} \frac{di}{dt} \rightarrow L_{eq} = L_1 + L_2 + \dots + L_N$$

for inductors in series

**→ inductors in parallel :-**





KCL  $\rightarrow$

$$i(t) = i_1 + i_2 + \dots + i_n$$

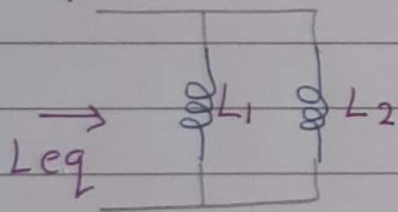
$$i(t) = \frac{1}{L_1} \int_{-\infty}^t v(t) dt + \frac{1}{L_2} \int_{-\infty}^t v(t) dt + \dots + \frac{1}{L_n} \int_{-\infty}^t v(t) dt$$

$$i(t) = \left( \frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_n} \right) \int_{-\infty}^t v(t) dt$$

$$\frac{1}{L_{eq}}$$

$$i = \frac{1}{L_{eq}} \int_{-\infty}^t v(t) dt \rightarrow L_{eq} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_n}}$$

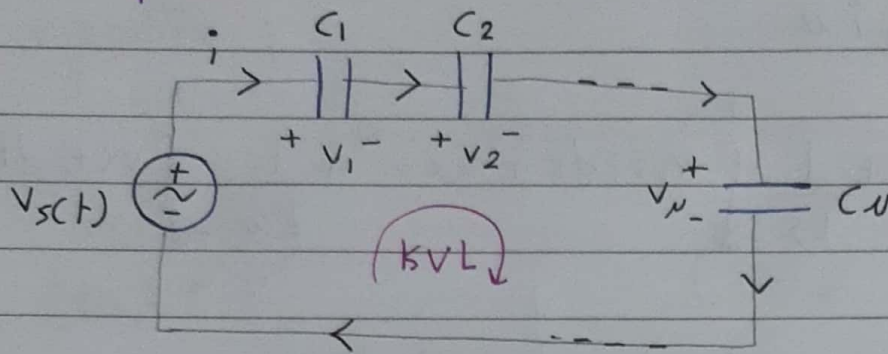
$\rightarrow$  special case :-



$$L_{eq} = \frac{L_1 L_2}{L_1 + L_2}$$



## # Capacitors in series :-



single loop circuit :- ( $i$  is common)

→ KVL :-

$$-V_s + V_1 + V_2 + \dots + V_N = 0$$

$$V_C = \frac{1}{C} \int_{-\infty}^t i(t) dt$$

$$V_s = V_1 + V_2 + \dots + V_N$$

$$i = C \frac{dV}{dt}$$

$$= \frac{1}{C_1} \int_{-\infty}^t i(t) dt + \frac{1}{C_2} \int_{-\infty}^t i(t) dt + \dots + \frac{1}{C_N} \int_{-\infty}^t i(t) dt$$

$$V = \left( \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_N} \right) \int_{-\infty}^t i(t) dt \Leftrightarrow \frac{1}{C} \int_{-\infty}^t i(t) dt$$

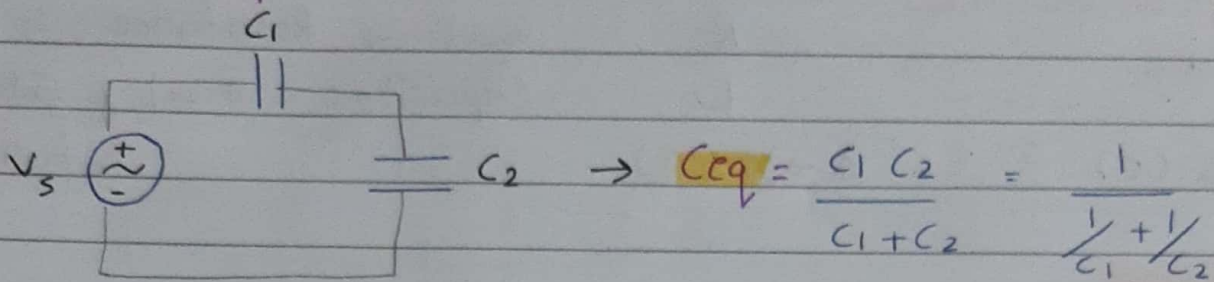
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_N}$$

$$C_{eq} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_N}}$$

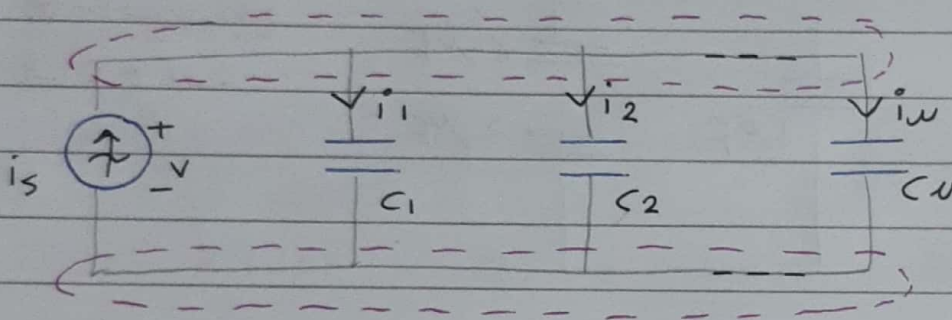




For two capacitors in series :-



# Capacitors in Parallel :-



single Node-pair circuit :- ( $V$  is common)

→ KCL at upper Node :-

$$i_s = i_1 + i_2 + \dots + i_N$$

$$= C_1 \frac{dV}{dt} + C_2 \frac{dV}{dt} + \dots + C_N \frac{dV}{dt}$$

$$= (C_1 + C_2 + \dots + C_N) \frac{dV}{dt} \Leftrightarrow C \frac{dV}{dt}$$

$$C_{eq} = C_1 + C_2 + \dots + C_N$$



$\Delta \rightarrow Y$

R

L

$Y \rightarrow \Delta (C)$

$Y \rightarrow \Delta$

R

L

$\Delta \rightarrow Y (C)$

\* ال inductor نفس

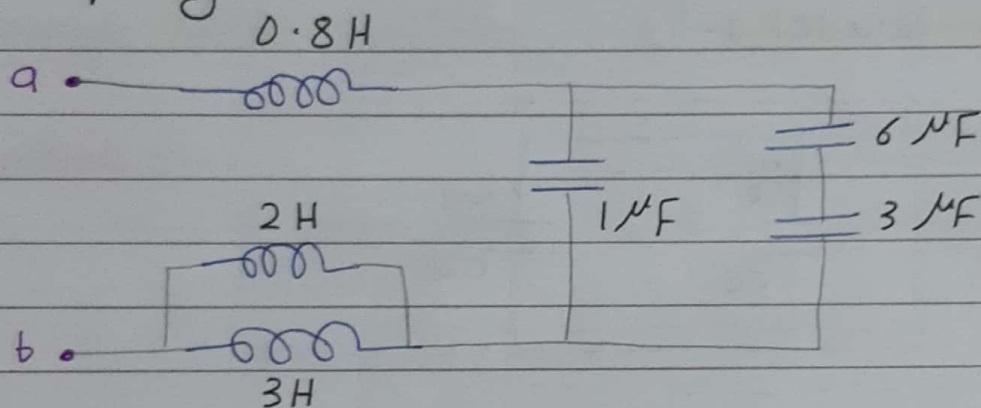
ال Resistance من ناحية

التوالي أما ال capacitor

العكس

# Example 3-

Simplify



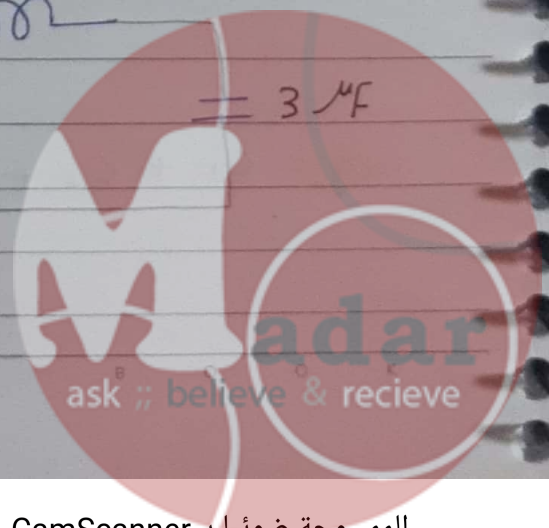
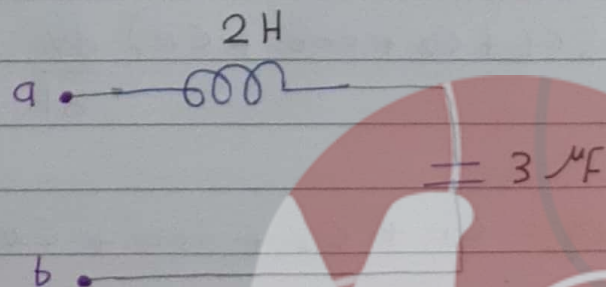
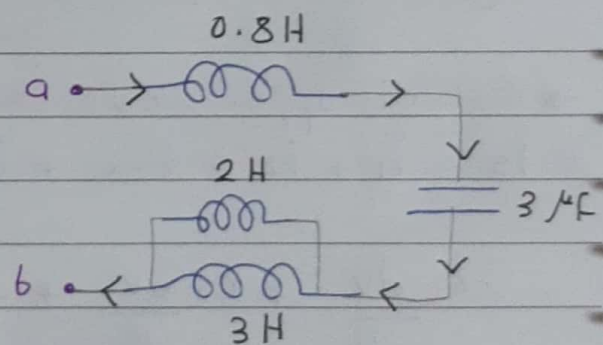
\* ما يبقى الجح  
ال C ح ال L

$$6 \mu F \text{ \& } 3 \mu F \text{ (series)} \rightarrow \frac{6 * 3}{6 + 3} = 2 \mu F$$

$$2 \mu F // 1 \mu F \rightarrow 3 \mu F$$

$$2 H // 3 H \rightarrow \frac{6}{5} H = 1.2 H$$

$$1.2 H \text{ \& } 0.8 H \rightarrow 2 H$$

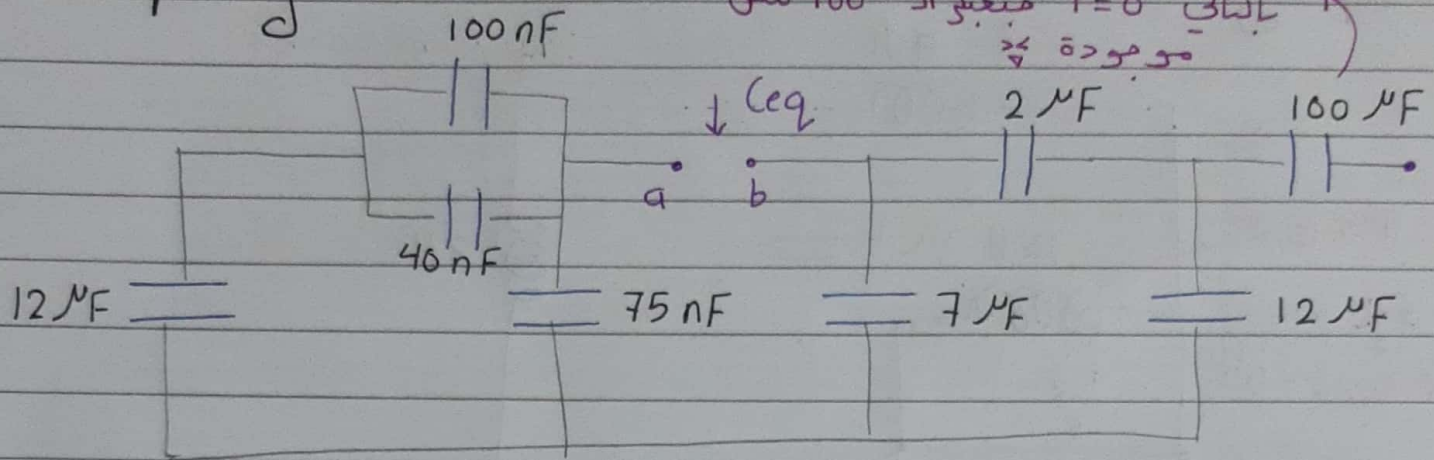




## # Example :-

Simplify

هون عنا open loop

إبتلي  $i = 0$  ضيقو الـ 100 مش موجودة

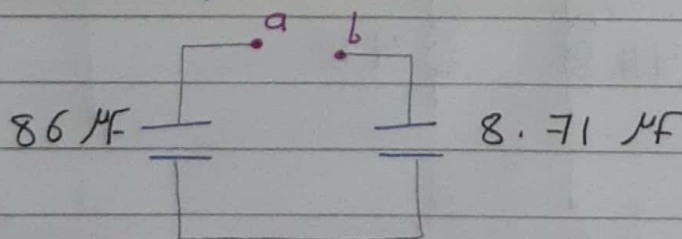
$$100 \text{ nF} \parallel 40 \text{ nF} \rightarrow 140 \text{ nF}$$

$$140 \text{ nF} \times 12 \text{ nF (series)} \rightarrow \frac{140 \times 12}{152} = 11 \text{ nF}$$

$$11 \text{ nF} \parallel 75 \text{ nF} \rightarrow 86 \text{ nF}$$

$$2 \mu\text{F} \times 12 \mu\text{F (series)} \rightarrow \frac{2 \times 12}{14} = \frac{12}{7} = 1.71 \mu\text{F}$$

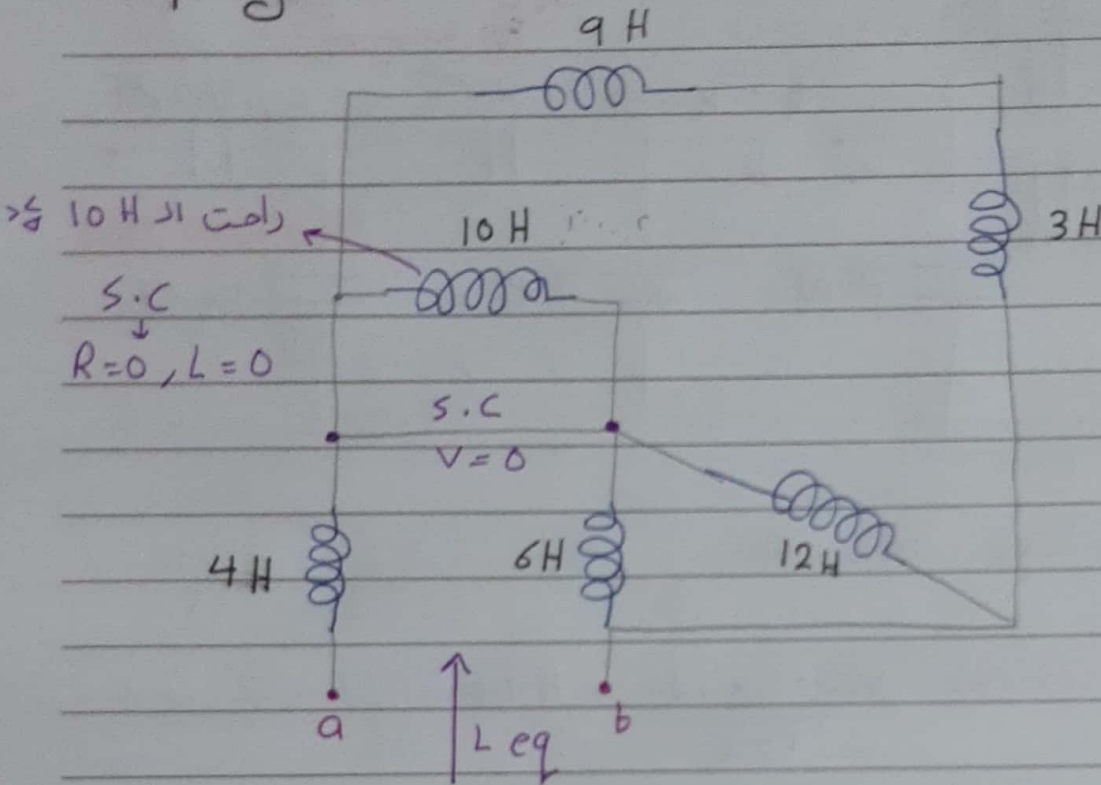
$$\frac{12}{7} \parallel 7 \rightarrow \frac{61}{7} \mu\text{F} = 8.71 \mu\text{F}$$



$$C_{eq} = \frac{86 \times 10^{-9} \times 8.71 \times 10^{-6}}{86 \times 10^{-9} + 8.71 \times 10^{-6}} = 85.2 \text{ nF}$$

# Example :-

Simplify



9H & 3H (series)  $\rightarrow$  12H

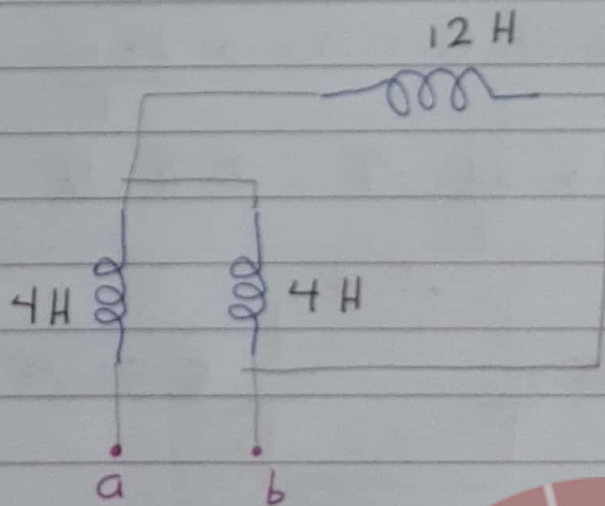
12H // 6H  $\rightarrow$  4H

12H // 4H  $\rightarrow$  3H

3H & 4H (serie)

↓

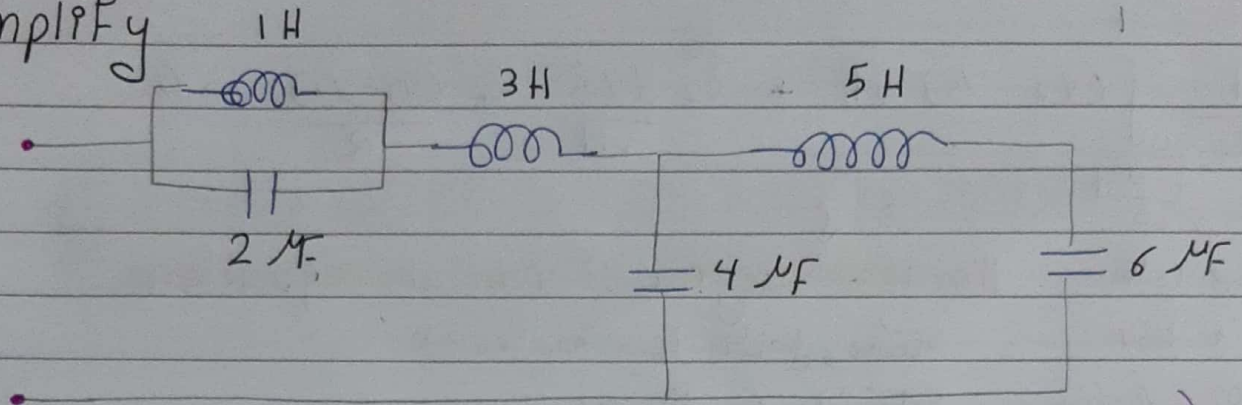
$$C_{eq} = 3H + 4H = 7H$$





# # Example :-

Simplify



ما بقدر آخذ ال 4 وال 6 توازي  
لأنو بينهم ال 5H

Can't be simplified  
till now ><

$$i_R = \frac{v}{R}$$

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

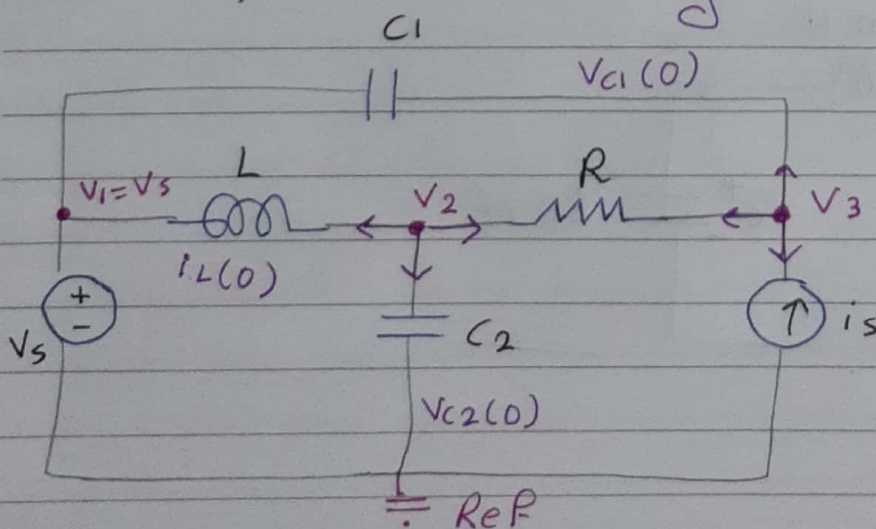
$$i_L = \frac{1}{L} \int_{-\infty}^t v dt$$

$$v_R = i_R R$$

$$v_C = \frac{1}{C} \int_{-\infty}^t i dt$$

$$v_L = L \frac{di}{dt}$$

# # Consequence of linearity :-



Nodal  $\rightarrow$  2 KCL  
mesh  $\rightarrow$  2 KVL



KCL at node  $V_2$  :-

$$\frac{1}{L} \int_0^t (V_2 - V_s) dt + C_2 \frac{dV_2}{dt} + \frac{(V_2 - V_3)}{R} = 0$$

لو شلت  $\infty$

هاي بخط بنهلي  
اكملانه

$$i_L(0) + V_{C2}(0)$$

linear - integrodifferential equation

له معادله فيها تكامل ومشتقة

وحد linear كل المشتقات

كل اكيود  $\nabla$

KCL at node  $V_3$  :-

$$\frac{(V_3 - V_2)}{R} - i_s + C_1 \frac{d(V_3 - V_s)}{dt} = 0$$

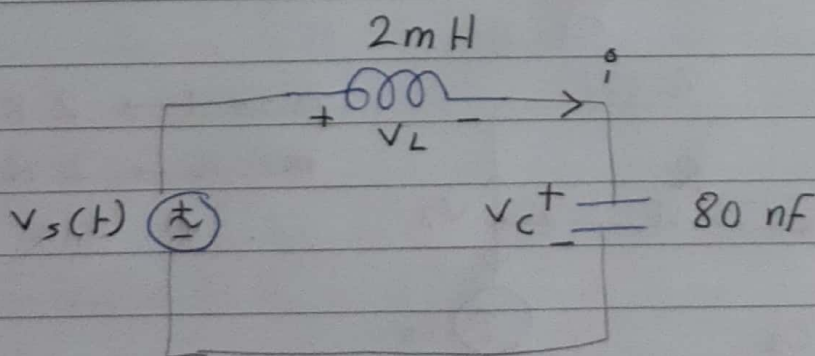
linear ordinary differential equation

له مشتق فيها تكامل  $\nabla$

# Example :-

$$\text{if } v_c(t) = 4 \cos 10^5 t \text{ (V)}$$

$$\text{find } v_s(t) = ?$$





$$\dot{i}_c = C \frac{dV_c}{dt} = 80 \times 10^{-9} \times (-4 \times 10^5) \sin 10^5 t$$

$$= -32 \sin 10^5 t \text{ mA}$$

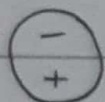
$$V_L = L \frac{di}{dt} = (2 \times 10^{-3}) (-32 \times 10^5 \times 10^{-3} \cos 10^5 t)$$

$$= -6.4 \cos 10^5 t \text{ V}$$

KVL :-

$$V_s(t) = V_L + V_C = -2.4 \cos 10^5 t \text{ V}$$

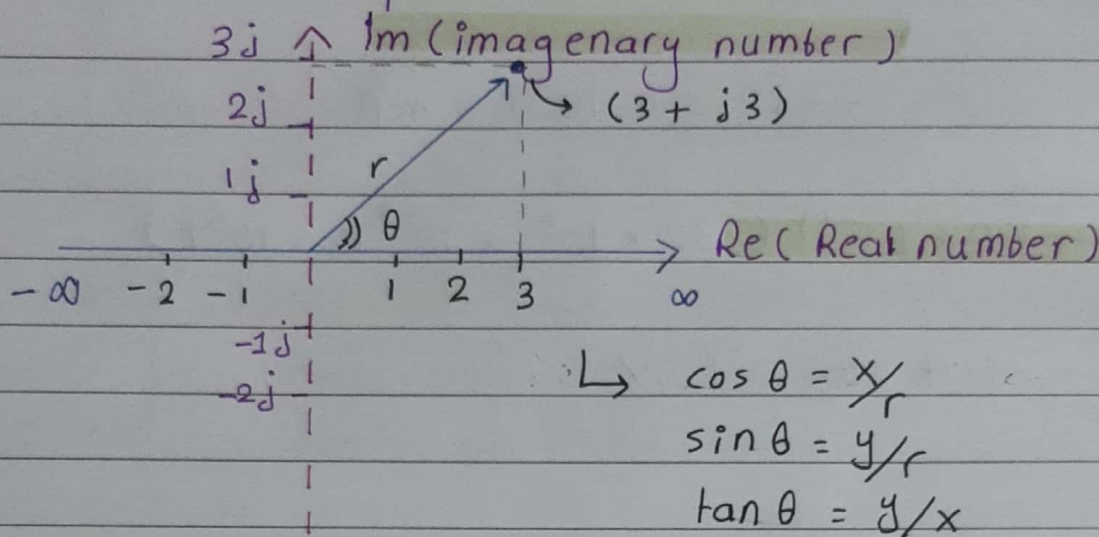
لـ سالبة يعني لازم



أعلى الأقطار



## # Review of complex Numbers :-



$j = \sqrt{-1} \equiv$  called imaginary operator

$$x = \sqrt{9} = \pm 3$$

$$x = \sqrt{-9} = \sqrt{-1} \sqrt{9} = \pm j3$$

1- Rectangular Form :-  $a \pm jb$  (complex no)  
 Re  $\rightarrow$   $a$   $\rightarrow$  Im  $\rightarrow$   $b$

2- Polar Form :-  $z = r \angle \theta$

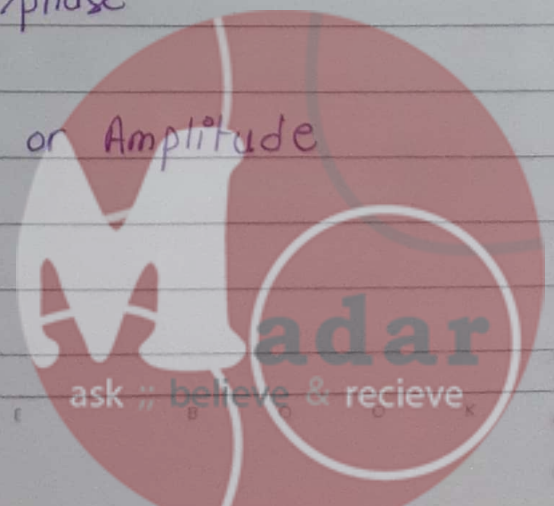
Rectangular  $\rightarrow$  Polar

$$z = x + jy \rightarrow z = r \angle \theta$$

$r$   $\rightarrow$  magnitude or Amplitude  
 $\theta$   $\rightarrow$  angle / phase

$$r = \sqrt{x^2 + y^2}$$

$$\theta = \tan^{-1}(y/x)$$





## Polar $\rightarrow$ Rectangular

$$Z = r \angle \theta \rightarrow Z = x + jy$$

$$x = r \cos \theta$$

$$y = r \sin \theta$$

$$\therefore Z = r \cos \theta + jr \sin \theta$$

## 3- exponential Form :

$$Z = r e^{j\theta}$$

للتحويل نستخدم نفس  
القوانين التي حكمنا عنهم  
فوق

## # Operations using complex no :-

$$Z_1 = a_1 + jb_1 \quad Z_2 = a_2 + jb_2$$

$$Z_1 + Z_2 = (a_1 + a_2) \boxed{+} j(b_1 + b_2)$$

$\hookrightarrow$  Real  $\quad \quad \quad \hookrightarrow$  imaginary

$$Z_1 - Z_2 = (a_1 - a_2) \boxed{+} j(b_1 - b_2)$$

$$Z_1 * Z_2 = (a_1 + jb_1) * (a_2 + jb_2)$$

$$= a_1 a_2 + ja_1 b_2 + ja_2 b_1 + j^2 b_1 b_2$$

$\hookrightarrow$  Real  $\quad \quad \quad \hookrightarrow$  imaginary  $\quad \quad \quad \hookrightarrow$  Real

$$= a_1 a_2 - b_1 b_2 + j(a_1 b_2 + a_2 b_1)$$

**\* Note :-**

$$j = \sqrt{-1}$$

$$j^2 = -1$$

$$j^3 = -j$$

$$j^4 = 1$$

\* لو بي اكل  $j^5$  يرجع  
أكر من عند ال  $j$  وهكذا

$$\frac{Z_1}{Z_2} = \frac{a_1 + jb_1}{a_2 + jb_2} \times \frac{a_2 - jb_2}{a_2 - jb_2}$$

