

⊛ Units : Time → seconds
 electrical current → Ampere A
 voltage → volt
 mass → kg
 length → m
 Power → Watt
 charge → coulomb

⊛ Prefixes

Pico → 10^{-12}	Kilo → 10^3
nano → 10^{-9}	Mega → 10^6
micro → 10^{-6}	Giga → 10^9
milli → 10^{-3}	

⊛ Power supply

ⓐ types : ① voltage source
 ② current source

ⓑ output signal : ① DC O/P signal: value of supply is fixed with time

ex: supply $v = 3$ volt
 $I = 2$ A → (constants)

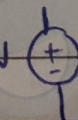
② AC O/P signal: value of supply varies with time.

ex: $v(t) = 3 \sin 4t$ volt

$I(t) = 2 e^t$ A (variables)

ⓐ Dependency

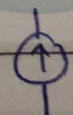
① independent P.S : its value doesn't depend on any element in the circuit

Symbol : 

Polarity

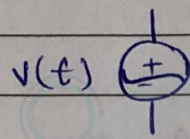
independent voltage

DC source

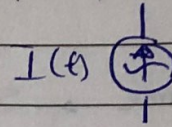
Symbol : 

independent

DC current source



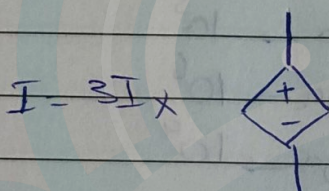
independent
AC voltage source
منبع ولتاژ متغیر



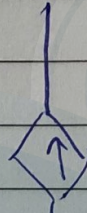
independent
AC current source.

② Dependent: its value depends on i or function of voltage
current

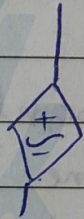
Symbols:



dependent
DC voltage
source



dependent DC
current source



dep. AC
voltage source



dep AC
current source.

* loads

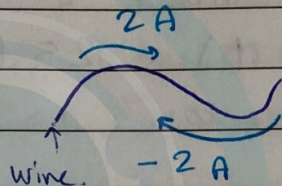
resistance	R	
inductive	L	
capacitive	C	

* charge $q_e : 1.6 \times 10^{-19} \text{ C}$

* Electrical current: charges in motion in a wire for closed loop

$$I = \frac{dQ}{dt} \quad \text{unit} \rightarrow \text{Ampere} \quad (\text{vector}) \quad \text{I} \rightarrow$$

slope.

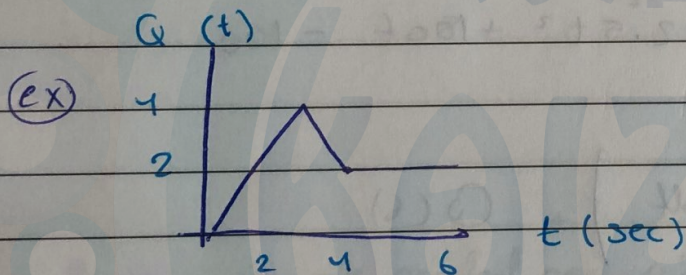


$$dQ = \int I dt + \text{initial condition (initial condition)}$$

(ex) $Q(t) = 3e^{-t} \text{ C}$ find $i(t)$

Solu $\rightarrow$

$$i(t) = -3e^{-t} \text{ A}$$



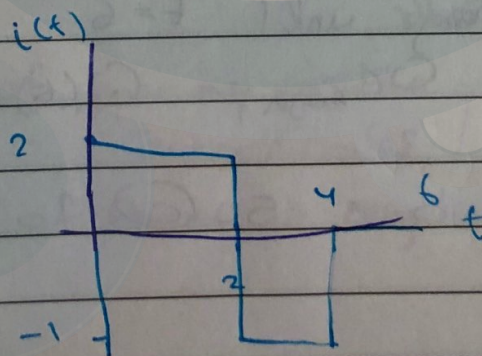
* Find $i(t)$ *

find $i(t) \rightarrow$

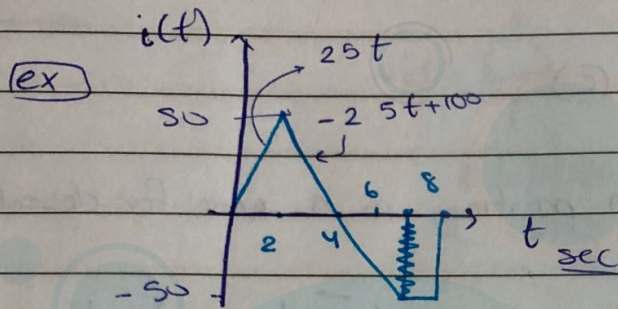
for $0 \leq t \leq 2$ $i = 2 \text{ A}$

for $2 \leq t \leq 4$ $i = -1 \text{ A}$

for $4 \leq t \leq 6$ $i = 0$



$i(t)$ curve.



find $Q(t)$ = for total amount of charge

for $0 \leq t \leq 2$ $i(t) = 25t$ $\int_0^t 25t \, dt$
initial condition $Q = 0$

for $2 \leq t \leq 6$ $= \left(\int_2^t -25t + 100 \, dt \right) + Q(2)$

$$\left[\frac{25t^2}{2} \right]_2^t = 50 = Q(2)$$

$$= -\frac{25}{2}t^2 + 100t + 50 - (-50 + 200)$$

$$= -12.5t^2 + 100t - 100$$

for $6 \leq t \leq 8$

$$Q(t) = \left(\int_6^t -50 \, dt \right) + Q(6)$$

$$Q(6) = -12.5 \times 36 + 50 \times 6 - 100 = 50$$

$$Q(t) = -50t + 350$$

* total amount of charge until $t=6$

$$Q(6) - Q(\text{begin}) = Q(6) - Q(0)$$

$$50 - 0 = 50 \text{ C}$$

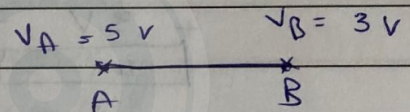
* find total amount of charge between $t = 2 \text{ sec}$ to $t = 8 \text{ sec}$

$$Q(8) - Q(2) = \text{(المجموع في ملاحظة الفترتين)}$$

$$-50 - 50 = -100 \text{ (C)}$$

* Voltage: work needed to move unit charge in a wire.
(حركات حث في السلك بوحدة شحنة يتحركوا بينها مستغل)

$$V = \frac{\text{work}}{\text{charge}} \Rightarrow \text{volt}$$

$$V_A = 5 \text{ V} \quad V_B = 3 \text{ V}$$


voltage @ ground = zero

B & A $\rightarrow$ إلى الأرض

$$V_{AB} = V_A - V_B = 5 - 3 = 2 \text{ V}$$

$$V_{BA} = V_B - V_A = 3 - 5 = -2 \text{ V}$$

$$V_{AB} = -V_{BA}$$

$$V_{A \text{ Ground}} = V_A - V_G = 5 - 0 = 5 \text{ V}$$

* Power: work needed per unit time

$$P = \frac{\text{work}}{\text{time}} \rightarrow \text{watt} \rightarrow \text{W, mW, } \mu\text{W, kW}$$

$$P = I * V$$

Power sup $\rightarrow$ مصدر

$\rightarrow$ السلك

السلك $\leftarrow$ Resistor $\rightarrow$ Load

* if sign of power is positive $\rightarrow$ power is dissipated / consumed
تستهلك / تضيع / $[IR]$ في المقاومة

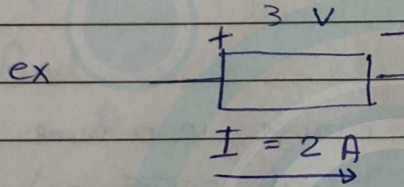
* if sign of power is negative $\rightarrow$ Power is generated / supplied
يتم إنتاجه

كيف اتعرف انه الطاقة موجبة / سالبة؟ من خلال:

* Passive sign convention:

if current enters from the (+) sign $\Rightarrow P \rightarrow +$

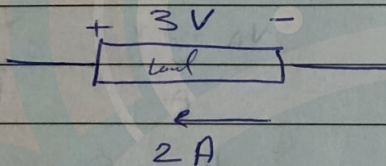
if current enters from the (-) sign $\Rightarrow P \rightarrow -$



find (P)

$$P = + (+2)(+3) = +6 \text{ watt (consumer)}$$

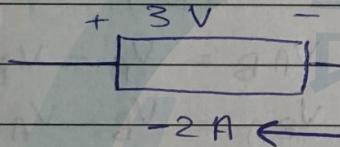
ex



التيار من اليمين
حقن

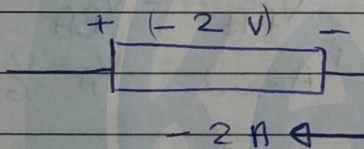
$$P = - (+2)(+3) = -6 \text{ watt (supply)}$$

ex



$$P = - (-2)(3) = 6 \text{ watt}$$

ex



$$P = - (-2)(-2) = -4 \text{ watt}$$

$$P = IV$$

$$P = I^2 R$$

$$P = V^2 / R$$

$$V = IR$$

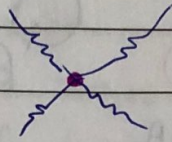
$$V = L * \pi r^2$$

N = volume * density

$$Q_{\text{charge}} = \# N * Q_e$$

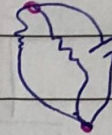
$$Q_e = -1.603 * 10^{-19}$$

ex



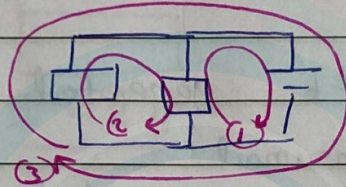
one node

ex:



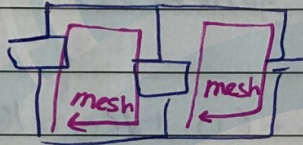
2 nodes

(3) **loops**: Closed connection of Branches



3 loops

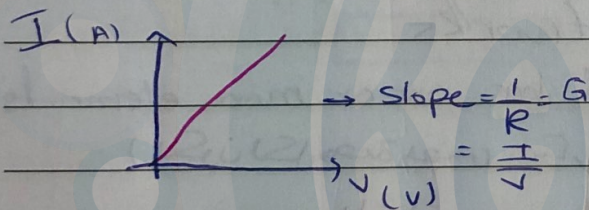
(4) **mesh**: loops (doesn't contain other loops)



has 2 meshes

* Ohms law

: current that passes through a wire faces resistance.



$V \propto I$ (Linear relationship)

$$V = RI$$

$$R = \frac{V}{I} \quad (\Omega)$$

Ohms law: voltage across an element is directly proportional to the current

* Conductance $\rightarrow G = \frac{1}{R}$ (S, Ω^{-1})

$$P = IV$$

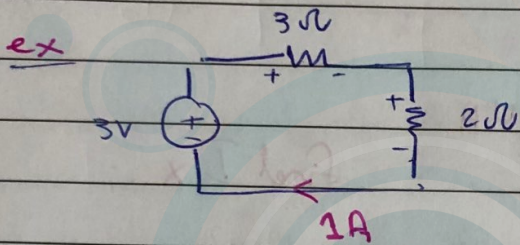
$$P = I^2 R$$

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

ex: Wire has resistance of 3Ω , passes a current of $2A$
And voltage across the wire

Soln

$$V = IR = 2 \times 3 = 6V$$

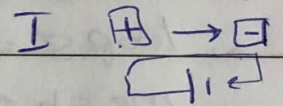
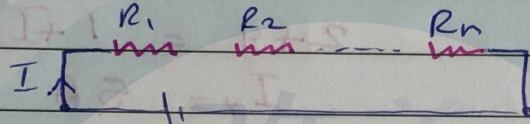


$$V_1 = IR_1 = 1 \times 3 = 3 \text{ volt}$$

$$V_2 = 2 \text{ volt}$$

* Circuits connections

1 series connections of resistors

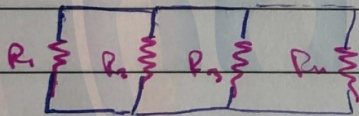


$$R_{\text{total}} = R_1 + R_2 + \dots + R_n = \sum_{n=1}^N R_n$$

→ Same current passes through the R .

→ voltage is different for each element

2 Parallel connections of resistors

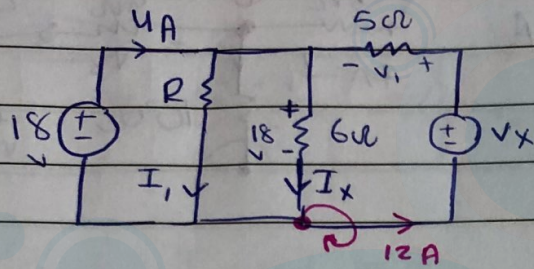


$$R_{\text{total}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}}$$

→ current is diff. for each element

→ Voltage is the same for each element

ex

Find V_1, I_x, V_x, R, I_1

* We can use $\rightarrow$ (Ohms law / KCL / KVL)
 $\rightarrow$ Parallel / series

Soln $\rightarrow V_R = 18 \text{ V} \rightarrow$ parallel

$$I_x = \frac{V}{R} = 3 \text{ A} \rightarrow \text{Ohms law}$$

$$V_1 = 5 \times 12 = 60 \text{ V} \rightarrow \text{Ohms law}$$

use KCL @ node $\Rightarrow \sum I_{in} = \sum I_{out}$

$$12 + 4 = 3 + I_1$$

$$I_1 = 13 \text{ A}$$

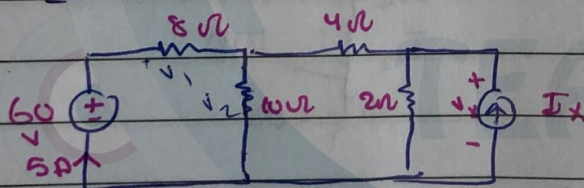
$$R = \frac{V}{I} = \frac{18}{13} = 1.38 \Omega \rightarrow \text{Ohms law}$$

use KVL

$$-18 - 60 + V_x = 0$$

$$V_x = 78 \text{ V}$$

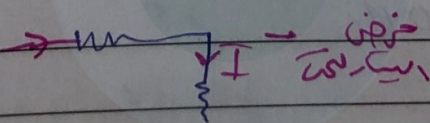
ex 2



find I_x, V_x & Power of the current source

* Part 1 $I \rightarrow$ assumption

$$V_1 = I R = 40 \text{ V}$$



$$-60 + 40 + V_2 = 0$$

$$V_2 = 20 \text{ V}$$

KCL

$$I = \frac{V}{R} = \frac{20}{10} \Rightarrow 2 \text{ A}$$

applying KCL

Node 1 $5 = 2 + I_2$

$$I_2 = 3 \text{ A}$$

Ohms law $V_3 = 4 \times 3 = 12 \text{ V}$

$$\text{KCL} = -20 + 12 + V_4 = 0$$

$$V_4 = 8$$

$$R \times I_3 = V_4$$

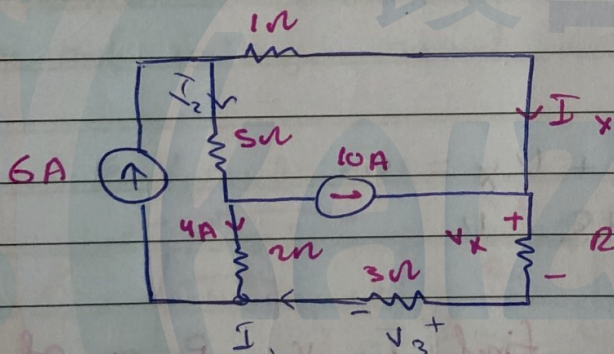
$$\frac{8}{2} = 4 = I_3$$

Node 2 $I_x = 1 \text{ A}$

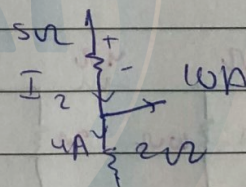
$$\text{Power} = I \times V$$

$$= -1 \times 8 = -8 \text{ W}$$

ex



Find I_x, V_x, R



$$I_1 = 2 \text{ A}$$

$$I_2 = 14 \text{ A}$$

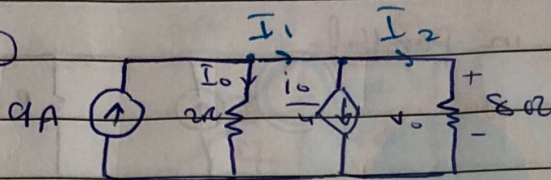
$$V_3 = 2 \times 3 = 6 \text{ V}$$

$$I_x = -8 \text{ A}$$

$$V_x = 80 \text{ volt}$$

$$R = 40 \Omega$$

2.7



سریز و موازی
series parallel
آهن موازی
← مقدار واپس
جدا کردن علیه هر دو

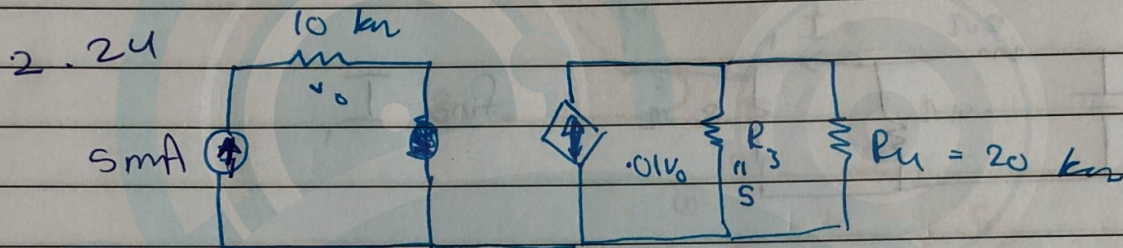
$$I_1 + I_0 = 9$$

$$5 \times I_2 = 2 I_0$$

$$I_2 + \frac{I_0}{4} = I_2$$

$$4 I_2 = I_0$$

ویندوز



$$V_0 = 5 \text{ V}$$

$$\diamond = .5 \text{ V} \rightarrow \text{kel } jR_0$$

* Idealization of Resistance

① Short circuit $R = 0 \Omega$

a
b $R=0$ $V=I \times R=0$
regardless the I that
passes through

② Open circuit $R = \infty \Omega$ (G.M)

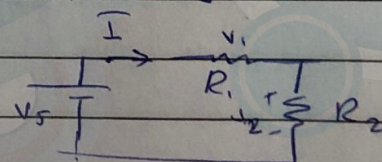
a
b $R=\infty$ $V=I \times R$
~~regardless the V across~~
 $I = \frac{V}{\infty} = 0$

* Voltage divider → used in [Series connection]

