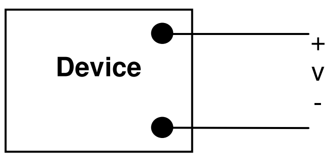
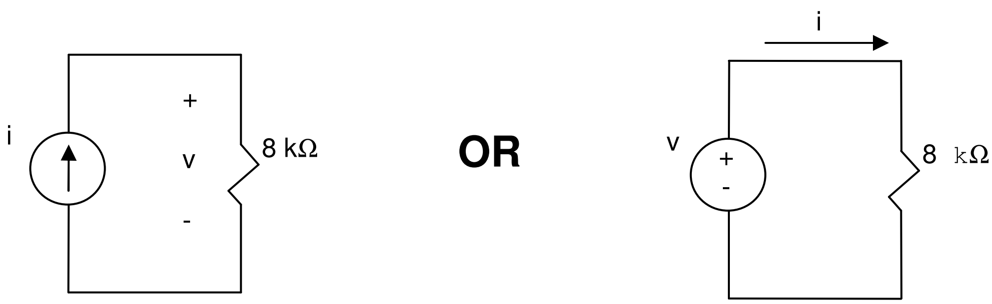
Fundamentals of Electrical Circuits - Chapter 2

1S. The terminal voltage and terminal current were measured on the device shown below. The values of v and I are given in the table below. Use the values in the table to construct a circuit model for the device consisting of a single resistor.

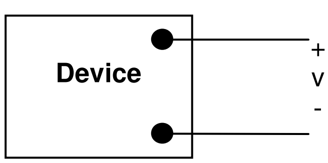


I(mA)	v(V)
-20	-160
-10	- 80
10	80
20	160
30	240

Solution:



1U. The terminal voltage and terminal current were measured on the device shown below. The values of v and I are given in the table below. Use the values in the following table to construct a circuit model for the device consisting of a single resistor.



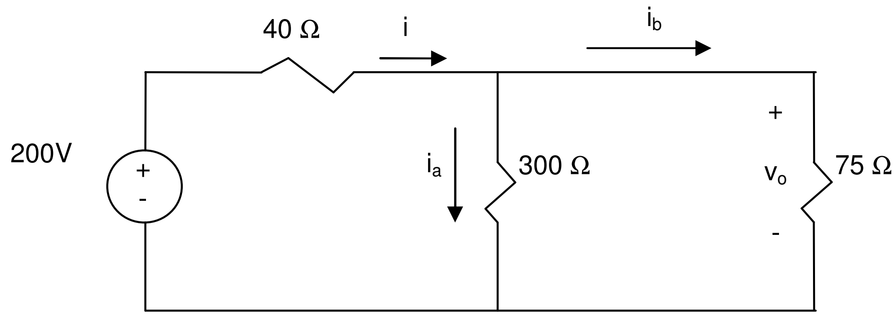
I(mA)	v(V)
-40	-1600
-20	- 800
20	800
40	1600
60	2400

Solution:

2S. Given the circuit below, use KCL method to find:

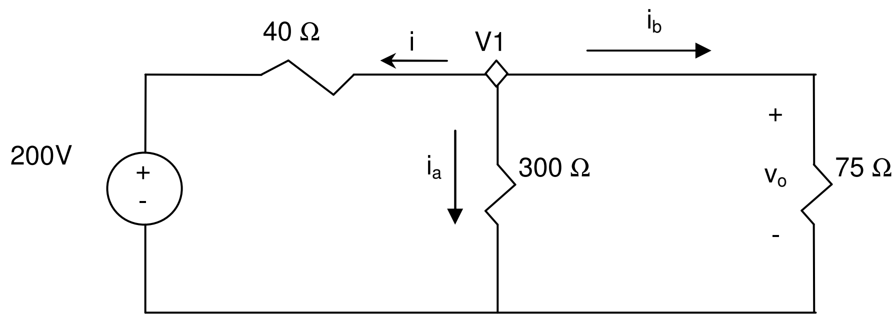
a) the value of i_a
b) the value of i_b
c) the value of v_o
d) the power dissipated in each resistor

e) the power delivered by the 200 V source.



Solution:

a) ia = ?



KCL at V1 → (V1 – 200)/40 + (V1 – 0)/300 + (V1 -0)/75 =0
Simplify equation 1 →25V1 = 3000 → V1 = 120 V

Ia = (V1 – 0)/300 = 120/300 = 0.4 A

b) i_b = ?
i_b = (V1 – 0)/75 = 120/75 = 1.6 A

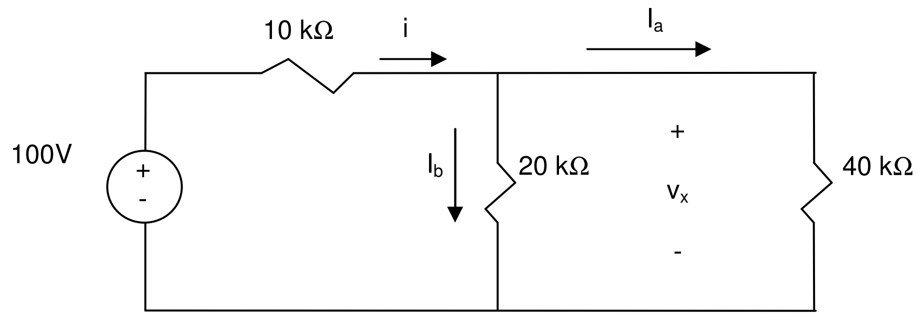
c) v_o = ?
v_o = V1 = 120V

e) Power at voltage source.
i=(V1 – 200)/40 = -2 A

P_{200v} = v * i =200 * (-2) = - 400 W Generated

2U. Given the circuit shown below find:

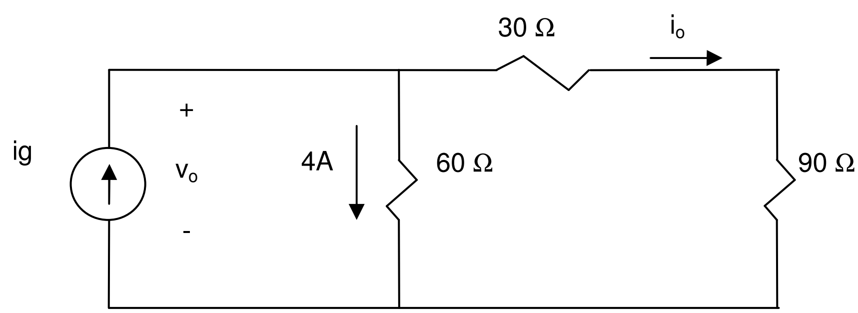
a) the value of i_a
b) the value of i_b
c) the value of v_x
d) the power dissipated in each element (resistors)
e) the power delivered by the 100 V source.



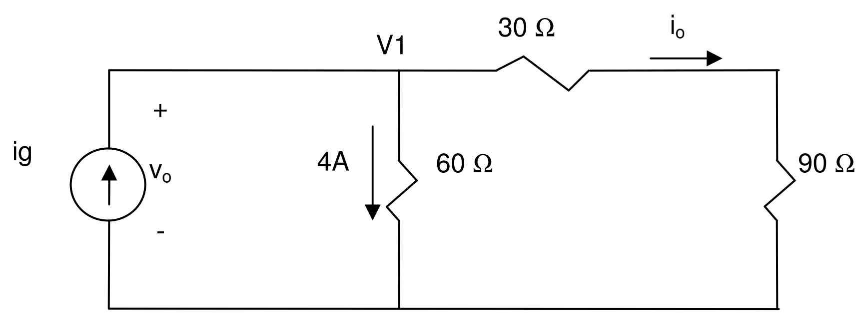
Solution:

3S. For the following circuit use KCL method to:

a) Find the current ig and io in the circuit shown below.
b) Find the voltage vo
c) Verify that the total power developed equals the total power dissipated.



Solution:



a) Find the current i_g and i_o?
Given → (V1 – 0)/60 = 4 → V1 =240 V

I_o = (V1 – 0)/120 = 2 A

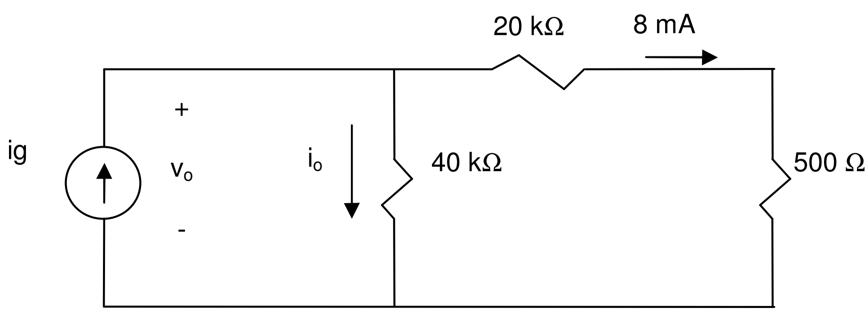
KCL at V1 → -ig + V1/60 + V1/120 = 0

→ ig = 6 A

b) v_o=?
v_o = V1 = 240 V

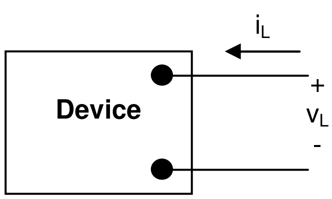
c) Total Power Developed ?= Total Power Dissipated
$P_{developed}$ = vo * ig = 240 * 6 = 1440 W
$P_{dissipated} = P_{60\Omega} + P_{30\Omega} + P_{90\Omega} = (60)*(4)^2 + (30)*(2)^2 + (90)*(2)^2 = 1440$ W
Therefore: $P_{developed} = P_{dissipated}$ = 1440 W

3U. For the following circuit use KCL method to:
a) Find the current ig and io in the circuit shown below.
b) Find the voltage vo
c) Verify that the total power developed equals the total power dissipated.