\* complex conjugate  $\Rightarrow$

$$Z^* = a - jb$$

$$Z^* = r \angle -\theta$$

$$Z^* = r e^{-j\theta}$$

بمطابق  
إشارة  
Z

$$x = r \cos(-\theta) = r \cos \theta$$

$$y = r \sin(-\theta) = -r \sin \theta$$

$$= \frac{a_1 a_2 + b_1 b_2 - a_1 j b_2 + j b_1 a_2}{a_2^2 + b_2^2 + j 0}$$

$$\hookrightarrow j b_2 a_2 - j a_2 b_2 = 0$$

**\* Note :-**

$$(x + jy)(x - jy) = x^2 + y^2$$

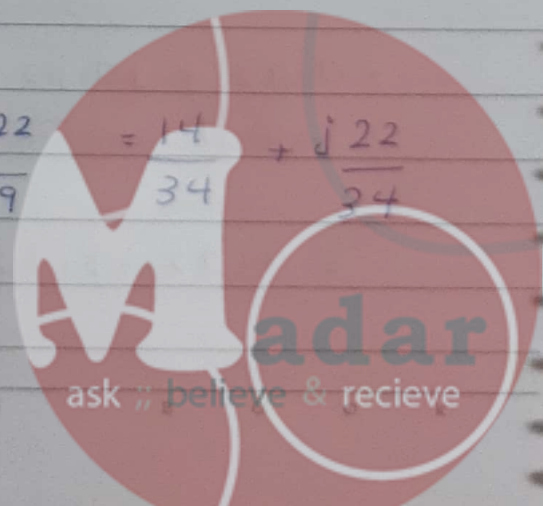
لما أضرب بالموافق

ميك يكون الجواب

**\* Example :-**

$$1) (4 + j2)(5 - j3) = (20 + 6) - j12 + j16 = 26 - j2$$

$$2) \frac{(4 + j2)}{(5 - j3)} \times \frac{(5 + j3)}{(5 + j3)} = \frac{20 - 6 + j22}{25 + 9} = \frac{14}{34} + j \frac{22}{34}$$





# Use polar or exponential form for multiplication, Division, Roots.

# Use Rectangular form for addition & subtraction.

in Polar form :-

$$Z_1 = r_1 \angle \theta_1 = r_1 e^{j\theta_1}$$

$$Z_2 = r_2 \angle \theta_2 = r_2 e^{j\theta_2}$$

$$Z_1 * Z_2 = r_1 r_2 \angle \theta_1 + \theta_2$$

$$\frac{Z_1}{Z_2} = \left( \frac{r_1}{r_2} \angle \theta_1 - \theta_2 \right) \rightsquigarrow \frac{r_1}{r_2} \cos(\theta_1 - \theta_2) + j \frac{r_1}{r_2} \sin(\theta_1 - \theta_2)$$

$$\sqrt{Z_1} = \sqrt{r_1} \angle \theta_1/2$$



## # Euler's Identity :-

$$\rightarrow r \angle \theta = r e^{j\theta} = r \cos \theta + j r \sin \theta \rightarrow (1)$$

$$\rightarrow r \angle -\theta = r e^{-j\theta} = r \cos \theta - j r \sin \theta \rightarrow (2)$$

$$\rightarrow \cos \theta = \frac{r e^{j\theta} + r e^{-j\theta}}{2r} \rightsquigarrow \cos \theta = \frac{e^{j\theta} + e^{-j\theta}}{2}$$

$$\rightarrow \sin \theta = \frac{r e^{j\theta} - r e^{-j\theta}}{2jr} \rightsquigarrow \sin \theta = \frac{e^{j\theta} - e^{-j\theta}}{2j}$$

$$e^{jn/2} = 1 \angle \pi/2 = 0 + j1 = j = \sqrt{-1} = 1 \angle 90^\circ *$$

$$e^{jn/4} = 1 \cos 45^\circ + j \sin 45^\circ = \frac{1}{\sqrt{2}} (1 + j)$$

## 4- instantaneous Form :- الصورة اللحظية

- ① always as a function of time. الد (t) وار (j) مستحيل
- ② No imaginary operator included in it. يلتفتوا

### Time Domain

→ Real

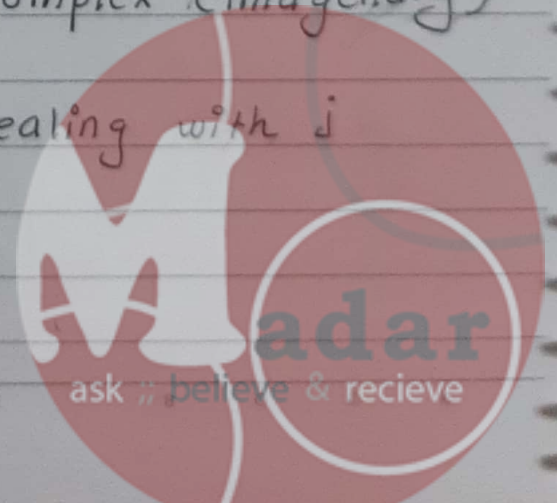
→ dealing with time

### Phasor domain ( $r \angle \theta$ )

complex (imaginary)

dealing with j

لأ لوبري استغل هون  
راح يكون عندي اشتاق  
وتكامل ١/4





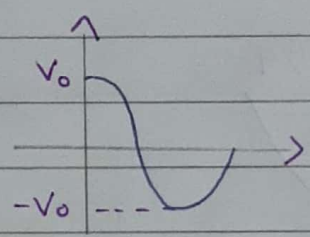
$V = 5 \cos 10t \rightarrow$  instantaneous Form

$\Rightarrow v(t) = V_o \cos(\omega t + \theta)$  (v)  $\rightarrow \bar{V}$  or  $V_s$  or  $V$   
 magnitude  $\downarrow$  phase  $\downarrow$  phasor.  
 or Amplitude argument

$V = V_o \angle \theta$   $\omega = ?!$  جنب  
 rect.

$v(t) = \text{Re}(V_o \cos(\theta + \omega t) + j V_o \sin(\theta + \omega t))$

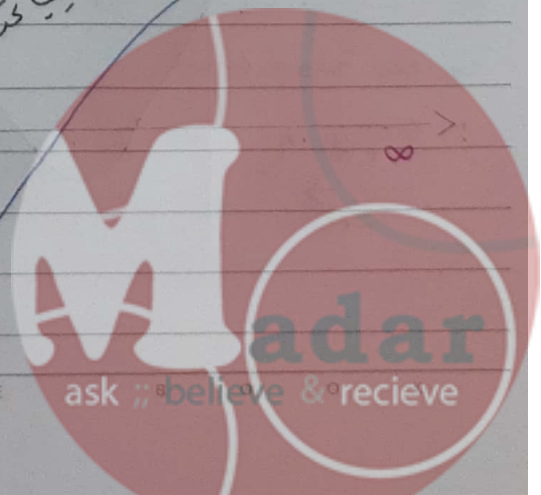
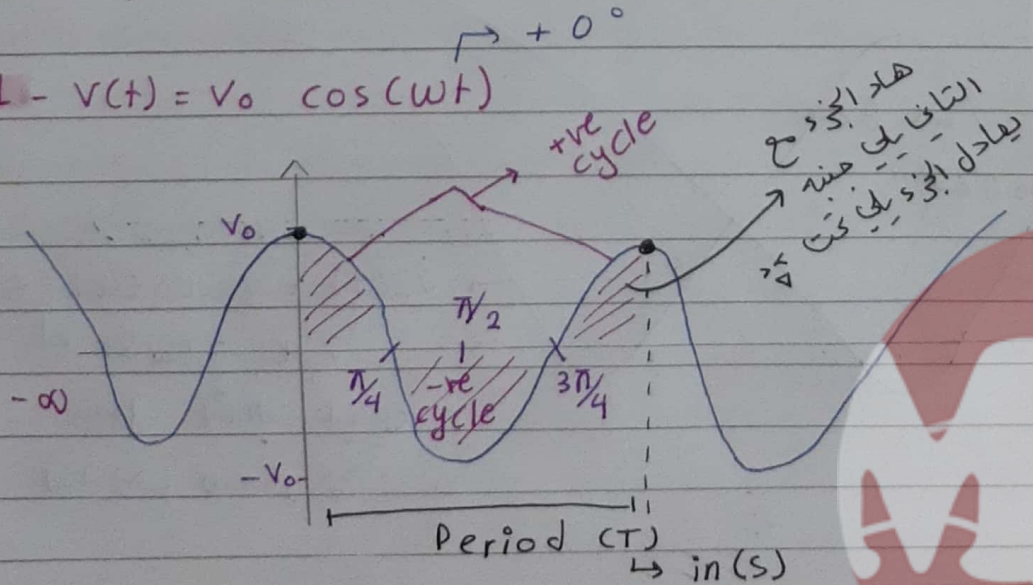
له يعني جوا  
 Real القوس  
 و Im وانا بي  
 استغل على انا  
 if  $\theta = 0$  بيلش من الصفر



$v(t) = V_o \cos(\omega t + \theta)$  (v)

Properties of sinusoidal Functions :-

1-  $v(t) = V_o \cos(\omega t)$



$$\omega = 2\pi f$$

angular  
Frequency

(rad/s)

سرعة الدوران

أو الإزاحة

Frequency ( $1/s$ ) or Hz

$$f = \frac{1}{T}$$

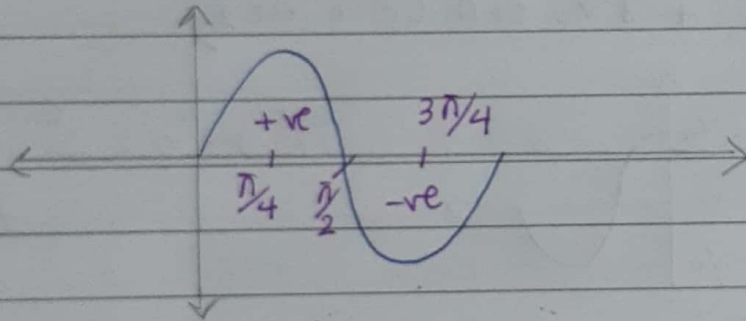
$$\omega = \frac{2\pi}{T}$$

$$f = 50 \text{ Hz} \quad T = \frac{1}{50} = 0.02 \rightarrow 20 \text{ ms}$$

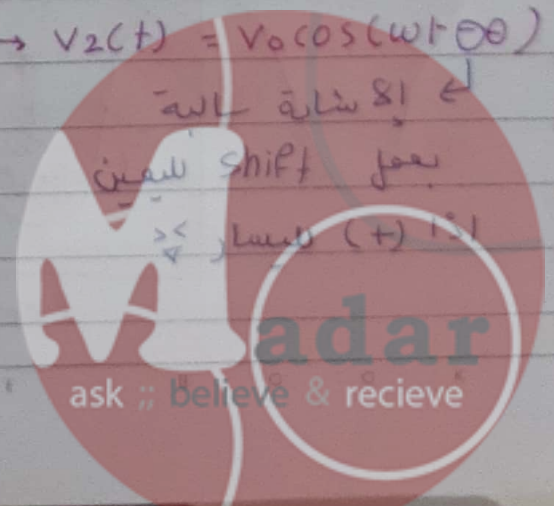
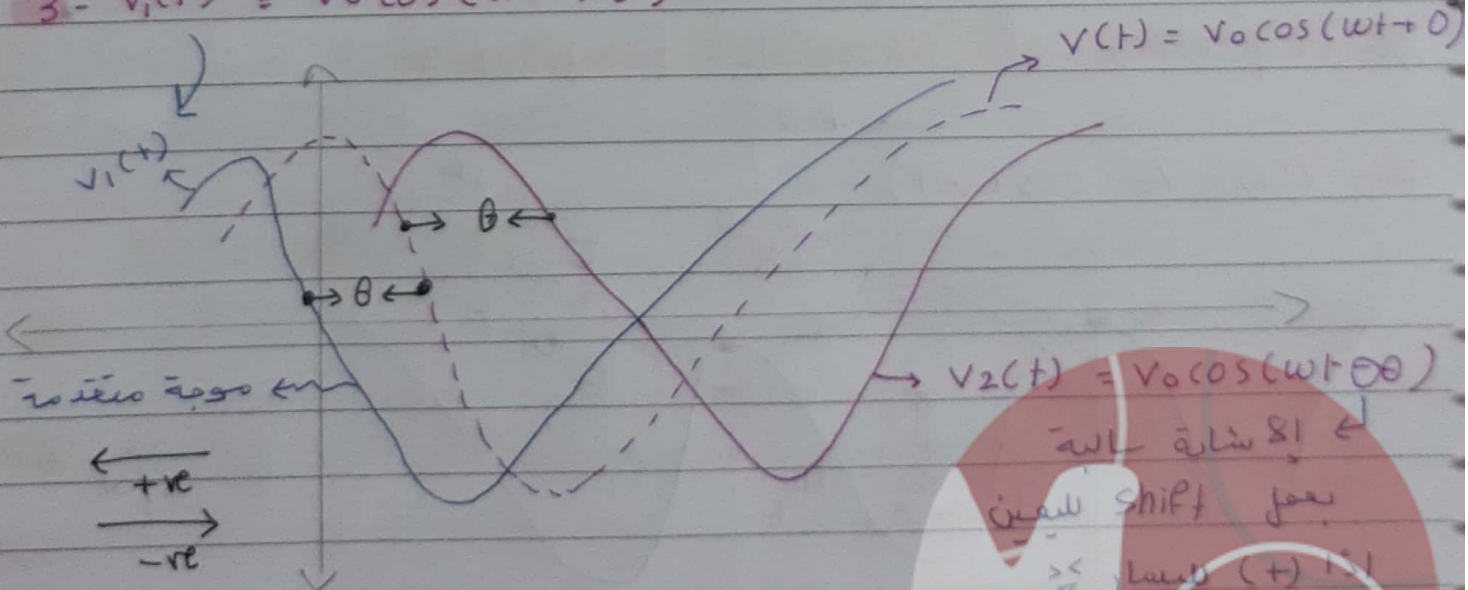
إذا بي  $f = 50$  كل 20 ms

راح أشف period مثل هاي

## 2- $\sin(\omega t)$



## 3- $v_1(t) = V_o \cos(\omega t + \theta)$





$v_1(t)$  leads  $v(t)$  by  $\theta$

$v(t)$  lags  $v_1(t)$  by  $\theta$

$v(t)$  leads  $v_2(t)$  by  $\theta$

$v_1(t)$  leads  $v_2$  by  $2\theta$

\* يعني واضح من الرسمة

ان  $v_1(t)$  متقدم على

$v(t)$  بمقدار  $\theta$

### # Example :

$$i_1(t) = I_{01} \cos(\omega t + 10^\circ)$$

$$i_2(t) = I_{02} \cos(\omega t + 30^\circ)$$

$i_2$  leads  $i_1$  by  $20^\circ$

في مقياس  $\theta$  له أكبر

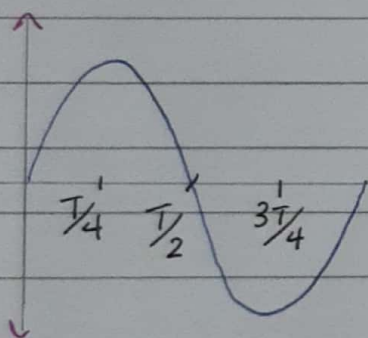
يكون هو  $i_2$  leads

\* العلاقة بين  $\sin$  و  $\cos$

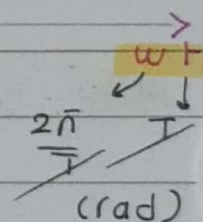
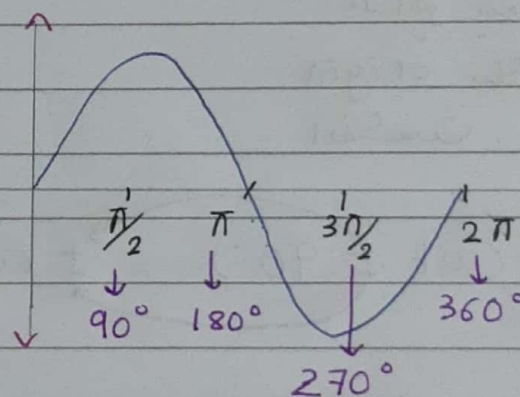
$\cos$   $90^\circ$  يعني  $\sin$  عوي على

$\cos$  ال

$\Rightarrow \sin(\omega t)$



> FCS <



$\sin \rightarrow \cos \rightarrow ? < ?$

$$1 - \sin(\omega t \pm 2\pi) = \sin \omega t$$

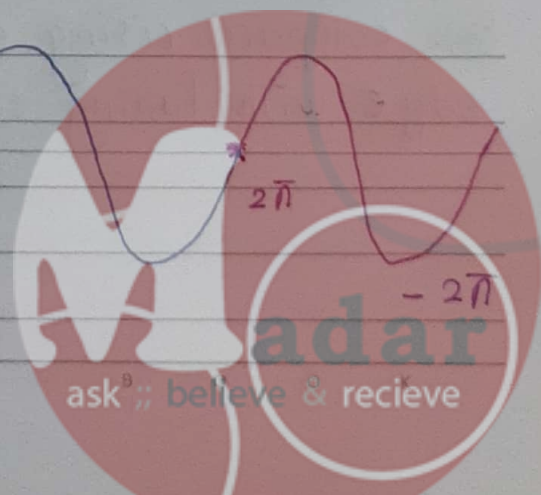
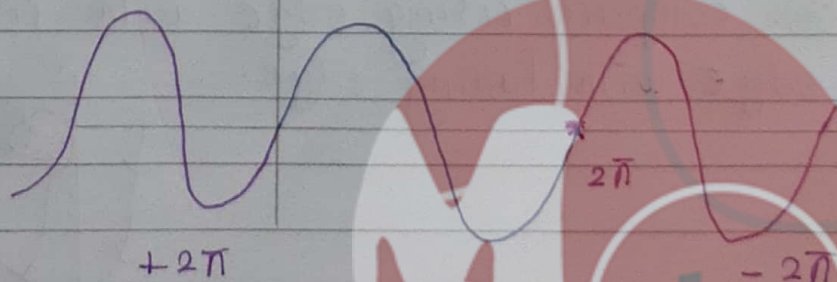
لأنه ليس  $\pi$  لأن نقطة  $0$

وال  $360$  هي وحدة

(سواء جوا القوس جمع

أو طرح دايمًا نفس

الكران)

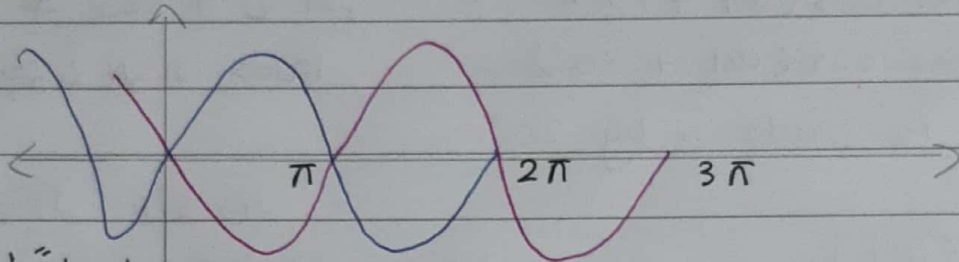


2-  $\cos(\omega t \pm 2\pi) = \cos \omega t$

$\cos(\omega t + 370^\circ) = \cos(\omega t + 10 + 360)$

3-  $\sin(\omega t \pm \pi) = -\sin \omega t$

$\cos(\omega t \pm \pi) = -\cos \omega t$



لـ دَائِعَا عَشَان أَثُوف  
التأثير يتفرد من ال  
origin نلاحظ السرعة  
انفكست.

4-  $\sin(\omega t \pm 90^\circ) = \pm \cos \omega t$

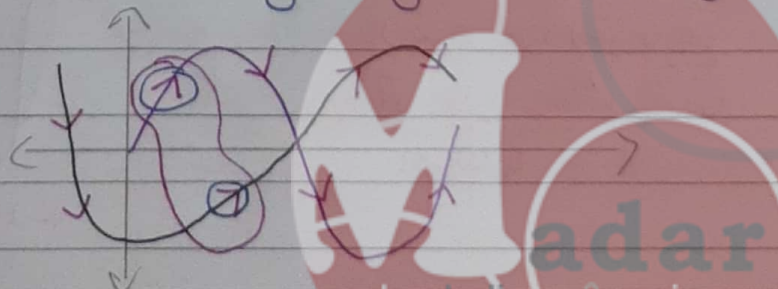
$\cos(\omega t \pm 90^\circ) = \mp \sin \omega t$

\* lead / lag :-

1- both are sin or both are cos .

2- both are +ve ampl. or both are -ve amplitude.

3- compare rising edge with rising edge & Falling edge with Falling edge.





# Example :-

$$\underline{v_1(t)} = \underline{v_{01} \sin(\omega t + 100)} \rightarrow v_{01} \cos(\omega t + 10)$$

$$\underline{v_2(t)} = \underline{v_{02} \cos(\omega t + 30^\circ)}$$

$v_2$  leads  $v_1$  by  $20^\circ$



## # The phasor :-

$$v(t) = V_m \cos(\omega t + \theta)$$

$$\bar{V} = V_m \angle \theta$$

→ های مبتدیه

cos. های کان

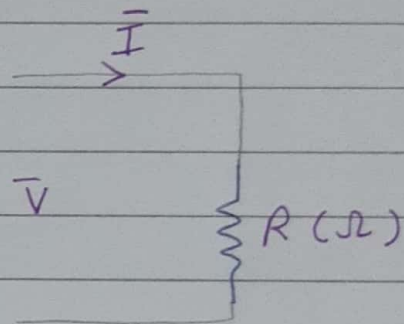
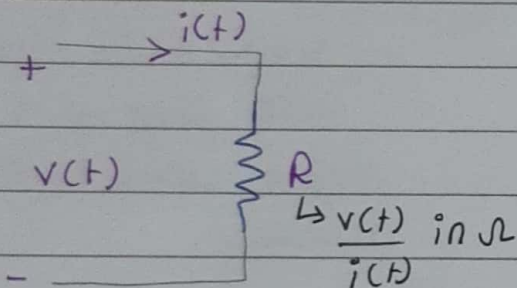
اما اذا sin دي

أصول cos بهمين الأعلى

$$i(t) = I_m \cos(\omega t + \phi)$$

$$\bar{I} = I_m \angle \phi$$

### ① Resistor :-



time domain

phasor (Frequency) domain

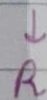
**\*\*\*** if  $i(t) = I_m \sin(\omega t + \phi) = I_m \cos(\omega t + \phi + 90^\circ)$   
 $\cos \downarrow \sin$  تحول ال  $\leftarrow \bar{I} = I_m \angle \phi + 90^\circ = j I_m \angle \phi$   
 بهمين تحول ال phasor

$$v(t) = i(t) R$$



$$V_m \angle \theta = I_m \angle \phi R$$

$$R = \frac{V_m \angle \theta}{I_m \angle \phi} = \frac{V_m \angle \theta - \phi}{I_m} = \frac{V_m \angle 0^\circ}{I_m} = \frac{V_m (1) + j V_m (0)}{I_m}$$



R

ask " believe & recieve

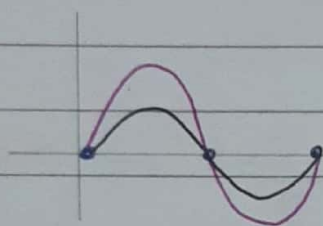


$$R = \bar{V} / \bar{I}$$

→  $\bar{V}$  is in-phase with  $\bar{I}$

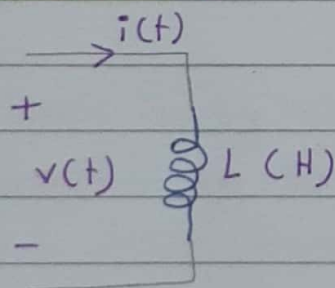


→ across a resistor always the voltage & current must have the same phase ( $\theta = \phi$ )



النهاية والبداية نفسها بس  
المagnitude عادي  
ممكن يختلف (هاد الكلي بس على  
Resistor)

## ② Inductor :-



Time domain

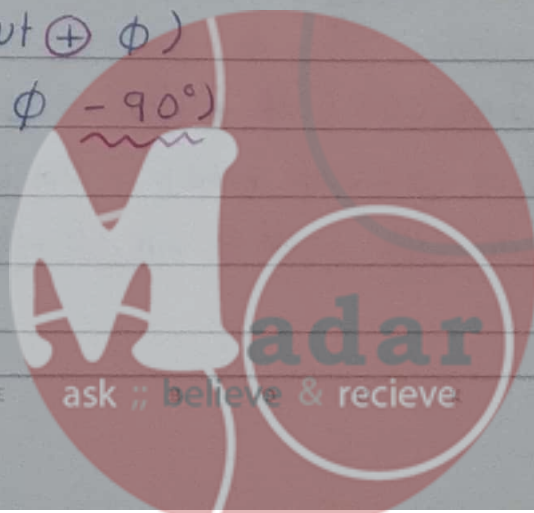
$$v(t) = L \frac{di(t)}{dt}$$

إذا بي أخلى السالب  
وأخلى الـ  
الوجب يعني  $-90^\circ$

$$V_m \cos(\omega t + \theta) = -L I_m \omega \sin(\omega t + \phi)$$

$$V_m \cos(\omega t + \theta) = -I_m L \omega \cos(\omega t + \phi - 90^\circ)$$

$$V_m \angle \theta = -I_m \omega L \angle \phi + 90^\circ$$



Or

$$V_m \cos(\omega t + \theta) = I_m \omega L \cos(\omega t + \phi + 90^\circ)$$

$$V_m \angle \theta = I_m \omega L \angle \phi - 90^\circ + 180^\circ$$

$$V_m \angle \theta = \omega L I_m \angle \phi + 90^\circ$$

$$V_m \angle \theta = j \omega L I_m \angle \phi$$

$$\bar{V} = (j \omega L) \bar{I} \rightarrow \text{Frequency domain}$$

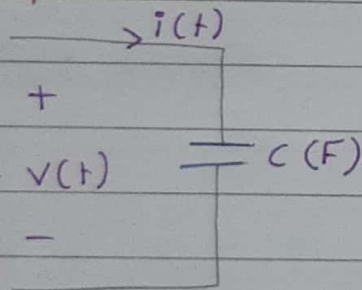
(↓)

Note :-

$$1 \angle 90^\circ = 0 + j(1)$$

$$1 \angle -90^\circ = 0 - j(1)$$

③ Capacitor :-



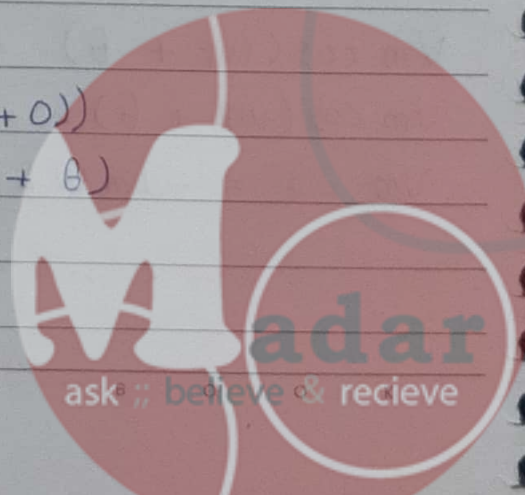
time domain

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

$$I_m \cos(\omega t + \phi) = C (-V_m \omega \sin(\omega t + \theta))$$

$$I_m \cos(\omega t + 90) = V_m \omega C \cos(\omega t + 90^\circ + \theta)$$

$$I_m \angle \phi = \omega C V_m \angle \theta + 90^\circ$$





$$\bar{I} = j\omega C \bar{V}$$

$$\frac{\bar{V}}{\bar{I}} = \frac{1}{j\omega C} \rightarrow \bar{V} = \left( \frac{1}{j\omega C} \right) \bar{I} = \frac{1}{\omega C} \bar{I} \angle -90^\circ$$

$\hookrightarrow (\Omega)$

Note :-

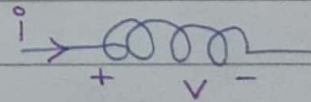
$$\frac{1}{j} = -j \rightarrow \frac{1}{\angle 90^\circ} = \frac{1}{\angle 90^\circ} = -j$$

Resistor  $\rightarrow R = \frac{\bar{V}}{\bar{I}}$  ,  $\bar{V}$  &  $\bar{I}$  are in-phase