جهت I_1 و I_2 و I_3

$$V_1 = \frac{V_s \times R_1}{R_1 + R_2}$$

$$V_2 = \frac{V_s \times R_2}{R_1 + R_2}$$



V_2 camp 1
 I pld R_{eq} pld

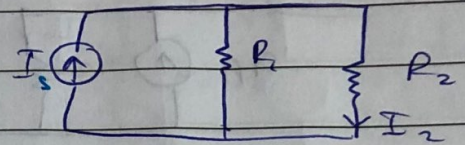
Ohm i_{12}

Five Apple

1/7/2020

* Current divider → used in parallel

$$I_n = I_s * \frac{1}{R_n}$$



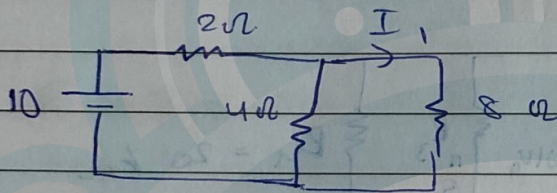
gap

$$\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

$$I_2 = I_s * \frac{1}{R_2} \Rightarrow \text{X}$$

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

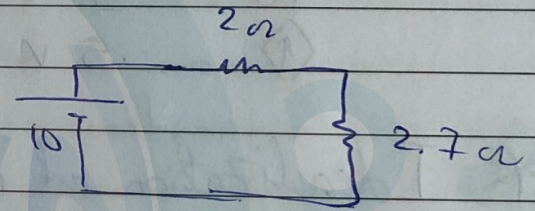
ex



find I_1

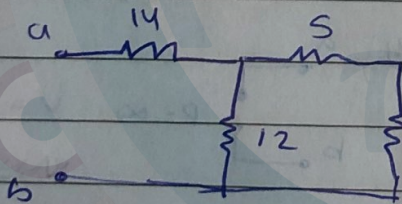
$$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{8} = \frac{8}{3} = R_{eq}$$

$$V_{2.7} = \frac{10 * 2.7}{4.7} = 5.74 \text{ (V)}$$



$$I_1 = .71 \text{ A} = \frac{5.74}{8}$$

ex



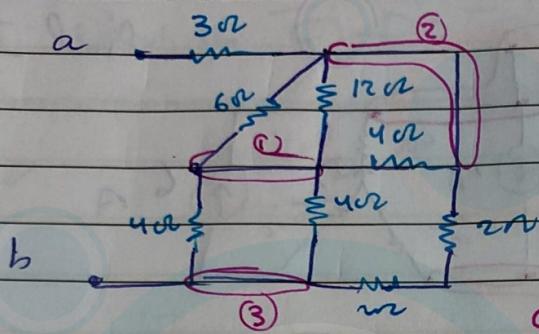
find R_{eq} seen from a & b

$$\frac{1}{6} + \frac{1}{12} = \frac{1}{4}$$

$$R_{eq} = 4 \Omega$$

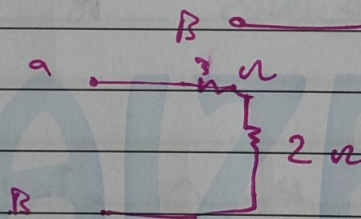
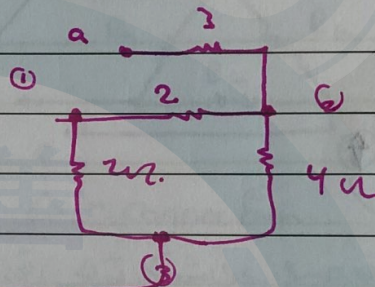
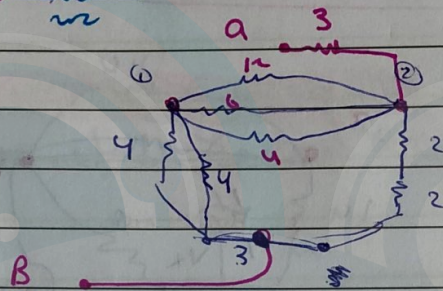
$$R_{eq} = 4 + 14 = 18 \Omega$$

Ex

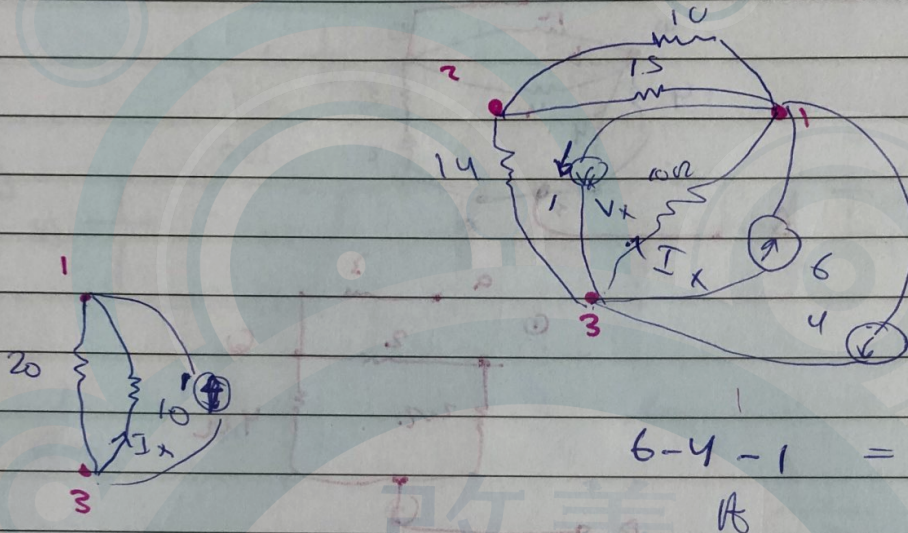
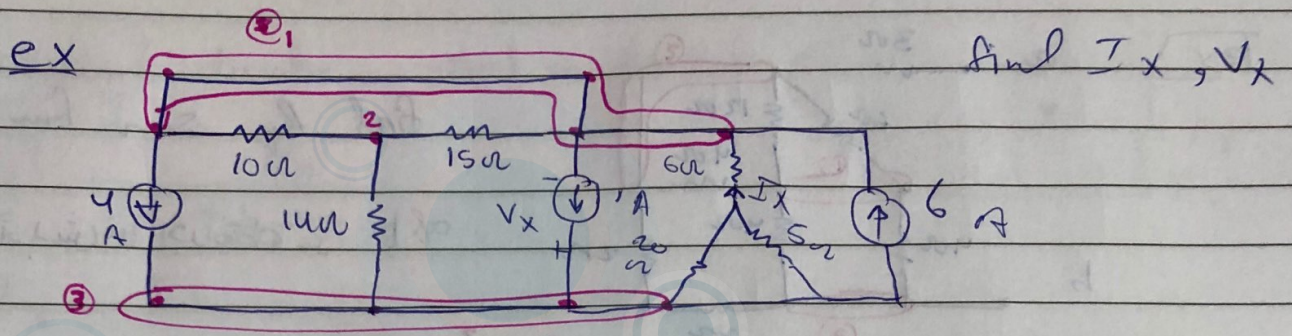


find R_{eq} seen from a & b

* لازم آید که ما ابتدا در نقطه a & b



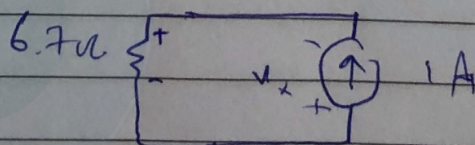
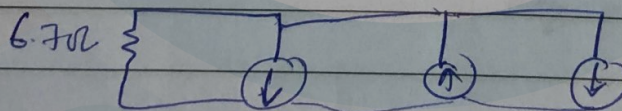
$$R_{eq} = 5\Omega$$



المصدر 4A
المصدر 6A
المصدر 1A

$$\boxed{I_x} = \frac{-1 \times \frac{1}{10}}{\frac{1}{10} + \frac{1}{20}} = -0.67 \text{ A}$$

المصدر 6A
المصدر 1A
المصدر 4A

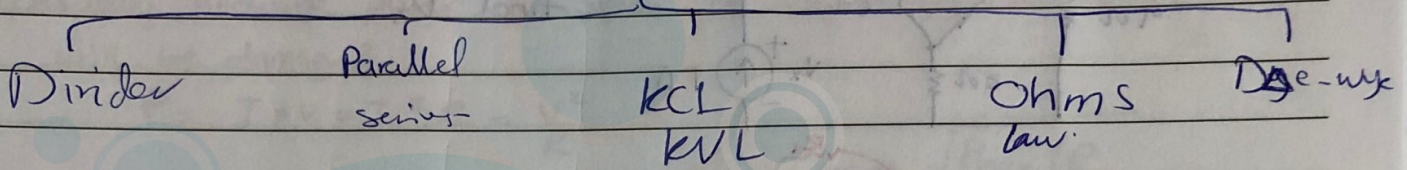


$$V_x = -6.7 \text{ V}$$

$$= -6.7 \text{ volt}$$

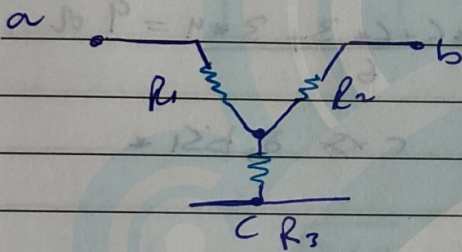
* متى أوصول على التوازي لازم المفاة و البداية واحد يكون

خريطة ذهنية حل الدوائر:



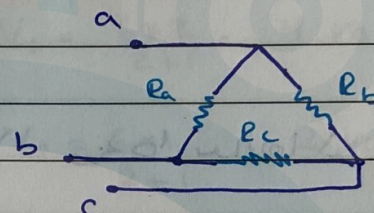
* Delta - wye connection resistor

* ملا الدائرة ما تكون لا سيزنوا بارايلل يستخدم طاه الجرسية



Y connection

* ما في توصيل توازي/توازي



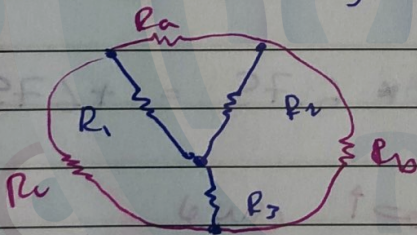
Δ - connection

* ما في توصيل على شكل توازي/توازي

* نكتب طاه الجرسية

* تحويلات Y الى Δ و Δ الى Y

* Conversion from Y → Δ



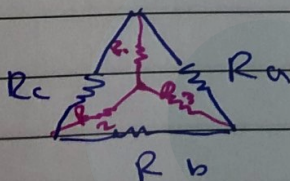
$$R_a = (R_1 R_2 + R_2 R_3 + R_1 R_3) / R_3$$

لـ تقسيم على مقاومة الجرسية مع R3

$$R_b = (R_1 R_3 + R_1 R_2 + R_2 R_3) / R_1$$

$$R_c = (R_2 R_3 + R_1 R_2 + R_1 R_3) / R_2$$

* Conversion from Δ → Y

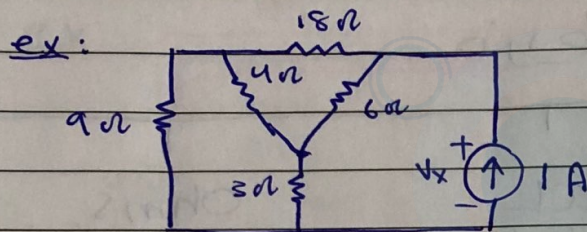


$$R_1 = R_a R_c / (R_a + R_b + R_c)$$

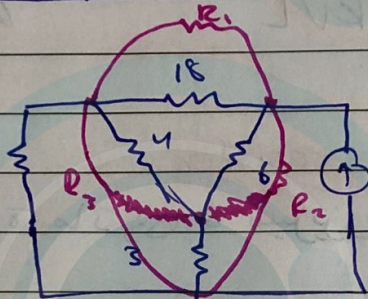
لـ تقسيم على مجموع المقاومات

$$R_2 = R_c R_b / (R_a + R_b + R_c)$$

$$R_3 = R_a R_b / (R_a + R_b + R_c)$$

find V_x .

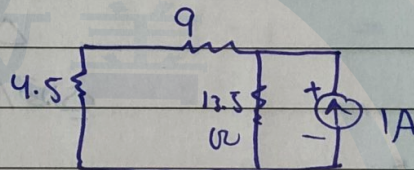
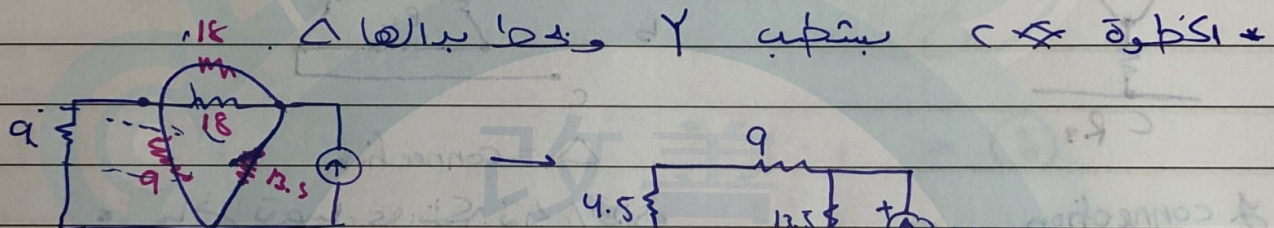
solu



$$R_1 = \frac{4 \times 6 + 6 \times 3 + 3 \times 4}{3} = 18 \Omega$$

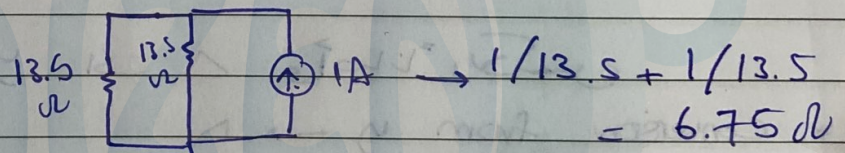
$$R_2 = \frac{4 \times 6 + 6 \times 3 + 3 \times 4}{4} = 13.5 \Omega$$

$$R_3 = \frac{4 \times 6 + 6 \times 3 + 3 \times 4}{6} = 9 \Omega$$



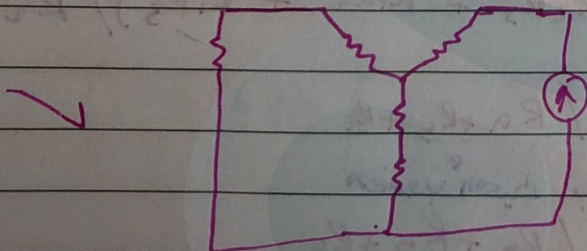
$$\frac{1}{9} + \frac{1}{9} \Rightarrow 4.5 \Omega$$

$$\frac{1}{18} + \frac{1}{18} \Rightarrow 9 \Omega$$



$$V = IR = +1 \times 6.75 = +6.75 \text{ volt}$$

لوبيتي أحول من ٤ ← ٧



* Power rating for resistors:

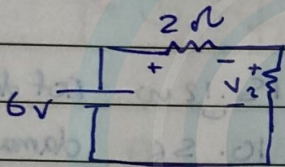
maximum allowable power dissipation, if we exceed max value, the (R) will be damaged.

$$P = I \cdot V = I^2 R = \frac{V^2}{R}$$

$$I_{\max} = \sqrt{P_{\max} / R}$$

أقصى تيار معتمد (R)

ex:



find max allowable $I_{\max}$ for each R

$$\text{Solu: } V_1 = \frac{6 \times 2}{2+1} = 4 \text{ volt}$$

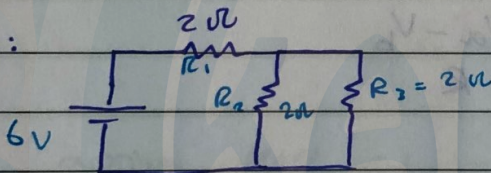
$$V_2 = \frac{6 \times 1}{2+1} = 2 \text{ volt}$$

$$I_{\max} = \sqrt{8/2} = 2 \text{ A}$$

$$P_{\max}(\text{ed}) = \frac{V_1^2}{2} = \frac{4^2}{2} = 8 \text{ W}$$

$$P_{\max}(\text{ed}) = \frac{V_2^2}{1} = \frac{2^2}{1} = 4 \text{ W}$$

ex:

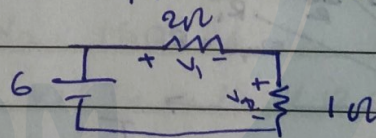


* Rating for R_2 & $R_3 = .25 \text{ W}$

Rating for $R_1 = 15 \text{ W}$

- What happens in resistors in circuits

Solu:



$$V_1 = \frac{6 \times 2}{3} = 4 \text{ volt}$$

$$V_2 = \frac{6 \times 1}{2} = 2 \text{ volt}$$

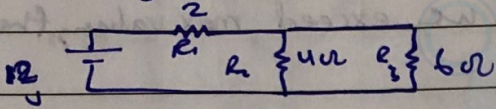
$$P(R_1) = \frac{4^2}{2} = 8 \text{ W} < 15 \text{ not damaged}$$

$$P(R_2) = \frac{2^2}{2} = 2 > .25 \text{ damaged}$$

$$P(R_3) = \frac{2^2}{2} = 2 > .25 \text{ damaged}$$

* $P_{rating} = P_{max}$

ex:

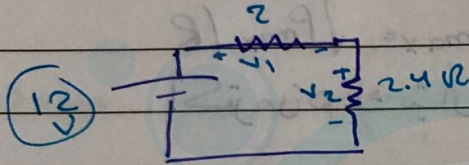


$P_{R_1 rating} = P_{rating R_3} = 100 \text{ W}$

$P_{R_2 rating} = 5 \text{ W}$

Which resistor will be damaged?