Solution:

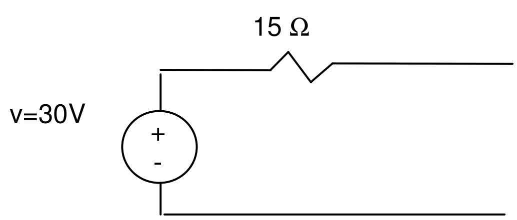
4S. The voltage and current were measured at the terminals of the device shown below along with the tabulated results.
a) Construct a circuit model for this device using an ideal voltage source and a resistor.



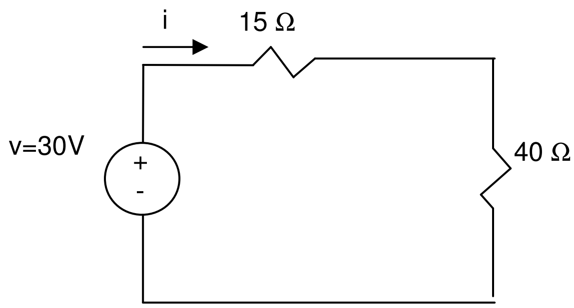
v_L (V)	i_L (A)
30	0
0	2

b) Use the model to predict the amount of power the device will deliver to a 40 Ω resistor.

Solution:
a) Construct a circuit model
when I_L = 0 "Open Circuit" → Source Voltage Vs = 30 V.
When V_L =0 "Open Circuit" → Source Resistance Rs = 30/2 =15 V.



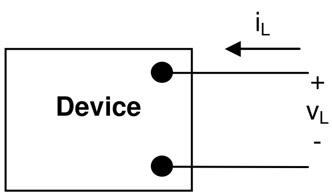
b) Power delivered to 40 ohms.



i = 31/(15+40) = 30/55 = 0.55 A
$P_{40\Omega} = r*i^2 = 40*(0.55)^2 = 11.9$ W   "Consumed"

4U. The voltage and current were measured at the terminals of the device shown below along with the tabulated results.

a) Construct a circuit model for this device using an ideal voltage source and a resistor.



v_L (V)	i_L (mA)
10	0
0	6

b) Use the model to predict the amount of power the device will deliver to a 10 kΩ resistor.

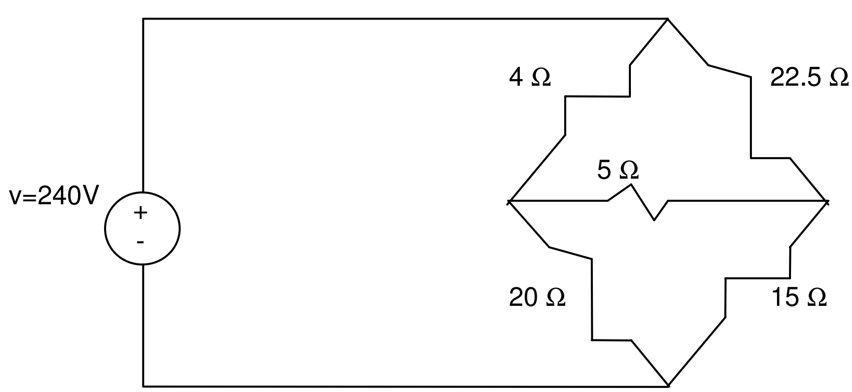
Solution:

5S. For the following circuit:

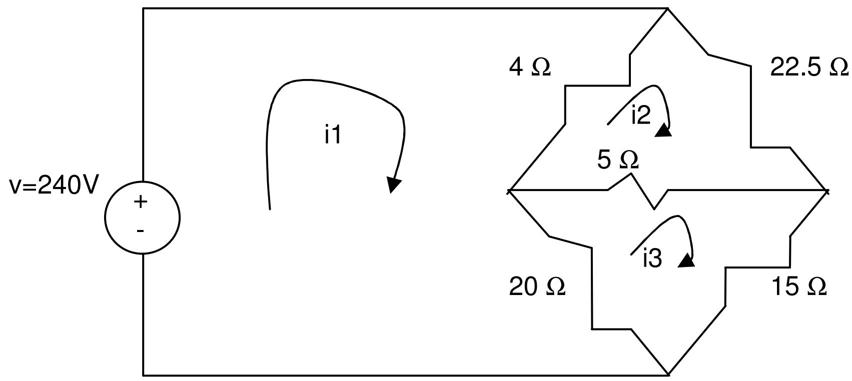
a) Find the power dissipated in each resistor.

b) Find the power supplied by the 240 V ideal voltage source

c) Verify that the power supplied equals the total power dissipated



Solution:



a) Power dissipated in each resistor

KVL I_1 → $-240 + 4(I_1 - I_2) + 20(I_1 - I_3)= 0$
KVL I_2 → $4(I_2 - I_1) + 5(I_2 - I_3) + 22.5\ I_2 = 0)$
KVL I_3 → $20(I_3 - I_1) + 5(I_3 - I_2) + 15\ I_3 = 0)$