Inductor  $\rightarrow j\omega L = \frac{\bar{V}}{\bar{I}}$  ,  $\omega L = \frac{\bar{V}}{\bar{I}} = \frac{\bar{V}}{\bar{I}} \angle 90^\circ = \frac{\bar{V}}{\bar{I}} \angle -90^\circ$

$$\Rightarrow \bar{I} = \frac{\bar{V}}{\omega L} \angle -90^\circ$$

$\bar{V}$  leads  $\bar{I}$  by  $90^\circ$   
 $\bar{I}$  lags  $\bar{V}$  by  $90^\circ$

$\bar{I} \rightarrow$    $\rightarrow \omega L = \frac{1}{2} L i^2$

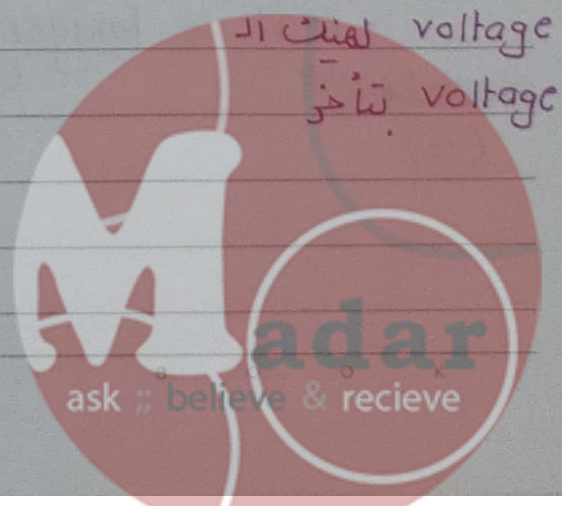
لـ الـ L بخزن يـتـار يـتـار  
 يـتـار الـ يـتـار جـوـاـة لـتـا يـتـار  
 لـهـك الـ I يـتـار

Capacitor  $\rightarrow \frac{1}{j\omega C} = \frac{\bar{V}}{\bar{I}}$  ,  $\bar{V}$  lags  $\bar{I}$  by  $90^\circ$   
 $\bar{I}$  leads  $\bar{V}$  by  $90^\circ$

\* الـ C بخزن

voltage لـهـك الـ

voltage يـتـار



# # Impedance (Z) :-

→  $\omega$  is frequency

Frequency domain

$$R \rightarrow Z_R = R \text{ in } (\Omega)$$

$$L \rightarrow Z_L = j\omega L = jX_L \text{ in } (\Omega)$$

$$C \rightarrow Z_C = \frac{1}{j\omega C} = -jX_C \text{ in } (\Omega)$$

$$X_L = \omega L \rightarrow \text{Reactance}$$

$$X_C = \frac{1}{\omega C}$$

Z = real + Imaginary

Resistor

Reactance

$$\text{if } \text{Im} = 0 \quad Z \rightarrow R$$

$$\text{if } \text{real} = 0 \quad Z \rightarrow \begin{matrix} Z_L \\ Z_C \end{matrix}$$

$$\frac{1}{Z} = Y$$

→ Admittance ( $\frac{1}{\Omega}$  or  $\Omega^{-1}$  or S or mho)

= real + Imaginary

conductance

(G)

susceptance

(B)





$$Z = R \pm jX \rightarrow R + jX_L$$

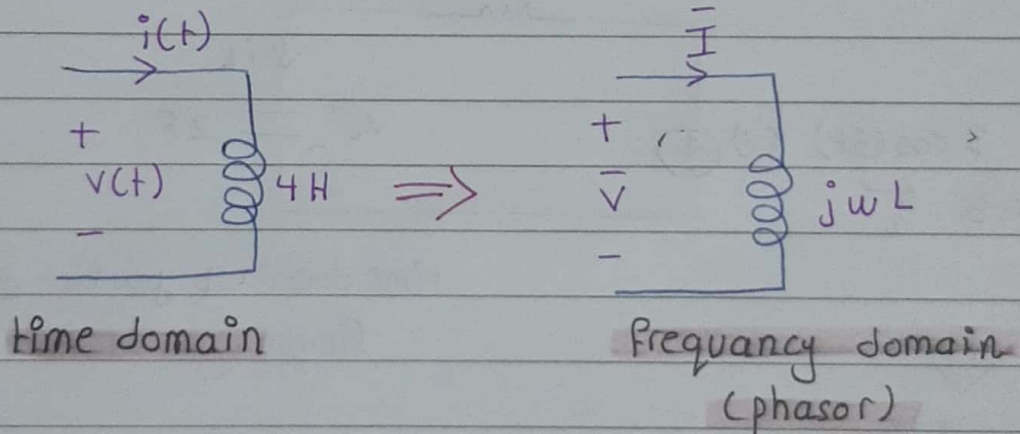
$$\text{or } R - jX_C$$

$$Y = G \pm jB \rightarrow B_L = \frac{1}{jX_L} = \frac{-j}{\omega L}$$

$$B_C = \frac{-j}{X_C} = j\omega C$$

### # Example :

Apply the voltage  $8 \angle -50^\circ \text{ V}$  at  $\omega = 100 \text{ rad/s}$  to a  $4 \text{ H}$  inductor & determine the current in time & phasor domain :-



← الأسهل بها > الوال نبليش بالـ phasor

Frequency domain  $\Rightarrow$

$$\bar{V} = j\omega L \bar{I}$$

$$\bar{I} = \frac{\bar{V}}{j\omega L} = \frac{8 \angle -50^\circ}{\frac{400 \angle 90^\circ}{400}} = \frac{8}{400} \angle -50^\circ - 90^\circ = 0.02 \angle -140^\circ \text{ (A)}$$

time domain  $\Rightarrow$

$$i(t) = 0.02 \cos(100t - 140^\circ) \text{ (A)}$$

الأميل في التحويل  $\rightarrow \omega$   
cos



$$v(t) = 8 \cos(100t - 50^\circ) \text{ (V)}$$

طريقة ثانية للحل  
بناشئ ايها >

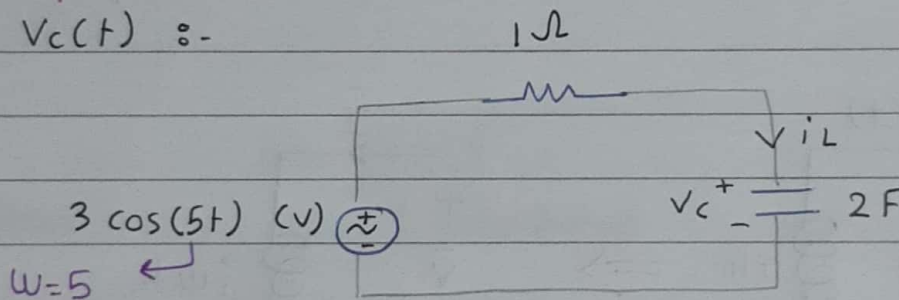
$$i(t) = \frac{1}{L} \int v(t) dt$$

$$= \frac{1}{4} \times \frac{8}{100} \sin(100t - 50^\circ) \Big|_{-\infty}^t$$

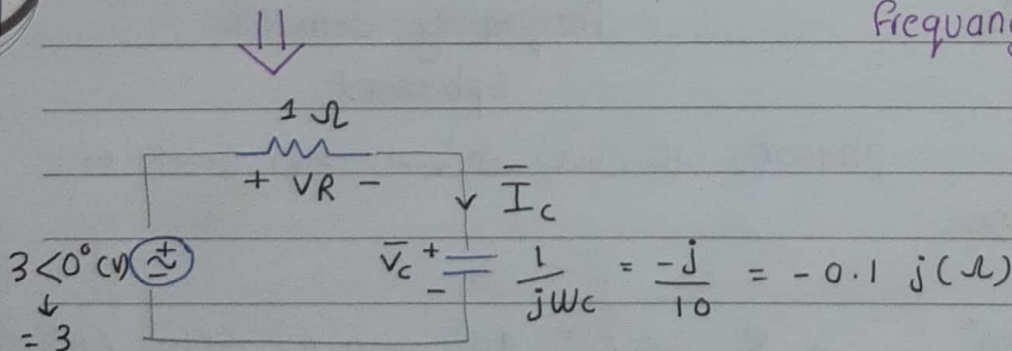
$$= \frac{8}{400} \cos(100t - 50^\circ - 90^\circ) \text{ (A)}$$

### # Example :-

find  $v_c(t)$  :-



هنا السؤال ما ينحل بال Time domain  
بنا نحوله ل Frequency domain



VDR :-

$$\bar{v}_c = 3 \angle 0^\circ \times \frac{0.1 \angle -90^\circ}{1 - j0.1} = \frac{3(0.1) \angle -90^\circ}{\sqrt{1.01} \angle \tan^{-1}(-0.1)}$$

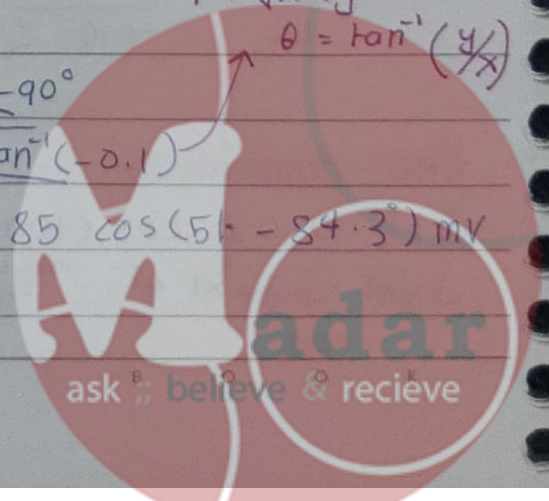
$$v_c = 29.85 \angle -84.3^\circ \text{ mV}$$

$$v_c(t) = 29.85 \cos(5t - 84.3^\circ) \text{ mV}$$

$$x + jy = r \angle \theta$$

$$r = \sqrt{x^2 + y^2}$$

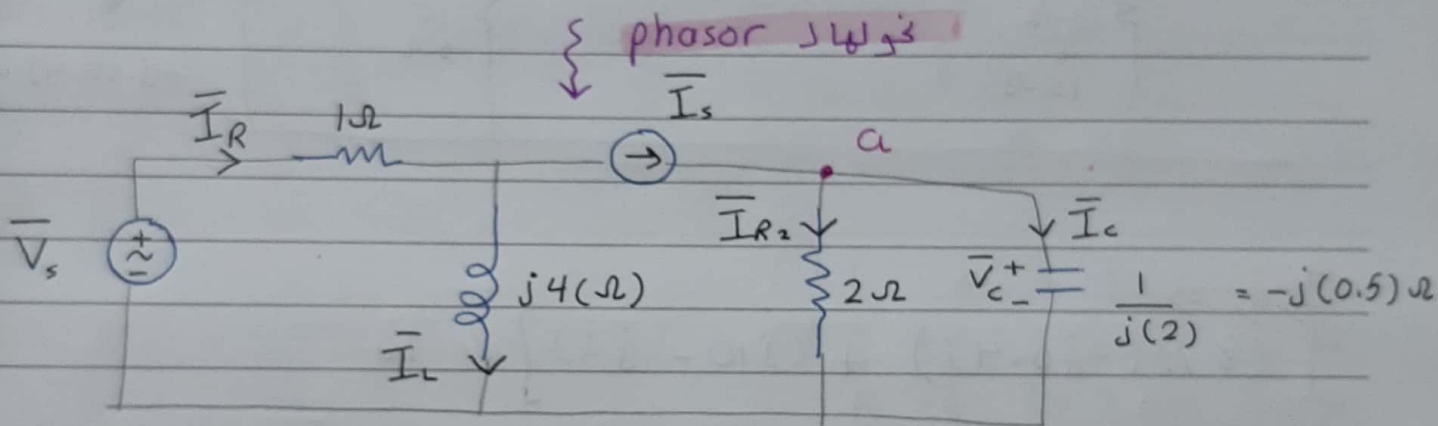
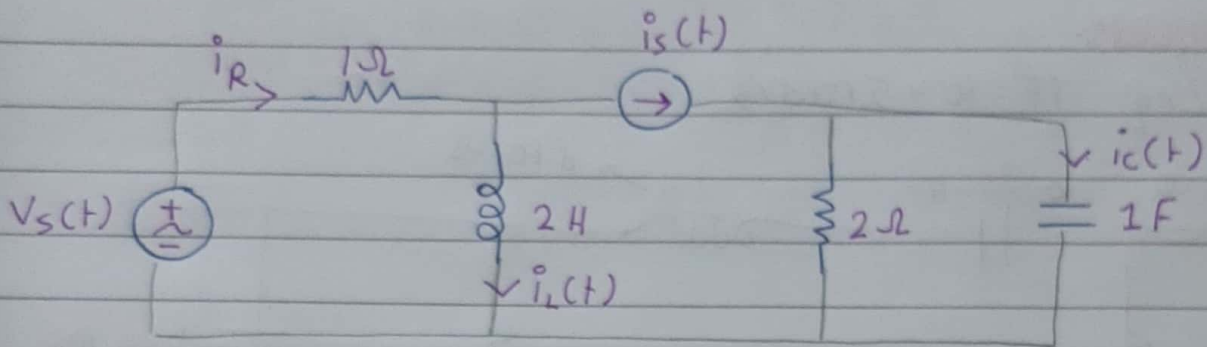
$$\theta = \tan^{-1}(y/x)$$





### # Example :

Find  $\bar{I}_s$  &  $i_s(t)$  if  $\omega = 2 \text{ rad/s}$  &  $\bar{I}_c = 2 \angle 28^\circ \text{ A}$  :-



$$\bar{V}_c = -j(0.5) \bar{I}_c$$

$$= 0.5 \angle -90^\circ \times 2 \angle 28^\circ = 1 \angle -62^\circ \text{ V}$$

$$\bar{I}_{R2} = \frac{1 \angle -62^\circ}{2 \angle 0^\circ} = 0.5 \angle -62^\circ$$

$\bar{V}$  &  $\bar{I}$  are in-phase across R

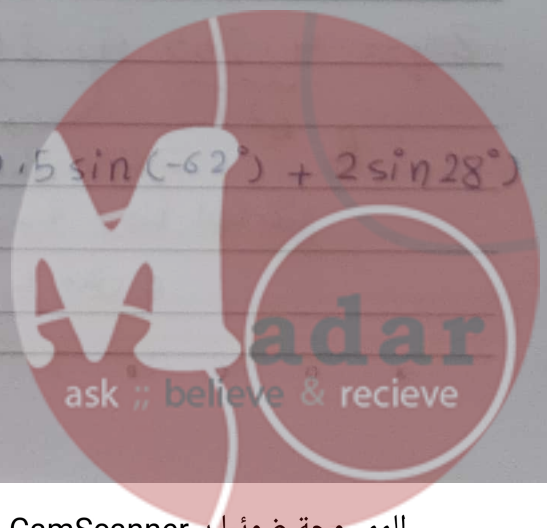
KCL at node (a) :-

$$\bar{I}_s = \bar{I}_R + \bar{I}_c$$

$$= 0.5 \angle -62^\circ + 2 \angle 28^\circ$$

$$= 0.5 \cos(-62^\circ) + 2 \cos(28^\circ) + j(0.5 \sin(-62^\circ) + 2 \sin 28^\circ)$$

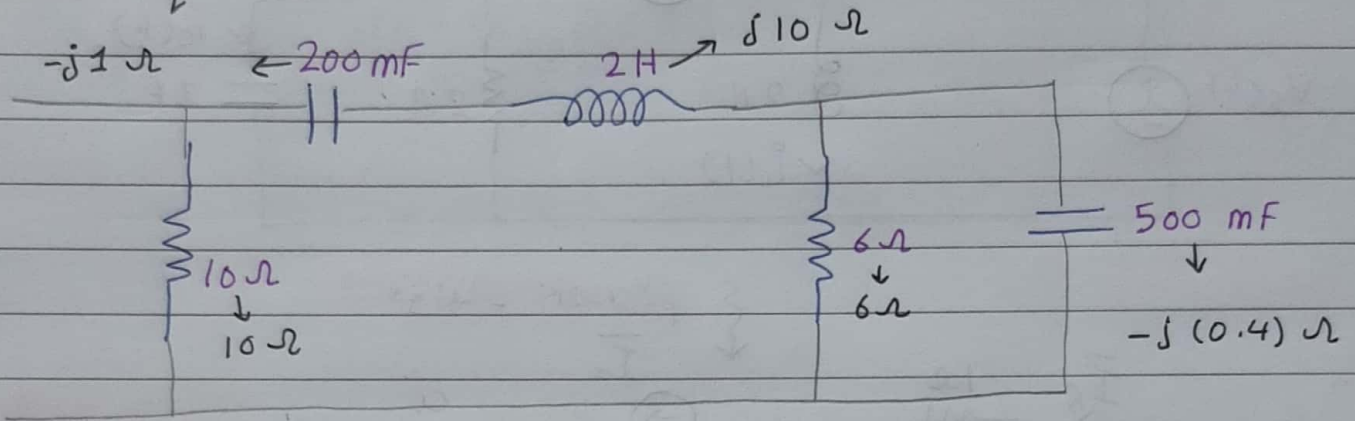
$$= 2.24 \angle 1.53^\circ$$



$$i_s(t) = 2.24 \cos(2t + 1.53)$$

### # Example :-

Find  $Z_{eq}$  if  $\omega = 5 \text{ rad/s}$



$Z_{eq} \Rightarrow$

$$\left[ (6 \parallel (-j0.4)) + (j10 - j1) \right] \parallel 10$$

$$= \frac{6 * (-j0.4)}{6 - j0.4} = \frac{6 \angle 0^\circ * 0.4 \angle -90^\circ}{\sqrt{36 + 0.4^2} \angle \tan^{-1}(-0.4/6)}$$

$$= 0.027 - j0.398 + j9$$

$$= 0.027 + j8.602$$

$$Z_{eq} = 4.255 \angle (+) j(4.929) \Omega$$

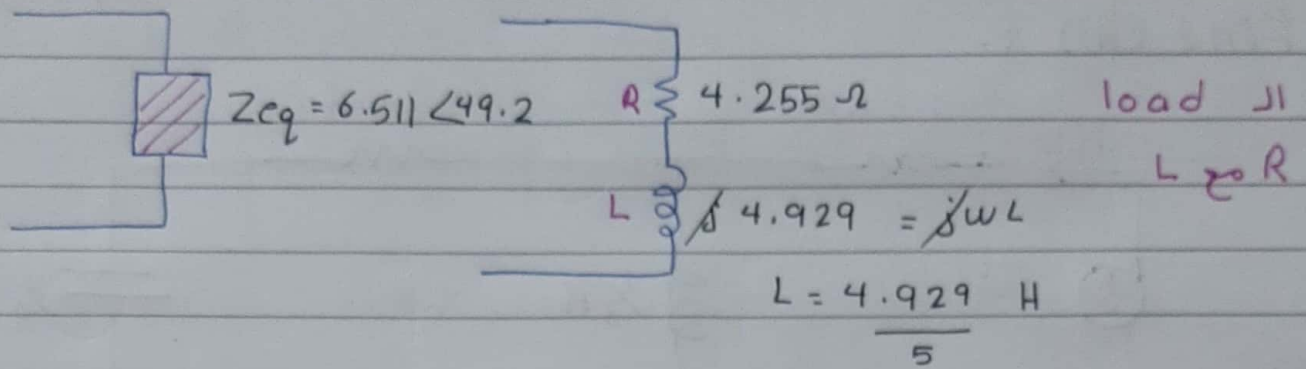
$R \leftarrow$   $L \rightarrow$   
عشان الإشارة موجبة عرفنا انها نقلت  
L مش C

Inductance load

$$= 6.511 \angle 49.2^\circ$$

الزاوية بين الـ 90 والـ 0  
يعني ما عندي pure R عندي  
فيليت C, L ولأن الزاوية موجبة  
يا هو المستطيل





\* Notes :-

$$R = \frac{V \angle ?}{I \angle ?} = \frac{V}{I} \angle ? - ? = \frac{V}{I} \angle 0^\circ$$

إعنا R زاويتها 0

$$L = j\omega L = \omega L \angle 90^\circ$$

$$C = \frac{1}{j\omega C} = \frac{1}{\omega C} \angle -90^\circ$$

\* إذا الزاوية + R & L

\* إذا الزاوية - R & C

\* إذا الزاوية 0 R  
pure resistance

$$V = RI \rightarrow V = RI \angle 0^\circ$$

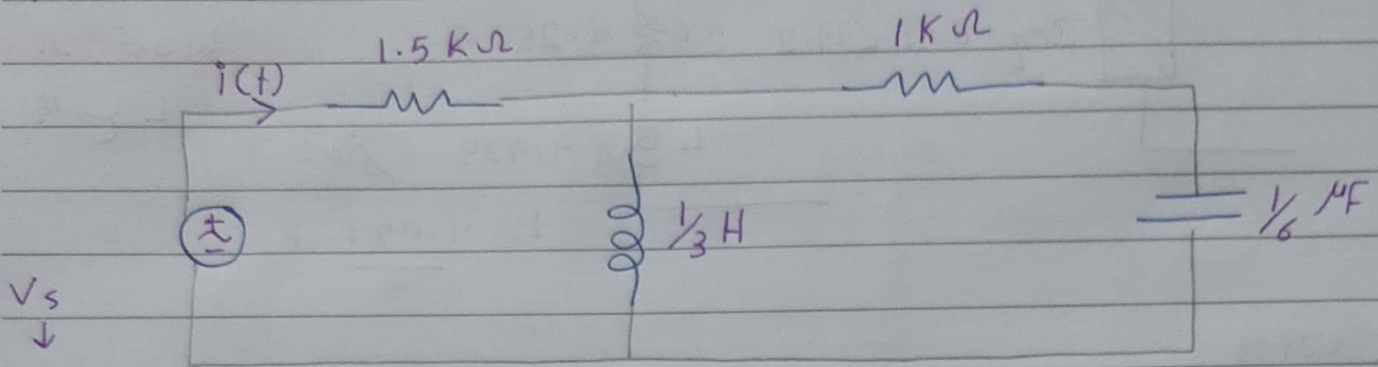
$$V = j\omega L I \rightarrow V = \omega L I \angle 90^\circ$$

$$V = \frac{1}{j\omega C} I \rightarrow V = \frac{1}{\omega C} I \angle -90^\circ$$



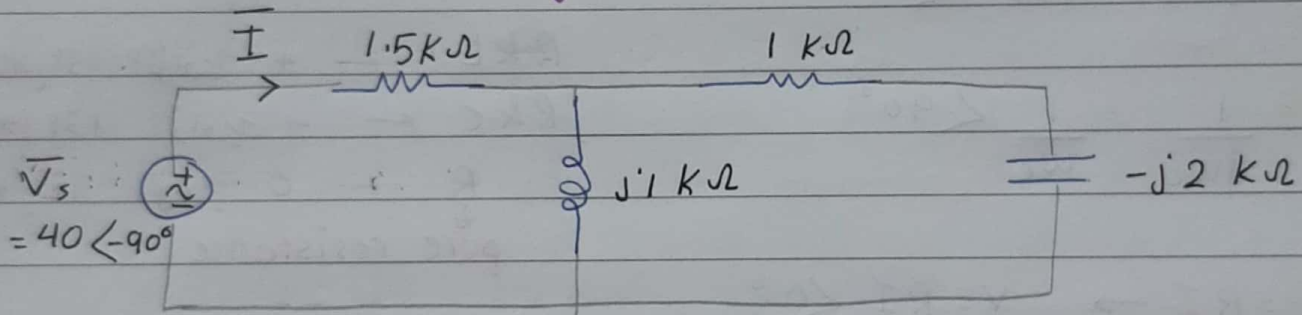
### # Example :

Find  $i(t)$  :-



$$= 40 \sin 3000t \rightarrow 40 \cos(3000t - 90^\circ)$$

phasor

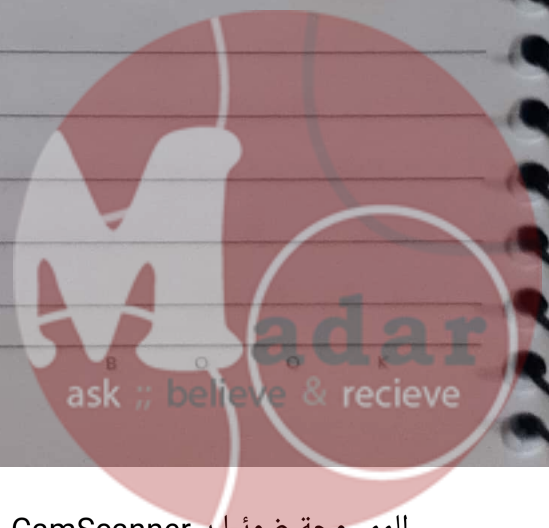


$$\bar{I} = \frac{\bar{V}}{\bar{Z}_{eq}}, \quad \bar{Z}_{eq} = [(1 - 2j)k \parallel j1k] + 1.5k\Omega$$

$$= 2.5 \angle 36.87^\circ k\Omega$$

$$\bar{I} = 16 \angle -126.9^\circ \text{ mA}$$

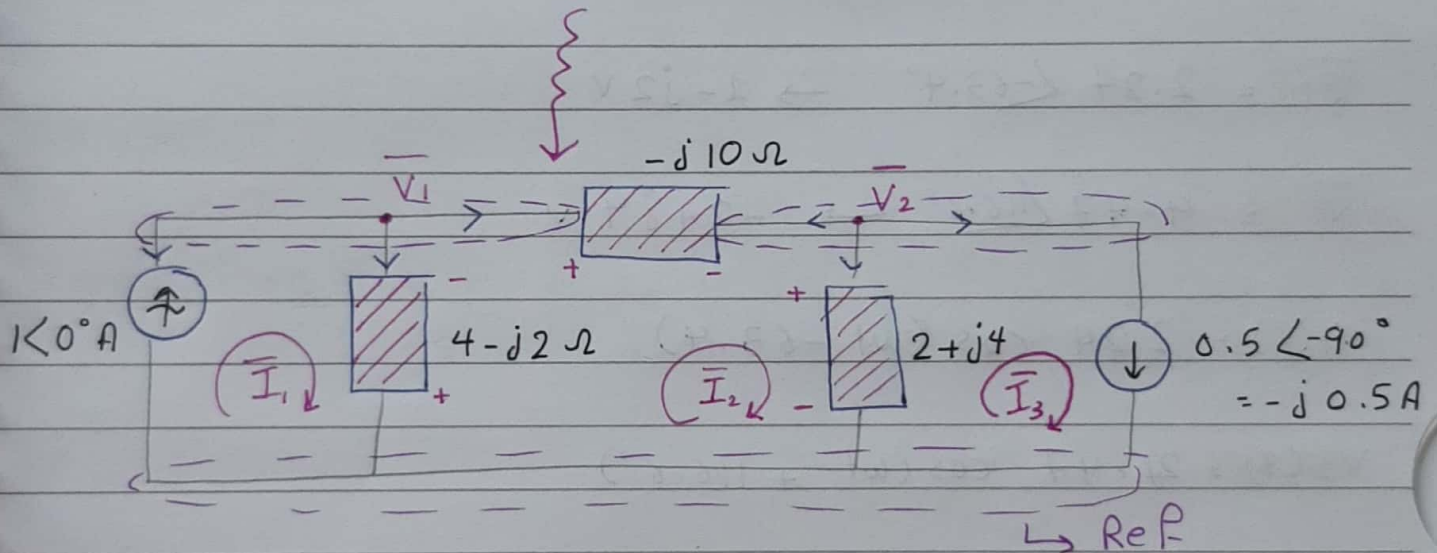
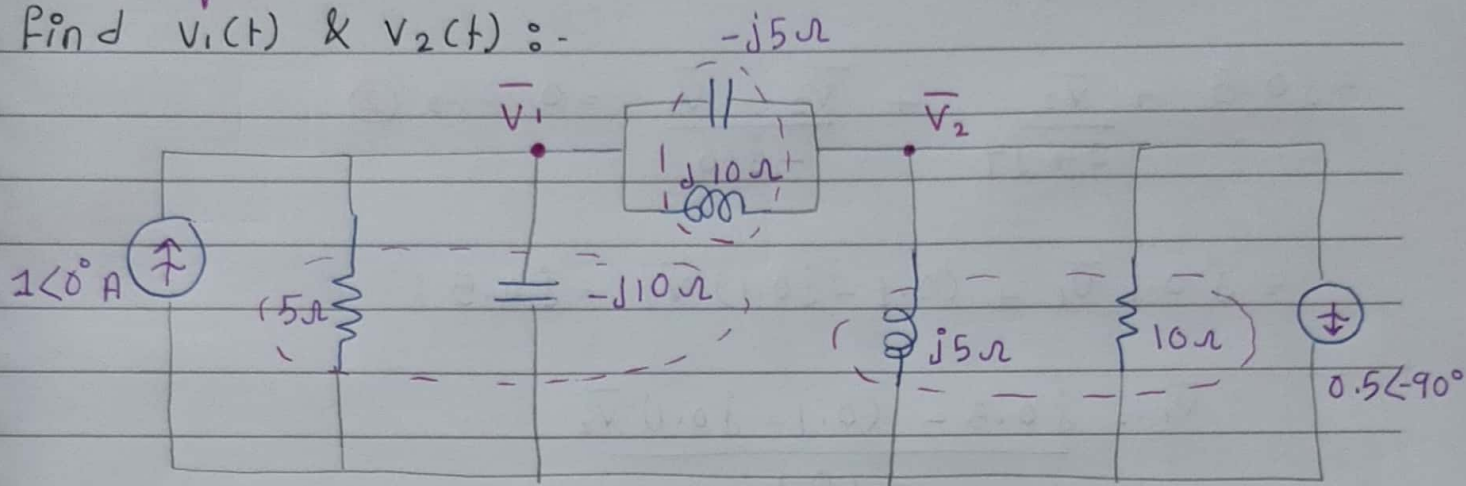
$$i(t) = 16 \cos(3000t - 126.9^\circ) \text{ mA}$$