Solu:



$V_1 = \frac{12 \times 2}{4.4} = 5.5 \text{ volt}$

$V_2 = \frac{12 \times 2.4}{4.4} = 6.5 \text{ V}$

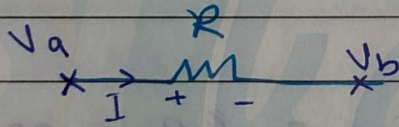
$P_{R_1} = 5.5^2 / 2 = 15.12 \text{ W}$ not damaged

$P_{R_2} = 6.5^2 / 4 = 10.56 \text{ W}$ damaged

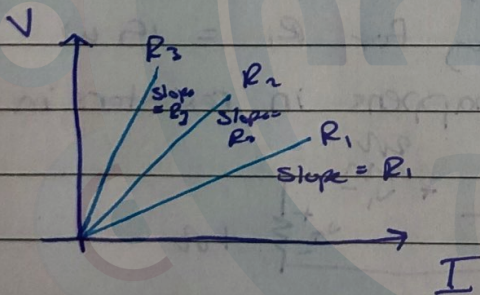
$P_{R_3} = 6.5^2 / 6 = 7.04 \text{ W}$ not damaged

* notes

① $I = \frac{V}{R}$

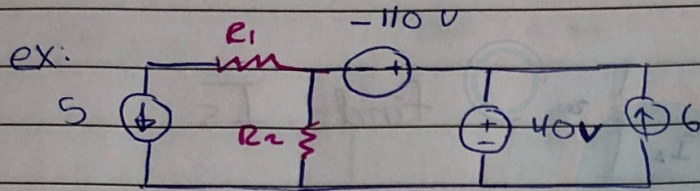


$I = \frac{V_a - V_b}{R}$



$R_1 < R_2 < R_3$

$G_1 > G_2 > G_3$



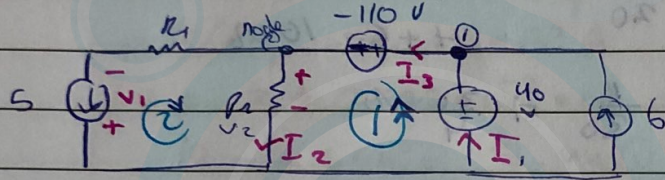
Given:

$$P_{SA} (\text{supplied}) = 100 \text{ W}$$

$$P_{40V} (\text{supplied}) = 500 \text{ W}$$

ثابتنا supplied من هنا يستنتج
اتجاه التيار واتجاه (V)

Soln →



ما التيار يدخل على اسباب

يعني supplied .

$$P_{40V} = 500 = I_1 \cdot V = I_1 \cdot 40 \Rightarrow I_1 = \frac{500}{40} = 12.5 \text{ A}$$

$$P_{SA} = 100 \text{ W} = 5 \cdot V \Rightarrow V_1 = 20 \text{ volt}$$

Q → Find R_1 & R_2

apply @ node 1
KCL

$$\sum I_{in} = \sum I_{out}$$

$$12.5 + 6 = I_{out} = 18.5 \text{ A} = I_2$$

$$\sum I_{in} = \sum I_{out} \Rightarrow 18.5 = 5 + I_2$$

$$I_2 = 13.5 \text{ A}$$

apply KVL @ L1

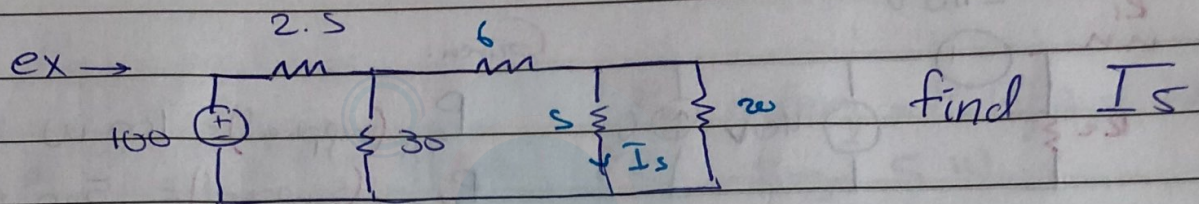
$$-40 - 110 + V_2 = 0$$

$$V_2 = 150 \text{ V}$$

$$R_2 = V_2 / I_2 = 150 / 13.5 = 11.11 \Omega$$

$$\text{KVL @ L2} \rightarrow 20 - 5 \cdot R_1 + 150 = 0$$

$$R_1 = 34 \Omega$$

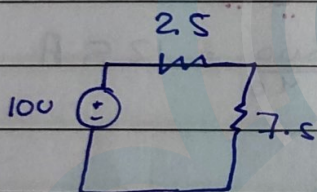


$$\frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{20} \Rightarrow R_{eq} = 4 \Omega$$

$$4 + 6 = 10 \Omega$$

$$\frac{1}{10} + \frac{1}{30} \Rightarrow \frac{30}{4}$$

$$7.5 + 2.5 = 10 \Omega = R_{eq}$$



$$I = 10$$

$$V = \frac{75}{7.5} V$$

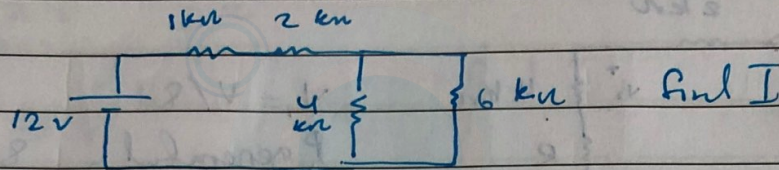
$$\frac{75}{10} = \frac{I}{6.4} = 7.5$$

$$7.5 \times 4 = 30 V \Rightarrow V_{5,20}$$

$$I = \frac{V}{R} \Rightarrow \frac{30}{5} = 6 A$$

$$R = 2.5 \Omega \quad \text{و } 100 = V_{5,20} \quad \text{نقطة اعتبار}$$

P/2.9



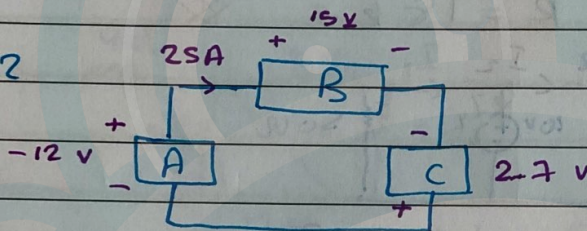
Solu: $\frac{1}{4} + \frac{1}{6} \rightarrow R_{eq} = 2.4 \text{ k}\Omega$ $1 + 2 \rightarrow R_{eq} = 3 \text{ k}\Omega$
 $R_{eq} = 2.4 + 3 = 5.4 \text{ k}\Omega$

$I = V/R_{eq} = 2.222 \times 10^{-3} \text{ A}$

$V = 3 + 2.222 \times 10^{-3} \times 13 = 6.66 \text{ (V)}$

$12 - 6.66 = 5.44 \text{ (V)} \rightarrow \frac{5.44 \text{ V}}{4 \text{ k}\Omega} = 1.33 \times 10^{-3} \text{ A}$

P/2.12



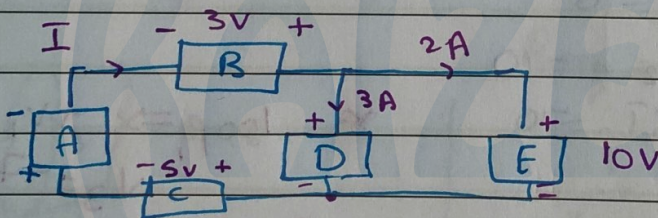
* Which element generates & which one absorbs power

$P_B = 25 \times 15 = 375 \text{ W (absorbed)}$

$P_C = 25 \times -2.7 = -67.5 \text{ W (generated)}$

$P_A = -12 \times -12 = +144 \text{ W (generated) absorbed}$

P/2.14



* Which element absorbs/ generates power?

$\sum I_{in} = \sum I_{out} \Rightarrow 2 + 3 = I = 5 \text{ A}$

$V_D = V_E = 10 \text{ (Parallel)}$

KCL $\rightarrow -3 + 10 + 5 + V_A = 0$
 $V_A = -12 \text{ (V)}$

$P_E = 10 \times 2 = 20 \text{ W ab}$

$P_D = 10 \times 3 = 30 \text{ W ab}$

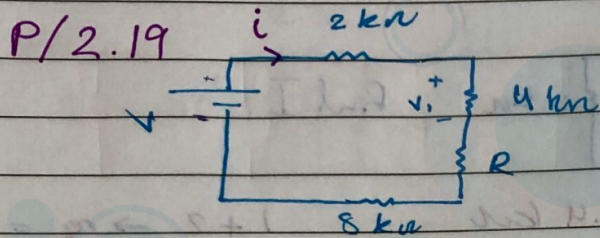
$P_B = 5 \times -3 = -15 \text{ W ge}$

$P_A = 5 \times -12 = -60 \text{ W gb}$

$P_C = 5 \times 5 = 25 \text{ ab}$

لها مقدار فنية $I = x$ (↑) *

5/2/2020



$V_1 = V/8$
 $P_{\text{generat}} = 8 \text{ mW}$
 find V, v_1, i, R

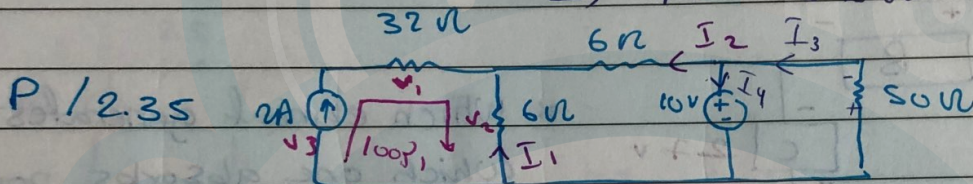
$$\begin{aligned} V \times i &= 8 \times 10^{-3} \\ i \times 4 \times 10^3 &= V_1 \\ i &= 0.5 \text{ A} \end{aligned}$$

$$V = 16 \text{ V}$$

$$V_1 = 2 \text{ V}$$

$$\text{KCL} \rightarrow 0.5 \times 2 \times 10^3 + V_1 - V + 5R + 8 \times 10^{-3} \times 5 = 0$$

$$\Rightarrow R = 18 \text{ k}\Omega$$



Find $i_1, i_2, P_{(10V)}, P_{(2A)}, P(R)$

$$V_{32} = 2 \times 32 = 64 \text{ V}$$

$$\text{KCL} \rightarrow 2 = -(I_1 + I_2) \Rightarrow I_1 = -(I_2 + 2)$$

$$\text{KVL} \quad V_6 - V_6 + 10 = 0$$

$$I_1 \times 6 - 6 \times I_2 = -10$$

$$-(I_2 + 2) \times 6 - 6I_2 = -10$$

$$I_2 = -1.67 \text{ A}$$

$$I_1 = -1.833 \text{ A}$$

$$V_{50} = 10 = V_{10V}$$

$$I_3 = \frac{10}{50} \text{ A}$$

$$\text{loop} \Rightarrow +V_1 - V_2 + V_3 = 0$$

$$V_3 = -74.98 \text{ V}$$

$$P_{2A} = 2 \times -74.98$$

$$= -149.98 \text{ W}$$

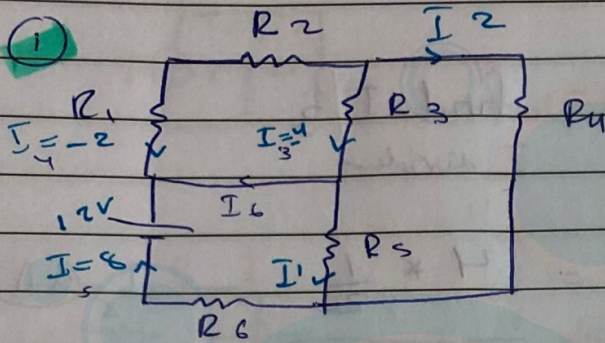
$$\frac{10}{50} = I_4 + 1.67 \Rightarrow I_3 = 0.033 \text{ A}$$

$$P_{10V} = 0.033 \times 10 = 0.33 \text{ W}$$

$$P_{2A} = I^2 R = 32^2 \times 2 = 2048 \text{ W}$$

$$P_{6\Omega} = I^2 R = (-1.67)^2 \times 6 = 16.7 \text{ W}$$

$$P_{6\Omega} = (-1.833)^2 \times 6 = 20.09 \text{ W}$$



find I_1

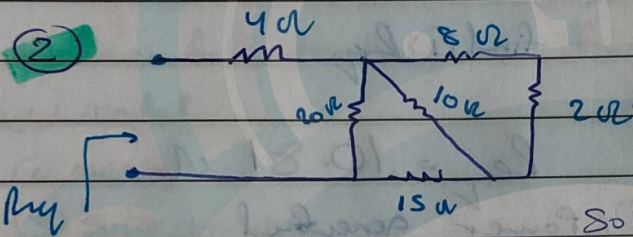
$$\sum I_{in} = \sum I_{out}$$

$$-4 = I_6 + I_1$$

$$-2 + 8 + I_6 = 0$$

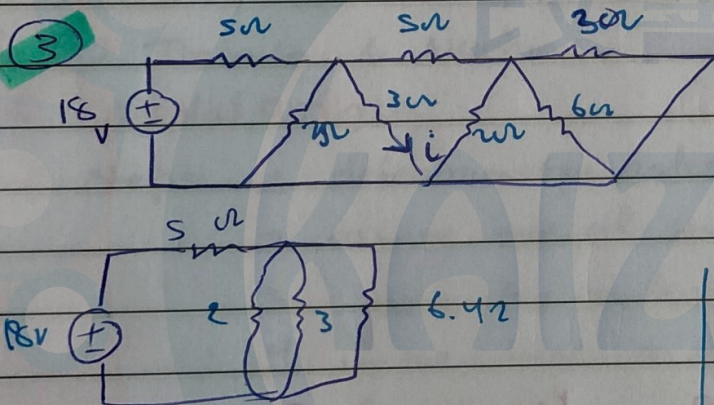
$$I_6 = -6 \text{ A}$$

$$I_1 = 2 \text{ A}$$



find R_{eq}

Soln $\Rightarrow R_{eq} = 14 \Omega$



find R_{eq} seen by source & i

$$R_{eq} = \frac{1}{\frac{1}{30} + \frac{1}{6}}$$

$$\frac{1}{\frac{1}{30} + \frac{1}{6}} + \frac{1}{2}$$

$$\frac{1}{\frac{1}{6} + \frac{1}{30} + \frac{1}{2}} + \frac{1}{3}$$

$$\frac{1}{\frac{1}{6} + \frac{1}{30} + \frac{1}{2} + \frac{1}{3}} + \frac{1}{5}$$

$$\frac{1}{\frac{1}{6} + \frac{1}{30} + \frac{1}{2} + \frac{1}{3} + \frac{1}{5}}$$

$$R_{eq} = 6 \Omega$$

$$R_{eq} = 6$$

$$V/R = I \Rightarrow$$

$$18/6 \rightarrow I = 3$$

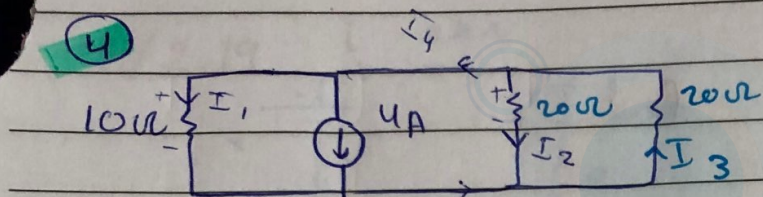
~~X divider~~

$$V_s = 3 \times 5 = 15 \text{ V}$$

$$18 - 15 = 3 \text{ V} = V_3$$

$$I = V/R = 1 \text{ A}$$

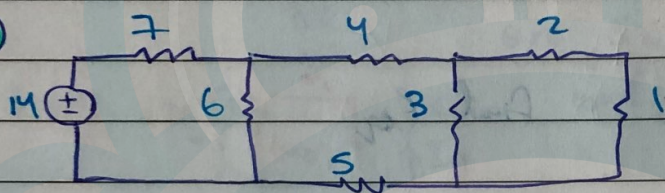
4



find I_3
I divider

$$I_3 = \frac{4 \times \frac{1}{20}}{\frac{1}{20} + \frac{1}{20} + \frac{1}{10}} \rightarrow I_3 = 1A$$

5



find ① R_{eq}

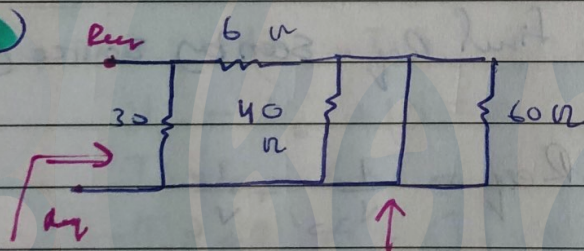
$$R_{eq} = 10.81 \Omega$$

② Power generated

$$I = V/R \Rightarrow 1.29 A$$

$$P = IV = 14 \times 1.29 = 18.11 W$$

6



Short circuit

$$R = 0$$

$$R_{eq} = \frac{60 \times 0}{60 + 0} = 0$$

$$R_{eq} = \frac{0 \times 40}{40 + 0} = 0$$

$$R_{eq_{6,0}} = 6 \Omega$$

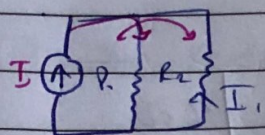
$$R_{eq} = \frac{1}{\frac{1}{30} + \frac{1}{6}} \Rightarrow 5 \Omega$$

Short circuit

شورت کٹ

نہیں ملے

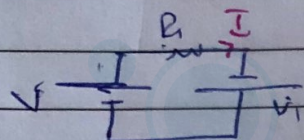
Parallel



(Tricks) $\frac{I R_1 R_2}{R_1 + R_2}$

Find I_1

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



$$V_1 = \frac{V \cdot R}{R_1 + R_2}$$

Power generated $\Rightarrow$ when a circuit is below

Chp 3 Nodal analysis

Fundamental techniques for resistive circuit analysis

- (1) Nodal
- (2) mesh
- (3) superposition
- (4) source transformation
- (5) Thevenin & Norton

* Nodal analysis

Steps: 1 determine the nodes

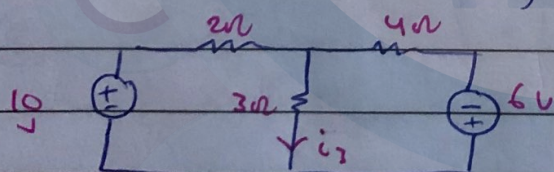
2 assume one of the nodes as a reference

3 name the nodes $\rightarrow V_1, V_2$ (relative to ground)

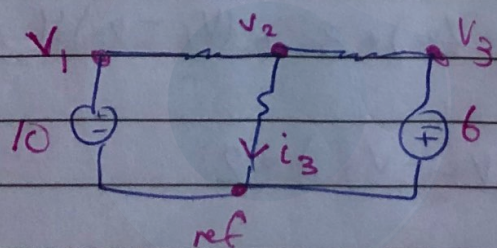
4 if we have a voltage source between node & reference $\Rightarrow V_i$ @ that node is known