Simplify
$24\ I_1\ - 4\ I_2 + 20\ I_3 = 240$
$-4\ I_1\ + 31.5\ I_2 - 5\ I_3 = 0$
$-20\ I_1\ - 5\ I_2 + 40\ I_3 = 240$

solve:
→ $i_1 = 19$ A, $i_2 = 4$ A, $i_3 = 10$ A,

$P_{4\Omega} = (I_1 - i_2))^2R = (19\text{-}4)^2(4) = 900$ W
$P_{20\Omega} = (I_1 - i_3))^2R = (19\text{-}10)^2(20) = 1620$ W
$P_{5\Omega} = (I_3 - i_2))^2R = (10\text{-}4)^2(5) = 180$ W
$P_{15\Omega} = (i_3))^2R = (10)^2(15) = 1500$ W
$P_{22.5\Omega} = (i_2))^2R = (4)^2(22.5) = 360$ W

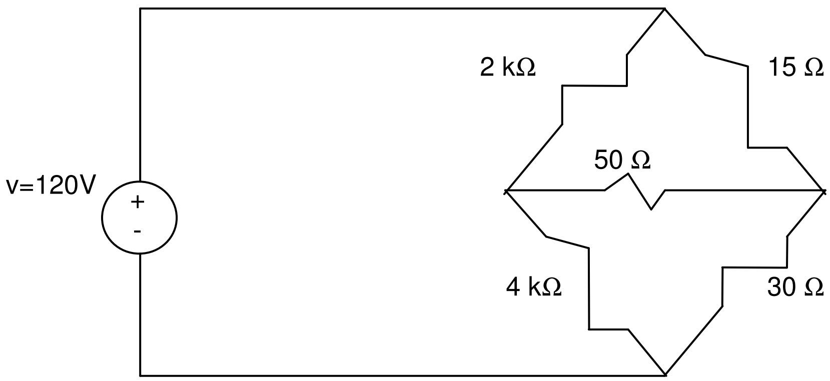
b) Power delivered by Voltage Source
$P_{240V} = VI = (240)(19) = 4560$ W

c) Verified power deliver is equal to power dissipated
$P_{dissipated} = P_{4\Omega} + P_{20\Omega} + P_{5\Omega} + P_{15\Omega} + P_{22.5\Omega} = 900 + 1620 + 180 + 1500 + 360 = 4560 = P_{delivered}$

This fact means the system is valid.

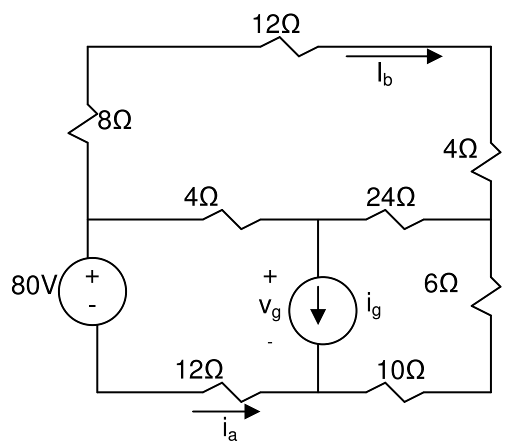
5U. For the following circuit, use KVL method to:
a) Find the power dissipated in each resistor.
b) Find the power supplied by the 120 V ideal voltage source

c) Verify that the power supplied equals the total power dissipated



Solution:

5Sb. The current i_a and i_b in the following circuit are 4A and 2A respectively. Apply KVL to find the power delivered by the current source.



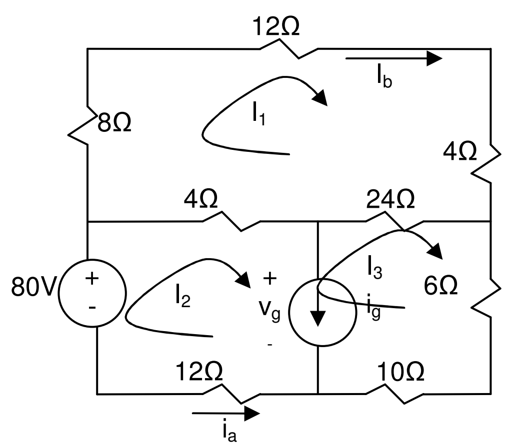
Solution

Loop1 → $8I_1 + 12I_1 + 4I_1 + 24(I_1 - I_3) + 4(I_1 - I_2) = 0$
Loop2 → $I_2 - I_3 = Ig$
Other relationships:
$I_z = -I_a = -4$ A
$I_1 = I_b = 2$ A
Plug I_1 & I_3 in Loop 1 →
$24(2) + 24(2+4) + 4(2 - I_2) = 0$ → $I_2 = 50$ A

From Loop2 eq. → $Ig = 50-(-4) = 54$ A

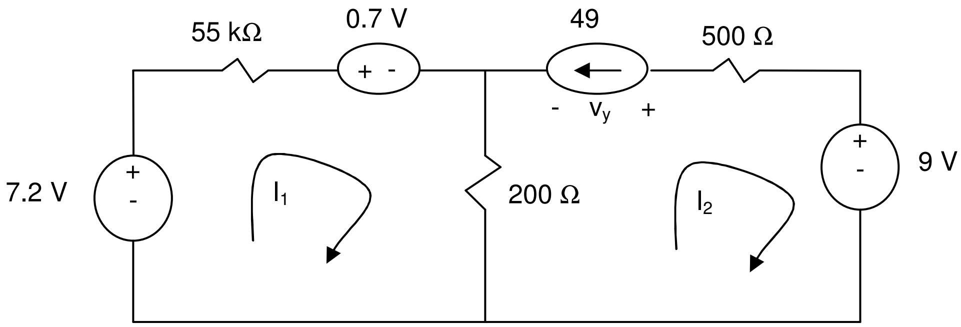
From Loop 2 KVL → $-80 + 4(I_2 - I_1) + Vg + 12 I_2 = 0$
$-80 + 4(50-2) + Vg + 12(50) = 0$ → $Vg = 712$ V