### # Example :-

Find  $V_1(t)$  &  $V_2(t)$  :-



### ① Nodal :-

Kcl at  $\bar{V}_1 \Rightarrow$

$$-1 + \frac{\bar{V}_1 - 0}{4 - j2} + \frac{\bar{V}_1 - \bar{V}_2}{-j10} = 0 \rightarrow \textcircled{1}$$

$$(0.2 + j0.2) \bar{V}_1 - j0.1 \bar{V}_2 = 1$$

Kcl at  $\bar{V}_2 \Rightarrow$

$$-j0.5 + \frac{\bar{V}_2}{2+j4} + \frac{\bar{V}_2 - \bar{V}_1}{-j10} = 0 \rightarrow (2)$$

$$= j0.1 \bar{V}_1 + (0.1 - j0.1) \bar{V}_2 = j0.5$$

$$\bar{V}_1 = \frac{j0.5 - (0.1 - j0.1) \bar{V}_2}{-j0.1}$$

$$\bar{V}_1 = 2.24 \angle -63.4^\circ \rightarrow 1 - j2 \text{ V}$$

$$\bar{V}_2 = 4.47 \angle 116.6^\circ \rightarrow -2 + j4 \text{ V}$$

$$v_1(t) = 2.24 \cos(\omega t - 63.4)$$

$$v_2(t) = 4.47 \cos(\omega t + 116.6^\circ)$$

② mesh :-

Kcl at the middle mesh  $\Rightarrow$

$$(4 - j2)(\bar{I}_2 - \bar{I}_1) - j10 \bar{I}_2 + (2 + j4)(\bar{I}_2 - \bar{I}_3) = 0$$

$$(4 - j2)\bar{I}_1 + \bar{I}_2 (4 - j2 - j10 + 2 + j4) - (2 + j4)\bar{I}_3 = 0$$

$$\rightarrow 6 - j8$$

$$\bar{I}_1 = 1 \text{ A}$$

$$\bar{I}_3 = -j0.5 \text{ A}$$

$$\bar{I}_2 = 0.6 + 0.3j$$

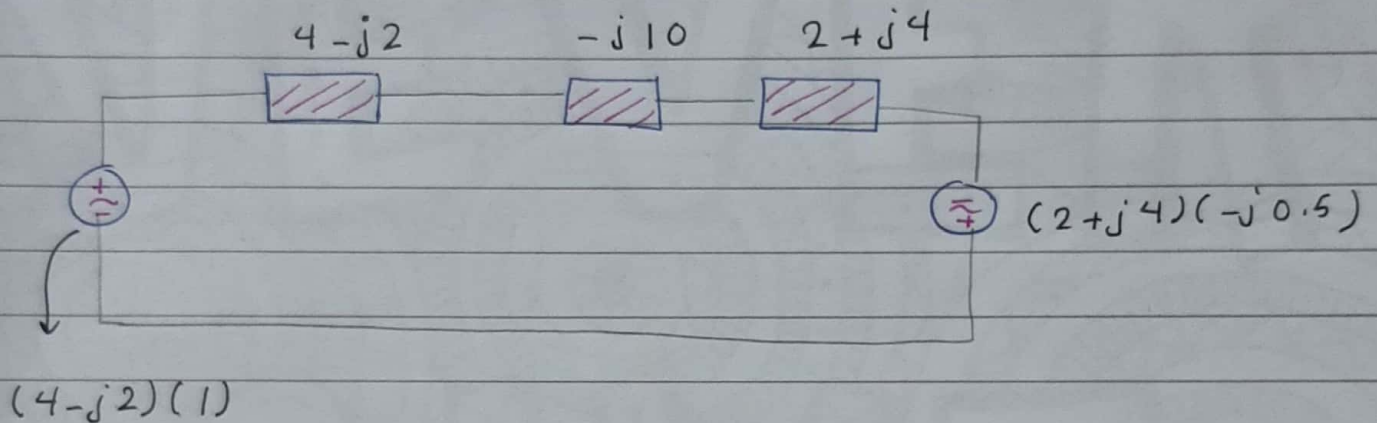


$$\bar{V}_1 = (\bar{I}_1 - \bar{I}_2)(4 - j2)$$

$$\bar{V}_2 = (\bar{I}_2 - \bar{I}_3)(2 + j4)$$

$$\bar{V}_1 - \bar{V}_2 = -j0.1 \bar{I}_2$$

3.5.T :-



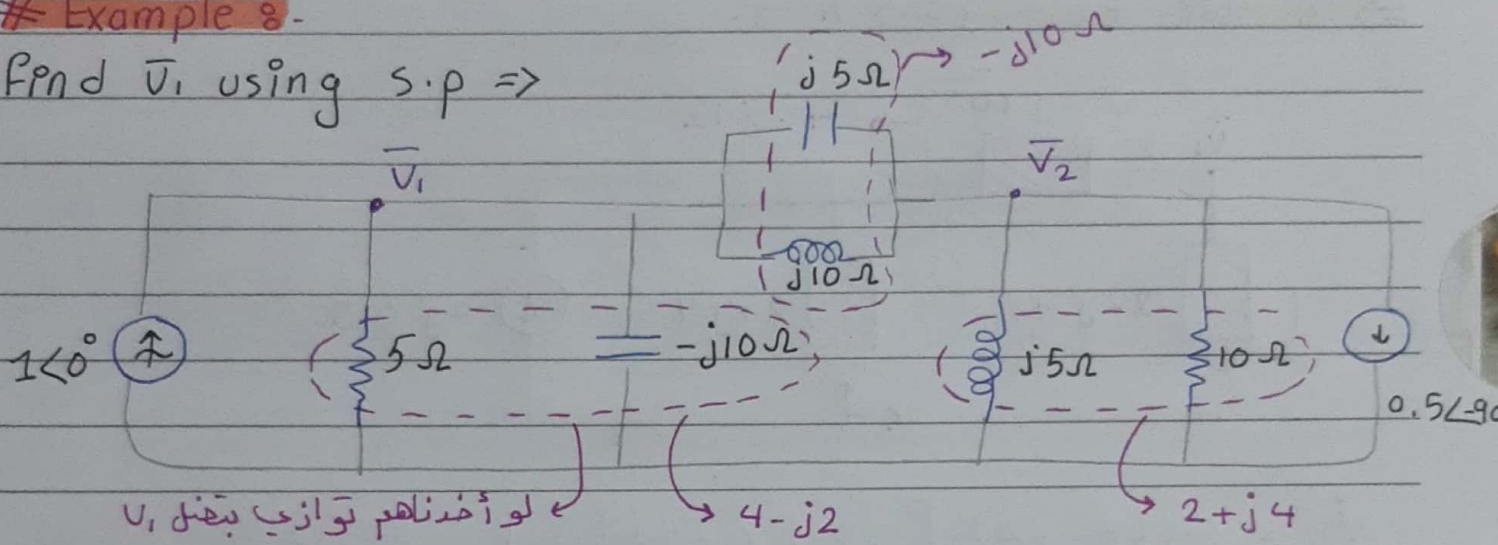
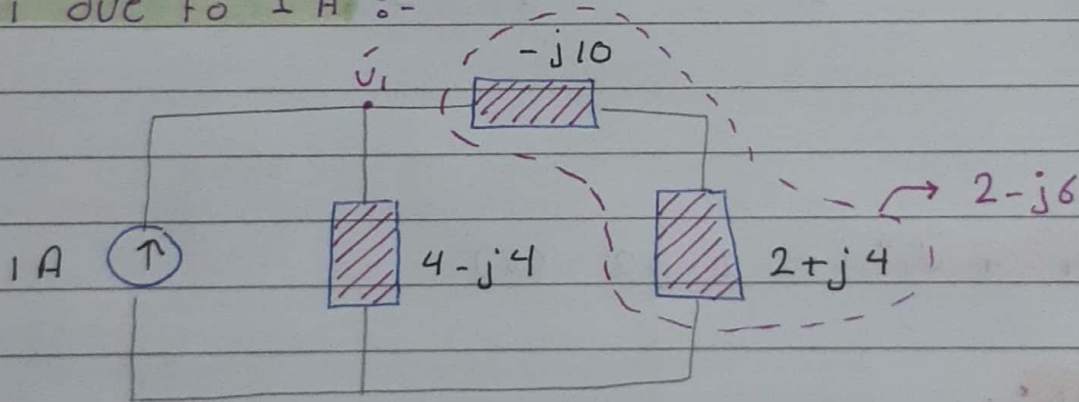
\* ملاحظة :-

إذا في السؤال أعطاني قيمتين لـ  $W$  ما ينحل إلا على الـ superposition  
كل مرة بحول الـ  $C$  و الـ  $L$  حسب  $W$  لا source الشغال

7  
Δ



## # Example 8 -

Find  $\bar{V}_1$  using s.p  $\Rightarrow$  $\Rightarrow V_1$  due to 1 A :-

$$\bar{V}_1' = (4-j2) \left[ \frac{1 (2-j6)}{6-j8} \right] \rightarrow \text{ohm's law}$$

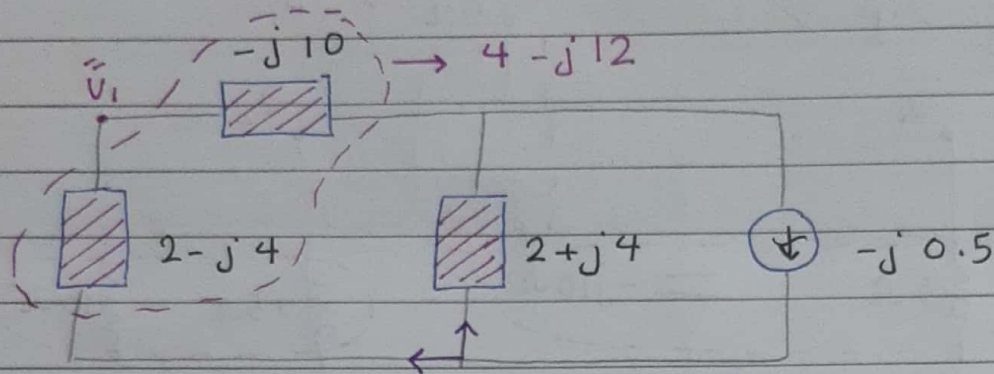
CDR

$$= 2.83 \angle 135^\circ \text{ (V)}$$





$\Rightarrow V_1$  due to  $-j0.5 A$  :-



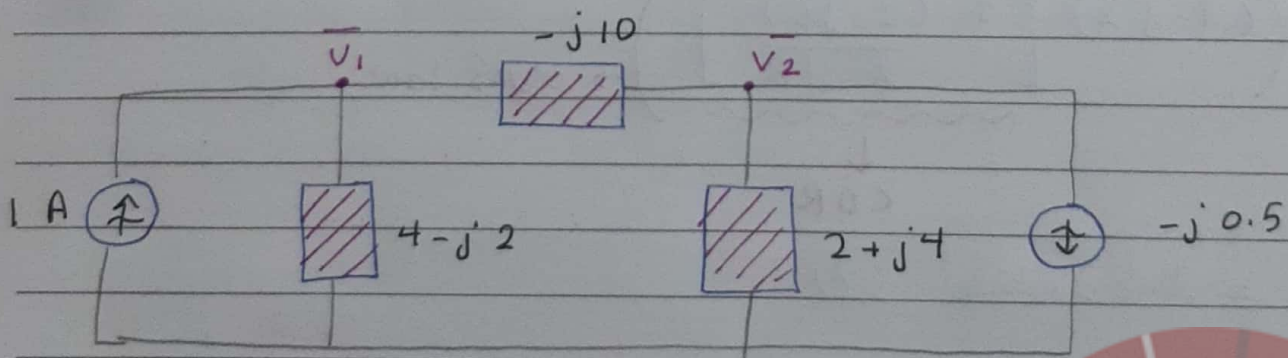
$$\bar{V}_1 = \ominus (4-j2) \left[ -j0.5 \left( \frac{2+j4}{6-j8} \right) \right] = -1 V$$

← های عشان  
اتجاه التيار  
منفکس

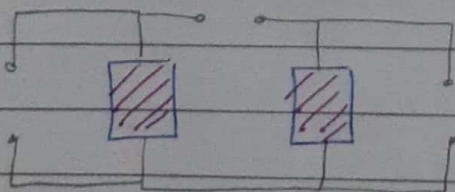
$$\bar{V}_1 = \bar{V}_1' + \bar{V}_1'' = 1 - j2 \text{ (V)}$$

### Example :-

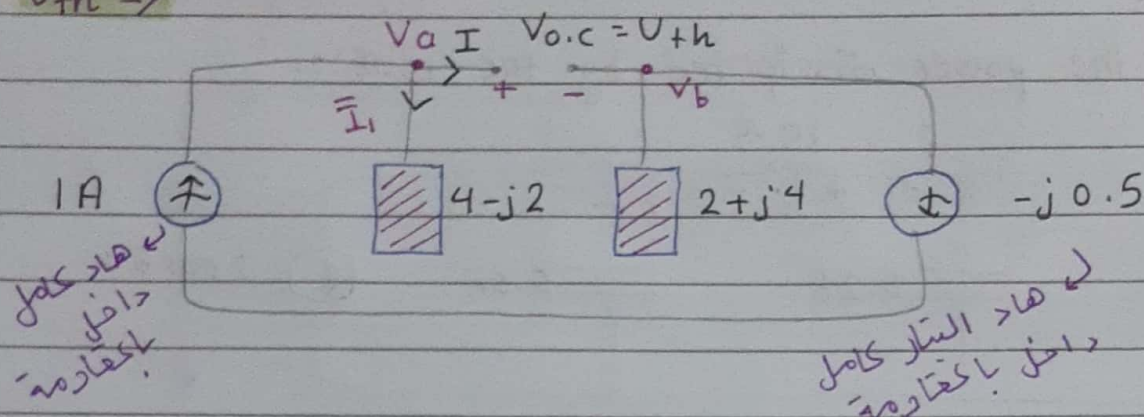
Find the Thevenin's equivalent as seen by  $(-j10 \Omega)$  :-



$Z_{th} \Rightarrow$



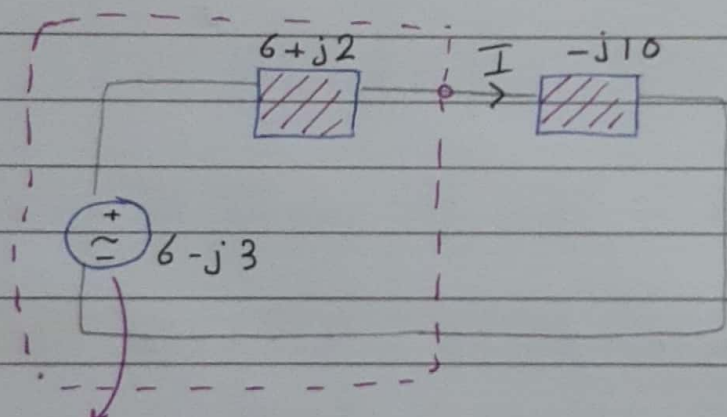
$$Z_{th} = 4 - j2 + (2 + j4) = 6 + j2$$

$V_{th} \Rightarrow$ 

$$V_{o.c} = V_a - V_b$$

$$= (1)(4-j2) - (-)(-j0.5)(2+j4)$$

$$= (4-j2) - j0.5(2+j4) = 6-j3$$



$$I = \frac{6-j3}{6-j8}$$

بناءً على  
الإشارات في  
مؤشرات  
→ + -

\* ملاحظة :-

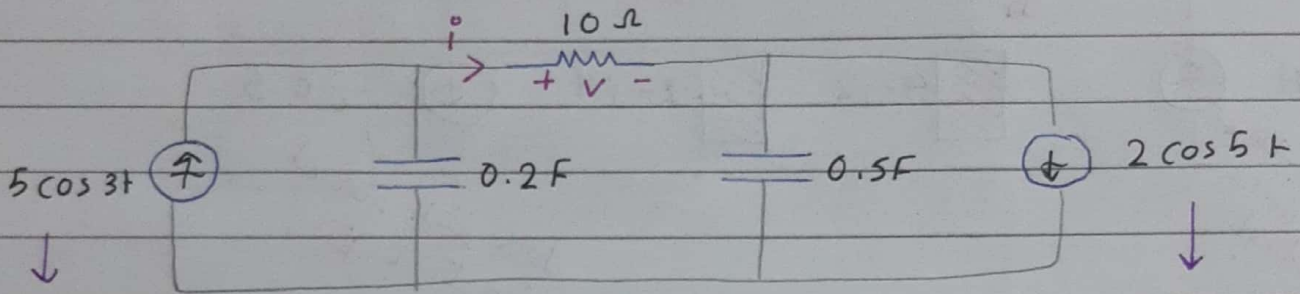
إذا كان عندي 2 Branch مغلق بجهة  
ومفتوح من جهة السار ما راح يتفرع





## # Example :-

Determine the power dissipated by the  $10\Omega$  :-



$$\omega = 3 \text{ rad/s}$$

\* بما اننا جافين لا  $\omega$

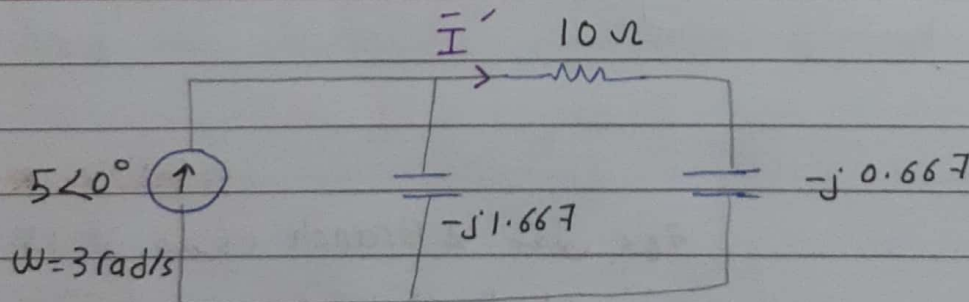
$$\omega = 5 \text{ rad/s}$$

فها السؤال بنحل بس (S.P)

→  $P$  is a non-linear quantity → لهك يا حسب  $i$  يا  $v$

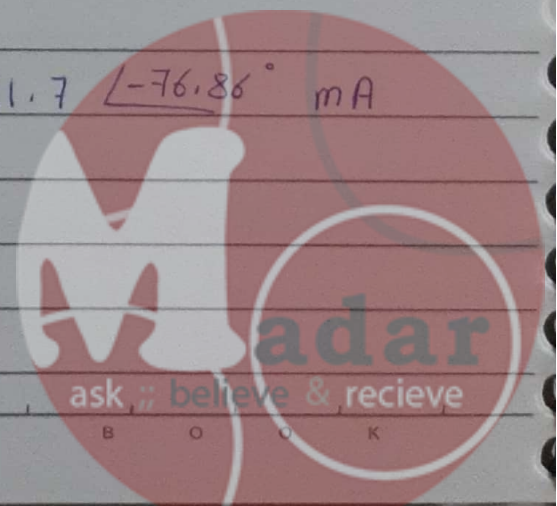
To find  $i \Rightarrow$

$i$  due to  $5 \cos 3t$  :-

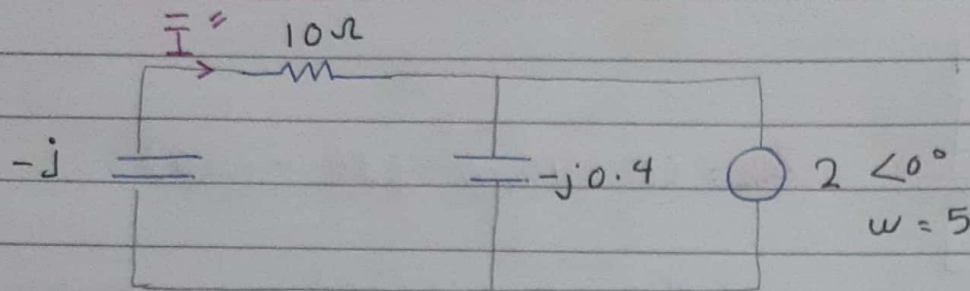


CDR :-

$$\bar{I}' = \frac{5(-j10.6)}{10 - j10.667 - j1.667} = 811.7 \angle -76.86^\circ \text{ mA}$$



$i_{due} 2 \cos 5t$  :-



CDR :-

$$\bar{I}'' = \frac{2(-j0.4)}{10 - j1.4} = 79.23 \angle -82.03^\circ \text{ mA}$$

\* ما يصير أخرج  $\bar{I}'$

د  $\bar{I}'$  لأنو كل

واحد من frequency

لهيك يرجعه لا time domain

$$i(t) = 811.7 \cos(3t - 76.86^\circ) \text{ mA}$$

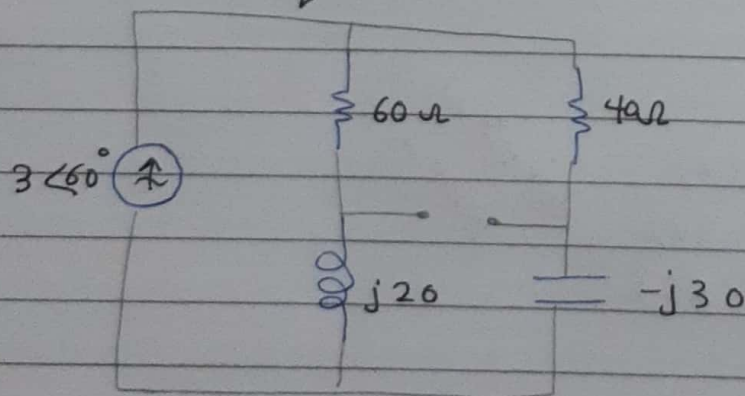
$$i(t) = 79.23 \cos(5t - 82.03^\circ) \text{ mA}$$

$$i(t) = i(t) + i(t) = 811.7 \cos(3t - 76.86^\circ) + 79.23 \cos(5t - 82.03^\circ)$$

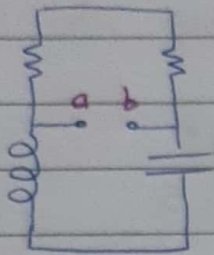
لـ بترك الجواب هيك ما يبسطو

# Example :-

Thevenin eq. between a & b :-

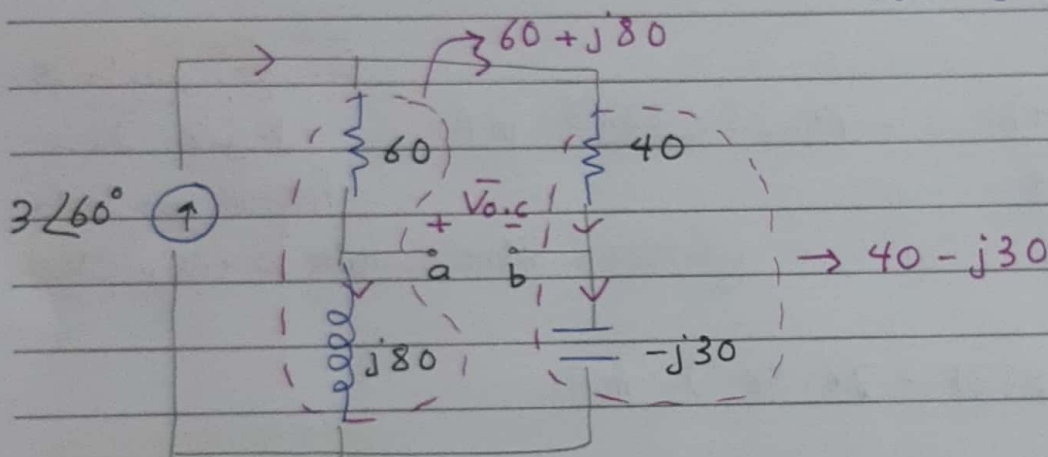




$Z_{th} \Rightarrow$ 

$$Z_{th} = (60 + 40) // (j80 - j30)$$

$$100 // j50 = \frac{(100)(j50)}{100 + j50} = 20 + j40$$



$$V_{o.c} = j80 \left( 3\angle 60^\circ \frac{(40 - j30)}{100 + j50} \right) - (-j30) \left( 3\angle 60^\circ \frac{(60 + j80)}{100 + j50} \right)$$

### # Phasor Diagram :-

A way to demonstrate the leading / lagging current & voltage in the circuit.

### \* Ex :-

$$\bar{V}_1 = 6 + j6 (V) = 10 \angle 53.1^\circ (V)$$

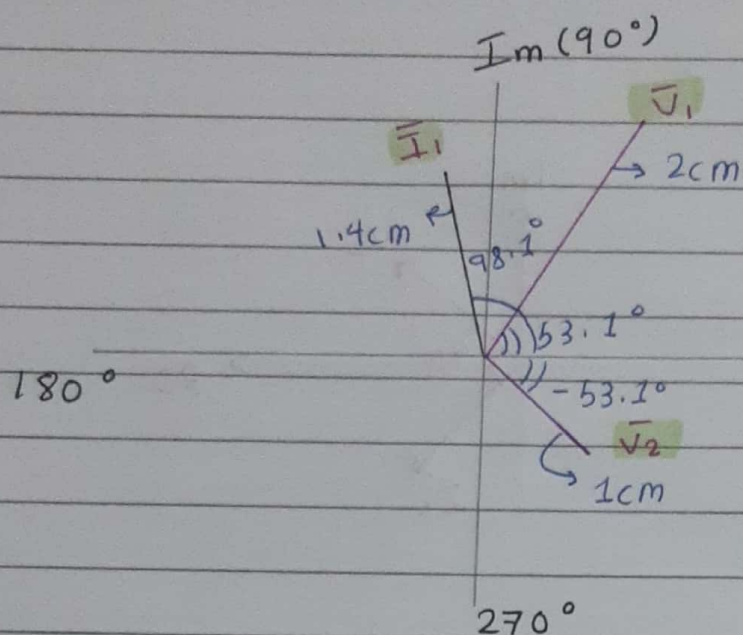
$$\bar{V}_2 = 3 - j4 (V) = 5 \angle -53.1^\circ (V)$$

$$\bar{V} = 1 + j15 (S) = \sqrt{2} \angle 45^\circ (S)$$

$$\bar{I}_1 = 10\sqrt{2} \angle 98.1^\circ (A)$$

↙ polar  
↘ polar



 $\bar{I}_1$  leads  $\bar{V}_1$  $\bar{I}_1$  leads  $\bar{V}_2$  $\bar{V}_1$  leads  $\bar{V}_2$ 

Re

 $0^\circ$ 

→ Drawing scale :-  $\frac{\text{1cm}}{5V}$   $\frac{\text{1cm}}{10A}$

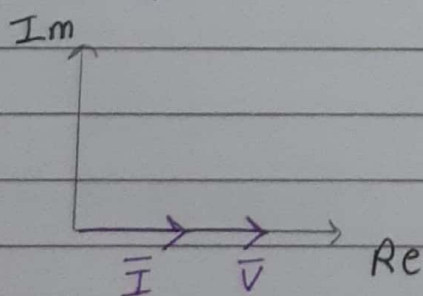
→

$$V \rightarrow 5V = 1\text{cm}$$

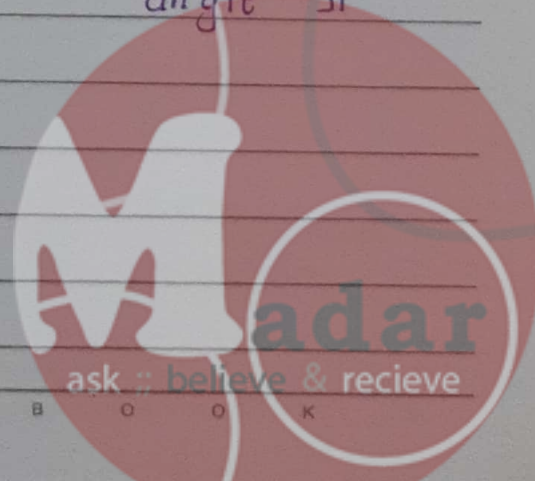
$$I \rightarrow 10A = 1\text{cm}$$

### ① Resistor :-

$V, I$  are inphase ,  $R = V/I$



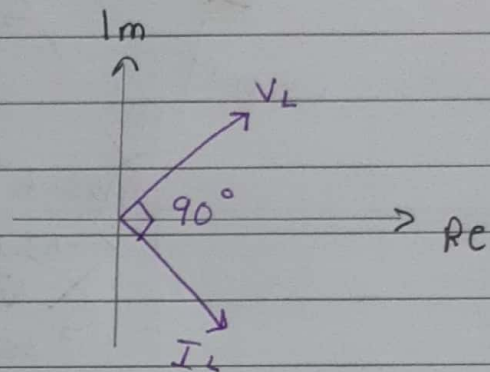
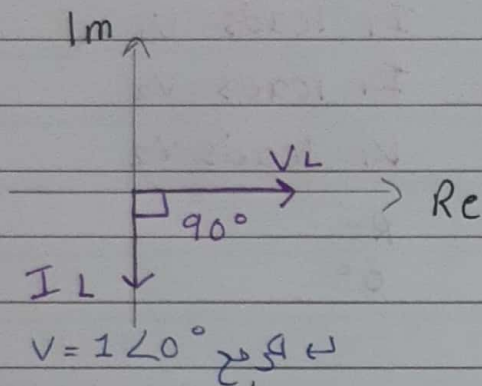
→ عادة التيار  $I$  magnitude يكون أقل من الجهد  $V$  نفس angle





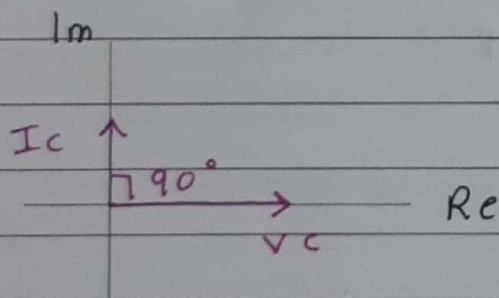
② For L :-

$\bar{V}$  leads  $\bar{I}$  by  $90^\circ$



③ For C :-

$\bar{V}$  lags  $\bar{I}$  by  $90^\circ$



### # at Resonance :-

$$Z_L = Z_C$$

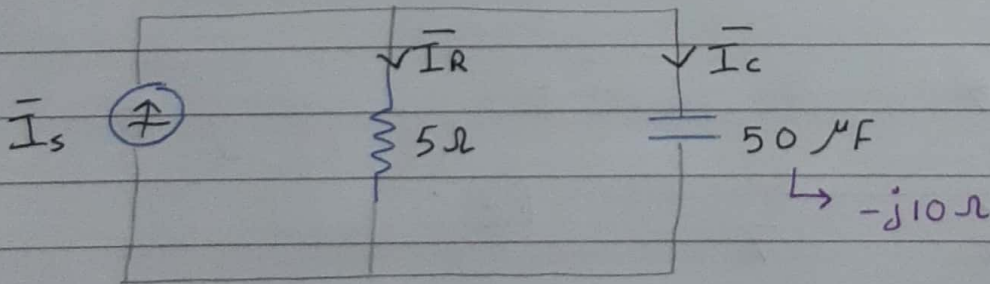
$$j\omega L = \frac{1}{j\omega C}$$

$$\text{or } X_L = X_C \rightarrow \omega L = \frac{1}{\omega C} \rightarrow \omega^2 = \frac{1}{LC}$$

$$\therefore \omega = \frac{1}{\sqrt{LC}} = 2\pi f$$

$$\therefore P = \frac{1}{2\pi\sqrt{LC}}$$

### # Example :-



$$\omega = 2000 \text{ rad/s}$$

Draw the phasor diagram ?!