5 apply KCL @ each node

ex find i_3 (P) (2u) using nodal analysis



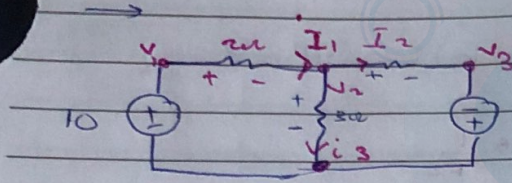
$V_{ref} = 0$



$V_1_{ref} = +10V$
 $V_3_{ref} = -6V$

الكبير V ←
الكبير V ←

$$V_{ref} = 0$$



$$I_1 = \frac{V_1 - V_2}{2\Omega}$$

الكبير - سالب

$$I_2 = \frac{V_2 - V_3}{4\Omega}$$

$$I_3 = \frac{V_2 - V_{ref}}{3}$$

$$\sum I_{in} = \sum I_{out}$$

$$\frac{V_1 - V_2}{2} = \frac{V_2 - V_3}{4} + \frac{V_2 - 0}{3}$$

$$V_2 = 3.24$$

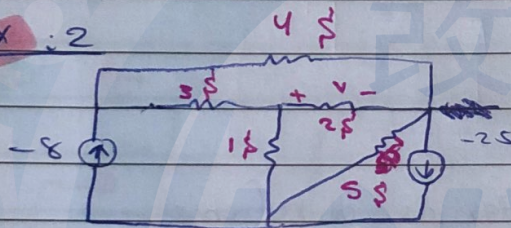
$$I_3 = \frac{3.24 - 0}{3} = 1.08 \text{ A}$$

$$\text{Power (w)} = \frac{V^2}{R}$$

$$= \frac{(V_1 - V_2)^2}{R}$$

$$= \frac{(10 - 3.24)^2}{2} = 22.8 \text{ W absorbed}$$

ex : 2



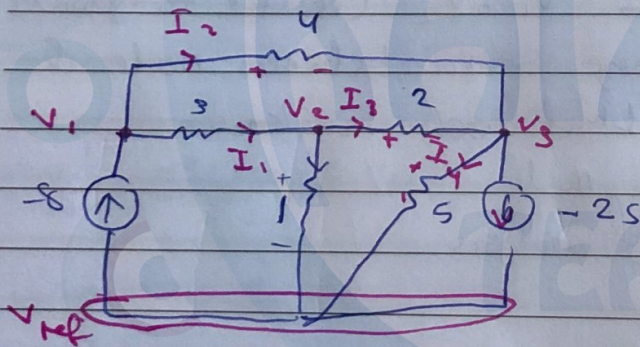
Find V using nodal analysis

$$\text{conductance} \Rightarrow G = \frac{1}{R} \quad (\text{S, } \Omega^{-1})$$

$$V = IR \Rightarrow I = \frac{V}{R} = \frac{V \times 1}{R} = VG$$

$$I = VG$$

$\sum I_{in} = \sum I_{out}$ Node 1 & 2



@ node 1 $\sum I_{in} = \sum I_{out}$

$$-8 = I_1 + I_2 = (V_1 - V_2) \times 3 + (V_1 - V_3) \times 4$$

@ node 2

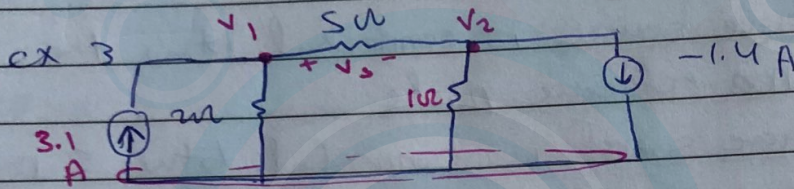
$$3 \times (V_1 - V_2) = V_2 \times 1 + (V_2 - V_3) \times 2$$

① Node 3

$$V_3 \times 5 - 25 = (V_1 - V_3) \times 4 + (V_2 - V_3) \times 2$$

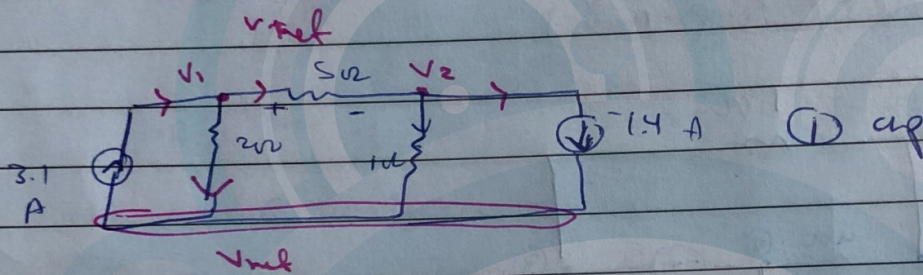
find V using nodal analysis

Soln $\rightarrow V = V_2 - V_3$



① Given V_s

② Power by (-1.4 A) source



② $V_1 \Rightarrow \sum I_{in} = \sum I_{out}$

$$3.1 = \frac{V_1 - V_2}{5} + \frac{V_1}{2}$$

② $V_2 \Rightarrow \frac{V_1 - V_2}{5} = -1.4 + \frac{V_2}{1}$

$$V_1 = 5 \text{ (V)} \quad V_2 = 2 \text{ (V)}$$

① $V_s = V_1 - V_2 = 3 \text{ (V)}$

② $P_{gen} = + (-1.4) \times 2 = -2.8 \text{ W}$
 $\therefore P_{gen} = 2.8 \text{ W}$

اعتبر Ref اکثر سے متعلقہ حصے

ref $\leftarrow$ (ground) $\equiv$ Nodes

حالة
لبن

time
media =
micro structure
properties

عامة
7.7
Project

1. ربط الـ global
مع الـ local

استخدام الـ الكابتر للتحليل

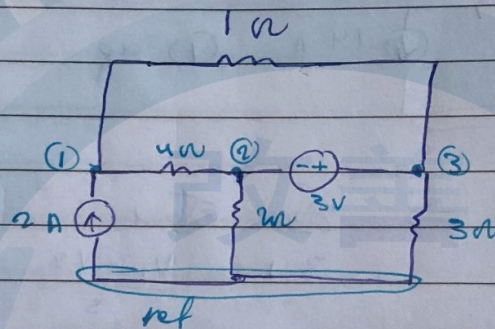
mode $\rightarrow$ 5 eqn $\rightarrow$ 2 (3 معادلة
نقطة)

Nodal usages:

① When the voltage source is connected btw the
reference node & non reference node

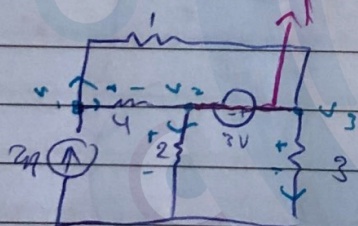
② When the voltage source is connected btw 2 non
reference nodes (supernode)

* Supernode



يسمى الـ V_1 و V_2 بين V_1 و V_2 ← Supernode
نقطة و نقطة

Solu $\rightarrow$ Supernode



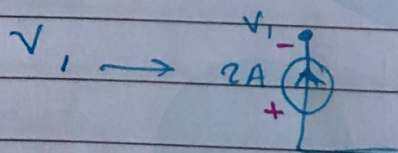
node 1

$$2 = \frac{V_1 - V_2}{4} + \frac{V_1 - V_3}{1}$$

node 2

$$\frac{V_1 - V_2}{4} + \frac{V_1 - V_3}{1} = \frac{V_2 - 0}{2} + \frac{V_3 - 0}{3}$$

$$* V_3 - V_2 = 3 \quad \text{supernode voltage}$$

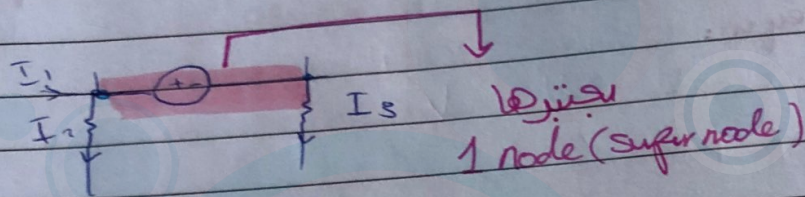


$$P = IV$$

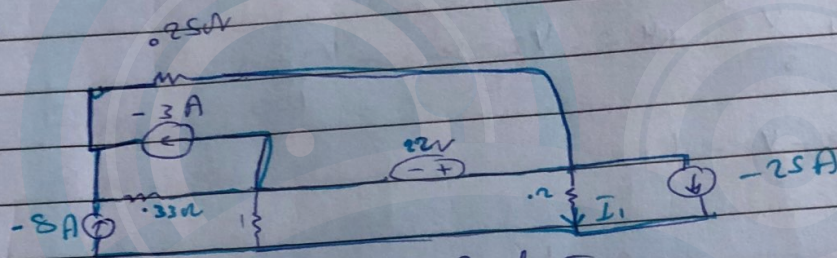
$$= 2 * -V \rightarrow \text{generated}$$

7.7.2020 :)

Super node: when there's a voltage source between nodes, we can't know the current as function of voltage

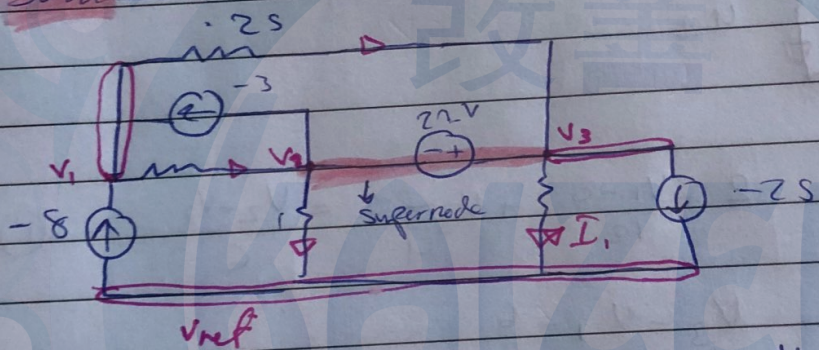


ex →



use nodal analysis to find I_1

Solu →



@ node 1
$$-8 - 3 = \frac{V_1 - V_2}{0.33} + \frac{V_1 - V_3}{0.25}$$

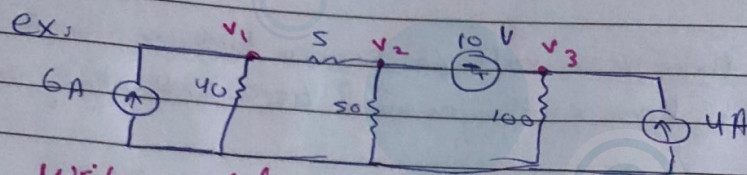
@ node 2 & 3 = super
$$\frac{V_1 - V_2}{0.33} + \frac{V_1 - V_3}{0.25} = -3 + \frac{V_2}{1} + \frac{V_3 - 25}{0.2}$$

Super node eqn:
$$V_3 - V_2 = 22$$

$$I_1 = \frac{V_3 - V_{ref}}{0.2}$$

ref node is 0V

$$I_1 = \frac{V_{ref} - V_3}{0.2}$$



write nodal eqns

write nodal eqn:

@ v₁ (1)

$$\rightarrow \Sigma I_{in} = \Sigma I_{out}$$

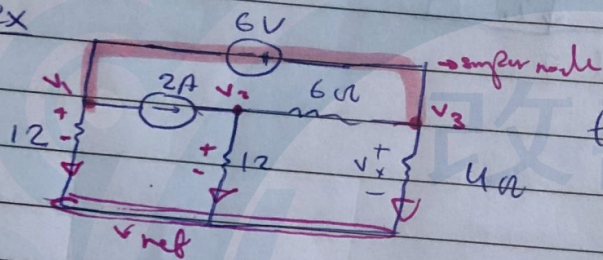
$$6 = \frac{v_1 - 0}{40} + \frac{v_1 - v_2}{5}$$

@ v_{2,3}

$$\frac{v_1 - v_2}{5} + 4 = \frac{v_2 - 0}{50} + \frac{v_3 - 0}{100}$$

$$v_3 - v_2 = 10$$

ex



find V_0 using nodal analysis

@ node v₁/v₂

$$\rightarrow 2 + \frac{v_1 - 0}{12} + \frac{v_3 - 0}{4} = \frac{v_2 - v_3}{6} \rightarrow (1)$$

Super node

$$v_3 - v_1 = 6$$

@ node v₂

$$2 = \frac{v_2 - 0}{12} + \frac{v_2 - v_3}{6}$$

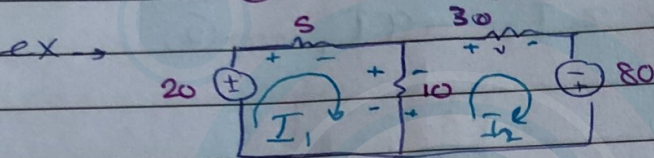
$$v_3 - v_0 = V_x$$

$$v_3 = V_x$$

mesh analysis

mesh analysis

- steps:
- (1) Define meshes
 - (2) assign mesh current CW for all meshes
 - (3) apply KVL for each mesh
 - (4) solve eqn's

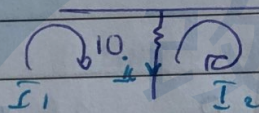


@ mesh (1) → $-20 + 5I_1 + 10I_1 - 10I_2$

@ mesh (2) → $30 - 80 + 10I_2 - 10I_1$

$V = I_2 \times 30$
find I

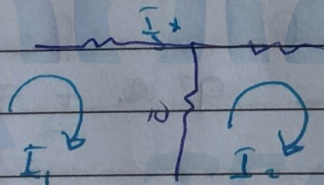
لو آجی ۱۱ ڈال پیس :



$i = I_1 - I_2$

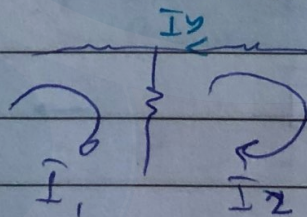
I_1 آجی ۱۱

find I_x : لو آجی ۱۱ ڈال



$I_x = I_1$

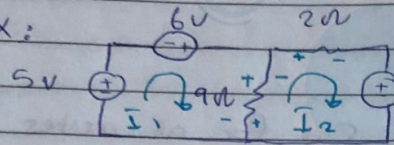
find I_y : لو آجی ۱۱ ڈال



$I_y = -I_2$

Unwired

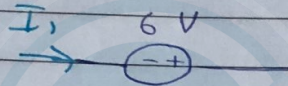
ex:



find the absorbed power by the 6V supply using mesh analysis

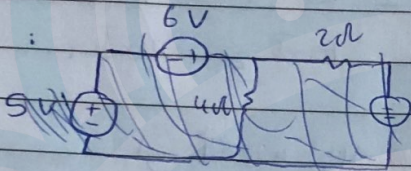
① mesh (1) $-5 - 6 + 9I_1 - 9I_2 \rightarrow (1)$

② mesh (2) $3 + 9I_2 + 2I_2 - 9I_1 \rightarrow (2)$

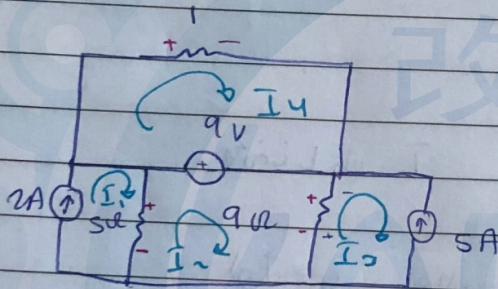


Power absorbed = $(-I_1)(-6)$
 $= 6I_1$ ✗

ex:



find the absorbed power by



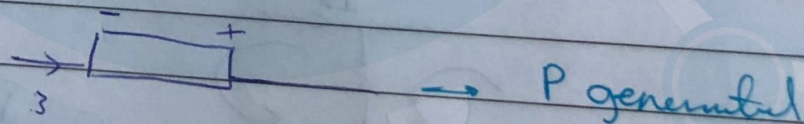
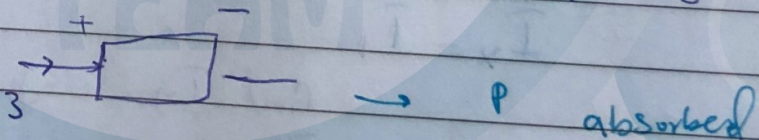
find $P_{\text{generated}}$ by 9V supply using mesh analysis

① $I_1 \rightarrow I_1 = 2 \text{ A}$

② $I_3 \rightarrow I_3 = -5 \text{ A}$

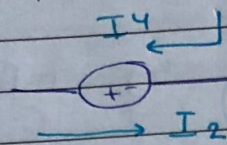
③ $I_2 \rightarrow 9I_2 + 5I_2 - 5I_1 + 9 - 9I_3 = 0$

④ $I_4 \rightarrow 1I_4 - 9 = 0$



Note

* 8 Sources lot *



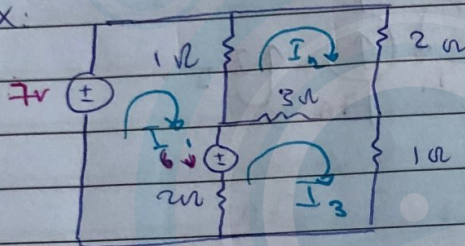
Final P generated

$$P = V * (I_4 - I_2)$$

final P absorbed

$$P = V * (I_2 - I_4)$$

ex:



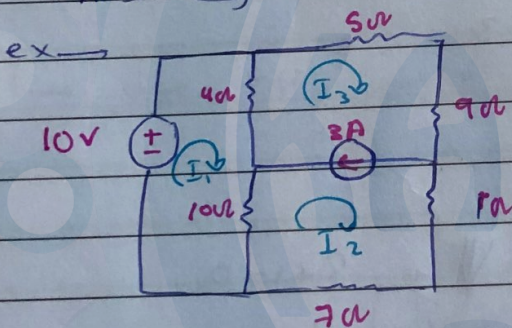
using mesh analysis write mesh equation

@ mesh 1: $6 - 7 + 1 I_1 + 2 I_1 - I_2 - 2 I_3 = 0$

@ mesh 2: $2 I_2 + 3 I_2 + 1 I_2 - 3 I_3 - I_1 = 0$

@ mesh 3: $I_3 + 2 I_3 - 6 - 2 I_1 - 3 I_2 = 0$

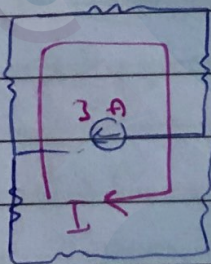
Super mesh: When there's a current source between two meshes, so we take larger loop that has both meshes



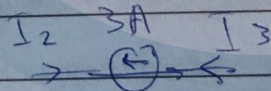
find the Pgen by 10V supply using mesh analysis

$$-10 + 4 I_1 + 10 I_1 - 4 I_3 - 10 I_2$$

super mesh $\rightarrow 5 I_3 + 9 I_3 + 4 I_3 + 1 I_2 + 7 I_2 + 10 I_2 - 4 I_1 - 10 I_1 = 0$