$P = Ig\ Vg = (54)*(712) = 38{,}448$ W



6S. For the following circuit, use KVL Method to:
a) Find the voltage v_y.

b) Show that the power generated in the circuit equals the total power absorbed.



Solution:

a) Find Vy

KVL at I_1 → $-7.2 + 55x10^3\ I_1 + 0.7 + (I_1 – I2)200 = 0$

KVL at I_2 → $I_2 = -49$

Therefore → $-7.2 + 55x10^3\ I_1 + 0.7 + (I_1 + 49)200 = 0$ → $I_1 = -0.178$ A

KVL at I_2 → $200(I_2 – I_1) – Vy + 500(I_2)+9 = 0$ → $200(-49 + 0.178) –Vy + 500 (-49) + 9 = 0$

Vy = -34255.4 V

b) $P_{generated} = P_{absorbed}$?

Power	Absorbed (+)	Generated (-)
$-(7.2)(I_1)=-(-7.2)(-0.178)$	1.28	
$(55000)*I_1^2 = (55000)*(0.178)^2$	1,742.62	
$+(0.7)(I_1) = (0.7)(-0.178)$		-1.39
$200\ (I1 – I2)^2 = 200\ (-0.178+49)^2$	476,727.50	
(Vy)(-I2) = (-34255.4)(49)		-1,678,515
$500*\ I_2^2 = 500*(49)^2$	1,200,500	
9*(-49)		-441
Total:	1,678,971 W	-1,678,957 W

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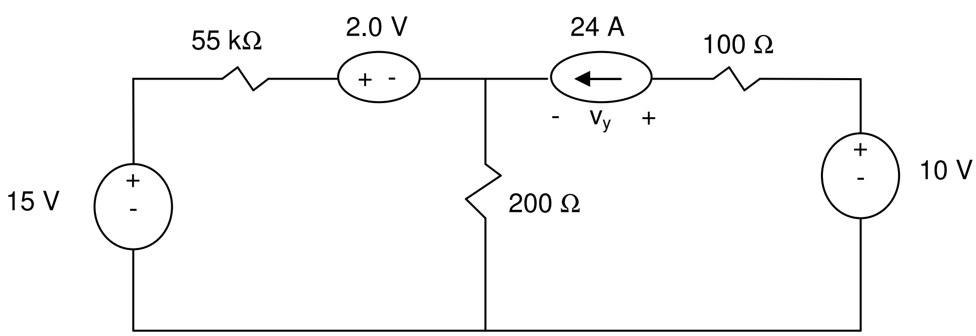
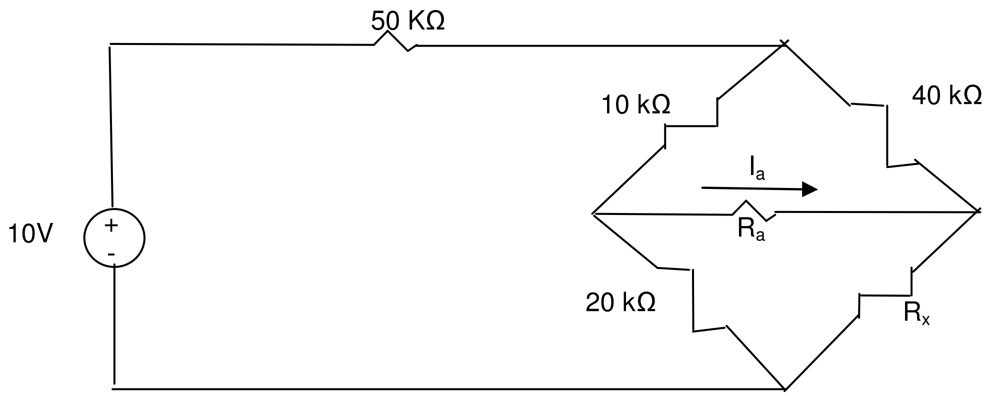
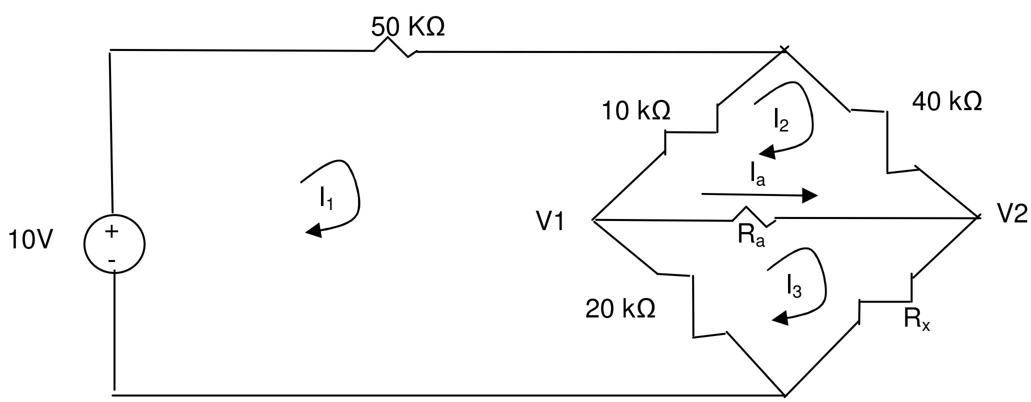