→ since this circuit is single node pair circuit (v is common)



→ Assume  $\bar{V} = 1 \angle 0^\circ$  as a reference. لو حكاى 10V بهفوب  
الجواب آلفاية بـ 0.18

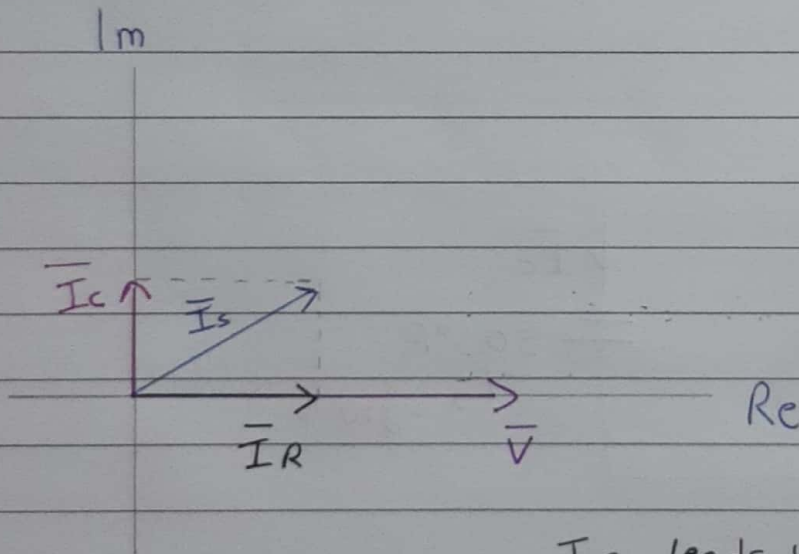
→ بفرض  $\bar{I}$  أو  $\bar{V}$  حسب الدارة

$$\bar{I}_C = \frac{V}{R_C} = \frac{1 \angle 0^\circ}{10 \angle -90^\circ} = 0.1 \angle 90^\circ \text{ A}$$

$$\bar{I}_R = \frac{V}{R} = \frac{1 \angle 0^\circ}{5 \angle 0^\circ} = 0.2 \angle 0^\circ \text{ A}$$

KCL at upper node :-

$$\bar{I}_S = \bar{I}_R + \bar{I}_C = 0.2 \angle 0^\circ + 0.1 \angle 90^\circ = 0.2 + j0.1$$

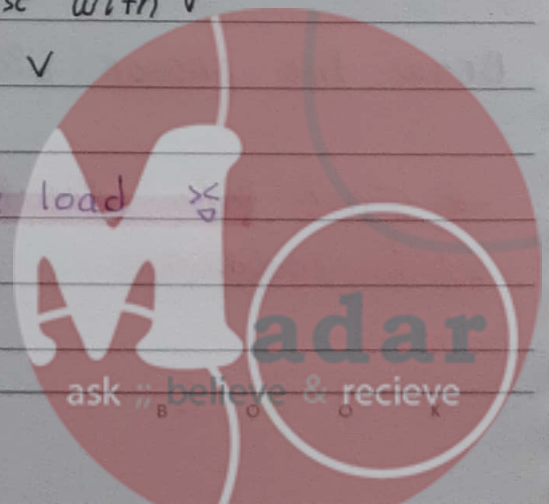


$I_C$  leads  $V$

$I_R$  in-phase with  $V$

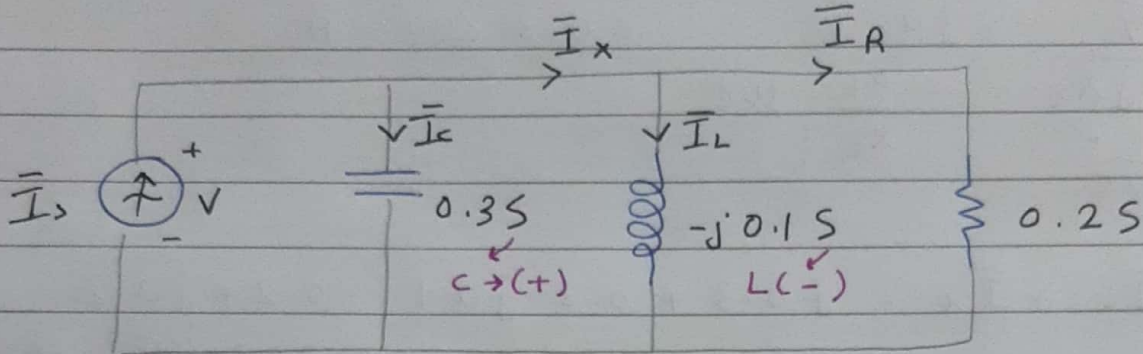
$I_S$  leads  $V$

Capacitive load



### # Example :-

Construct a phasor diagram & determine how much  $\bar{I}_s$  leads  $\bar{I}_x$ ,  $\bar{I}_R$  &  $\bar{I}_C$  :-

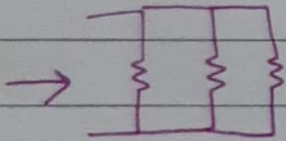


$$Z = R + jX$$

$$Y = G + jB$$

\* ما تكون الأشياء موازية  
بنفسه تتعامل مع الخواص

Note :-



$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$or \text{ } S_{eq} = S_1 + S_2 + S_3$$

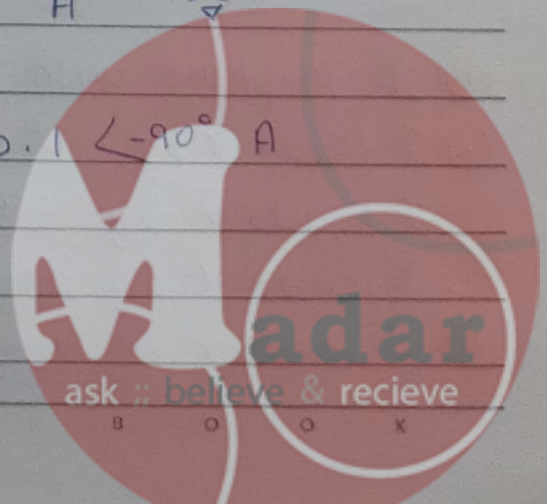
جمع متبادلة و آخر اشي بقلب  
الجواب النهائي .

→ Let  $\bar{V} = 1 \angle 0^\circ$  → single node pair circuit.

$$\bar{I}_R = \frac{\bar{V}}{R} = \frac{1 \angle 0^\circ}{0.2} = 0.2 \angle 0^\circ \text{ A}$$

$$\bar{I}_L = \frac{\bar{V}}{jX_L} = \frac{1 \angle 0^\circ}{j0.1} = -j0.1 = 0.1 \angle -90^\circ \text{ A}$$

$\frac{1}{X_L} = \frac{1}{\omega L}$





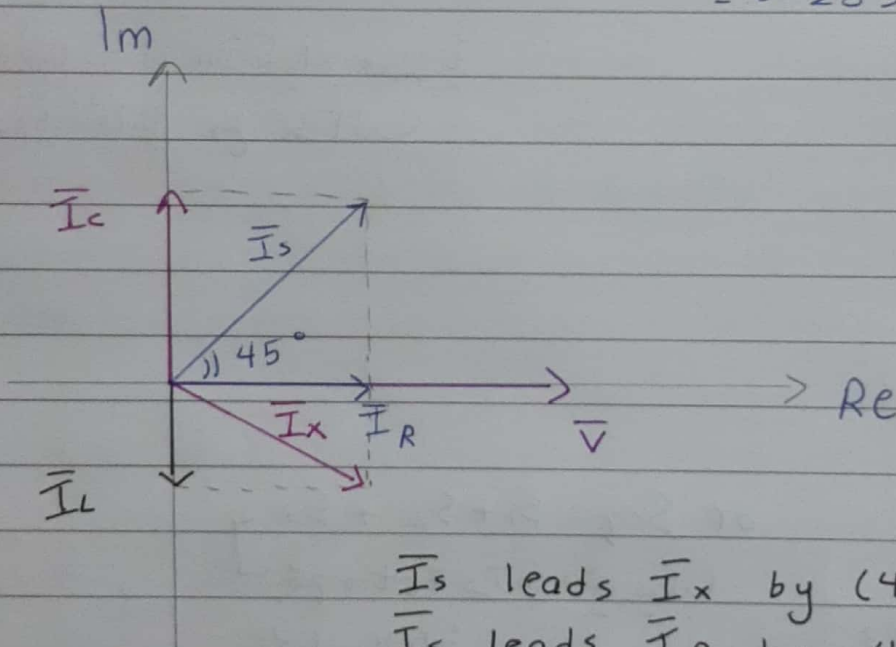
KCl :-

$$\bar{I}_x = \bar{I}_L + \bar{I}_R = 0.2 - j0.1 = 0.224 \angle -26.6^\circ \text{ A}$$

$$\bar{I}_C = \frac{\bar{V}}{-jX_C} = j\beta_C \bar{V} = 0.3 \angle 90^\circ \text{ A}$$

$\frac{1}{-jX_C} \rightarrow \frac{1}{X_C} = \omega C$

$$\bar{I}_s = \bar{I}_C + \bar{I}_x = j0.3 + 0.2 - j0.1 = 0.2 + j0.2 = 0.283 \angle 45^\circ \text{ A}$$



$\bar{I}_s$  leads  $\bar{I}_x$  by  $(45 + 26.6)$

$\bar{I}_s$  leads  $\bar{I}_R$  by  $45^\circ$

$\bar{I}_s$  leads  $\bar{I}_C$  by  $-45^\circ$

↓  
Capacitive load

①  $\bar{I}$  in-phase with  $\bar{V} \rightarrow R$

②  $\bar{I}$  leads  $\bar{V}$  by  $90^\circ \rightarrow C$

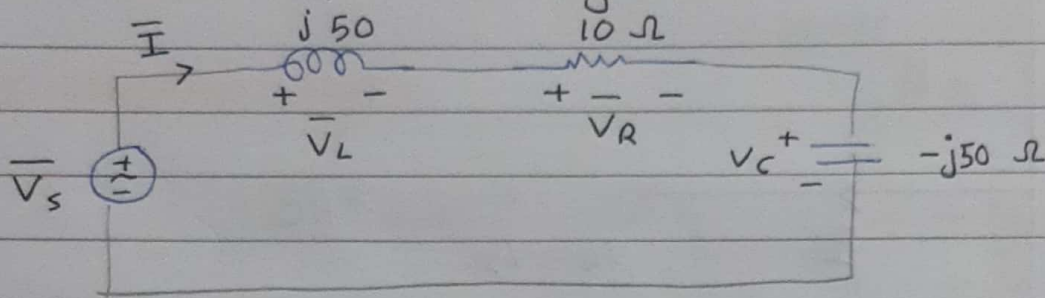
③  $\bar{I}$  lags  $\bar{V}$  by  $90^\circ \rightarrow L$

④  $\bar{I}$  leads  $\bar{V}$  by angle  $\in (0, 90^\circ) \rightarrow$  capacitive load

⑤  $\bar{I}$  lags  $\bar{V}$  by angle  $\in (-90, 0) \rightarrow$  inductive load

### # Example 8

Construct the phasor diagram :-



→ single loop circuit ( $I$  is common)

Let  $I = 1 \angle 0^\circ$  (A) as a reference

$$\bar{V}_C = -j50 \cdot 1 \angle 0^\circ = 50 \angle -90^\circ \text{ V}$$

$$\bar{V}_R = 10 \times 1 = 10 \angle 0^\circ \text{ V}$$

$$\bar{V}_L = j50 \cdot 1 \angle 0^\circ = 50 \angle 90^\circ \text{ V}$$

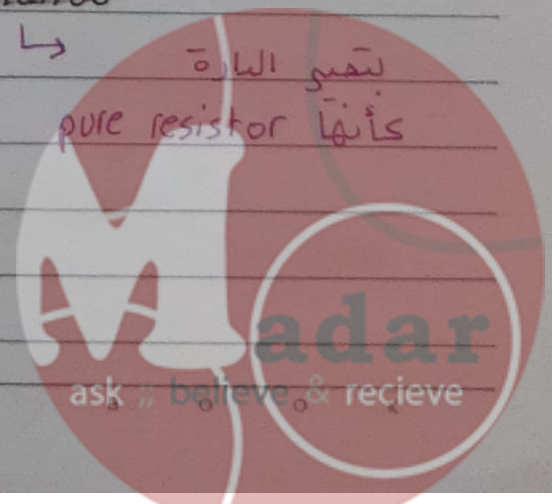
$$\bar{V}_S = \bar{V}_L + \bar{V}_R + \bar{V}_C = 10 - j50 + j50 = 10 \angle 0^\circ \text{ V}$$

$$Z_{eq} = 10 + j50 - j50 = 10 \Omega$$

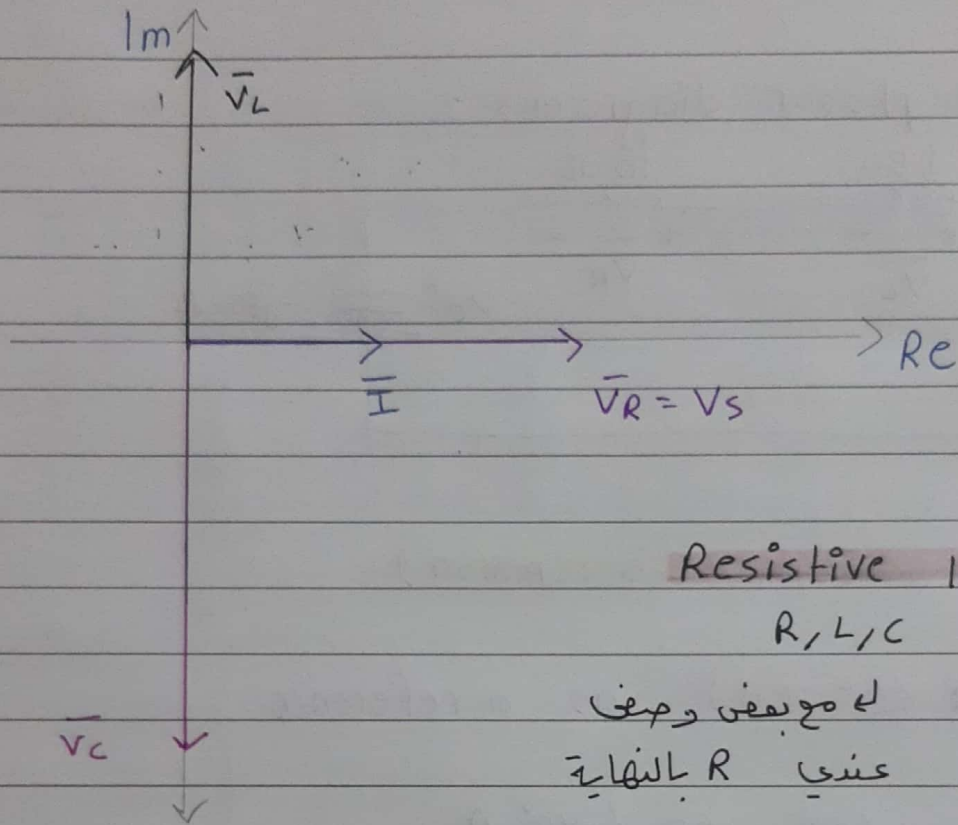
∴ The circuit is at resonance

→ له  $\omega$  واحد  $L$  متساويان

بقي البارة  
كانها pure resistor







## # AC Power Analysis :-

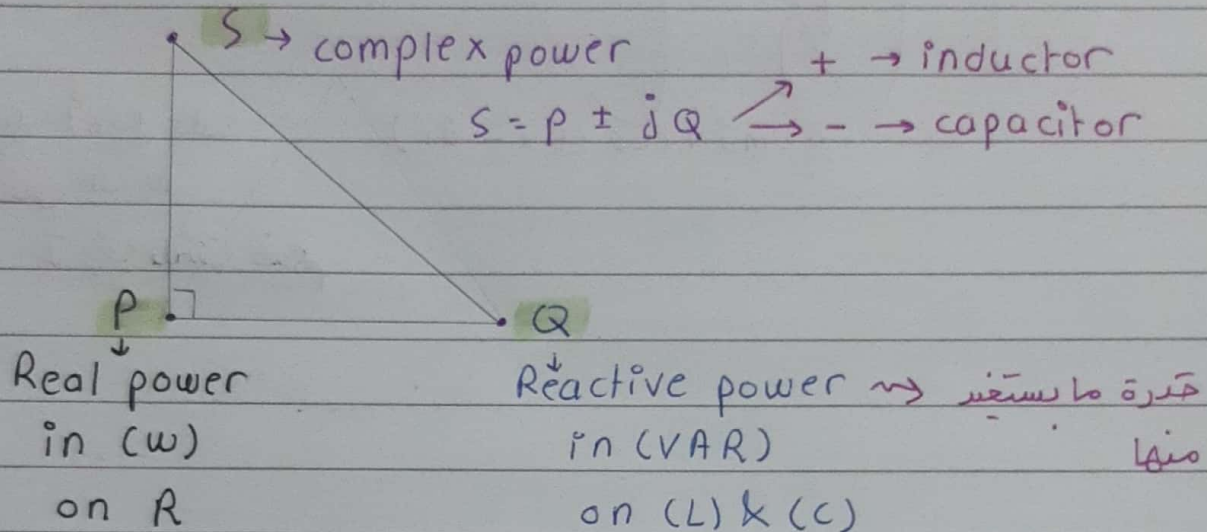
$$P = V \times i$$

↪ time domain

↪ power

↪ Freq. domain

## ⇒ Power triangle ⇒



$$P(t) = v(t) i(t)$$

$$\text{let } v(t) = V_m \cos(\omega t + \theta_v) \rightarrow \bar{V} = V_m \angle \theta_v$$

$$i(t) = I_m \cos(\omega t + \theta_i) \rightarrow \bar{I} = I_m \angle \theta_i$$

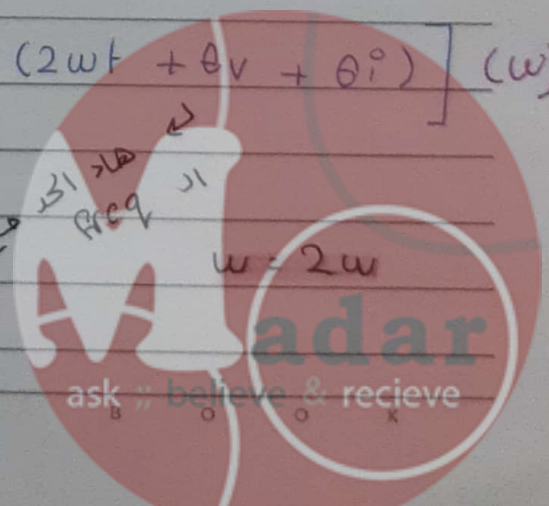
$$P(t) = V_m I_m \cos(\omega t + \theta_v) \cos(\omega t + \theta_i)$$

$$\text{identity} \Rightarrow \cos A * \cos B = \frac{1}{2} [\cos(A-B) + \cos(A+B)]$$

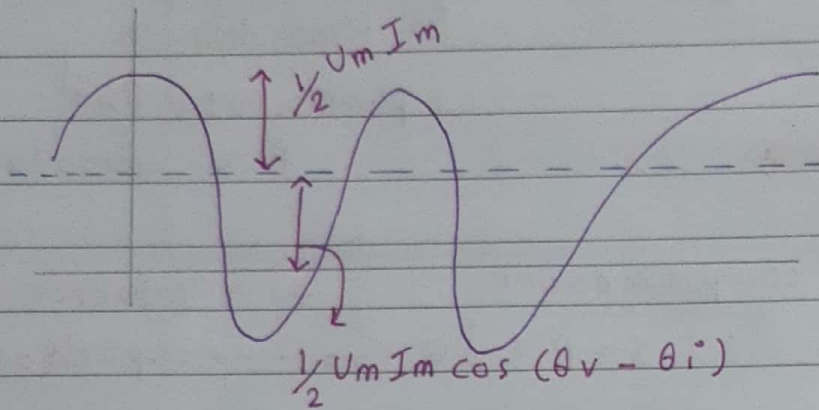
$$P(t) = \left( \frac{V_m I_m}{2} [\cos(\theta_v - \theta_i) + \cos(2\omega t + \theta_v + \theta_i)] \right) (w)$$

↪ دقة  
 $\omega = 0$

↪ هذا هو  
 Freq  
 $\omega = 2\omega$







\* مستقل اوسطی کی

P کی نفس ال W

W وال I کی بلشت فیہم

$$P(t) = v(t) \times i(t)$$

↳ instantaneous power in (w)

# Average power :-

$$P = \frac{1}{T} \int_0^T P(t) dt$$

$$= \frac{1}{2} \frac{V_m I_m}{T} \int_0^T \cos(\theta_v - \theta_i) + \cos(2\omega t + \theta_v + \theta_i) dt$$

$$= \frac{V_m I_m}{2T} \left[ \cos(\theta_v - \theta_i) T + \frac{\sin(2\omega t + \theta_v + \theta_i)}{2\omega} \right]_0^T$$

$$\frac{1}{2\omega} \sin(2\pi + \theta_v + \theta_i) - \sin(\theta_v + \theta_i)$$

ask :: believe & recieve

$$P = \frac{V_m I_m}{2} \cos(\theta_v - \theta_i) \text{ W} \quad \#$$

average power (time independent)

$$P = \frac{1}{2} \bar{V} \bar{I}^* \text{ (W)}$$

↪ I conjugate

$$\bar{I}^* = I_m \angle -\theta_i$$

$$P = \frac{1}{2} \text{Re} [\bar{V} \bar{I}^*]$$

لازم أحفظها

عشان أتأبني حد الـ cos

بدلش حد الـ sin

$$\bar{V} \bar{I}^* = V_m I_m \angle (\theta_v - \theta_i) = V_m I_m \cos(\theta_v - \theta_i) + j V_m I_m \sin(\theta_v - \theta_i)$$

# Example :-

Given  $v(t) = 120 \cos(377t + 45^\circ) \text{ V}$  ,  $i(t) = 10 \cos(377t - 10^\circ) \text{ A}$

$$P(t) = v(t) i(t)$$

$$= 600 \cos(55^\circ + \cos(754t + 35^\circ)) \text{ W}$$

$$= 600 \cos(55^\circ) = 344.2 \text{ W}$$

or

$$P = \frac{1}{2} \text{Re} (\bar{V} \bar{I}^*)$$

$$= \frac{1}{2} (\text{Re} (120 \angle 45^\circ \times 10 \angle 10^\circ)) = \frac{1}{2} \text{Re} (1200 \angle 55^\circ)$$

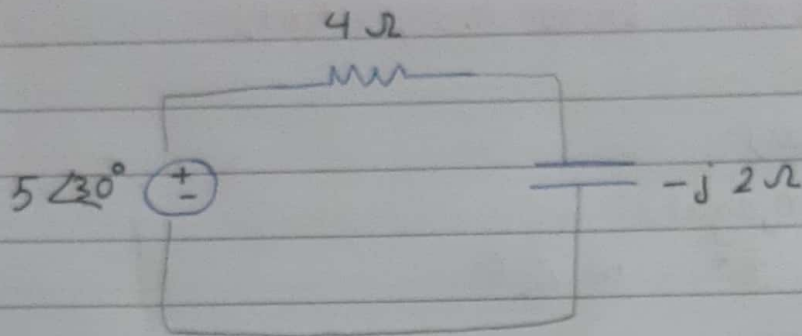
$$= 600 \cos(55^\circ)$$

ask :: believe & recieve



**Example :**

Find average power  $P_{s \text{ gen}}$  &  $P_{R \text{ abs}}$ !



$$P = \frac{1}{2} \operatorname{Re} (\bar{V} \bar{I}^*)$$

$$\bar{I} = \frac{V}{Z} = \frac{5 \angle 30^\circ}{4 - j2} = 1.118 \angle 56.57^\circ \text{ A}$$

$$* P_{s \text{ gen}} = \frac{1}{2} \operatorname{Re} [5 \angle 30^\circ \times 1.118 \angle -56.57^\circ] = 2.5 \text{ W}$$

$$* P_{R \text{ abs}} = \frac{1}{2} \operatorname{Re} [\bar{V}_R \bar{I}^*]$$

$$\bar{V}_R = 4 \bar{I}$$

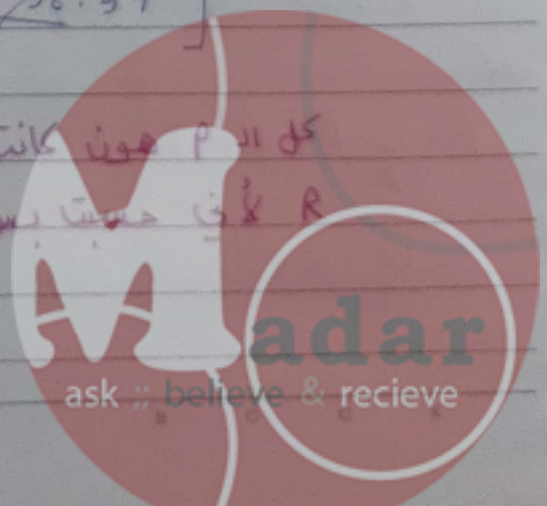
$$= \frac{1}{2} \operatorname{Re} [4 \times 1.118 \angle 56.57^\circ \times 1.118 \angle -56.57^\circ]$$

$$= 2(1.118)^2 = 2.5 \text{ W} \rightarrow \text{كل الـ } P \text{ هون كانت لـ } R$$

$P_{\text{real}}$  لأن في حقيقتنا بس

$$P_{\text{capacitor}} = 0$$

بس بهذا الـ مثال



## # Maximum Power transfer :-

$V_{th}, \bar{Z}_{th}$   
 occurs at  $\bar{Z}_L = \bar{Z}_{th}^*$

$$Z_L = R_L \pm jX_L$$

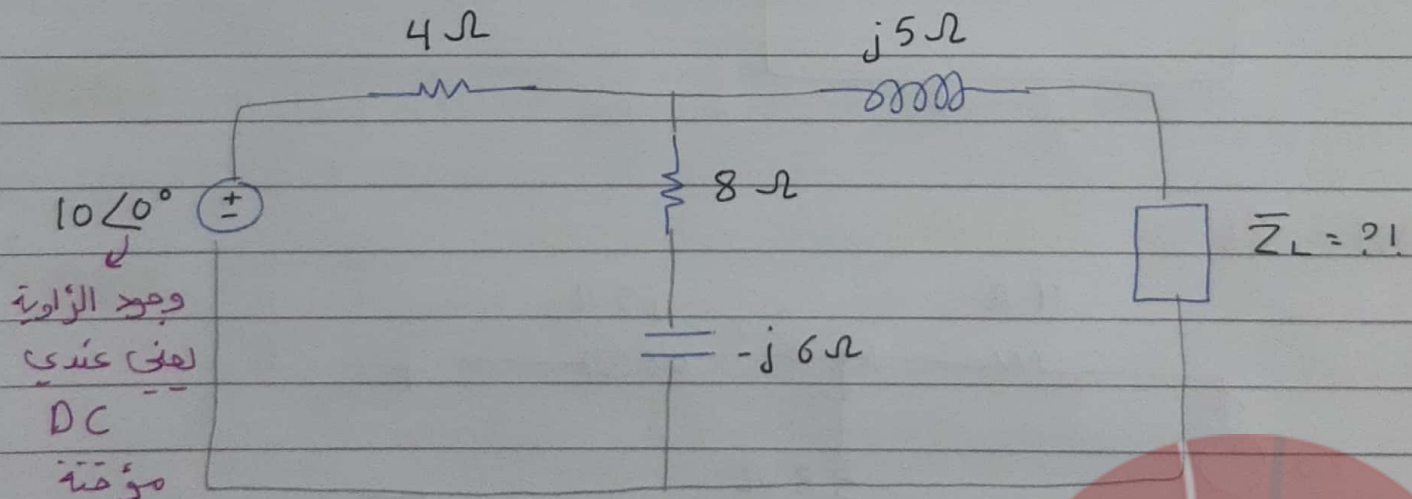
$$Z_{th} = R_{th} \pm jX_{th}$$

$$R_L = R_{th} \quad \& \quad X_L = X_{th}^*$$

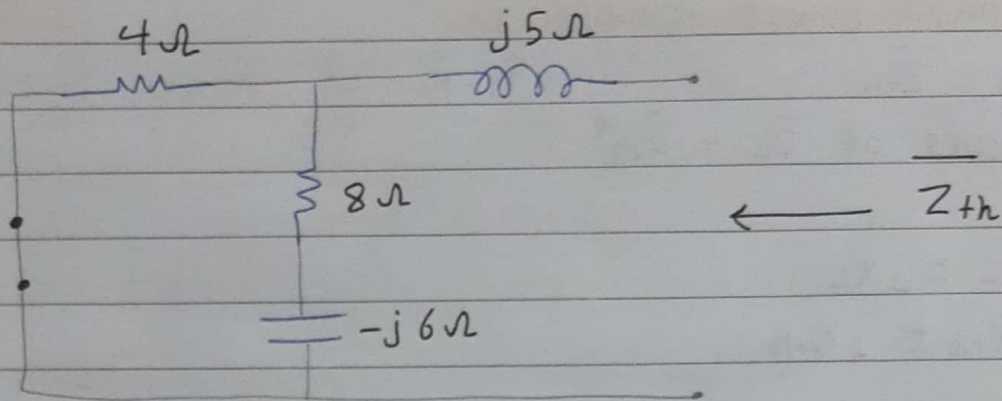
$$P_{max} = \frac{|\bar{V}_{th}|^2}{8 R_{th}}$$

## # Example :-

find  $\bar{Z}_L$  to absorb max average power & find the value of this power ?!