Big loop



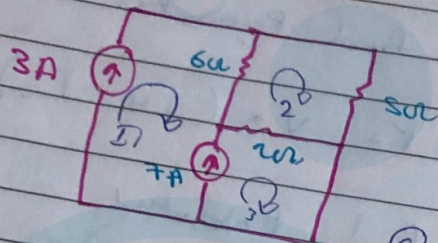
$$I_3 - I_2 = 3$$

$$P = -I_1 * V$$

$$P_{gen} = |-I_1 * V| = I * V$$

nice 802url

ex →



find P_{gen} by 7A

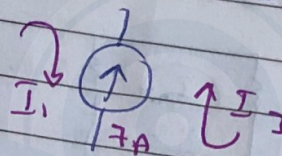
@ $I_1 \rightarrow$

$$I_1 = 3A$$

@ $I_2 \rightarrow$

$$6I_2 + 2I_2 + 5I_3 - 6I_1 - 2I_3 = 0$$

@ $I_3 \rightarrow$



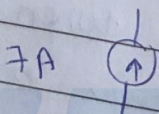
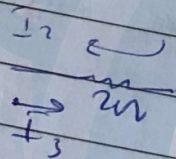
$$I_3 - I_1 = 7A$$

$$I_3 = 10A$$

$$13I_2 - 6 \times 3 - 2 \times 10 = 0$$

$$I_2 = 3A$$

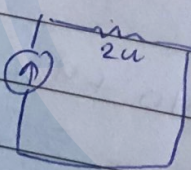
$$P = I V$$



$$I_3 > I_2 \rightarrow 4 > 3$$

$$I_{2\Omega} = 1A$$

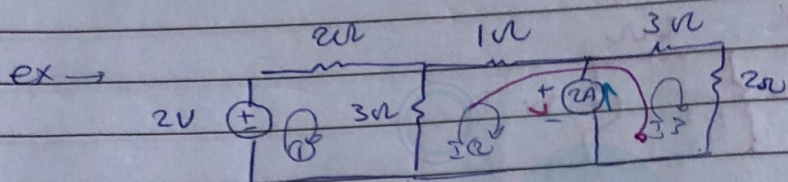
apply KVL



$$V = 2 \times 1 = 0$$

$$V = -2$$

$$P = -2 \times 10 = -20W$$



using mesh analysis
find Q.V

- ② P_{gen} by 2A source
- ③ P_{abs} by 1Ω resistor
- ④ P_{gen} by 2V source

mesh ①

Soln $\rightarrow \sum V = 0$

$$-2 + 2I_1 + 3I_1 - 3I_3 = 0$$

$$5I_1 - 3I_3 = 2$$

mesh ② $\sum V = 0$

$$2I_2 + (1\Omega)I_2 + 3I_3 + 2I_3 - 3I_1 = 0$$

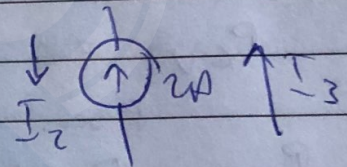
$$I_3 - I_2 = 2$$

Soln $\rightarrow$

$$I_1 = -3.3 \text{ A}$$

$$I_2 = -1.22 \text{ A}$$

$$I_3 = 1.78 \text{ A}$$



1 $\rightarrow$ use KVL loop 3 $\sum V = 0$

$$-V + 3I_3 + 2I_3 = 0$$

$$V = 3.9 \text{ V}$$

$$P = -2 \times 3.9 = -7.8 \text{ W}$$

$$[P_{\text{gen}} = 7.8 \text{ W}]$$

2 $\rightarrow P_{\text{abs}} \rightarrow 1 \times I_2^2 = 1.49 \text{ W}$

3 $\rightarrow P_{2V} = -2 \times 1.33 = 1.66 \text{ W}$ (absorbed)

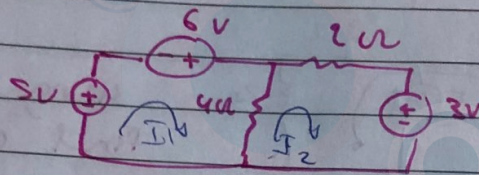
gen 113.16 up to 1 W

~~113.16~~ $P_{\text{gen}} = -1.66 \text{ W}$

← node, voltage
nodal

نودال ← پوائنٹوں کو
mesh ← تار کا
mesh ← کھنڈ کو

ex →



$$\text{mesh 1} \rightarrow -5 - 6 + 4I_1 - 4I_2 = 0 \rightarrow \text{①}$$

$$\text{mesh 2} \rightarrow 4I_2 + 2I_2 + 3 - 4I_1 = 0$$

$$-4I_1 + 6I_2 = -3 \rightarrow \text{②}$$

$$I_1 = 6.75 \text{ A}$$

$$I_2 = 4 \text{ A}$$

find

$$P(5V) = -5 \times 6.75 \text{ W} = -33.75 \text{ W (generated)}$$

$$P_{\text{gen}} = 33.75 \text{ W} / P_{\text{abs}} = -33.75 \text{ W}$$

$$P(6V) = -6 \times 6.75 = -40.5 \text{ W}$$

$$P_{\text{gen}} = 40.5 \text{ W} / P_{\text{abs}} = -40.5 \text{ W}$$

$$P_{3V} = 3 \times 4 = 12 \text{ W}$$

$$P_{\text{abs}} = 12 \text{ W} / P_{\text{gen}} = -12 \text{ W}$$

$$P_{\text{nd}} = (I_1 - I_2)^2 \times 4 = +3.025 \text{ W}$$

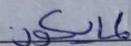
$$P_{\text{abs}} = 3.025 \text{ W} / P_{\text{gen}} = -3.025 \text{ W}$$

generating → where power is

abs → where power is

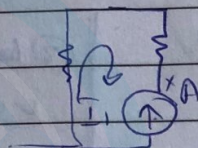
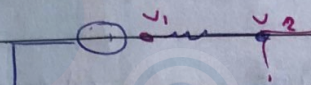
single node $\leftarrow$ 2 nodes in 100

mesh is used



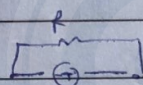
محذوفين $\bar{I}_1 \bar{I}_2 = \times \emptyset$

ولای کانه R موصوفه



ملا رکوں

$$I_1 = -x \text{ A}$$



UL 59

supernova $\rightarrow$ P $\rightarrow$ تفسیر

من العلاقة بين (I & V) واستنتاج (P)

Steps : 1- Choose on supply & short circuit the other
 wires as follow :

(A) current source $\Rightarrow$ open circuit ^{K.II}

حذف = Kill

(B) voltage source $\xrightarrow{\text{kill}}$ short circuit

② Find the currents & voltages in the circuit.

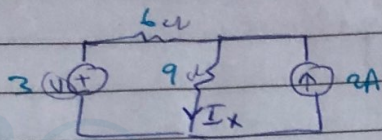
(3) repeat steps 1 $\rightarrow$ 2 for other suppliers

④ the total current or voltage is the sum of volumes founded in previous steps

بسته ها ملاکون عینے کثیر sources

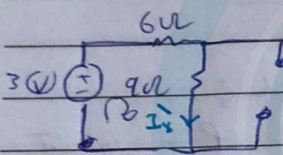
12/7/2020 :)

Find I_x using super position method



kill voltage & current source

① leave voltage source & kill current source

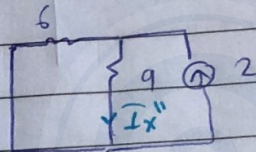


KVL

$$9I_x' - 3 + 6I_x' = 0$$

$$I_x' = .2A$$

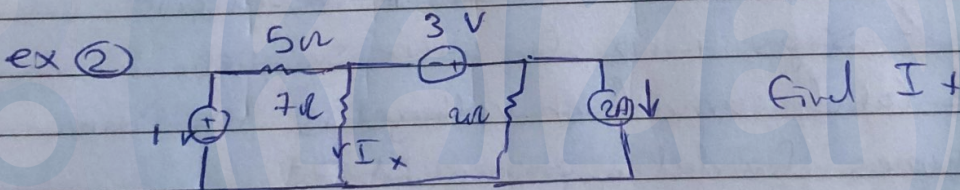
② leave current source & kill voltage source



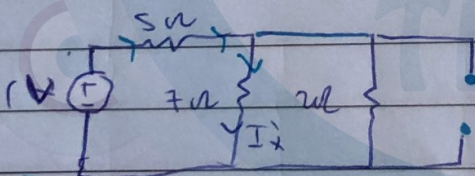
6 || 9 → parallel
current division

$$I_x'' = \frac{2 \times \frac{1}{9}}{\frac{1}{6} + \frac{1}{9}} = .8A$$

$$I_x = I_x' + I_x'' = .2 + .8 = 1A$$



① leave 1V & kill (3V, 2A)



$$7 || 2 \rightarrow \text{parallel} \quad \frac{7 \times 2}{9} = \frac{14}{9}$$

$$\frac{14}{9} + 5 = R_{eq} = 6.55$$

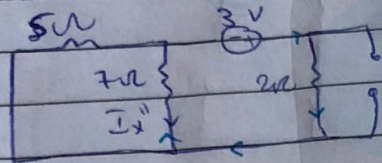
$$I = \frac{1}{6.55} \times 1V = .152A$$

$$.152 \times \frac{14}{9} = .236 = (V)$$

$$I_x' = .236 \times \frac{7}{9} = .0337$$

التيار في المقاومة 5Ω هو I_x

(2) leave $3V$ & kill ($1V, 2A$)



$7 \parallel 2 \rightarrow$ parallel

$$R_{eq} = \frac{35}{13}$$

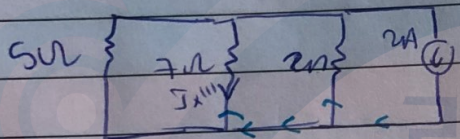
$$V = 3 + \frac{35}{13} = 1.78V$$

$$\frac{35}{13} + 2$$

$$I_x'' = -0.254A$$

I_x'' value

(3) leave $2A$ & kill ($3V, 1V$)

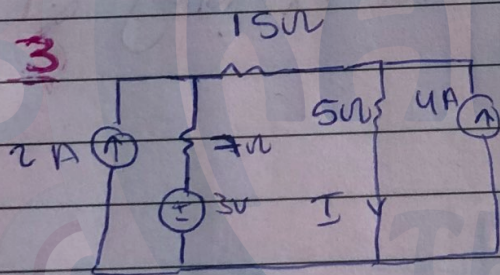


current divider

$$I_x''' = 2 \times \frac{1}{\frac{1}{7} + \frac{1}{2} + \frac{1}{5}} = -0.34A$$

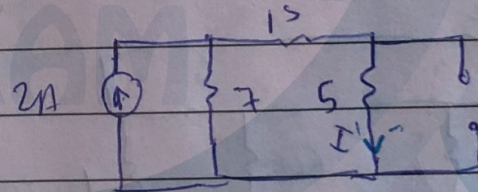
$$\Sigma I_x = I_x' + I_x'' + I_x''' = -0.564A$$

ex 3



find I using super position.

(1) leave $2A$

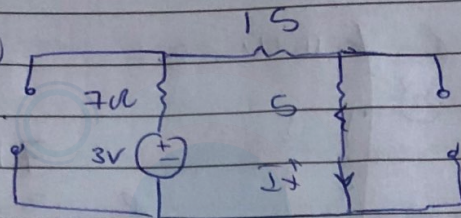


$15 \parallel 5 \rightarrow$ series

$$R_{eq} = 20$$

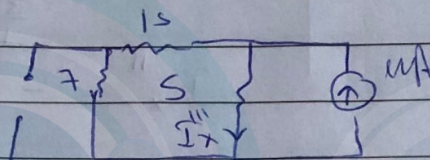
$$I = \frac{2 \times \frac{1}{20}}{\frac{1}{20} + \frac{1}{7}} = 0.52A$$

② leave 3V



$$I = \frac{3}{27} = .111 \text{ A}$$

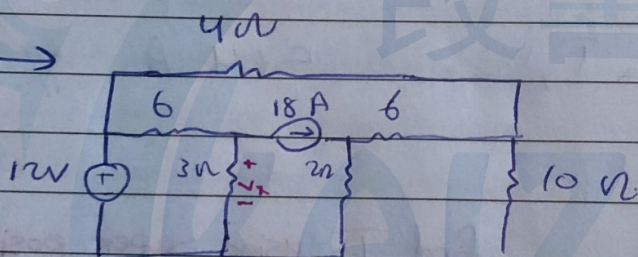
③ leave 4A



$$I' = 4 \times \frac{1}{\frac{1}{22} + \frac{1}{5}} = .326 \text{ A}$$

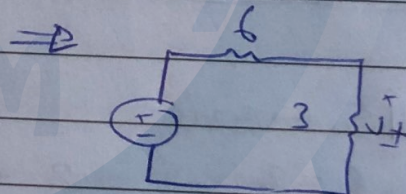
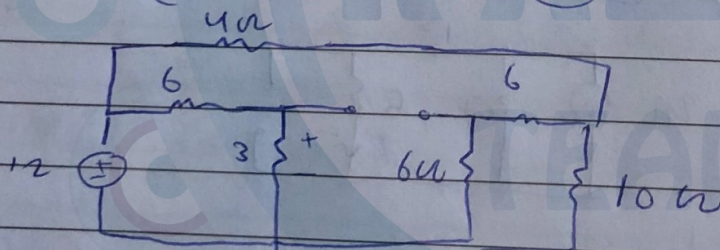
$$[\Sigma I] = 3.89 \text{ A}$$

ex →



find V_x using S.P

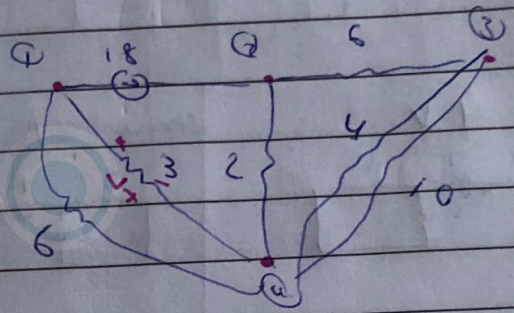
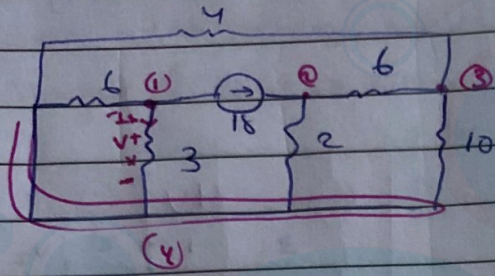
leave (12V) kill 18A



$$V_x' = \frac{12 \times 3}{9} = 4 \text{ V}$$

$$V_x' = 4 \text{ V}$$

② Leene 18 A & 12 V



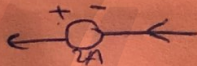
$$I_{15} = \frac{18 \times \frac{1}{3}}{\frac{1}{3} + \frac{1}{6}} = -12 \text{ A}$$

$$V_x'' = 3 + (-12) = -9 \text{ V}$$

$$V_x = V_x' + V_x'' = 4 - 9 = -5 \text{ V}$$

P ابل و

V & I



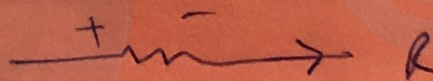
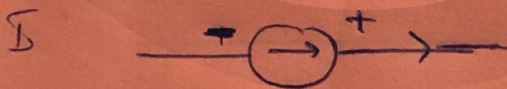
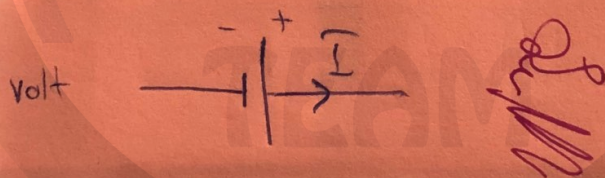
$$I = -2 \text{ A}$$

S.P ابل و

V و I ابل و

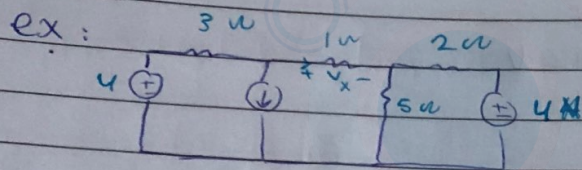
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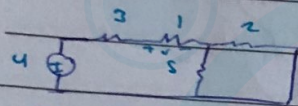


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Find V_x using S.P

① leave 4V

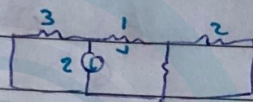


$$V_{x'} = \frac{4 \times 1}{3 + 1 + 1.43}$$

$$V_{x'} = +.74V$$

② leave 2A

leave (2A)

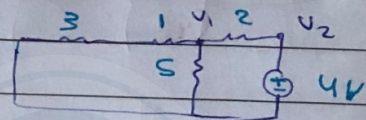


$$I = \frac{2 \times \frac{1}{2.43}}{\frac{1}{2.43} + \frac{1}{1}} = 1.1A$$

$$V_{x''} = -1.1 \times 1 = -1.1V$$

P wks I ois oWlw

leave 4V



Nodal

$$V_2 = 4$$

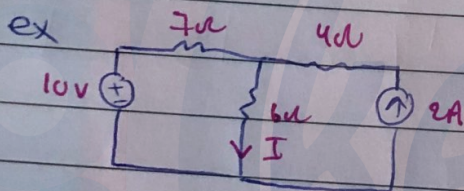
@ Node 1

$$0 = \frac{V_1 - 0}{4} + \frac{V_1}{3} + \frac{V_1 - V_2}{2}$$

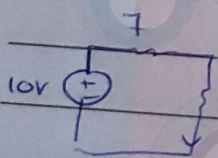
$$\frac{V_1}{4} = -I_1$$

$$V_{x'''} = -I_1 \times 1 = -.53V$$

$$\Sigma V_x = .74 - 1.1 - .53 = -.89V$$

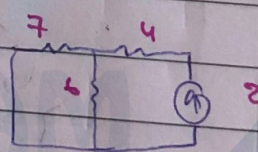


leave 10V



$$I' = \frac{10}{13} = .77A$$

leave (2A)



R 6Ω

$$R_{eq} = 3.23$$

$$V = 2 \times 3.23$$

$$I'' = \frac{6.46}{6} = 1.05A$$

$$\Sigma I = 1.85A$$

$$P = I^2 \times R = 6 \times 1.85^2 = 20.52W$$

*Note

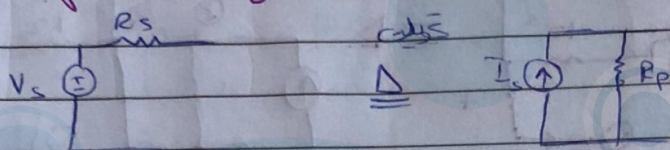
$$I^2 R \neq (I')^2 R + I''^2 R$$

* Superposition is not applied on powers

Source transformation

(4)

Source transformation : in some circuits replacing current source with voltage source or vice versa makes the circuit simpler & easy to solve



بستين و عشان تسهل اكل

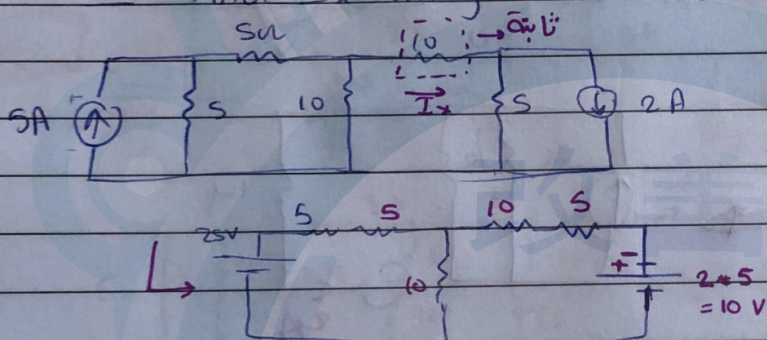
$$R_s = R_p$$

$$V_s = I_s \cdot R_s$$

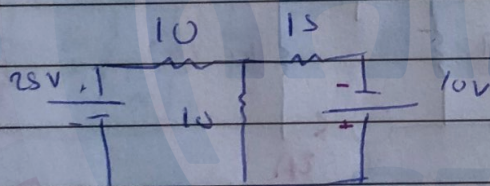
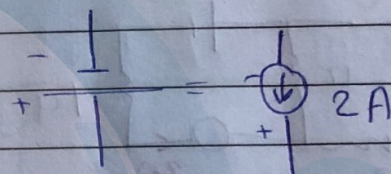
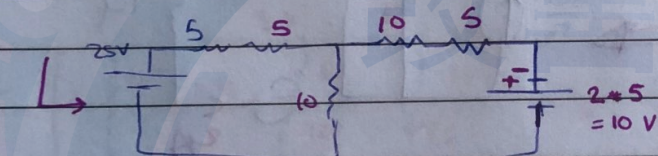
$$I_s = \frac{V_s}{R_s}$$