Solution:

6Sb. For the following circuit, find value R_x such that Ia = 0 for all values of R_a.



Solution



Option A – Shot cut SOLUTION

For Ia to be zero, we must have V1 = V2 which means the two sets of resistors must be proportional:

$10/20 = 40/Rx \rightarrow Rx = 80$ kΩ

Option B - FULL SOLUTION

Condition $\rightarrow I_3 - I_2 = I_a = 0 \rightarrow I_3 = i_2$

KVL Loop 1 $\rightarrow -10 + 50{,}000I_1 + 10{,}000\,(I_1 - I_2) + 20{,}000\,(I_1 - I_3) = 0 \;\rightarrow 80{,}000\,I_1 - 30{,}000\,I_2 = 10$

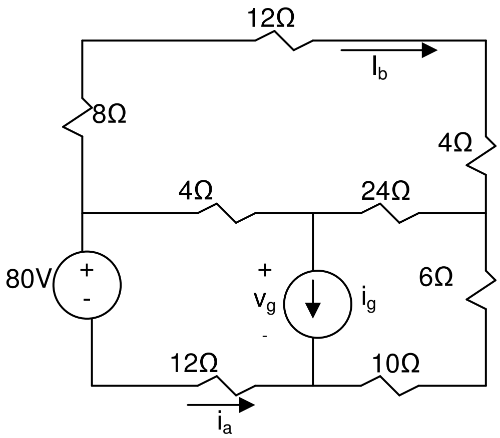
KVL Loop 2 $\rightarrow 10{,}000\,(I_2 - I_1) + 40{,}000\,I_2) = 0 \rightarrow 50{,}000\,I_2 - 10{,}000\,I_1 = 0 \;\rightarrow\; I_1 = 5I_2$

KVL Loop 3 $\rightarrow 20{,}000\,(I_3 - I_1) + R_x I_3 = 0 \rightarrow (20{,}000 + R_x)\,I_2 \;\; -20{,}000\,I_1 = 0$

Plug second equation into first loop equation $\rightarrow$ 400,000i2 – 30,000i2 = 0 $\rightarrow$ i2 = 1/37,000

Use third equation to find Rx = 80 kΩ

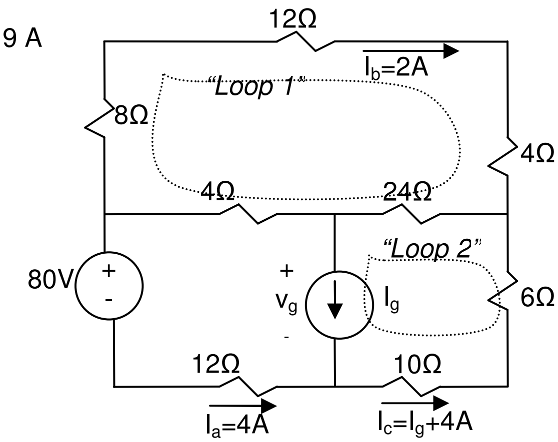
6Sc. The current i_a and I_b in the following circuit are 4A and 2A respectively. Apply KVL to find the power delivered by the current source.



Solution:

KVL Loop1 → (8+12+4) 2 + 24(Ig + 6) + 4(4+2) =0 → Ig = - 9 A
KVL Loop2 → Vg = -(6 + 10)(Ig +4) – 24(ig+6) → Vg= 152 V

Therefore
P = Ig Vg = (-9)*(152) = -1368 W



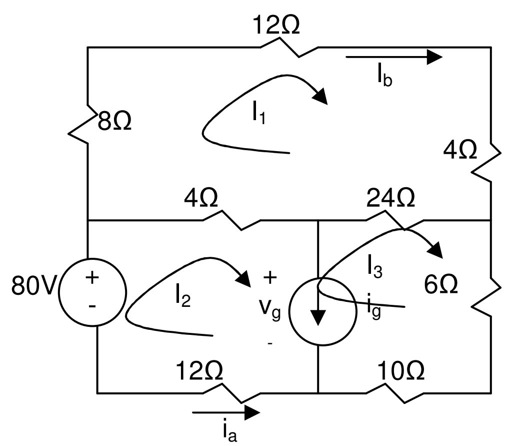
or

Mesh 1 → $8I_1 + 12I_1 + 4I_1 + 24(I_1 - I_3) + 4(I_1 - I_2) = 0$
Mesh 2 → $I_2 - I_3 = Ig$
Other relationships:
$I_2 = -I_a = -4$ A
$I_1 = I_b = 2$ A
Plug I_1 & I_2 in Loop 1 →
$24(2) + 24(2 - I_3) + 4(2+4) = 0$ → $I_3 = 5$ A