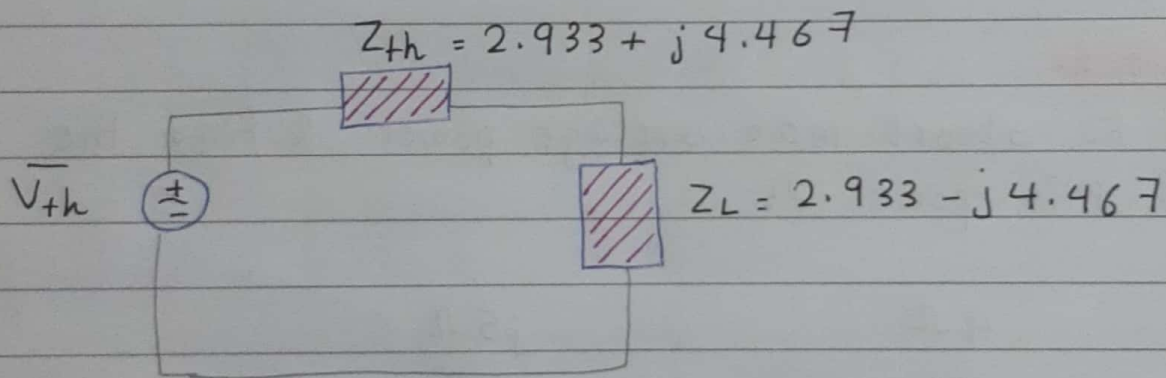




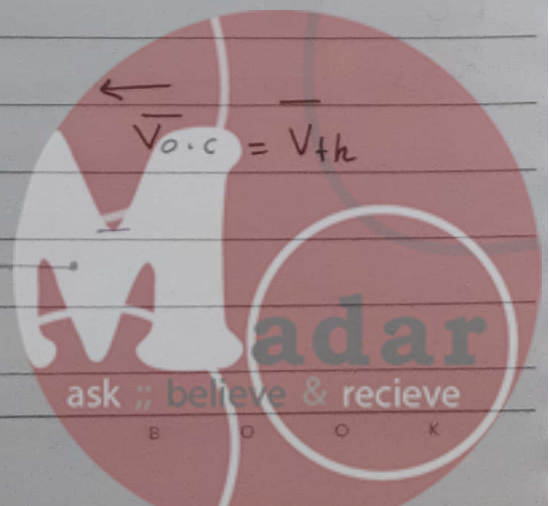
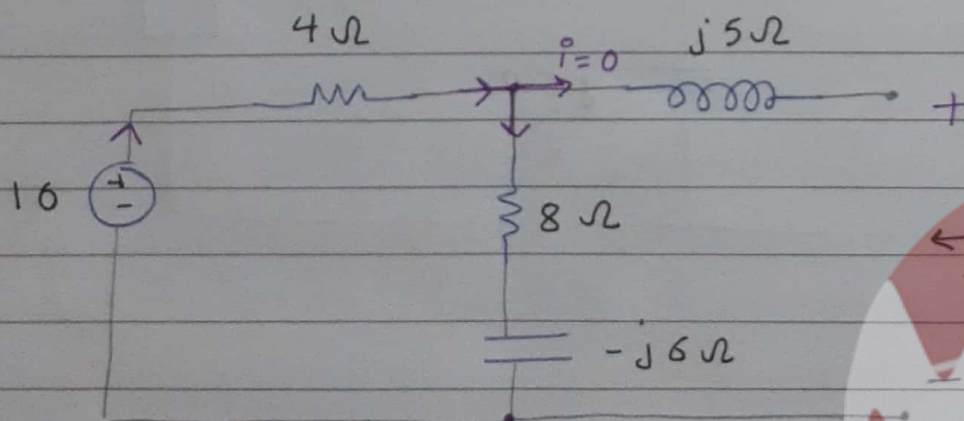


$$\bar{Z}_{th} = [(8 - j6) // 4] + j5 = 2.933 + j4.467 \Omega$$

$$\bar{Z}_L = 2.933 - j4.467 \Omega$$



$$V_{th} = ?!$$



VDR :-

$$V_{th} = V_{o.c} = \frac{10 (8 - j6)}{12 - j6} = 7.454 \angle -10.3^\circ \text{ V}$$

$$P_{max} = \frac{(7.454)^2}{8 (2.933)} = 2.368 \text{ W}$$

# Effective or RMS value :-

↳ Root mean square

$$v(t) = V_m \cos(\omega t + \theta_v) \quad \text{V}$$

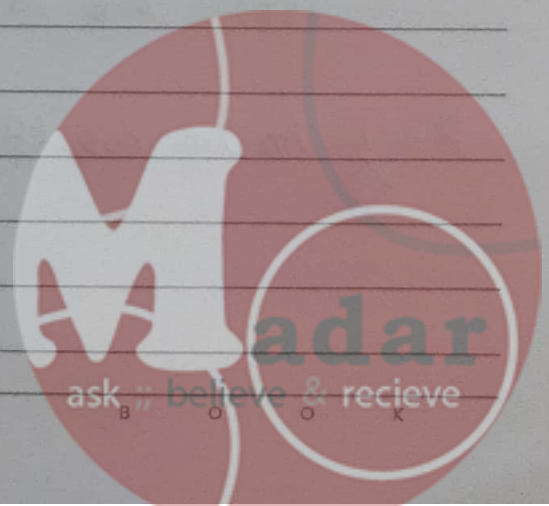
$$i(t) = I_m \cos(\omega t + \theta_i) \quad \text{A}$$

$$I_{rms} = I_{eff} = \sqrt{\frac{1}{T} \int_0^T i^2(t) dt}$$

$$V_{rms} = \sqrt{\frac{1}{T} \int_0^T v^2(t) dt}$$

$$I_{rms} = \sqrt{\frac{1}{T} \int_0^T I_m^2 \cos^2(\omega t + \theta_i) dt}$$

$$\cos^2 \omega t = \frac{1}{2} (1 + \cos 2\omega t)$$





$$I_{rms} = \sqrt{\frac{I_m^2}{T} \int_0^T 1 + \cos(2(\omega t + \theta_i)) dt}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} \rightarrow \text{Peak value}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

↳ only for  
sinosoid

$$P_{ave} = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$$

$$= \frac{1}{2} \operatorname{Re} \left[ \frac{\bar{V}}{V_{peak}} \frac{\bar{I}^*}{I_{peak}} \right] = \frac{1}{2} \operatorname{Re} [\bar{V}_p \cdot \bar{I}_p^*]$$

$$= \operatorname{Re} \left[ \frac{\bar{V}}{\sqrt{2}} \cdot \frac{\bar{I}^*}{\sqrt{2}} \right]$$

$$= \operatorname{Re} [\bar{V}_{rms} \bar{I}_{rms}^*] \quad \#$$

**# Apparent power & power factor :-**

$$let \quad v(t) = V_m \cos(\omega t + \theta_v)$$

$$i(t) = I_m \cos(\omega t + \theta_i)$$

$$P = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i) \quad W$$



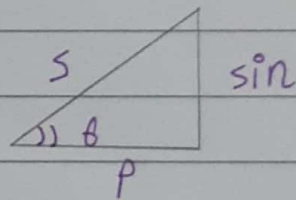
$$S = \bar{V}_{rms} \bar{I}_{rms} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} = \frac{1}{2} V_m I_m$$

↳ Complex power  
or apparent power  
(الـ P الفـاهـوـجـة)

$$PF = \frac{P}{S} = \cos(\theta_v - \theta_i)$$

$$P = S \cos(\theta_v - \theta_i) = S(PF)$$

$$\text{reactive power } Q = S \sin(\theta_v - \theta_i)$$



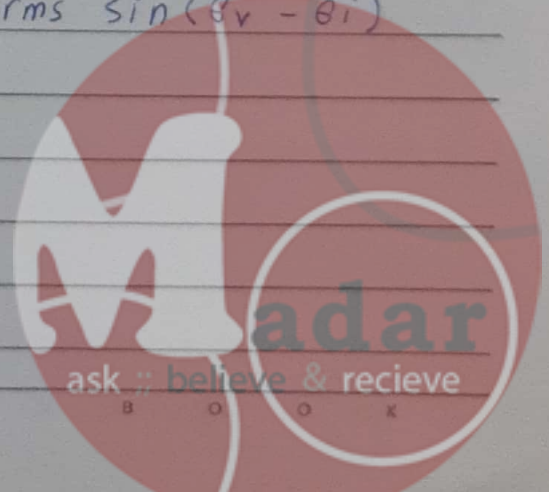
$$\bar{S} = \bar{V}_{rms} \bar{I}_{rms}$$

$$= V_{rms} \angle \theta_v I_{rms} \angle -\theta_i$$

$$= V_{rms} I_{rms} \angle \theta_v - \theta_i$$

$$= V_{rms} I_{rms} \cos(\theta_v - \theta_i) + j V_{rms} I_{rms} \sin(\theta_v - \theta_i)$$

$$= P + jQ$$





# **Complex power $\bar{S}$ :-**

$$S = \frac{1}{2} \bar{V} \bar{I}^*$$

$$\bar{V} = V_m \angle \theta_v$$

$$\bar{I} = I_m \angle \theta_i$$

$$= \bar{V}_{rms} \bar{I}_{rms}^*$$

$$= \frac{1}{2} V_m I_m \angle (\theta_v - \theta_i) = P + jQ$$

inductive load  
capacitive load

$$P = \frac{1}{2} V_m I_m \cos (\theta_v - \theta_i) = \frac{1}{2} V_m I_m (PF)$$

$$Q = \frac{1}{2} V_m I_m \sin (\theta_v - \theta_i)$$

$$PF = \cos (\theta_v - \theta_i) \quad 0 \leq PF \leq 1$$

↳ power factor

$PF = 1 \rightarrow$  unity power factor.

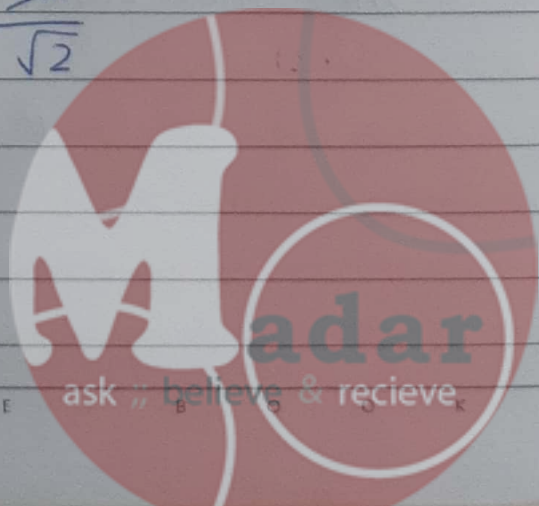
$Q = 0 \rightarrow PF = 1 \Rightarrow \bar{S} = P \rightarrow$  resistive load.

$Q > 0 \rightarrow \theta_v > \theta_i \Rightarrow PF \neq 1 \rightarrow$  inductive load.

$Q < 0 \rightarrow \theta_i > \theta_v \Rightarrow PF \neq 1 \rightarrow$  capacitive load.

$$Q = I_{rms}^2 X = \frac{1}{2} I_m^2 X, \quad I_{rms} = \frac{I_m}{\sqrt{2}}$$

↓  
reactance



⇒ for inductance :-

$$Q_L = I_{rms}^2 X_L \quad , X_L = \omega L$$

$$= I_{rms}^2 \omega L$$

$$\therefore Q_L = \frac{V_{rms}^2}{X_L} = \frac{V_{rms}^2}{\omega L} = \frac{V_m^2}{2\omega L}$$

$$L = \frac{V_{rms}^2}{\omega Q_L} \text{ in (H)}$$

⇒ for capacitance :-

$$Q_C = I_{rms}^2 X_C \quad , X_C = \frac{1}{\omega C}$$

$$\therefore Q_C = \frac{V_{rms}^2}{X_C} = \frac{I_{rms}^2}{\omega C} = V_{rms}^2 \omega C$$

$$C = \frac{Q_C}{V_{rms}^2 \omega} = \frac{I_{rms}^2}{Q_C \omega} \text{ in (F)}$$

$$S = P \pm Q$$

↳ in (VA)      ↳ in (VAR)

if  $Q > 0 \rightarrow PF \neq 1 \rightarrow \text{inductive load}$

$$0 < PF < 1$$

↓

$$\bar{V} \text{ leads } \bar{I} \quad \text{or} \quad \bar{I} \text{ lags } \bar{V}$$

(lagging PF)

ask // believe & recieve



if  $Q < 0 \rightarrow$  capacitive load

$\downarrow$   
 $\bar{I}$  lead  $\bar{V}$  (leading PF)

يعني مثلاً إذا احتجت ارفع قيمة الـ PF

$$PF = 0.8 \rightarrow PF = 0.95$$

بدي ارفع قيمة الـ PF

يعني بدي أعطيه دفعة لـ  $\bar{V}$

Capacitive load

المتح عشان

يرفع الـ PF بـ  $\bar{V}$

capacitor

### # Example :-

بـ  $\bar{V}$  عشان أجيب  $W$

When connected to a 120V (rms), 60 Hz power line, a load absorbs 4kW at a lagging PF of 0.8. Find the value of capacitance necessary to raise the PF to 0.95 :-

بـ  $Q$  بحسب  $Q$  القديمة بعدين

$Q$  الجديدة

$$P = V_{rms} I_{rms} (\cos(\theta_v - \theta_i))$$

$\downarrow$

$$4000 \text{ W}$$

$$\cos \theta_1 = 0.8$$

$$\theta = \cos^{-1} 0.8 = 36.87^\circ$$

$$P = S \text{ PF}$$

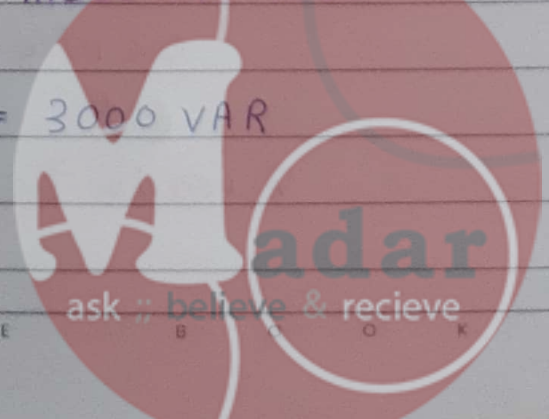
$$S = \frac{P}{\text{PF}} = \frac{4000}{0.8} = 5000 \text{ VA}$$

لـ موجبة لأن السؤال

حالة lagging يعني

inductive load

$$Q = S \sin(\theta_1) = 5000 \sin(36.87^\circ) = 3000 \text{ VAR}$$



$$S = P + jQ$$

$$5000 \angle 36.87^\circ = 4000 + j3000$$

$$* PF_2 = 0.95 \rightarrow \cos \theta_2 \rightarrow \theta_2 = 18.19^\circ$$

$$PF \text{ الـ } \downarrow \quad 0.95 = \cos \theta_2 \quad \uparrow$$

راح يفتل الكمنج  
يستهلك 4000 W

\* مادام بي أرفع الـ PF يعني بي  
capacitor حتى لو ماحكاي في

السؤال

$$S_2 = \frac{P}{PF_2} = \frac{4000}{0.95} = 4210.5 \text{ VA}$$

$$Q_2 = S \sin \theta_2 \rightarrow \theta_2 = \cos^{-1}(0.95) = 18.19^\circ \text{ VAR}$$

لـ هاي القيمة لي لازم

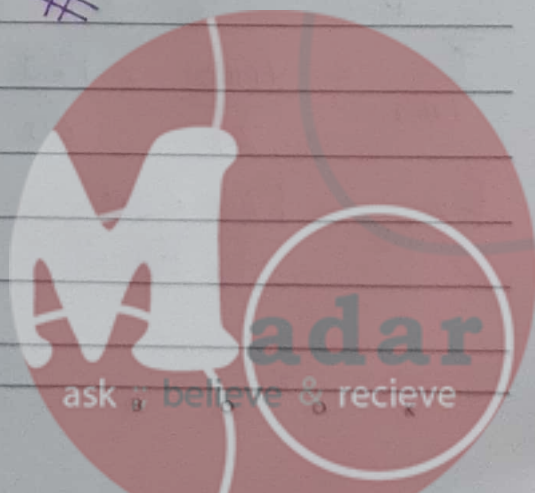
يحييها الكمنج عشان يحسن

الـ PF

$$Q = Q_{old} - Q_{new} = 3000 - 1314.4 = 1685.6 \text{ VAR}$$

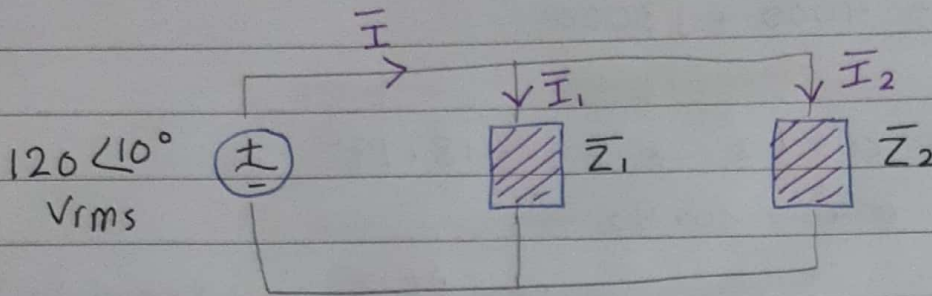
$$Q_c = \frac{V_{rms}^2}{X_c} = V_{rms}^2 (w_c) \rightarrow C = \frac{Q}{V_{rms}^2 w} = \frac{1685.6}{(120)^2 (2\pi 60)}$$

$$= 310.5 \mu F \quad \#$$





### # Example :-



$$\bar{Z}_1 = 60 \angle -30^\circ \Omega$$

$$\bar{Z}_2 = 40 \angle 45^\circ \Omega$$

Calculate :-

(a) apparent power (S) :-

(b) real power (P) :-

(c) reactive power (Q) :-

(d) Power Factor supplied by the source & seen by the source (PF) :-

$P_{\text{gen}} = P_{\text{abs}}$   
 supplied  $\rightarrow$  seen by the source

(a)

$$*S = V_{\text{rms}} I_{\text{rms}}^* \rightarrow \text{لا بحسب كلي}$$

$$*S = S_1 + S_2 \rightarrow \text{هنا القانون أو هاهنا}$$

$$V_{\text{rms}} \bar{I}_{\text{rms}}^* \rightarrow V_{\text{rms}} \bar{I}_{2\text{rms}}^*$$

$$\bar{I}_{1\text{rms}} = \frac{V_{\text{rms}}}{Z_1} = \frac{120 \angle 10^\circ}{60 \angle -30^\circ} = 2 \angle 40^\circ \text{ A}$$

$$\bar{I}_{2\text{rms}} = \frac{120 \angle 10^\circ}{40 \angle 45^\circ} = 3 \angle -35^\circ \text{ A}$$



$$\bar{I}_{rms} = \bar{I}_1 + \bar{I}_2 = 4.024 \angle -6.21^\circ \text{ A (rms)}$$

$$S_1 = 120 \angle 10^\circ \times 2 \angle -40^\circ = 240 \angle -30^\circ \text{ VA}$$

$$S_2 = 120 \angle 10^\circ \times 3 \angle 35^\circ = 360 \angle 45^\circ \text{ VA}$$

$$S_T = S_1 + S_2 = 462.4 + j134.6 \text{ VA}$$

P ←                      → Q

(b)  $P = 462.4 \text{ W}$

(c)  $Q = 134.6 \text{ VAR (inductive)}$

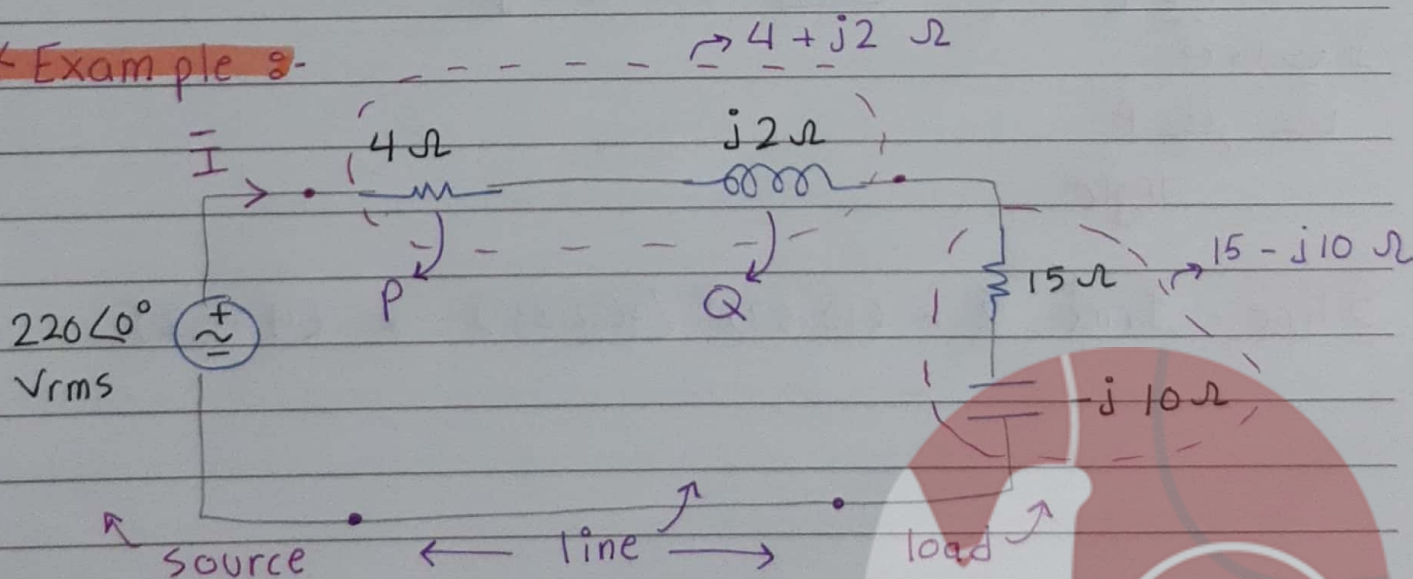
(d)

$$PF = \cos(\theta_v - \theta_i)$$

$$= \cos(10^\circ - -6.21) = \cos(16.21) = 0.96$$

(lagging)

**Example 8-**





Find the Real power & reactive power absorbed by the source, line & load :-

$$\bar{S} = \bar{V}_{rms} \bar{I}_{rms}^* = \frac{1}{2} \bar{V} \bar{I}^*$$

$$\bar{I} = \frac{\bar{V}}{Z_{eq}} = \frac{220 \angle 0^\circ}{19 - j8} = 10.67 \angle 22.83^\circ \text{ A (rms)}$$

$$PF = \cos(\theta_v - \theta_i) = \cos(0 - 22.83^\circ) = \cos(-22.83^\circ)$$

↳ leading  
 $\theta_i > \theta_v$

$$P_{line} = I_{rms}^2 \times R_{line}$$

↳ هذا الذي علينا  
 $\bar{S}$

$$P_{line} = I_{rms}^2 R_{line}$$

$$= \text{Re} [(10.67)^2 \angle 2(22.83^\circ) * 4]$$

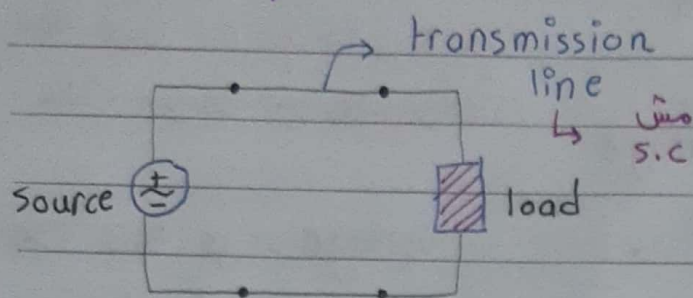
المالي ال

P يفتح بها  
 angle

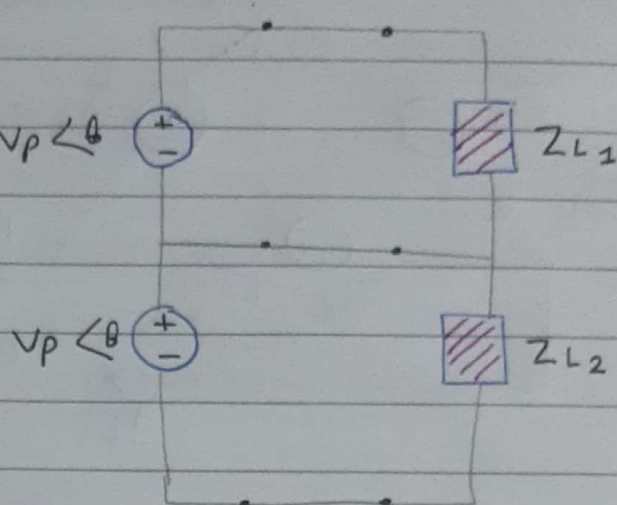
$$S_{line} = I_{rms}^2 \bar{Z} = (10.67)^2 \angle 2(22.83^\circ) * (4 + j2)$$



# # Three phase circuit :-



Single phase circuit

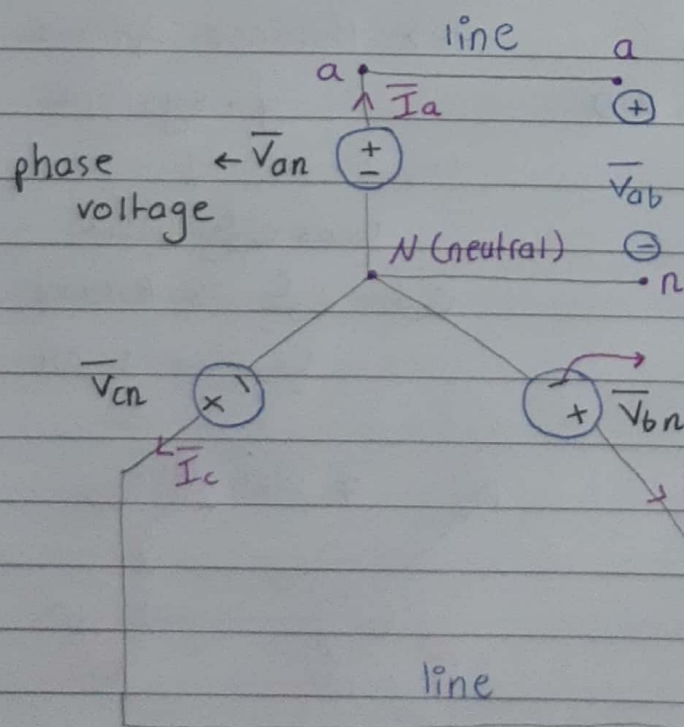


Two phase circuit

بناش حكي عنها

=> 3 phase circuit =>

Source connection



\* ينسب الدائرة (Ideal source connection)

لأنو ما عني مقاومات  
بس عني voltage source

السالب دايما  
باتجاه الـ (N)

\*  $V_{phase} \neq V_{line}$

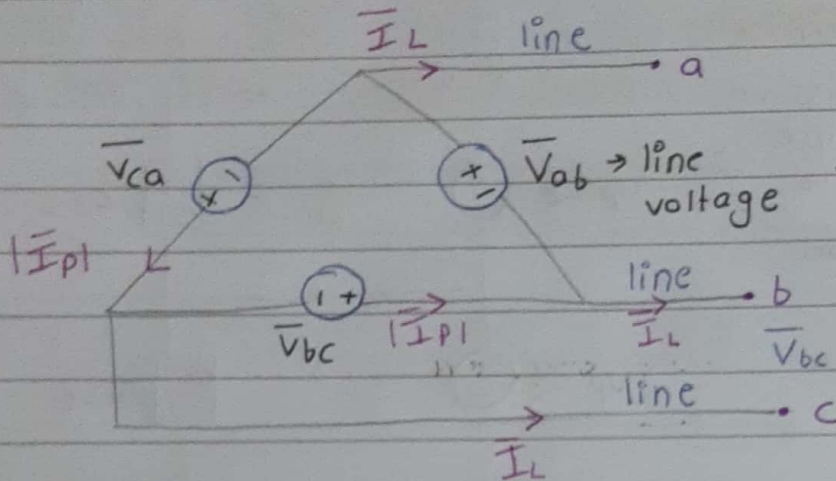
\*  $I_{phase} = I_{line}$

Wye or (Y) or star connection

3 phase - 4 wire system

ask :: believe & recieve





\* هون كنا الا شارتي زي  
ملقة موجبا مع سابا وهنذا.