* ايسا اكل مواتة

ex find I_x using source trans

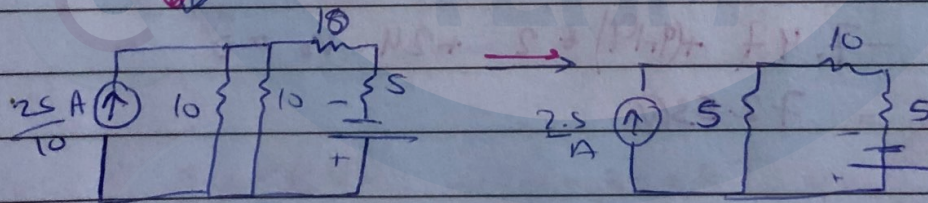


* ايسا اكل مواتة



من + - بستين باي

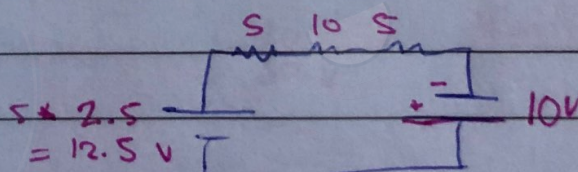
مقومات بيني آ وبقم $\frac{V}{R}$



*By KVL

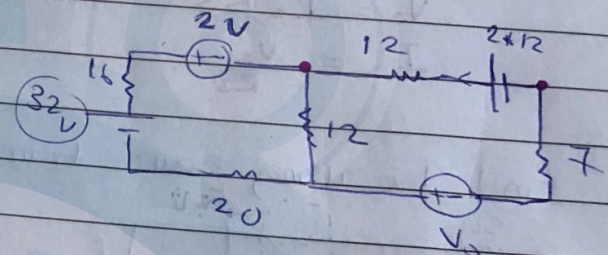
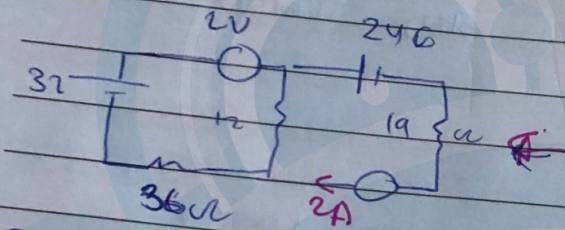
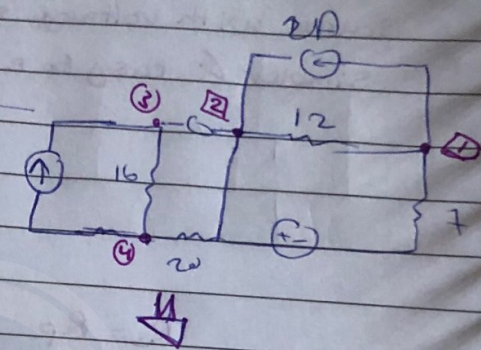
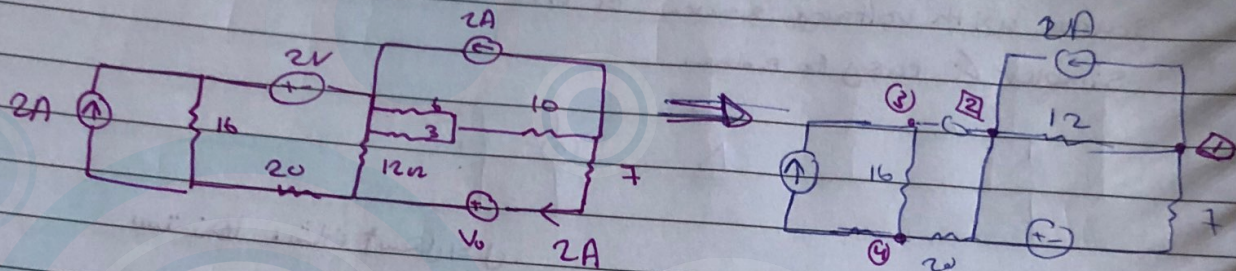
$$-10 - 12.5 + 20I_x = 0$$

$$I_x = 1.125 A$$

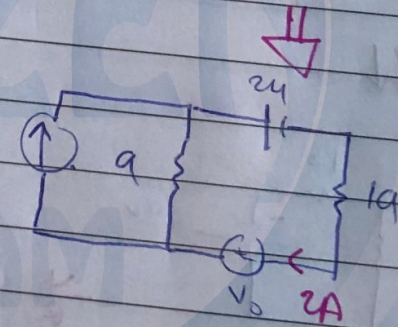
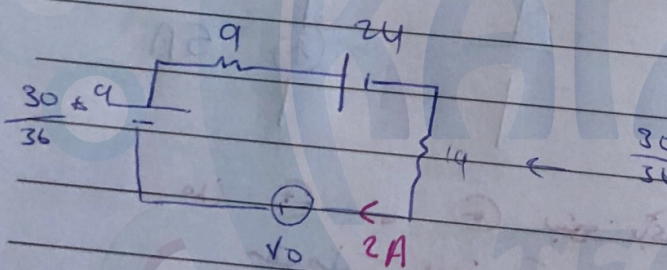
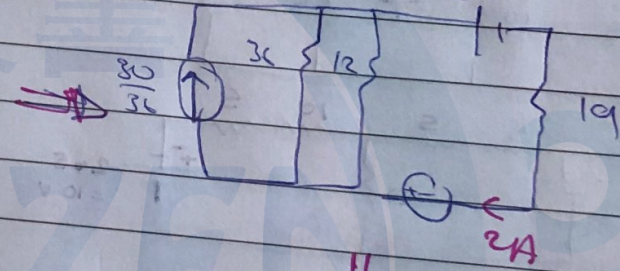
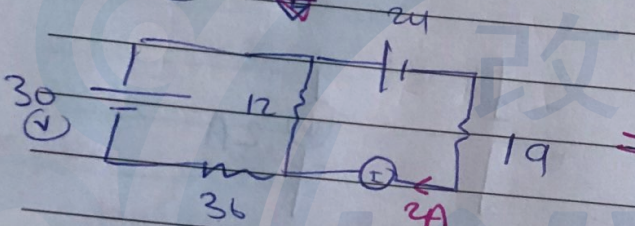


Current sources $\rightarrow$ Parallel $\rightarrow \Sigma$
 Voltage sources $\rightarrow$ Series $\rightarrow \Sigma$

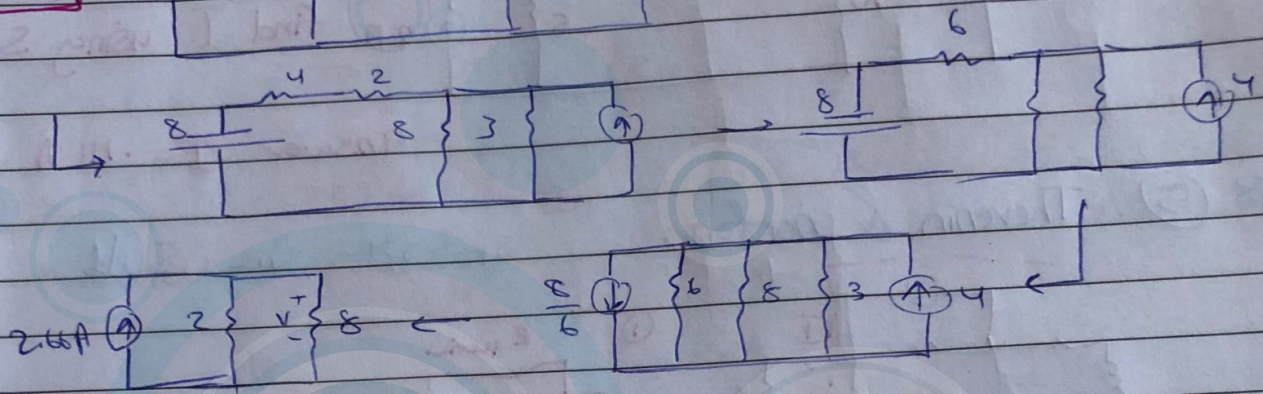
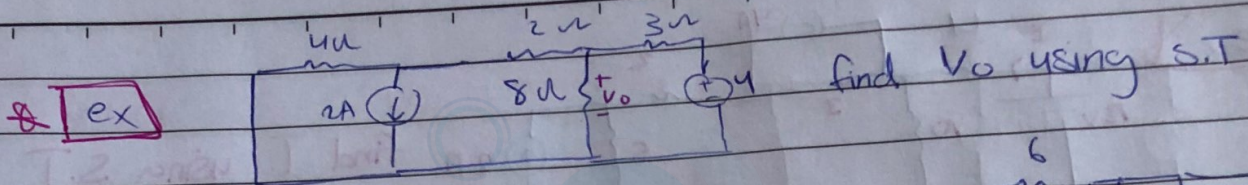
ex Find v_o by source transformation



(V) Σ as:

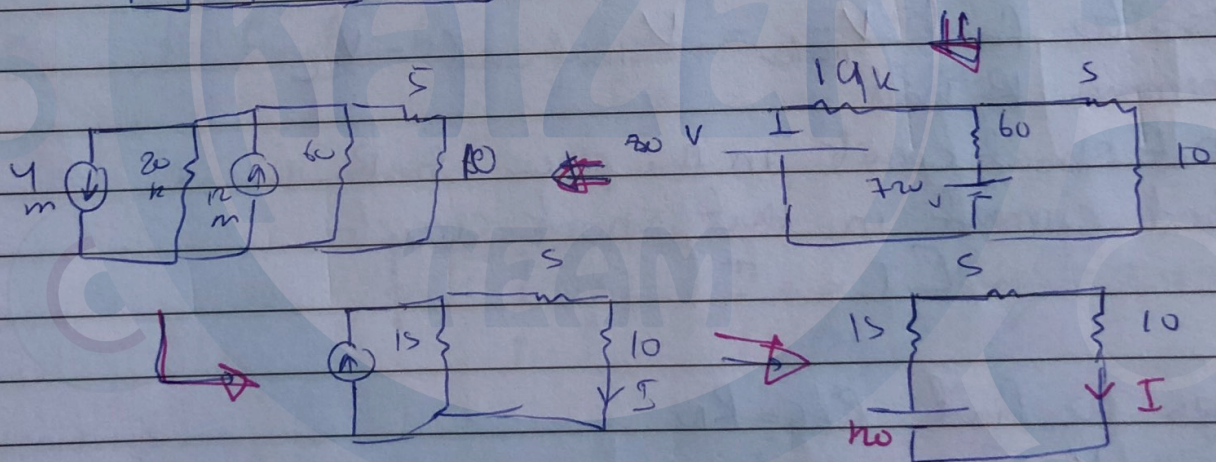
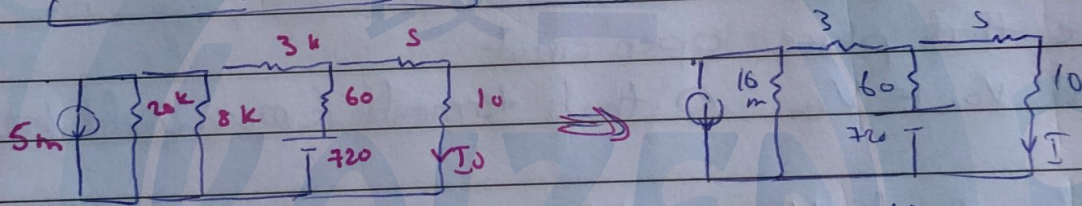
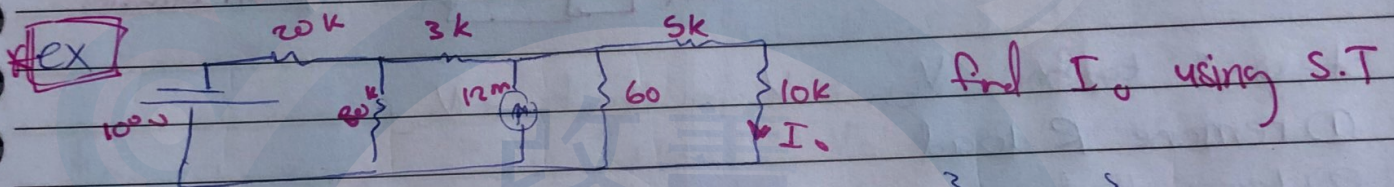


By KVL = $-7.47 + (9+19) \times 2 + 24 - v_o = 0$
 $v_o = 72.53V$



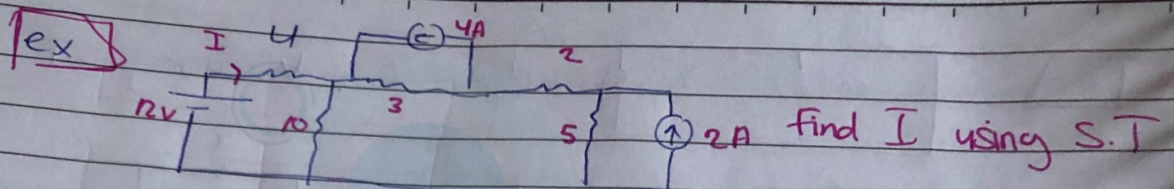
$$I_s = +2.66 + \frac{1}{8} = .532 \quad V_s = 8 \times .532 = +4.26$$

$\frac{1}{8} + \frac{1}{2}$ $\frac{8}{8+4}$ using S.T $\uparrow$ $\frac{16}{3}$ $\leftarrow$ $\frac{8}{6}$



By KVL: $-120 + 30 \times k I_o = 0$

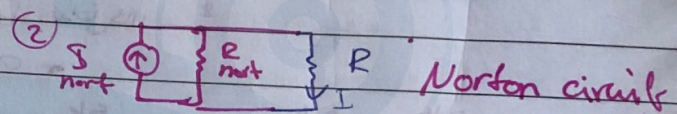
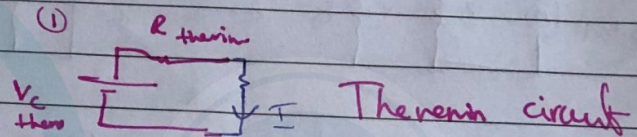
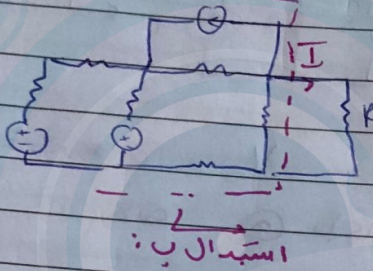
$$I_o = \frac{120}{30k} = 4mA$$



answer $I = .111 A$

⑤ Thevenin & norton:

دائرة ثيرنن و نورتون



① Steps: to find $V_{th} = V_{open\ circuit} = V_{oc}$

① remove R load

② leave that place open circuit

③ find $V_{oc} = V_{th}$ @ that terminals (mesh, nodal, KVL) $\frac{V}{I}$

② Steps: to find $V_{norton} = V_{short\ circuit} = V_{sc}$

① remove R load

② Put short circuit in the place of R_{load}

③ find current in that short circuit
[$I_{sc} = I_N$]

③ Steps to find $R_{th} = R_N$

① $R_{th} = \frac{V_{oc}}{I_{sc}}$

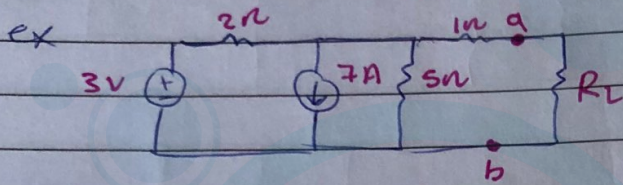
② @ remove R_{load}

③ kill our sources $\left\{ \begin{array}{l} \text{Voltage source} = \text{short} \\ \text{current source} = \text{open} \end{array} \right.$

④ find Req seen @ that terminals place @ R_{load}

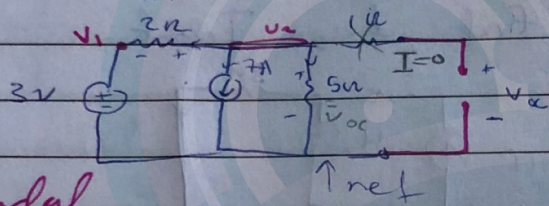
Note $\Rightarrow V_{th} = I_{nort} * R_{th}$

$I_{sc} = V_{th} / R_{th}$



find thevenin circuit seen from a & b + Norton circuit

k Find $V_{th} = V_{oc}$



Nodal

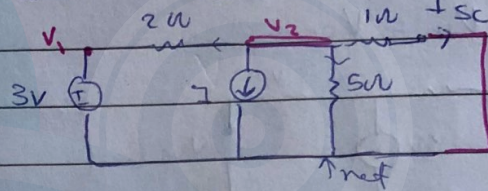
$V_1 = 3V$

$0 = 7 + \frac{V_2}{5} + \frac{V_2 - V_1}{2}$

$0 = 7 + \frac{V_2}{5} + \frac{V_2 - 3}{2} \Rightarrow V_2 = -7.86V$

$V_{oc} = V_2 = -7.86V$

* Find $I_{sc} = I_N$



$V_1 = 3$

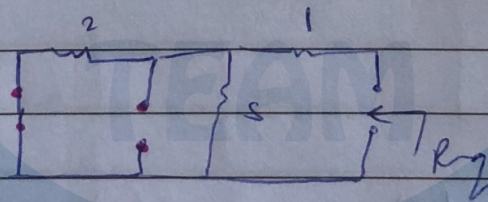
$0 = \frac{V_2 - V_1}{2} + 7 + \frac{V_2}{5} + \frac{V_2}{1}$

$V_2 = -3.24V$

$V_2 = I_{sc} = -3.24A$

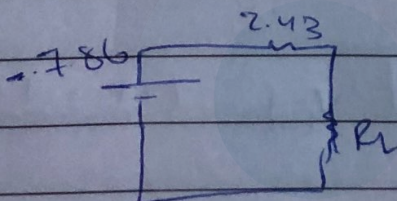
to find $R_{th} = \frac{V_{oc}}{I_{sc}} = \frac{-7.86}{-3.24} = 2.43\Omega$

