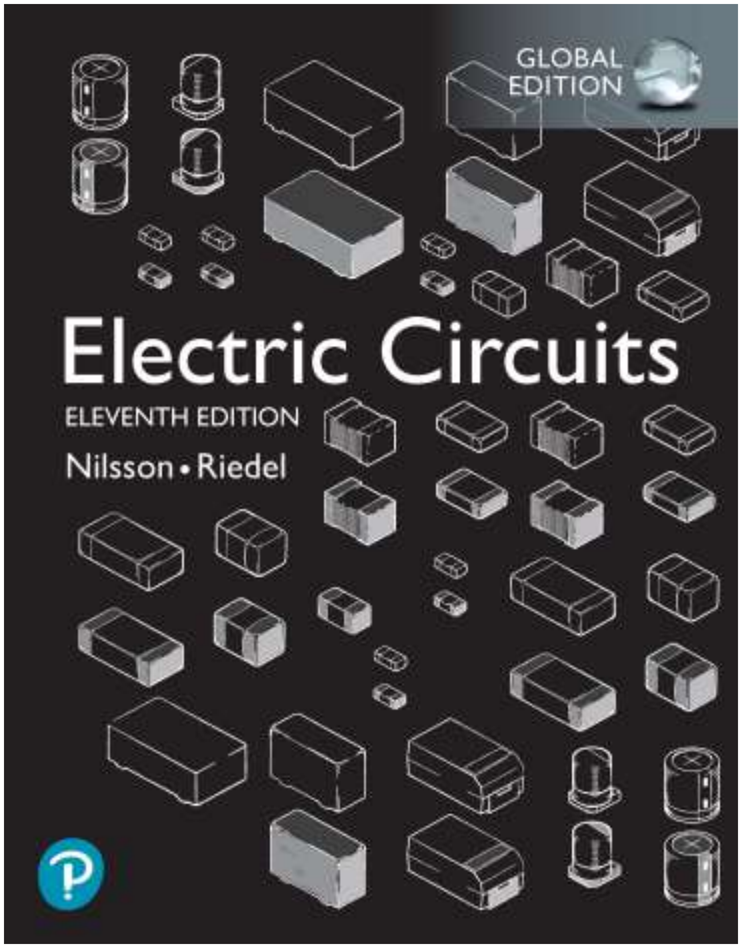
Electric Circuits

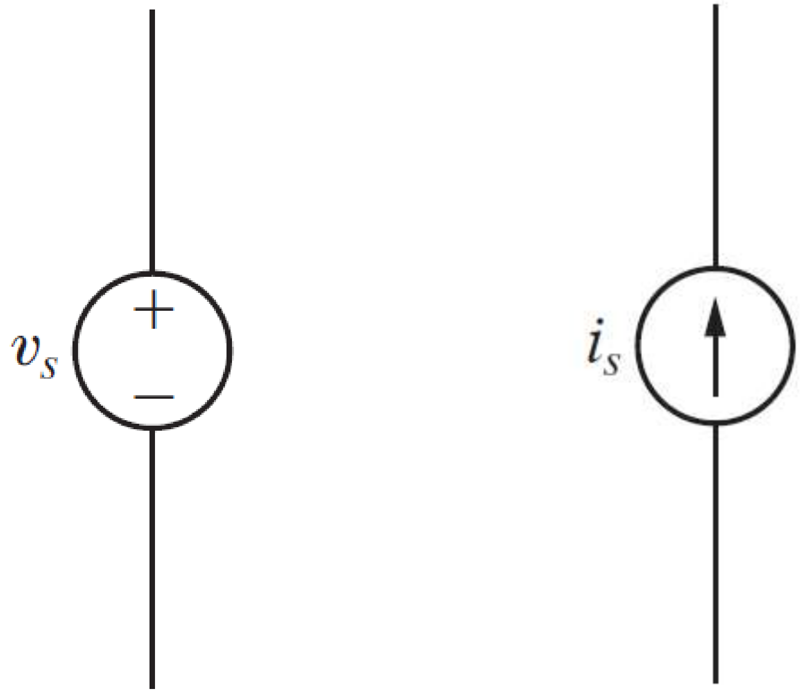
Eleventh Edition, Global Edition



Chapter 2

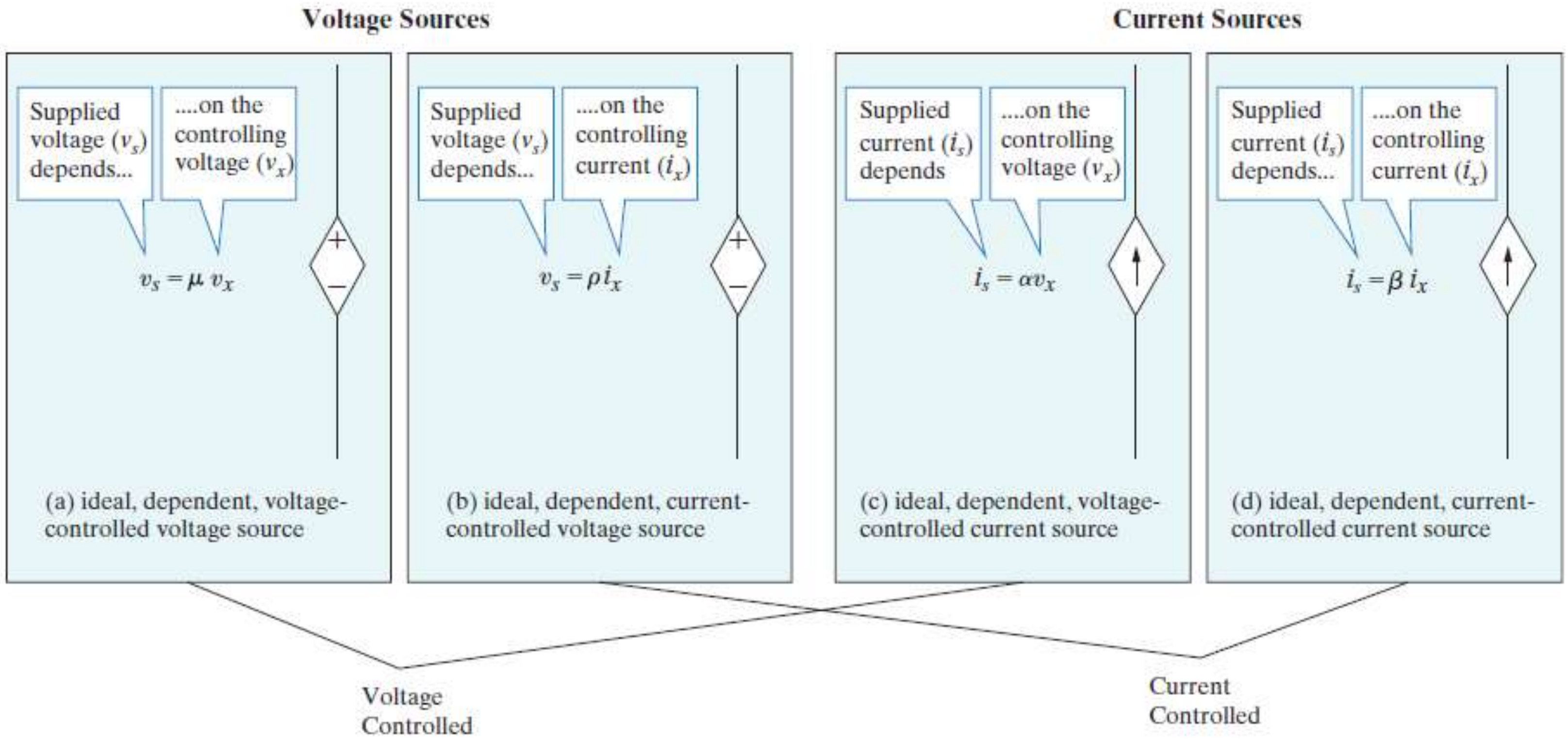
Circuit Elements

The circuit symbols for (a) an ideal independent voltage source and (b) an ideal independent current source.

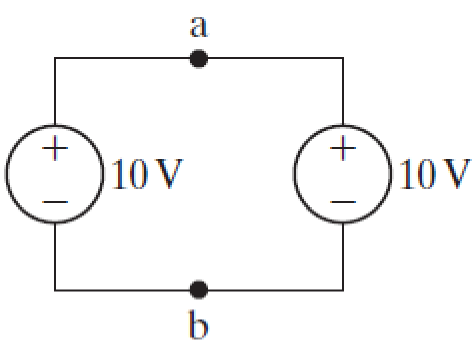