\* 5 حبة كل ال voltage  
متساويات

\* من a الى b عني  
line voltage

Δ or Delta connection

3 phase - 3 wire system

\*  $V_{phase} = V_{line}$

\*  $I_{phase} \neq I_{line}$

⇒ Y circuit :-

$$\bar{V}_{an} + \bar{V}_{bn} + \bar{V}_{cn} = 0$$

بنا نتكلم  
بالزوايا  $|\bar{V}_{an}| = |\bar{V}_{bn}| = |\bar{V}_{cn}| \neq 0$

$$V_p \equiv V_{phase}$$

Balance 3phase  
y-system

عشان يكون عني  
Balance لازم يكون الفرق  
بالزوايا متساوي

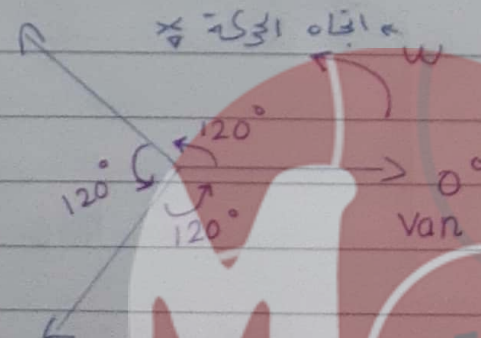
$$V_{an} = V_p \angle 0^\circ$$

$$V_{bn} = V_p \angle -120^\circ$$

$$V_{cn} = V_p \angle -240^\circ$$

$$V_a \text{ leads } V_c \text{ by } 240^\circ$$

$$V_a \text{ leads } V_b \text{ by } 120^\circ$$



$\Rightarrow$  abc sequence (+ve sequence)

$\hookrightarrow$  a leads b

& b leads c

if  $V_{cn} = V_p \angle 240^\circ$

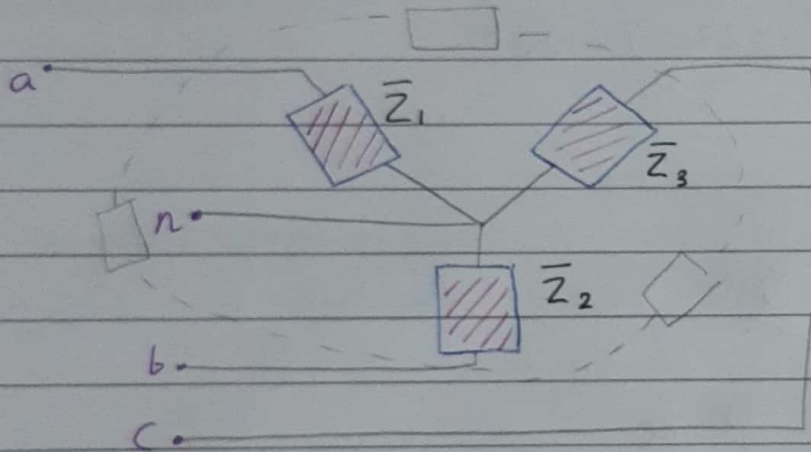
$V_{bn} = V_p \angle 120^\circ$

$V_{an} = V_p \angle 0^\circ$

$\rightsquigarrow$  cba sequence

(-ve sequence)

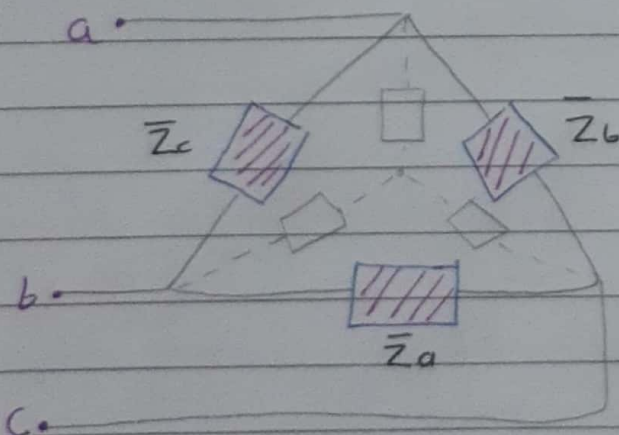
# load connection :-



$$\bar{Z}_1 = \bar{Z}_2 = \bar{Z}_3 = \bar{Z}_y$$

$$Z_\Delta = \frac{3 Z_y^2}{Z_y} \rightarrow Z_\Delta = 3 Z_y \quad \#$$

y or star



$$\bar{Z}_a = \bar{Z}_b = \bar{Z}_c = \bar{Z}_\Delta$$

$$\bar{Z}_y = \frac{Z_\Delta Z_\Delta}{3 Z_\Delta} \rightarrow Z_y = \frac{Z_\Delta}{3} \quad \#$$





### # Example :-

Determine the phase sequence :-

$$V_{an} = 200 \cos(\omega t + 10^\circ) \rightarrow \bar{V}_{an} = 200 \angle 10^\circ \text{ V}$$

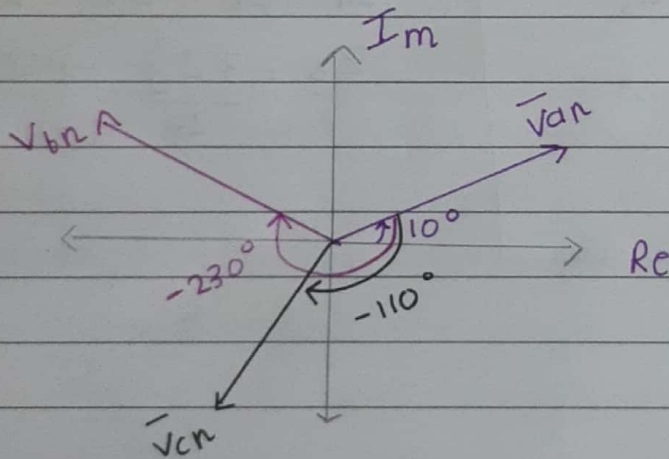
$$V_{bn} = 200 \cos(\omega t - 230^\circ) \rightarrow \bar{V}_{bn} = 200 \angle -230^\circ \text{ V}$$

$$V_{cn} = 200 \cos(\omega t - 110^\circ) \rightarrow \bar{V}_{cn} = 200 \angle -110^\circ \text{ V}$$

→ acb - sequence

لعلنا  
يفضل  
y connection

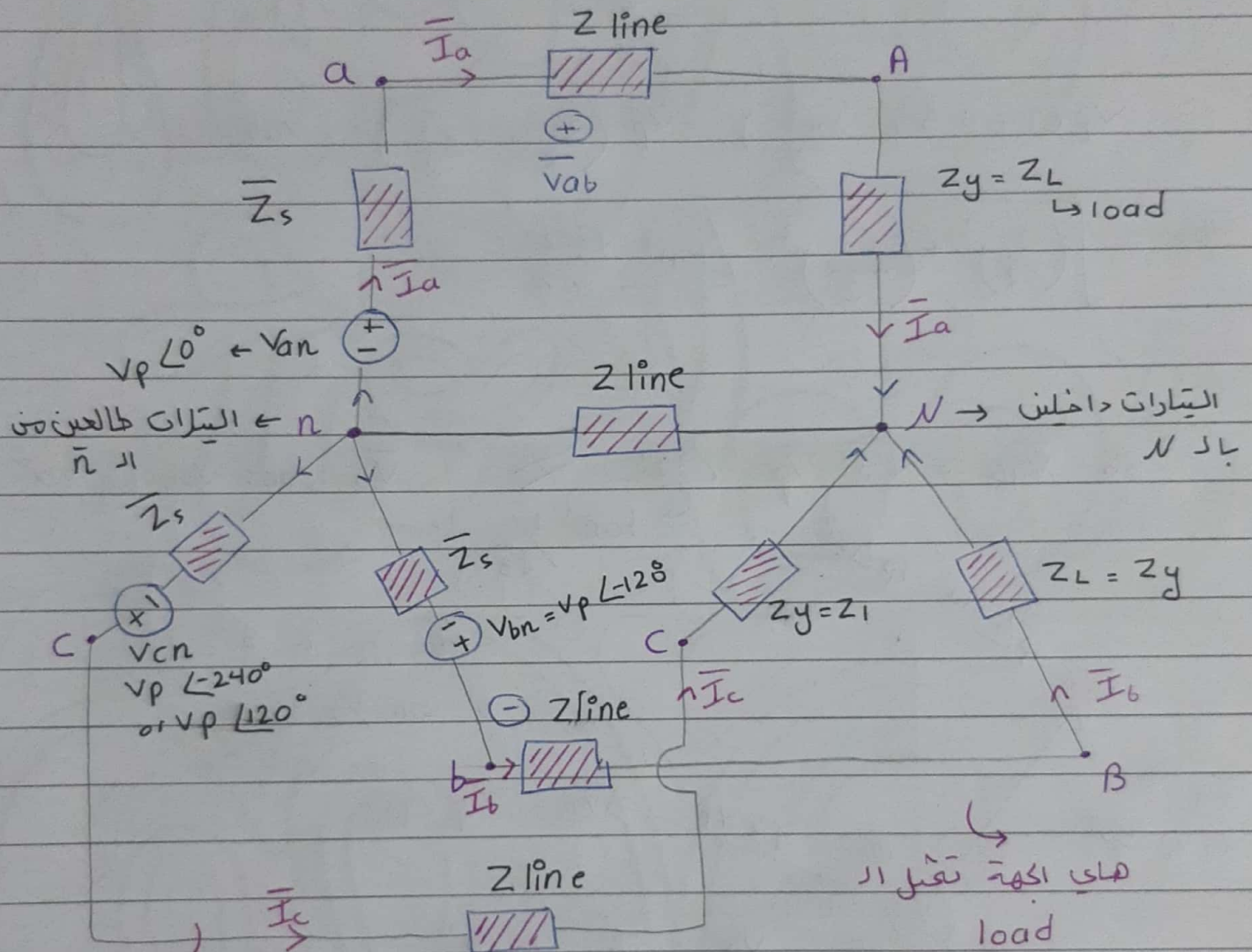
→  $\bar{V}_a$  leads  $\bar{V}_c$  by  $(10 - -110) = 120^\circ$  (Balanced)  
 $\bar{V}_c$  leads  $\bar{V}_b$  by  $(-110 - -230) = 120^\circ$



# # Balanced wye - wye connection (star - star connection) :-

↓  
الحديث  
نفس ال sequence

↓  
source ال  
load مششوكين  
y



↓  
هاي الجمة  
source ال

\* لازم يخل هيك الترتيب  
Balance  
عشان يكونو





$$\bar{V}_{ab} = \bar{V}_{an} - \bar{V}_{bn} \rightarrow (+V_{nb})$$

$$= V_p \angle 0^\circ - V_p \angle -120^\circ$$

$$= V_p \cos(0) + j V_p \sin(0) - V_p \cos(-120^\circ) - j V_p \sin(-120^\circ)$$

$$= V_p + 0.5 V_p + j \frac{\sqrt{3}}{2} V_p$$

$$V_p \left(1 + 0.5 + j \frac{\sqrt{3}}{2}\right) = V_p \left(\frac{3}{2} + j \frac{\sqrt{3}}{2}\right) = \bar{V}_{ab}$$

$$\bar{V}_{ab} = \sqrt{\left(\frac{3}{2}\right)^2 + \left(\frac{\sqrt{3}}{2}\right)^2} \angle \tan^{-1} \frac{\sqrt{3}/2}{3/2}$$

$$\bar{V}_{ab} = \sqrt{3} V_p \angle 30^\circ$$

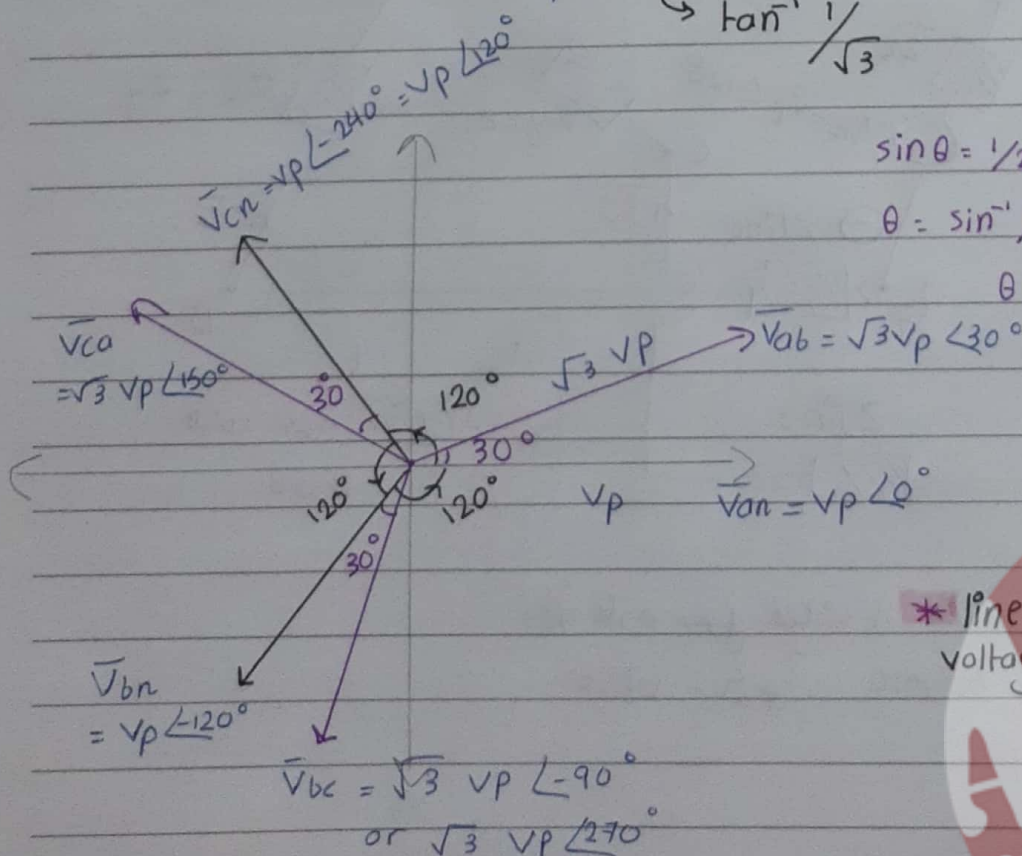
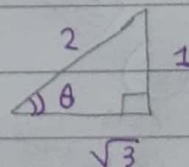
$\tan^{-1} \frac{1}{\sqrt{3}}$

$\bar{V}_{ab}$  leads  $\bar{V}_{an}$  by  $30^\circ$

$$\sin \theta = \frac{1}{2}$$

$$\theta = \sin^{-1} \frac{1}{2}$$

$$\theta = 30^\circ$$



\* line voltage > phase voltage by  $\sqrt{3}$

ask :: believe & recieve

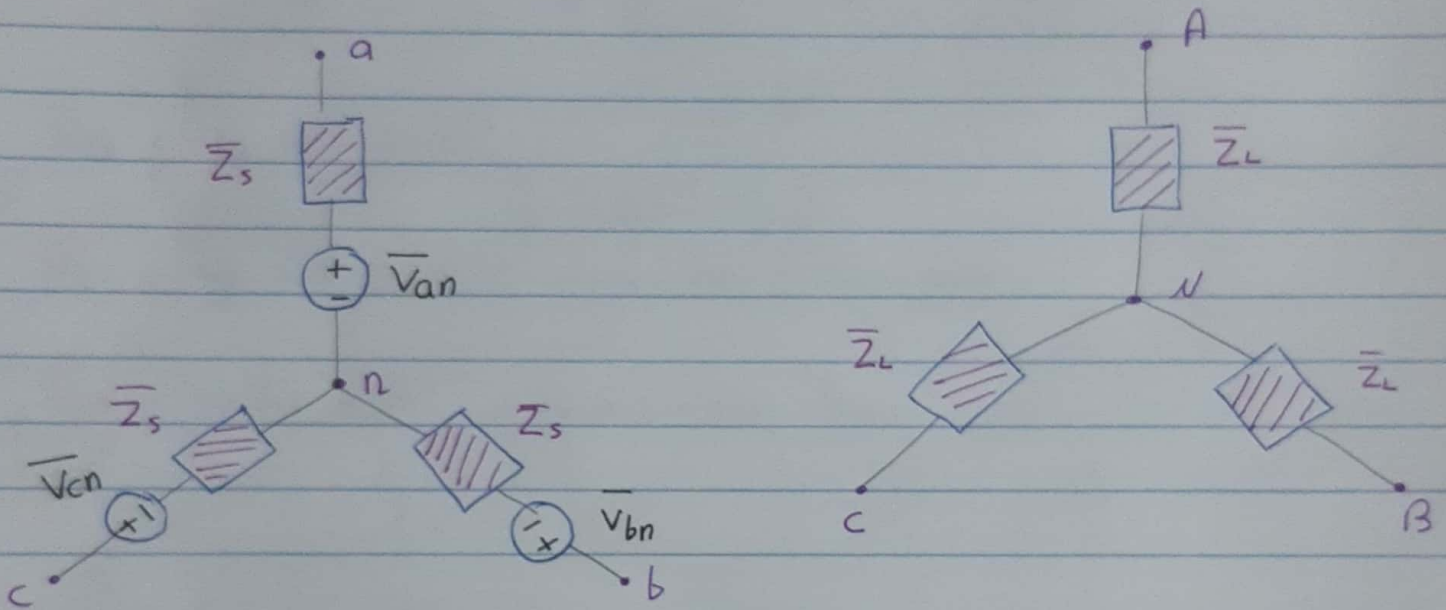
$$\bar{V}_{ac} = \bar{V}_{an} - \bar{V}_{cn}$$

$$= V_p \angle 0^\circ - V_p \angle -240^\circ$$

$$= V_p - V_p \cos(-240^\circ) - j V_p \sin(-240^\circ)$$

# **Balanced** :-

Wye - wye connection  $\Rightarrow$



\* أول شيء برسم ال source على شكل Y وبرسم ال load على شكل Y بعدين ببشكهم مع بعض بـ Z line (من A و a) وهكذا بطلع دائرة بنفس الجيرة لي حكيها عنها جيل

ملاحظات :-

① أي نقطة لا neutral اسمها

a → n phase

a → b ← هي اسمها

line

$$I_{\text{phase}} = I_{\text{line}}$$

$$|V|_{\text{line}} = \sqrt{3} |V|_{\text{phase}}$$

line phase

ask :: believe & recieve



$V_{ab}$  (line voltage) :-

$$\bar{V}_{ab} = \bar{V}_{an} - \bar{V}_{bn}$$

$$= V_p \angle 0^\circ - V_p \angle -120^\circ$$

$v_{phase}$   $\leftarrow$

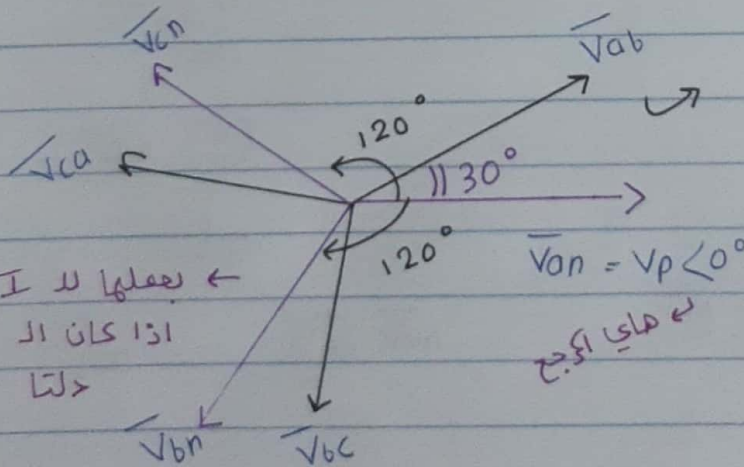
$$= V_p + \frac{V_p}{2} + j \frac{V_p \sqrt{3}}{2} = V_p \left( \frac{3}{2} + j \frac{\sqrt{3}}{2} \right)$$

$$\bar{V}_{ab} = V_p \sqrt{3} \angle 30^\circ$$

$$\bar{V}_{bc} = V_p \sqrt{3} \angle -90^\circ \quad \rightsquigarrow \quad V_{bc} = V_{bn} - V_{cn}$$

$$\bar{V}_{ca} = V_p \sqrt{3} \angle 150^\circ \quad \rightsquigarrow \quad V_{ca} = V_{cn} - V_{an}$$

+120°  
or -240°

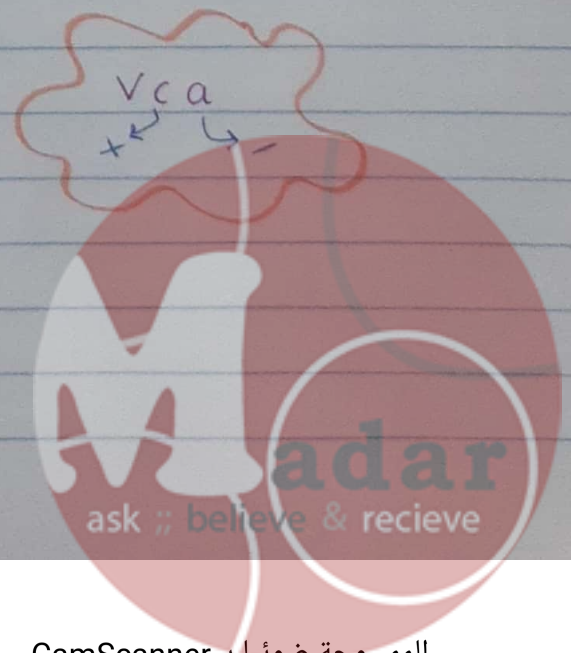


كل phase  
بعدي بـ  $30^\circ$   
في line

إذا كان الجهد  
10 بزيـد 10 للزادية  
يعني  $40^\circ$  وهكذا...