Or Kill all sources

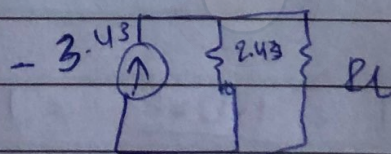


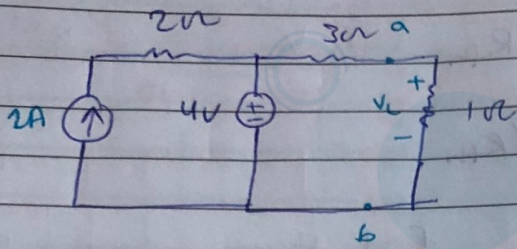
$R_{th} = 2.43\Omega$

Thevenin circuit:

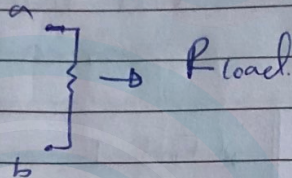


Norton circuit

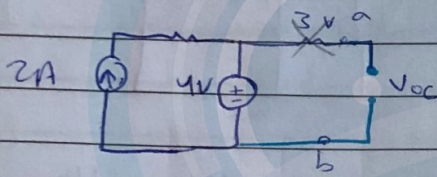




Find V_L using Thevenin & Norton methods

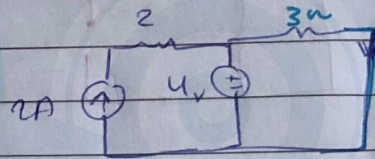


* find $V_{th} = V_{oc}$



$$V_{oc} = 4V$$

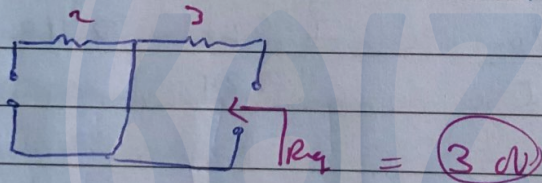
find $I_{sc} = I_{nort}$



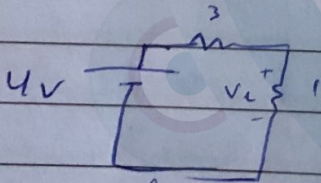
$$I_{sc} = \frac{4}{3} = 1.33 A$$

$$R_{th} = \frac{V_{oc}}{I_{sc}} = \frac{4}{1.33} = 3\Omega$$

or

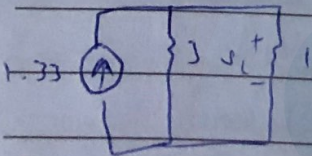


thevenin circuit



$$V_L = \frac{4 \times 1}{3+1} = \frac{4}{4} = 1V$$

Norton

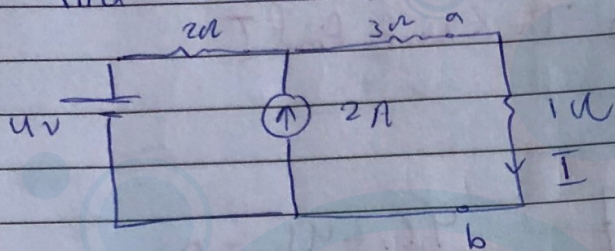


$$I = \frac{1.33 \times 1}{1 + \frac{1}{3}} = 1$$

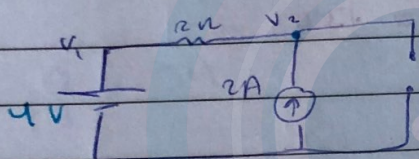
$$V_{L_{load}} = 1 \times 1 = 1 \text{ volt}$$

15/7/2020

Find thevenin & norton circuit seen from a & b



Find $V_{th} = V_{op}$



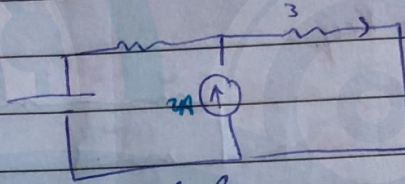
By nodal

$$V_1 = 4 \text{ V}$$

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

$$V_2 = 8 \text{ V}$$

Find I_{nsc}



use nodal

$$\sum I_{in} = \sum I_{out} \Rightarrow 2 = \frac{V_2 - V_1}{3} + \frac{V_2}{1}$$

$$V_1 = 4 \text{ V}$$

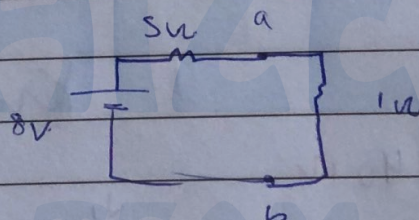
$$V_2 = 4.8 \text{ V}$$

$$I_{sc} = \frac{V_2 - 0}{3} \Rightarrow I_{sc} = 1.6 \text{ A}$$

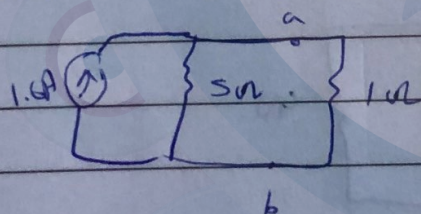
Find $R_{th} = R_N$

$$R_{th} = \frac{V_{oc}}{I_{sc}} = \frac{8}{1.6} = 5 \Omega$$

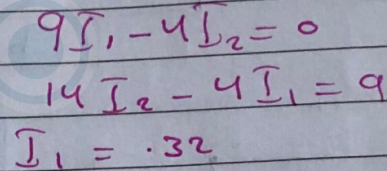
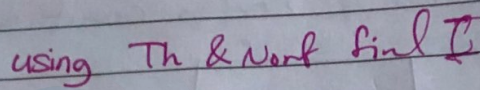
Thevenin circuit



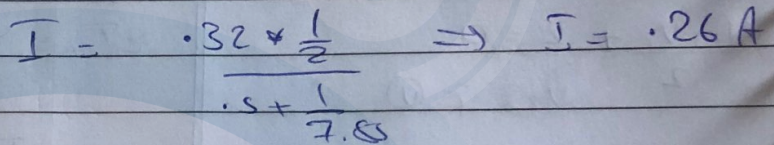
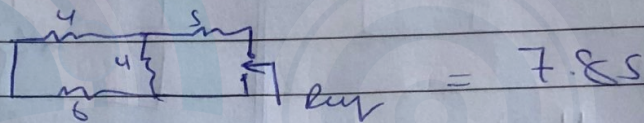
Norton circuit



15/7/2020:

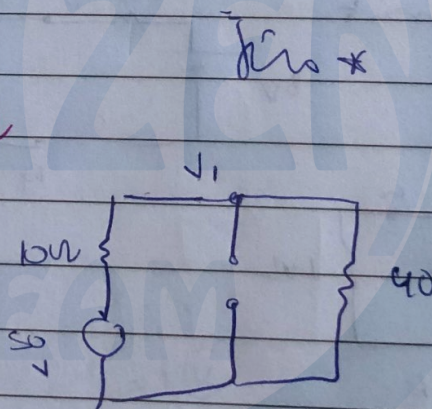


Rey =

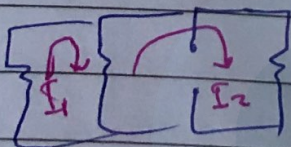


$V_{th} \rightarrow$

The circuit diagram shows a 50V DC source in series with a 10Ω resistor. This combination is in parallel with a 30V DC source and a 12Ω resistor. The output terminals are labeled 'a' and 'b'. A 40Ω resistor is shown in parallel with the output terminals.



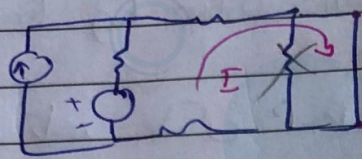
* انتہائی خوبصورت *



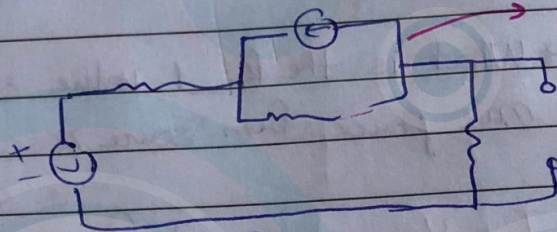
$$\frac{50 - V_1}{10} = \frac{V_1}{40}$$

$$v_1 = V_{fl}$$

Prob
4.11



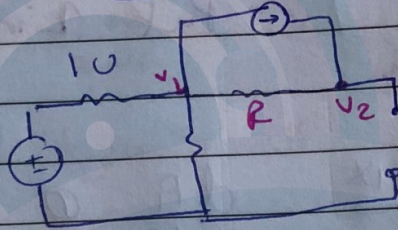
Prob 37



سلسلة
S.T. as

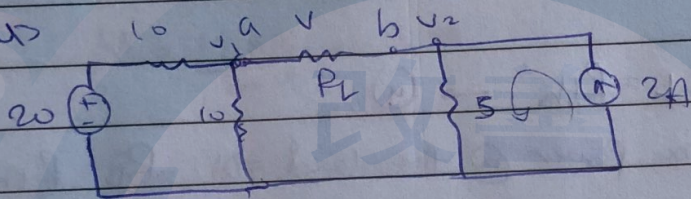
للتسلسل
S1

Prob 34



ناتج
R ما بيني
nodal
 $V_2 = V_{th}$

Prob 35



$$V_2 = 10$$

$$V_1 = V_{10}$$

$$I = \frac{20 - 10}{20}$$

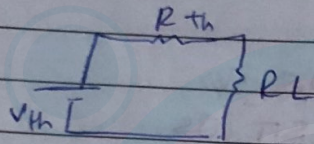
$$V_{10} = 1 \times 10 = 10$$

$$V_2 - V_1 = 0$$

16/7/2020

maximum Power Transfomer

We concern about power consumption by load after simplification of the circuit



supply is P_{source} i.e. P_{th} and P_L are

* What is the R_{load} value so it absorbs max power from source ??

$$P_{load} = I^2 R_L \quad (1)$$

$$I = \frac{V_{th}}{R_{th} + R_L} \quad (2)$$

Put 2 in 1

$$* P_L = \left(\frac{V_{th}}{R_{th} + R_L} \right)^2 R_L \xrightarrow{\text{max}} \frac{dP_L}{dR_L} = 0$$

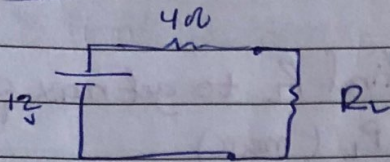
Results $\rightarrow R_L = R_{th} \rightarrow (4)$

for any circuit to get max power @ the load $\Rightarrow R_L = R_{th}$

Put 4 in 2

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

ex

find power @ load P_L when

① $R_L = 2\Omega$

② $R_L = 8\Omega$

③ $R_L = 4\Omega$

note

 $R_L = R_{th} \rightarrow P_{max}$: Maximum Power Transfer Theorem

Solu $\rightarrow$ ① $R_L = 2\Omega$

$P = IV = \frac{V^2}{R} = I^2 R$

$V_L = \frac{12 \times 2}{2+4} = 4V$

$P = \frac{16}{2} = 8 \text{ watt}$

② $R_L = 8\Omega$

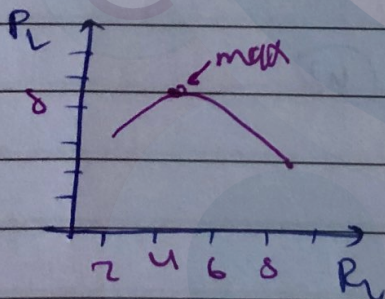
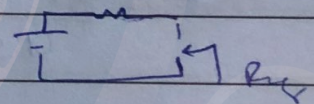
$V_L = \frac{12 \times 8}{8+4} = 8V$

$P = \frac{64}{8} = 8W$

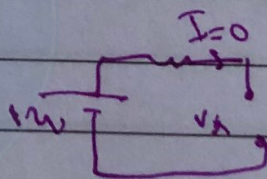
③ $R_L = 4\Omega$

$V_L = \frac{12 \times 4}{4+4} = 6V$

$P_L = \frac{36}{4} = 9W \Rightarrow [max]$

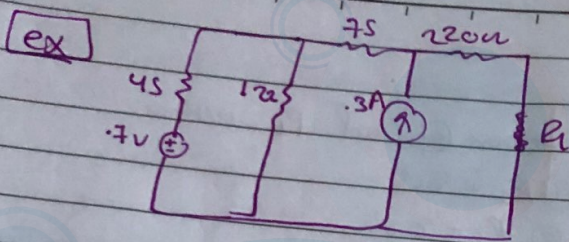
Refer to circuit find $R_{th} \rightarrow 4\Omega$ [max Power $\leftarrow R_{th} = R_L$ WISLL]

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

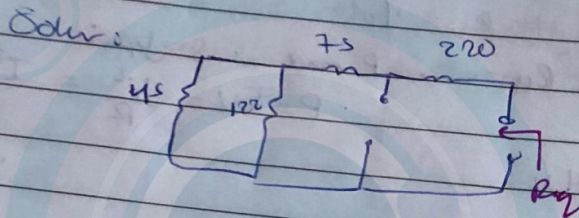


$V_x = 12V$

$\frac{12^2}{4 \times 4} = 9W$



- ① find R_L to get max power
- ② P_L (max)

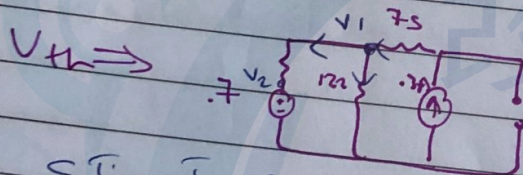


$R(4S || 12\Omega) \rightarrow$ Parallel
 $\frac{4}{1} \parallel \frac{12}{1} = \frac{4 \times 12}{4 + 12} = \frac{48}{16} = 3$

For max P $R_{load} = R_{th}$

$R_{eq} = 327.87 \Omega = R_{th}$

$P_L = \frac{V_{th}^2}{4 R_{th}}$



By nodal analysis:

$V_2 = -7V$

$\sum I_{in} = \sum I_{out}$

$3 = \frac{V_1 - (-7)}{4S} + \frac{V_1 - 0}{12\Omega} \Rightarrow V_1 = 10.45 \text{ volt}$

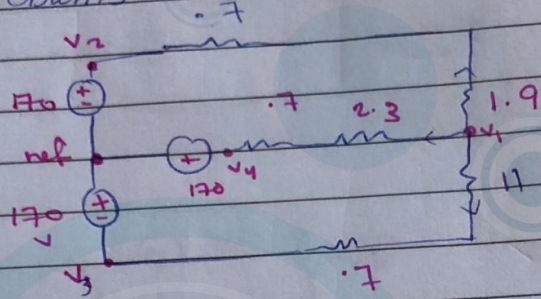
By KVL $-10.45 - 7S \times 3 + V_{th} = 0$

$V_{th} = 32.95 \text{ V}$
 $P_L = \frac{32.95^2}{4 \times 327.87} = 0.842 \text{ W}$

16/7/2020

* Book problems

p 3.24



* find Nodal voltages using nodal analysis

Solu → $V_2 = 170 \text{ V}$
 $V_3 = -170 \text{ V}$
 $V_4 = 170 \text{ V}$

$\sum I_{in} = \sum I_{out}$

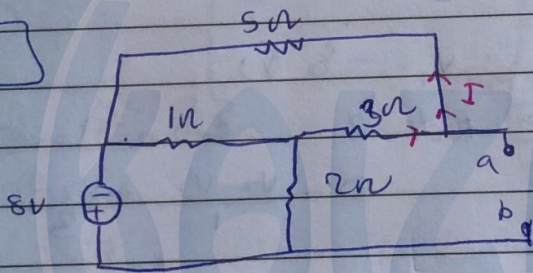
$0 = \frac{V_1 - V_4}{3} + \frac{V_1 - V_2}{2.6} + \frac{V_1 - V_3}{11.7}$

Circuit

* $V_1 = -7.23 \text{ V}$

$0 = \frac{V_1 - 170}{2.6} + \frac{V_1 + 170}{11.7} + \frac{V_1 + 170}{3}$

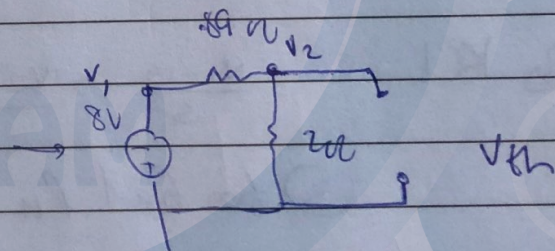
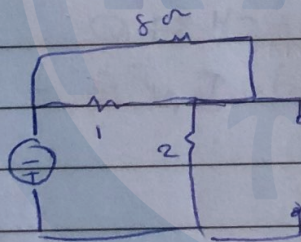
3.29



find Norton / th circuit btw a & B

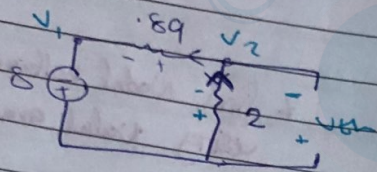
$I_{sc} = 2A$ (from circuit) open circuit

to find V_{th}



$V_{th} = V_2$

is an ideal voltage source



$$V_1 = -8$$

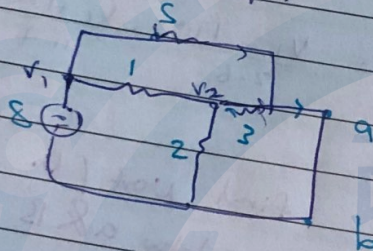
$$\textcircled{a} V_2 \Rightarrow$$

$$\frac{V_2 - -8}{0.89} = \frac{V_2}{2}$$

$$\Rightarrow V_2 = -6.48 \text{ V}$$

$$= \underline{V_{th}}$$

Norton circuit:



using nodal

$$V_1 = -8 \text{ V}$$

Node 2

$$\sum I_{in} = \sum I_{out}$$

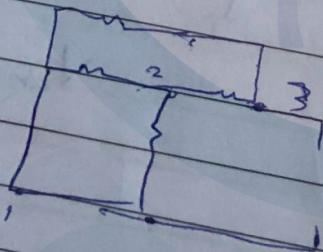
$$0 = \frac{V_2 - V_1}{1} + \frac{V_2 - 0}{3} + \frac{V_2}{2}$$

$$V_2 = -4.37 \text{ V}$$

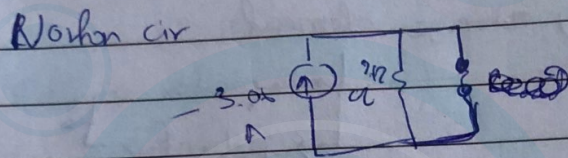
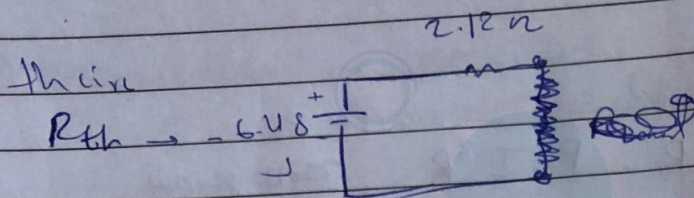
By KCL

$$\frac{V_1 - 0}{5} + \frac{V_2 - 0}{3} = \sum I = -3.06 \text{ A}$$

③ to find R_{th}

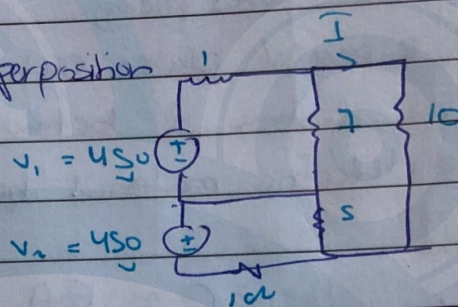


$$R_{th} = 2.12 \Omega$$

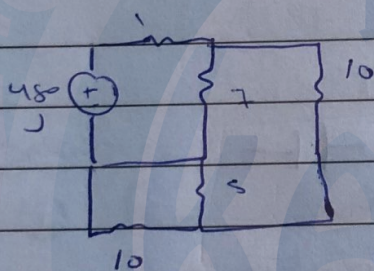


P 3.52 find I using superposition

2 sources في 3 دوائر *
يفي مرتين

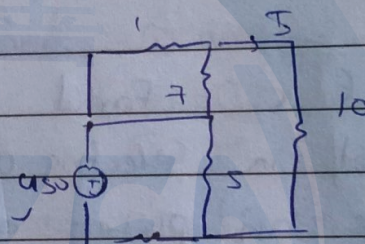


① leave V_1 kill V_2



$$I' = 33.7$$

leave V_2 kill V_1



$$I'' = 32.03 A$$

(mesh) في mesh *

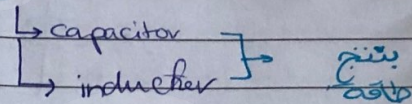
$$\Sigma I = 65.73 A$$

AC network analysis

$$I \rightarrow \frac{V}{R} \quad V = IR \quad P = I^2 R \quad \text{تلف في المقاومة}$$