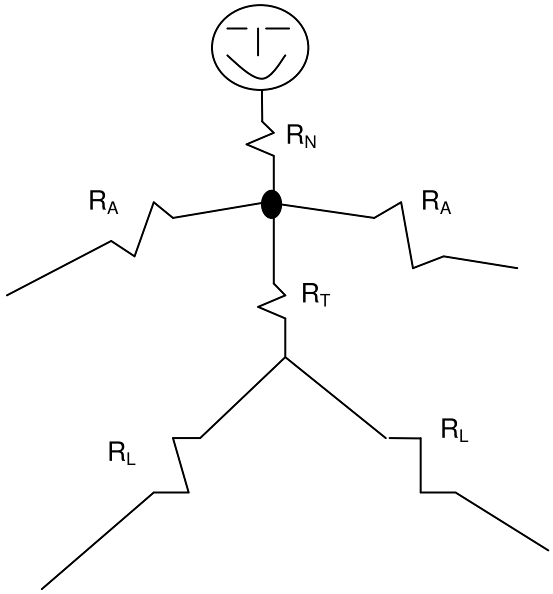
From Loop2 eq. → Ig = -4-(5)= -9 A

From Loop 2 KVL → $-80 + 4(I_2 - I_1) + Vg + 12 I_2 = 0$
-80 + 4(-4-2) + Vg + 12(-4) = 0 → Vg = 152 V

P = Ig Vg = (-9)*(152) = -1368 W

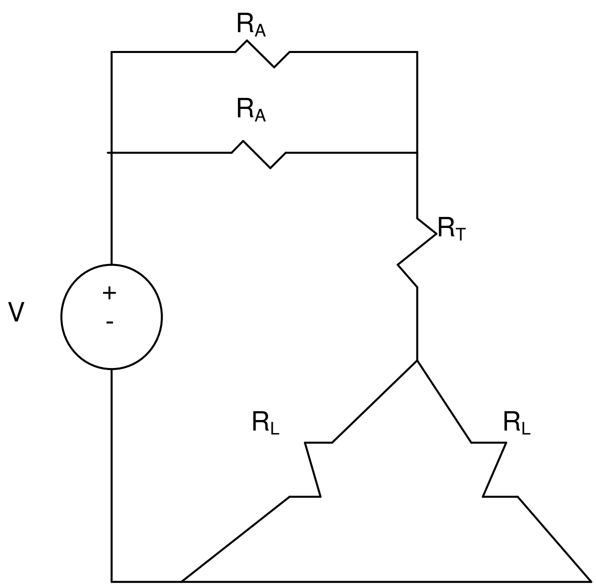


7S. Based on the following model, draw a circuit model of the path of current through the human body for a person touching a voltage source with both hands who has both feet at the same potential as negative terminal of the voltage source

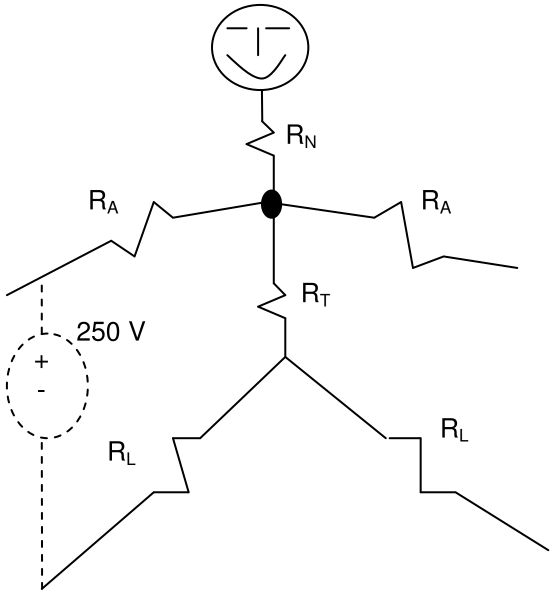


Physiological Reaction	**Current**
Barley Perceptible	3-5 mA
Extreme Pain	35-50 mA
Muscle Paralysis	50-70 mA
Heart Stoppage	500 mA

Solution:



7U. Suppose the power company installs some equipment that could provide a 250V shock to a human being. Is the current that results dangerous enough to warrant posting a warning sign and take other precautions to prevent such a shock?
Assume that if the source is 250V, the resistance of the arm is 400 Ω, the resistance of the trunk is 50 Ω and the resistance of the leg is 200 Ω. Use the model given below.