← يعني لا  
source إذا كان ال  
لنا

← هاي الجهد



$$\bar{Z}_y = \bar{Z}_s + Z_{line} + \bar{Z}_L \rightarrow$$

عامل جمع  
المقاومات فيما فوق  
(بالسرعة الكبيرة)

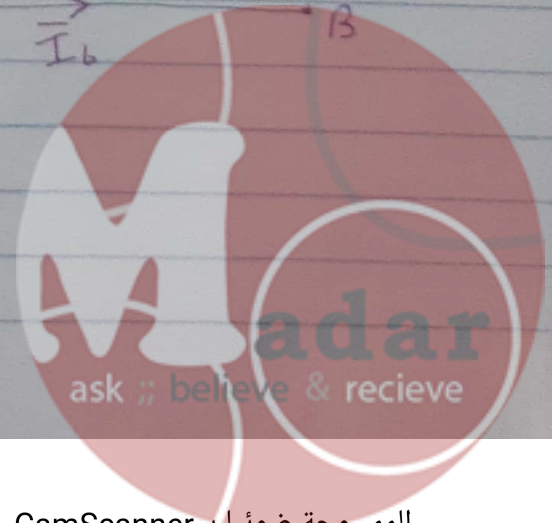
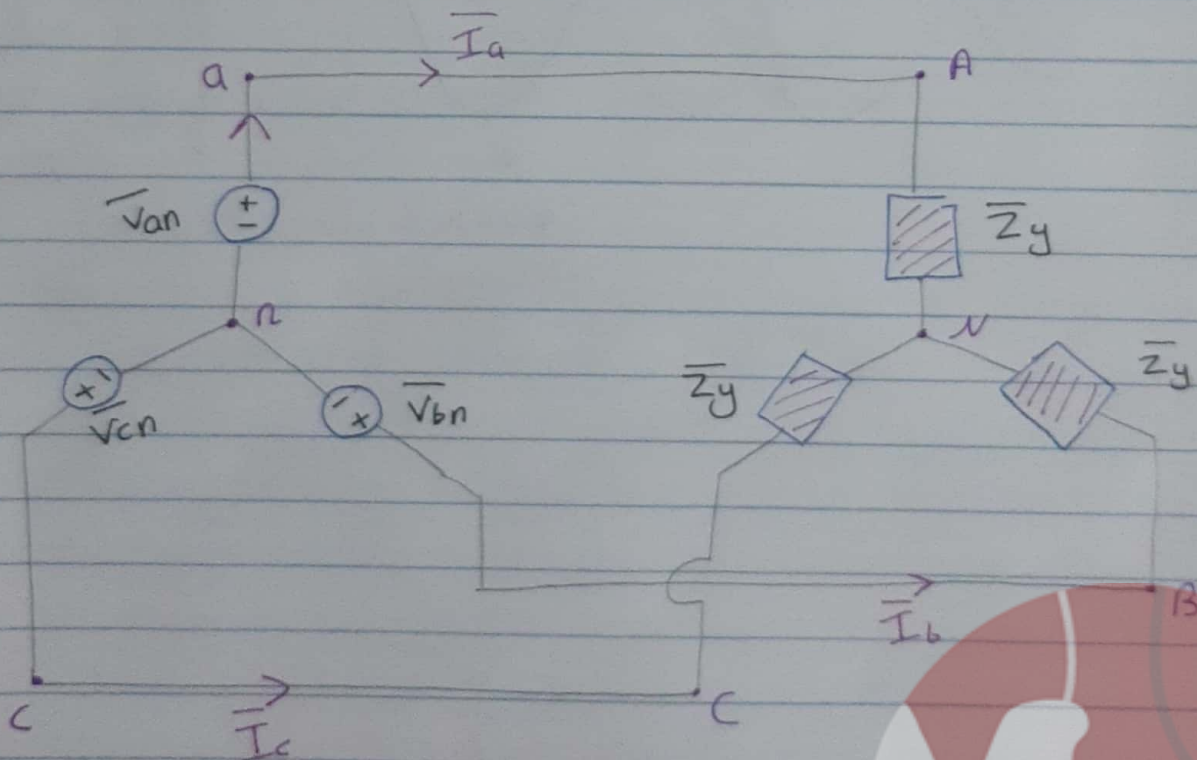
$$\bar{I}_N = -(\bar{I}_a + \bar{I}_b + \bar{I}_c) = 0 \rightarrow 0.c$$

سلك ال neutral ما الي  
> اي لأنو 0.c هاد الحكي بس اذا  
كان Balance يعني على النقاط الهه  
نفس  $\bar{Z}_y$

$$\bar{V}_{an} + \bar{V}_{bn} + \bar{V}_{cn} = 0$$

$$= V_p [1 \angle 0^\circ + 1 \angle -120^\circ + 1 \angle 120^\circ]$$

$$= V_p \left[ 1 - 0.5 - \frac{j\sqrt{3}}{2} - 0.5 + \frac{j\sqrt{3}}{2} \right] = 0$$

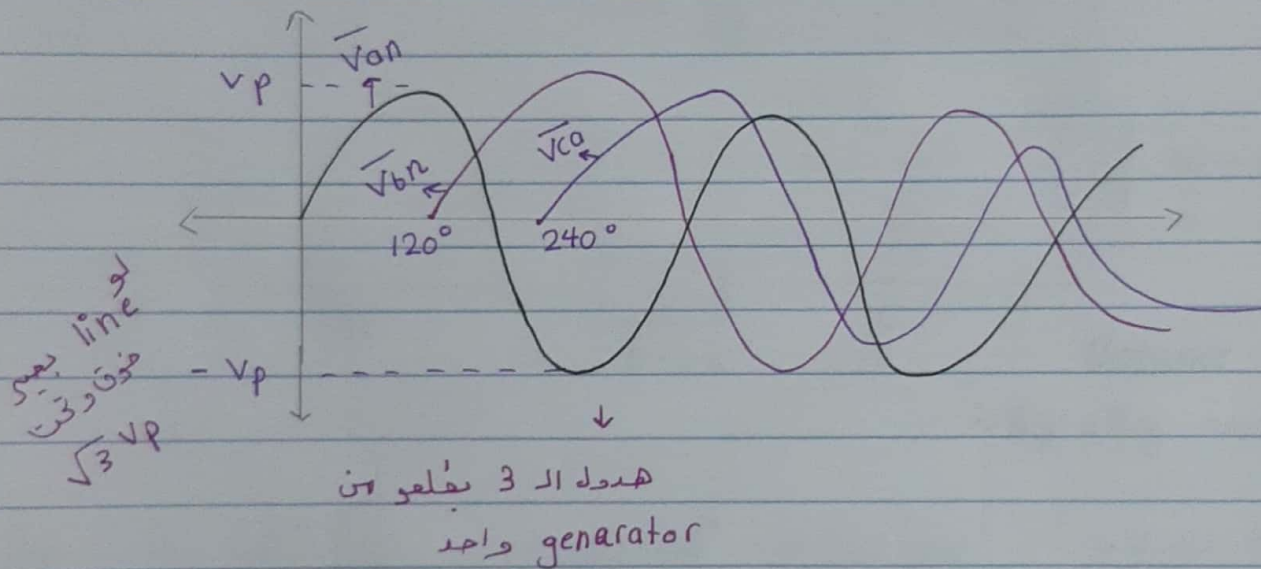
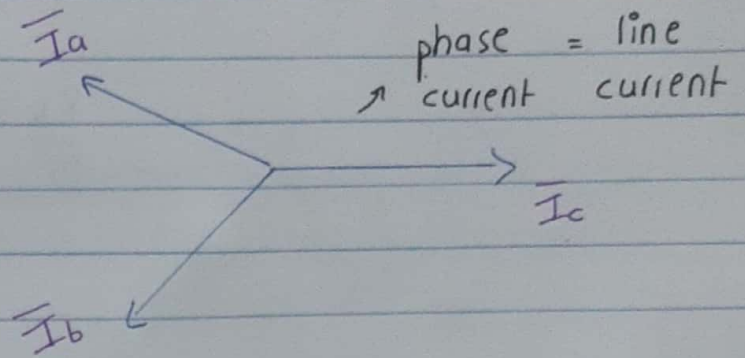




$$\bar{I}_a = \frac{\bar{V}_{an}}{Z_y} = \frac{V_p \angle 0^\circ}{Z_y}$$

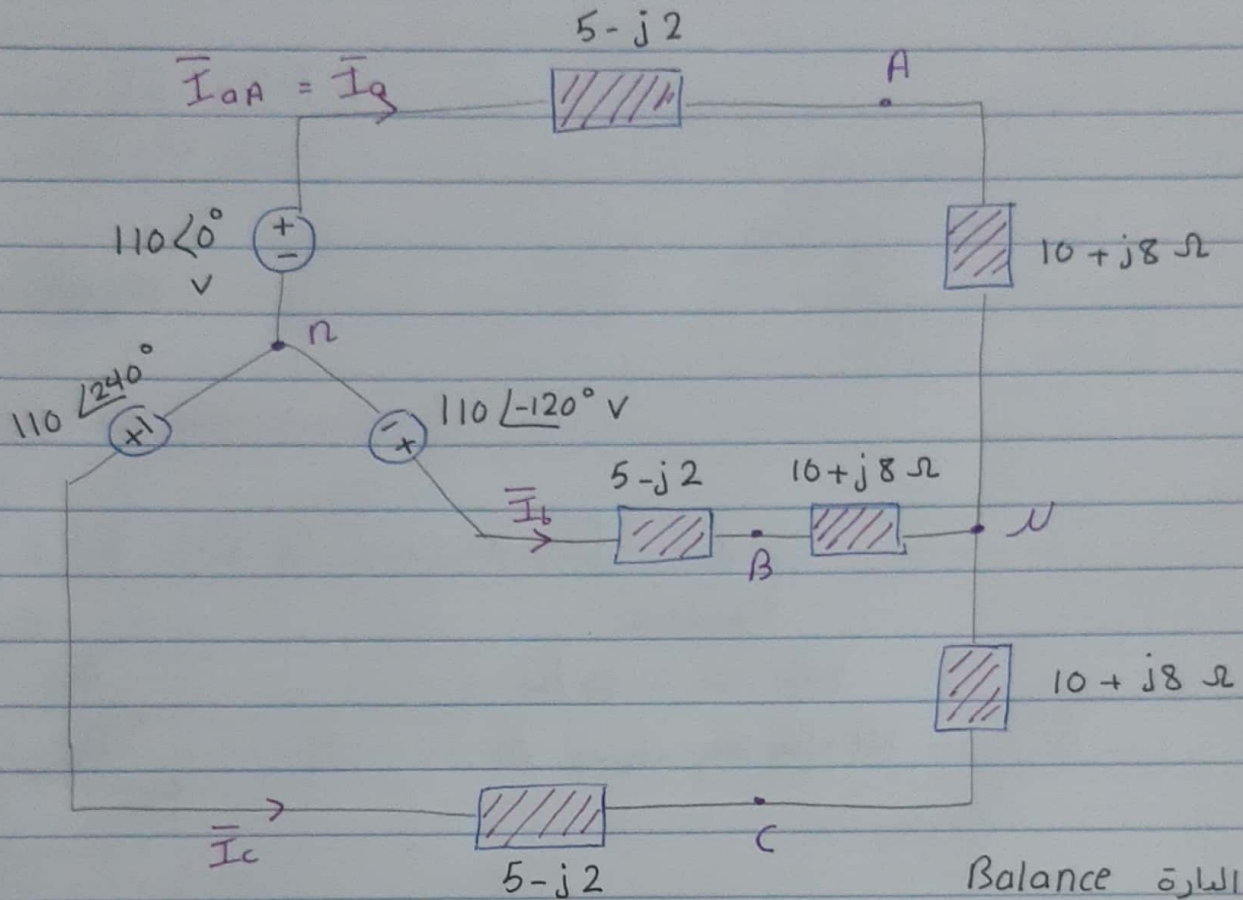
$$\bar{I}_b = \frac{\bar{V}_{bn}}{Z_y} = \frac{V_p \angle -120^\circ}{Z_y}$$

$$\bar{I}_c = \frac{\bar{V}_{cn}}{Z_y} = \frac{V_p \angle 120^\circ}{Z_y}$$



# # Example :

Calculate the currents :-



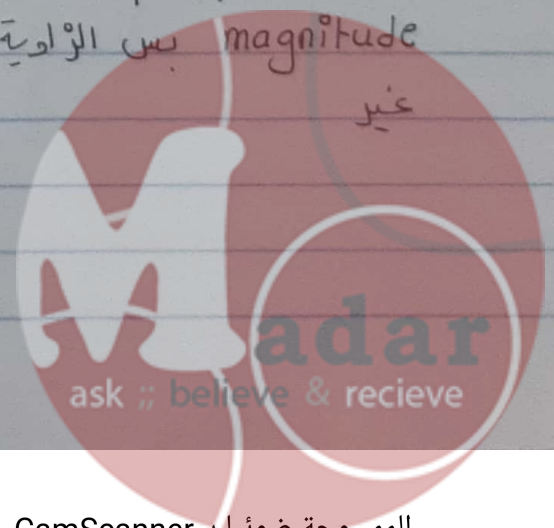
هنا البارة Balance  
لأن نفس قيمة  $Z_y$  والزوايا  
120°

$$\bar{I}_a = \frac{110 \angle 0^\circ}{(5 - j2) + (10 + j8)} = \frac{110 \angle 0^\circ}{15 + j6} = \frac{110 \angle 0^\circ}{16.155 \angle 21.8^\circ} = 6.81 \angle -21.8^\circ$$

$$\bar{I}_b = \frac{110 \angle -120^\circ}{15 + j6} = 6.81 \angle -141.8^\circ$$

$$\bar{I}_c = \frac{110 \angle -240^\circ}{15 + j6} = 6.81 \angle -48.2^\circ$$

كلهم بالهم نفس ال  
magnitude بس الزاوية  
غير





$$\overline{V}_{ab} = 110 \sqrt{3} \angle 30^\circ \text{ V}$$

$$\overline{V}_{bc} = 110 \sqrt{3} \angle -90^\circ \text{ V}$$

$$\overline{V}_{ca} = 110 \sqrt{3} \angle -210^\circ \text{ V}$$

$$\downarrow = 110 \sqrt{3} \angle 150^\circ \text{ V}$$

line voltages

→ Power on the load ?!

$$P = I^2 R = [6.81 \cos(-21.8)]^2 \times (10)$$

لـ power  
لـ power  
Power ما بين  
angle  
angle

لـ power

line باخذ الـ 10 أوم

إذا علمت كلهم بـ 15

$$Q = I^2 X$$

$$S = V I^* = I^2 Z_y = P + jQ$$

$$= (6.81)^2 \angle 21.8 \times 2 \times (16.155 \angle 21.8^\circ)$$

$$PF = \cos(\theta_v - \theta_i)$$

$$= \cos(0 - (-21.8)) = \cos(21.8)$$

لـ power  
لـ power  
Power ما بين  
angle  
angle



## \* Notes :

$$\bar{S} = P + jQ$$

↓ complex power

$$S = |\bar{S}|$$

↳ apparent power  
(الجواب بدون زاوية)

←  $S$  يأخذ ال  $I$

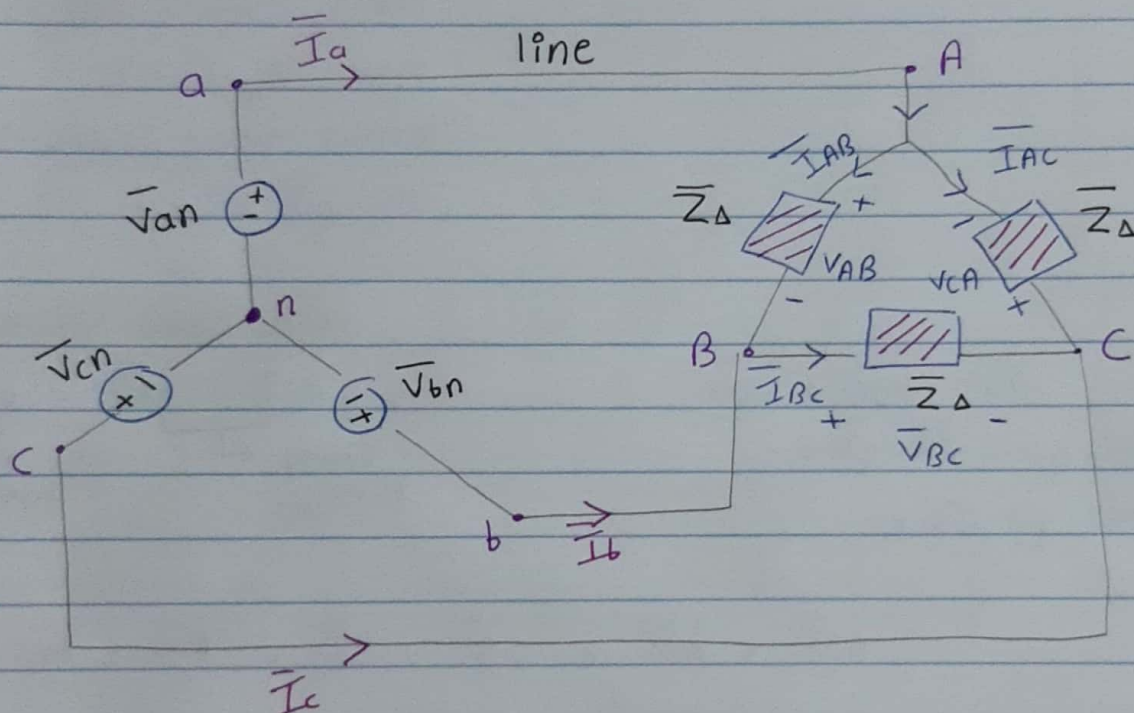
كاملة بس يأخذ  $P$  و  $Q$

Real يأخذ ال  $Q$

$$P = S \cos \theta$$

$$Q = S \sin \theta$$

## \* Wye - $\Delta$ connection :-



$I_{\text{phase}} \neq I_{\text{current}}$

$$* \bar{I}_L = \bar{I}_{AB} + \bar{I}_{AC} = \bar{I}_{AB} - \bar{I}_{CA} \rightarrow |\bar{I}_L| = \sqrt{3} |\bar{I}_P|$$

↓ line current

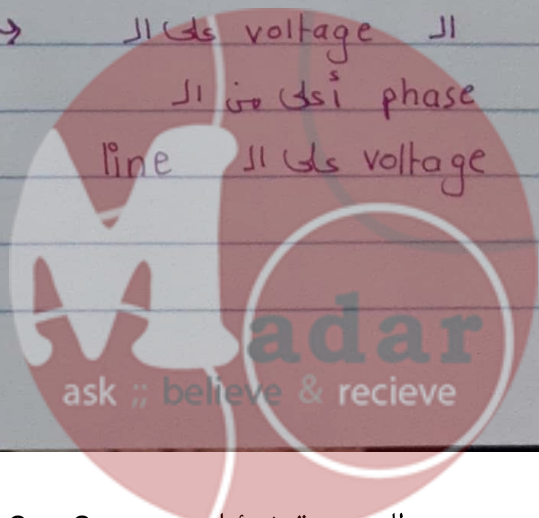
↳ phase current

$$* \bar{V}_{AB} = \bar{V}_{ob} = \sqrt{3} \bar{V}_{an}$$

↓ phase voltage

↳ line voltage

ال voltage على ال phase  
line voltage على ال line





**✱ phase current at the load :-**

$$\bar{I}_{AB} = \frac{\bar{V}_{AB}}{Z_{\Delta}} = \left| \frac{V_{AB}}{Z_{\Delta}} \right| \angle \chi$$

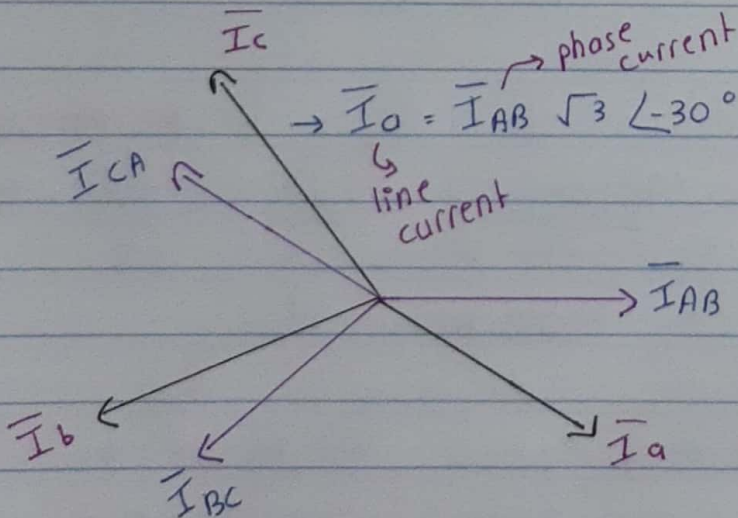
line current = source current

$$\bar{I}_{BC} = \bar{I}_{AB} \angle -120^{\circ} = \left| \frac{V_{AB}}{Z_{\Delta}} \right| \angle \chi - 120^{\circ}$$

$$\bar{I}_{CA} = \bar{I}_{AB} \angle -240^{\circ}$$

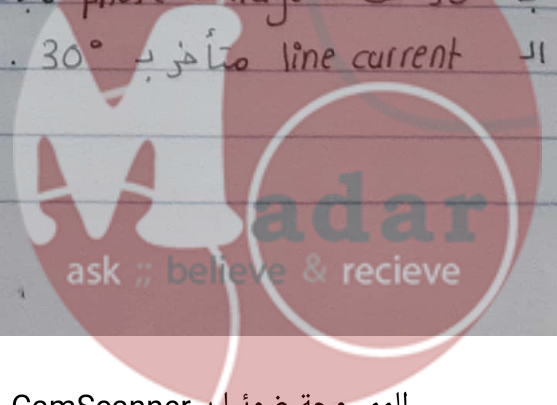
$$\begin{aligned} \text{✱ } \bar{I}_a &= \bar{I}_{AB} - \bar{I}_{CA} = \bar{I}_{AB} (1 - 1 \angle -240^{\circ}) \\ &= \bar{I}_{AB} (1 - (-0.5) - j \frac{\sqrt{3}}{2}) \\ &= \bar{I}_{AB} \left( \frac{3}{2} - j \frac{\sqrt{3}}{2} \right) \end{aligned}$$

$$\text{✱ } \bar{I}_a = \bar{I}_{AB} \sqrt{3} \angle \tan^{-1} \left( \frac{\sqrt{3}/2}{3/2} \right) \rightarrow \tan^{-1} \left( \frac{-1/\sqrt{3}}{3/2} \right) = \theta = -30^{\circ}$$



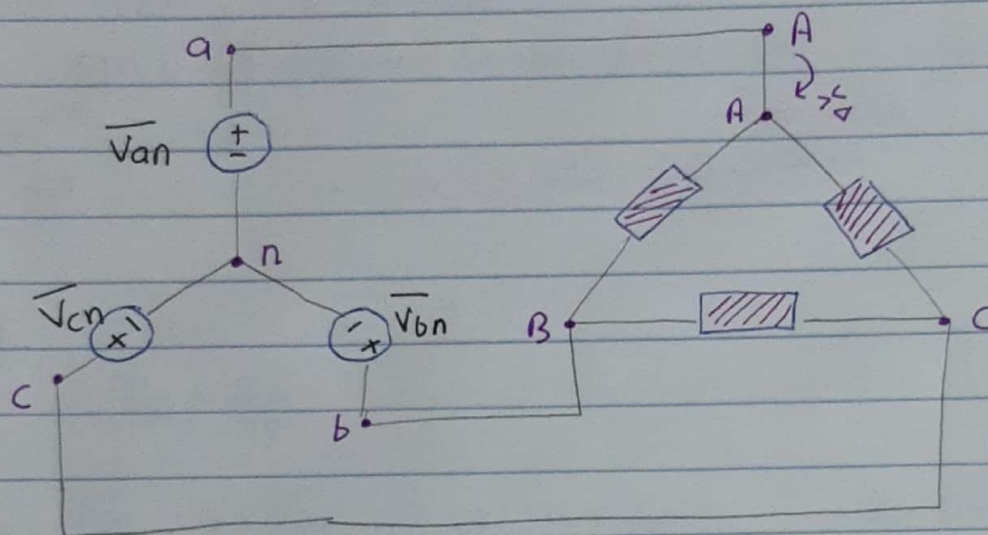
$$\begin{aligned} \bar{I}_c &= \bar{I}_{CA} - \bar{I}_{BC} \\ \bar{I}_b &= \bar{I}_{BC} - \bar{I}_{AB} \end{aligned}$$

✱  $\Delta$  wye line voltage كان متقدم  $30^{\circ}$  على phase voltage  $\Delta$  line current متأخر  $30^{\circ}$ .



### Example :-

A Balance abc sequence with  $\bar{V}_a = \bar{V}_{an} = 100 \angle 10^\circ$  (V), if  $Z_\Delta = 8 + 4j \Omega$ , calculate phase & line currents, the source is connected in wye & the loads are connected in Delta ( $\Delta$ ) :-



\* phase currents

$I_{AB}, I_{BC}, I_{CA}$

\* line currents

$I_a, I_b, I_c$

phase voltage in  $\Delta$  = line voltage in Y

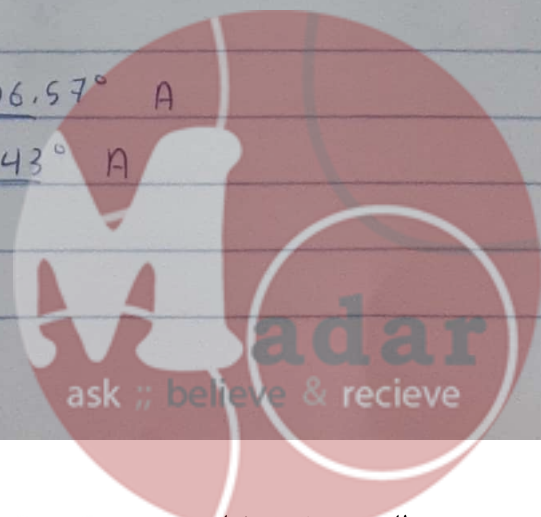
$$\begin{aligned} abc \rightarrow V_{bn} &= 100 \angle -110^\circ \text{ V} \\ &= 100 \angle -230^\circ \text{ V} \\ &= 100 \angle 130^\circ \text{ V} \end{aligned}$$

Ohm's law :-

$$\begin{aligned} \bar{I}_{AB} &= \frac{\bar{V}_{AB}}{Z_\Delta} = \frac{\bar{V}_{ob}}{Z_\Delta} = \frac{\sqrt{3} \cdot 100 \angle 40^\circ}{8.944 \angle 26.57^\circ} = 19.36 \angle 13.43^\circ \text{ A} \\ &\hookrightarrow 8.944 \angle 26.57^\circ \Omega \end{aligned}$$

$$\bar{I}_{BC} = 19.36 \angle 13.43^\circ - 120^\circ = 19.36 \angle -106.57^\circ \text{ A}$$

$$\bar{I}_{CA} = 19.36 \angle 13.43^\circ + 120^\circ = 19.36 \angle 133.43^\circ \text{ A}$$





$$\bar{I}_a = \bar{I}_{AB} - \bar{I}_{CA} = \sqrt{3} \ 19.36 \angle 13.43^\circ - 30^\circ = 33.53 \angle -16.57^\circ \text{ A}$$

$$\bar{I}_b = 33.53 \angle -16.57^\circ - 120^\circ = 33.53 \angle -136.57^\circ \text{ A}$$

$$\bar{I}_c = 33.53 \angle -16.57^\circ + 120^\circ = 33.53 \angle 103.43^\circ \text{ A}$$

→ voltage ⇒

$$\bar{V}_{bc} = \bar{V}_{BC} = \sqrt{3} \ 100 \angle -80^\circ \text{ V}$$

$$\bar{V}_{ac} = -100 \sqrt{3} \angle -200^\circ \text{ V} = 100 \sqrt{3} \angle -20^\circ = -100 \sqrt{3} \angle 160^\circ$$

-200 + 180

← عشان صا  
← عشان صا

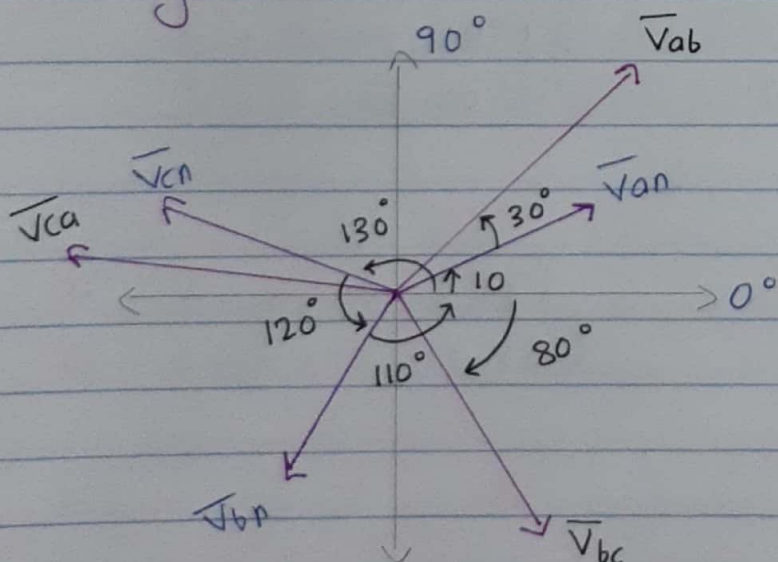
← عشان نسيّل السالب بيبرة

or

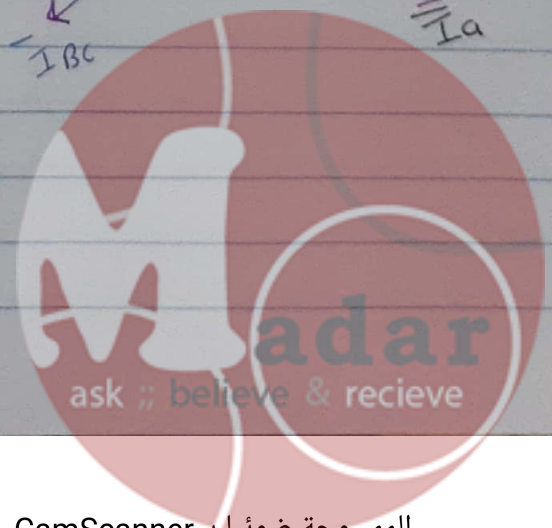
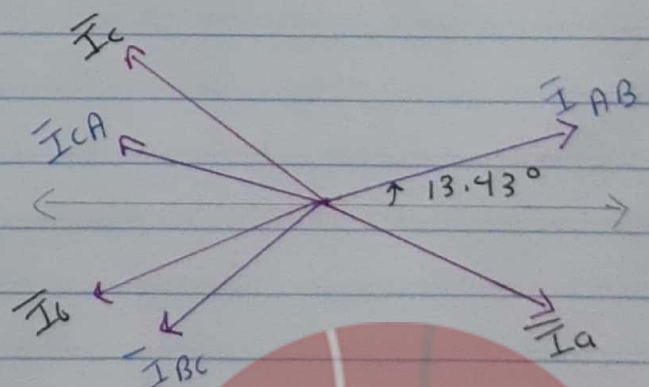
$$Z_y = \frac{Z_\Delta}{3}$$

$$\bar{I}_a = \frac{\bar{V}_{an}}{Z_y} = 3 \frac{\bar{V}_{an}}{Z_\Delta} = \frac{(3)(100 \angle 10^\circ)}{6.444 \angle 26.57^\circ} = 33.54 \angle -16.57^\circ \text{ A}$$

# Wye :-



# Delta :-



## # Power in balanced system :- (Rms)

$$P_p = V_p I_p \cos \theta \quad (W)$$

$$\theta = \theta_v - \theta_i$$

$$Q_p = V_p I_p \sin \theta \quad (VAR)$$

$$S_p = V_p I_p^* \quad (VA)$$

phase

الزاوية بين  $V$  و  $I$

هي نفسها زاوية  $Z$

$$S_p = \frac{V_L I_L^*}{\sqrt{3}} \quad \begin{cases} \rightarrow I_L = I_p \rightsquigarrow V_L / \sqrt{3} \\ \rightarrow V_L = V_p \rightsquigarrow V_L / \sqrt{3} \end{cases}$$

$$S = 3 S_p = \sqrt{3} V_L I_L^*$$

$$Q = 3 Q_p = \sqrt{3} V_L I_L \sin \theta$$

$$P = 3 P_p = 3 V_p I_p \cos \theta = \sqrt{3} V_L I_L \cos \theta$$

Find  $S, P, Q$  total :- (للمثال السابق)

$$\bar{S} = 3(100)(19.36)$$

$$\bar{S} = 3(100 \angle 10^\circ)(19.36 \angle -13.43^\circ) = 3 \bar{V}_p \bar{I}_p^*$$

$$\bar{S} = 3(\sqrt{3} 100 \angle 10^\circ)(19.36 \angle -13.43^\circ) = 3 V_L I_L^*$$

$$P = S \cos (10 - 13.43^\circ)$$

$$Q = S \sin (10 - 13.43^\circ)$$