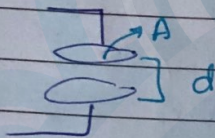
* we will talk about energy storage elements

capacitor:



① device (element) stores energy

② consists of 2 parallel plates each plate has cross sectional area A , have distance d between them, the separation is filled with dielectric material has certain permittivity (ϵ)



$$C = \frac{\epsilon A}{d}$$

③ unit of C = Farad $C \Rightarrow (F)$

④ symbol in electric circuit $\text{---} \text{||} \text{---}$

⑤ change on plates of capacitor

$$Q = CV \quad \text{تغير في الشحنة}$$

$$q(t) = C v(t)$$

$$⑥ i_c(t) = \frac{d q(t)}{dt} \Rightarrow i_c(t) = C \frac{d v_c(t)}{dt}$$

$$⑦ v_c(t) = \left[\frac{1}{C} \int_{t_0}^t i_c(\tau) d\tau \right] + v_c(t_0)$$

$$⑧ i_c(t) = C \frac{d v_c(t)}{dt} \quad \text{if } v_c(t) = D_c \text{ value} = \text{fixed} \quad \text{Initial condition}$$

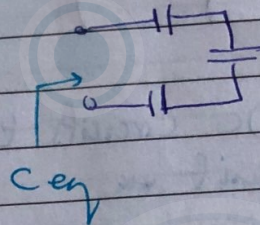
$i_c(t) = 0$ means that capacitor acts like open circuit in DC-circuit

⑨ energy stored in capacitor

$$E = \frac{1}{2} C V^2 = \frac{1}{2} Q V = \frac{1}{2} \frac{Q^2}{C} \quad (\text{Jou})$$

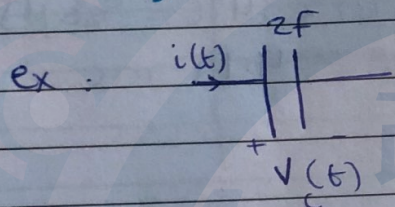
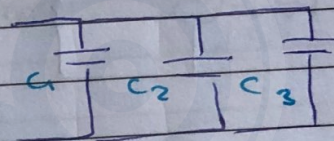
⑩ capacitors in series

$$C_{eq} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$



⑪ capacitors in parallel

$$C_{eq} = C_1 + C_2 + C_3$$



$$V_c(t) = 5 \sin(t)$$

find ① energy stored

② Q

③ I

soln

$$\text{① } E = \frac{1}{2} C V^2 = \frac{1}{2} \times 2 \times (5 \sin t)^2 = 25 \sin^2 t \quad \text{Jou}$$

$$\text{② } q = CV = 2 \times 5 \sin t = 10 \sin t \quad \text{coulomb}$$

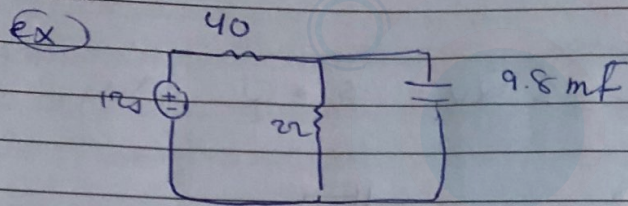
$$\text{③ } I = C \frac{dV_c(t)}{dt} = 2 \times 5 \cos(t)$$

$$i(t) = 10 \cos t \quad \text{A}$$

$$e^{-\infty} = 0$$

$$e^{\infty} = \infty$$

17/7/2020

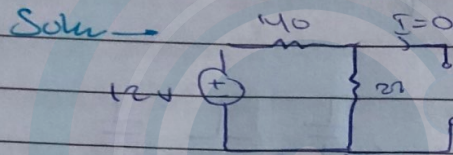


find:

(1) Energy stored in C

(2) Q on C

Note → in DC circuit the capacitor acts like open circuit



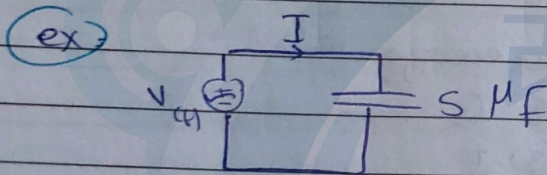
Energy →

by voltage division

$$V_C = \frac{12 \times 2}{2 + 40} = .426 \text{ volt}$$

$$\rightarrow \text{Energy} = C V^2 \times .5 = 9.8 \times 10^{-3} \times .426^2 = 88 \mu\text{J}$$

$$\rightarrow Q = C V = 9.8 \times 10^{-3} \times .426 = 4.17 \text{ mC}$$



$$V(t) = 12 e^{-3t} \quad (1)$$

find (1) $i_C(t)$

(2) $i_C(0)$

(3) $i_C(\infty)$

Solu →

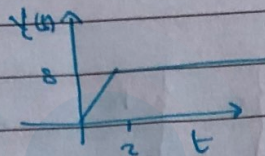
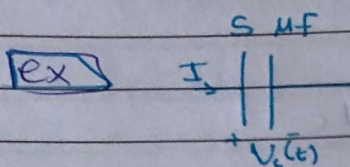
$$i_C = C \frac{dV(t)}{dt} \rightarrow V \text{ of capacitor not any } V \text{ given}$$

$$i_C = C \times 12 \times -3 e^{-3t} = 5 \times 10^{-6} \times 12 \times -3 e^{-3t}$$

$$i_C = -1.8 e^{-3t} \mu\text{A}$$

$$\text{when } t=0 \rightarrow i_C = -1.8 \mu\text{A}$$

$$\text{When } t(\infty) \rightarrow i_C = 0$$

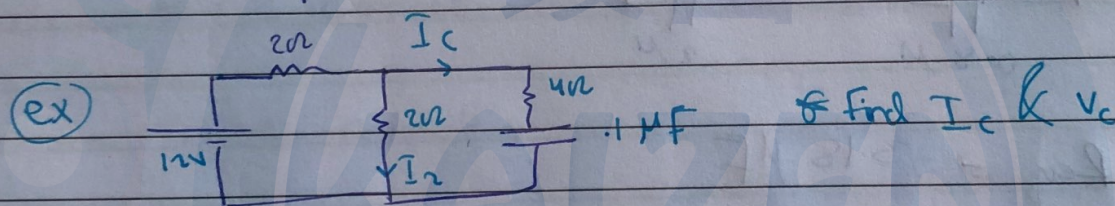
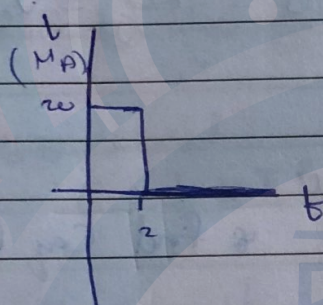


Sketch $i_c(t)$

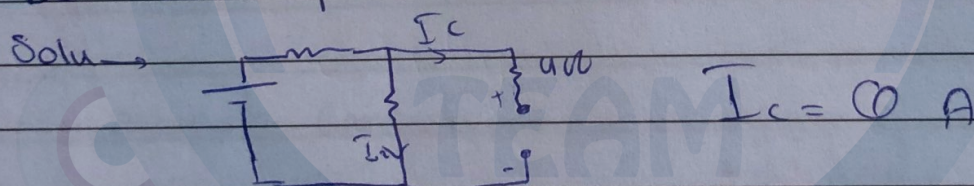
$$i_c(t) = C \frac{dv_c}{dt}$$

for $0 \leq t \leq 2 \rightarrow i_c(t) = 4 \times 5 \times 10^{-3} \text{ A}$

for $2 \leq t < \infty \rightarrow i_c(t) = 0 \times 5 \times 10^{-3} \text{ A}$
 Fixed 0V



DC circuit $\rightarrow$ open circuit



By KVL $-12 + 2I_1 + 2I_2 = 0$

$$I_2 = 3 \text{ A}$$

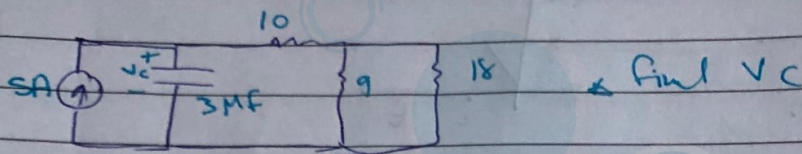
$$V_2 = 2 \times 3 = 6 \text{ volt}$$

By KVL $-V + V_c + V_u = -6 + V_c + 0 \times 4 = 0$

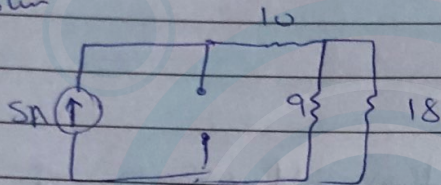
$$V_c = 6 \text{ V}$$

open circuit $\rightarrow i = 0$

ex



Soln

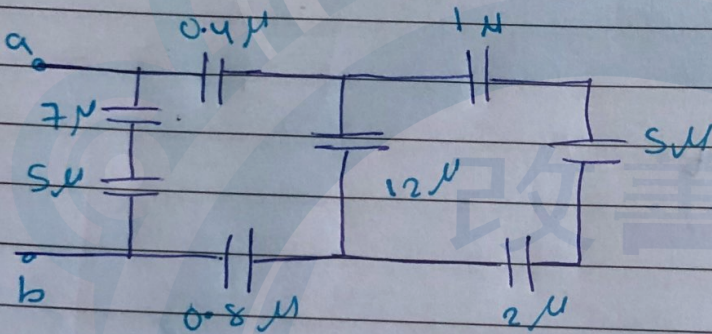


$$\rightarrow R(18||9) \rightarrow \text{parallel} = 6 \Omega$$

$$R(6||10) \rightarrow \text{series} = 16$$

$$V_R = 16 \times 5 = 80 \text{ V} = V_C$$

ex

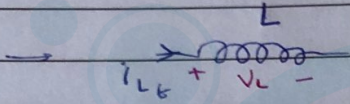


Soln $\rightarrow R_{eq} = 3.18 \mu F$

Inductors

Inductor: stores energy, made of winding a coil wire around a core

→ Core: could be insulated or ferromagnetic material
 μ (Permeability) ~~lets~~



Unit → henry $\Rightarrow$ (H)

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

$$\rightarrow i_L(t) = \left[\frac{1}{L} \int_{t_0}^t V_L(t) dt \right] + i_L(t_0)$$

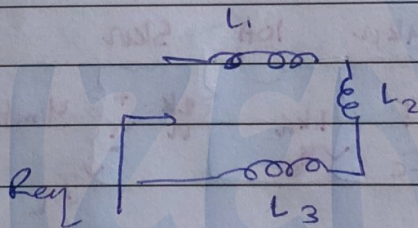
→ energy stored

$$E = \frac{1}{2} L I^2 \quad \text{Joul}$$

→ in DC circuit, the inductor acts like [short circuit] $V_L = 0$

→ Series connection

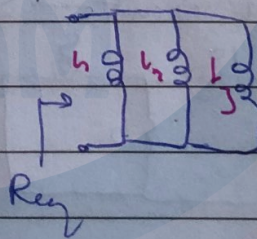
$$R_{eq} = L_1 + L_2 + L_3$$



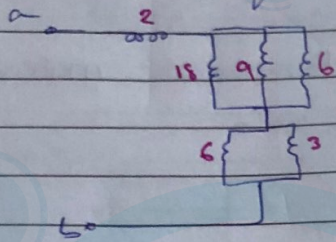
سلسلة (Series)

→ parallel connection

$$1/R_{eq} = 1/L_1 + 1/L_2 + 1/L_3$$

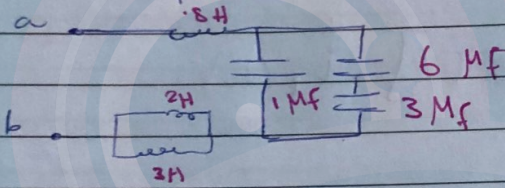


Ex → Find L_{eq} from a & b



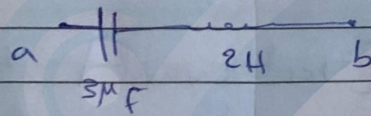
$$L_{eq} = 7 \text{ H}$$

Ex → Simplify the circuit



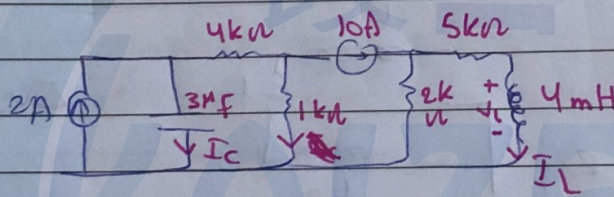
$$\frac{1}{6} + \frac{1}{3} = \frac{1}{2} \Rightarrow 2 \text{ MF}$$

$$R_{eq} = 2 + 1 = 3 \text{ MF}$$



$$\text{Inductors} \rightarrow \frac{6}{5} + 8 = 2$$

Ex →

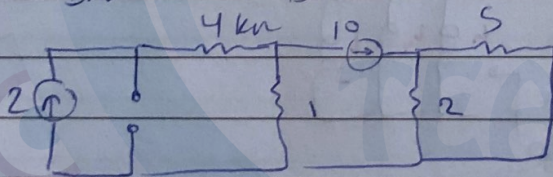


find I_C, V_C, I_L, V_L

Solu →

Note C in DC circuit → open circuit

Inductor in DC circuit → short circuit



$$I_C = 0 \text{ A}$$

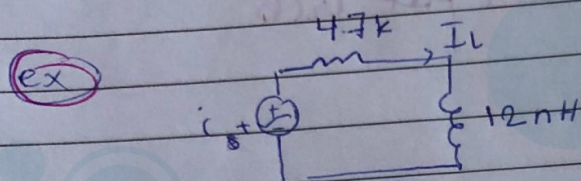
$$\text{KCL} \quad 2 = I_1 + 10 \Rightarrow I_1 = -8 \text{ A}$$

$$\text{KVL} \quad -V_C + 4k \times 2 + 1k \times -8 = 0 \Rightarrow V_C = 0 \quad I_C = 0$$

$$\text{Current division} \quad I_L = 10 \times \frac{\frac{1}{5k}}{\frac{1}{5k} + \frac{1}{2k}} = 2.86 \text{ A}$$

$$V_L = 0 \text{ (V)} \text{ short circuit}$$

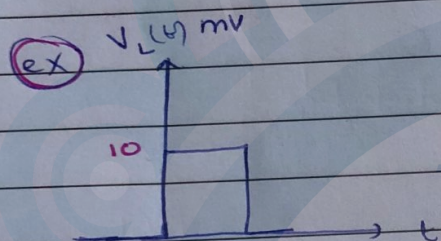
$V_L = 0 \rightarrow$ short circuit. $I_L = 0$ open circuit



$i_s(t) = 4e^{-t}$ * Find energy stored in inductor

* AC circuit $E = .5 L I_L^2 = .5 \times 12 \times 10^{-9} \times (4e^{-t})^2$
 $= 96 \times 10^{-9} e^{-2t}$ Joule

$V_L(t) = L \frac{di_s}{dt} = L \times -4e^{-t} = -4 \times 12 \times e^{-t}$



$L = 10 \text{ mH}$

$i_L(0) = 0 \text{ A}$

Find $i_L(t)$

$i_L(t) = \left[\frac{1}{L} \int_{t_0}^t V_L(t) dT \right] + i_L(t_0)$

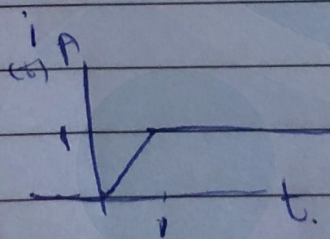
for $t < 0$ $i = 0 \rightarrow V_L = 0$

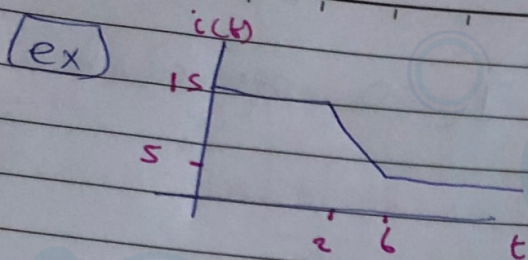
for $0 \leq t \leq 1$ $V_L(t) = 10 \text{ mV}$

$i_L(t) = \frac{1}{10 \times 10^{-3}} \times \left[\int_0^t 10 \times 10^{-3} dT \right] + 0 \Rightarrow t = i_L(t)$

for $1 \leq t < \infty$ $i_L(t) \Rightarrow V_L = 0$

$i = \frac{1}{L} \times \int 0 + i_L(1) = 1 \text{ A}$





$L = 50 \text{ mH}$
find & plot $V_L(t)$

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

for $0 \leq t \leq 2 \Rightarrow V_L(t) = 0$ ①

$2 \leq t \leq 6 = -2.5 \times 50 \times 10^{-3} = -125 \times 10^{-3}$ ②

for $6 \leq t \leq \infty \Rightarrow V_L(t) = 0$ ③