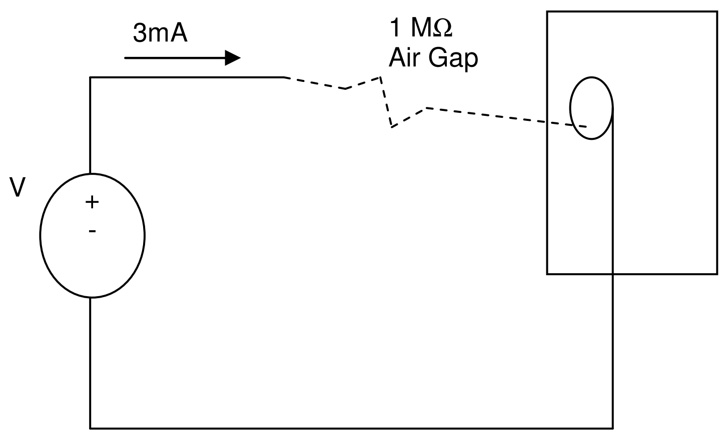
Physiological Reaction	**Current**
Barley Perceptible	3-5 mA
Extreme Pain	35-50 mA
Muscle Paralysis	50-70 mA
Heart Stoppage	500 mA

Solution:

8S. To understand why the voltage level is not the sole determinant of potential injury due to electrical shock, consider the case of a static electricity shock. When you shuffle your feet across a carpet, your body becomes charged. The effect of this charge is that your entire body represents a voltage potential. When you touch a metal door knob, a voltage different is created between you and the doorknob, and current flows -- but the conduction material is air, not your body!

Suppose the model of the space between your hand and the doorknob is a 1 MΩ resistance. What voltage potential exists between your hand and the doorknob to cause mild shock, if the current causing mild shock is 3 mA?

Solution:



$V = I*R = (3*10^{-3})\,(10^{6}) = 3{,}000\ V$

8U. To understand why the voltage level is not the sole determinant of potential injury due to electrical shock, consider the case of a static electricity shock. When you shuffle your feet across a carpet, your body becomes charged. The effect of this charge is that your entire body represents a voltage potential. When you touch a metal door knob, a voltage different is created between you and the doorknob, and current flows -- but the conduction material is air, not your body!

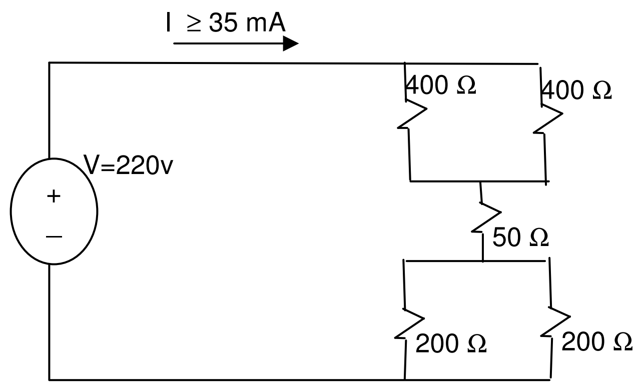
Suppose the model of the space between your hand and the doorknob is a 2 MΩ resistance. What voltage potential exists between your hand and the doorknob causes extreme pain, if the current causing extreme pain is 40 mA?

Solution:

8Sb. A person accidentally grabs one of the conductors of a 220 volts source with both bare hands while standing bare feet in a puddle of water where the other conductor lays. Given the resistance of each Arm is 400Ω, resistance of each leg is 200 Ω, and resistance of torso is 50Ω, draw the ideal circuit model of this configuration and calculate the current flow through the person's torso.

Solution:

Req= (400||400) + 50 + (200||200)=350 Ω
I = V/R = 220/350 = 0.63 A

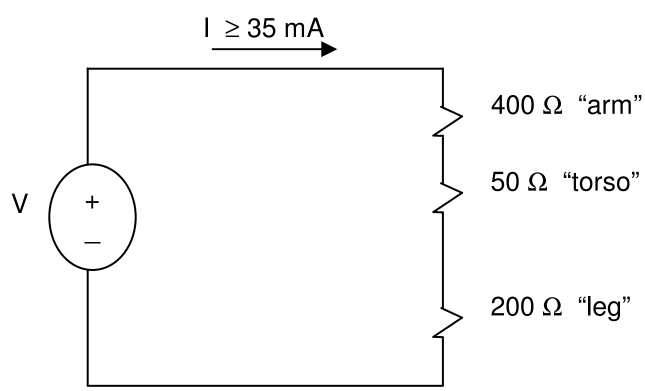


8Sc.A bare foot person accidentally steps on a conductor to one terminal of a DC voltage source while holding to the other terminal. Draw the equivalent circuit diagram and calculate the minimum voltage from the source that would cause electric shock.

Note: Human torso, leg and arm have 50 Ω, 200 Ω and 400 Ω resistance respectively. 35 mA current through human body is sufficient to shock.

Solution:

V = IR
V ≥ (35 mA) (650 Ω) = 22750 mV



8Sd. A person accidentally grabs conductors connected to each end of a dc voltage source, one in each arm. Assuming each arm has a resistance of 400Ω, Calculate the minimum voltage from the dc voltage source required to shock the person (35 mA is sufficient to shock). Draw the equivalent circuit diagram.

Solution:

$V = IR$
$V \geq (35\ mA)\ (\ 800\ \Omega) = 28000\ mV$
$V \geq 28\ V$