(a) (b)

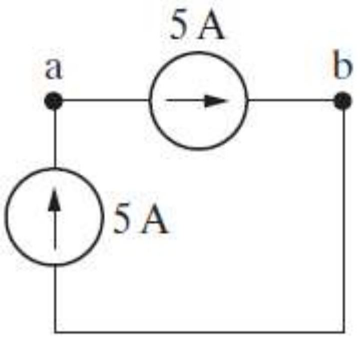
(a) (b) Circuit symbols for ideal dependent voltage sources and (c) (d) ideal dependent current sources.



Example 1 (1)

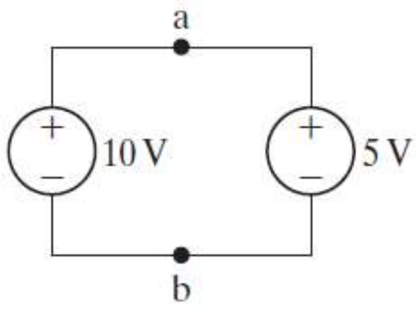


(a)

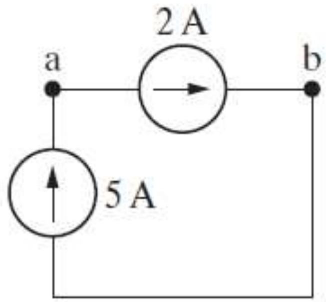


(b)

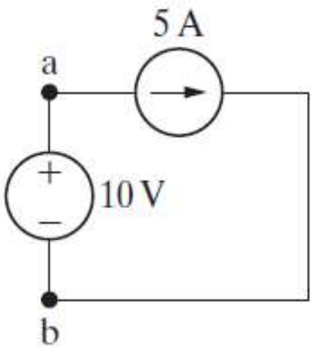
Example 1(2)



(c)

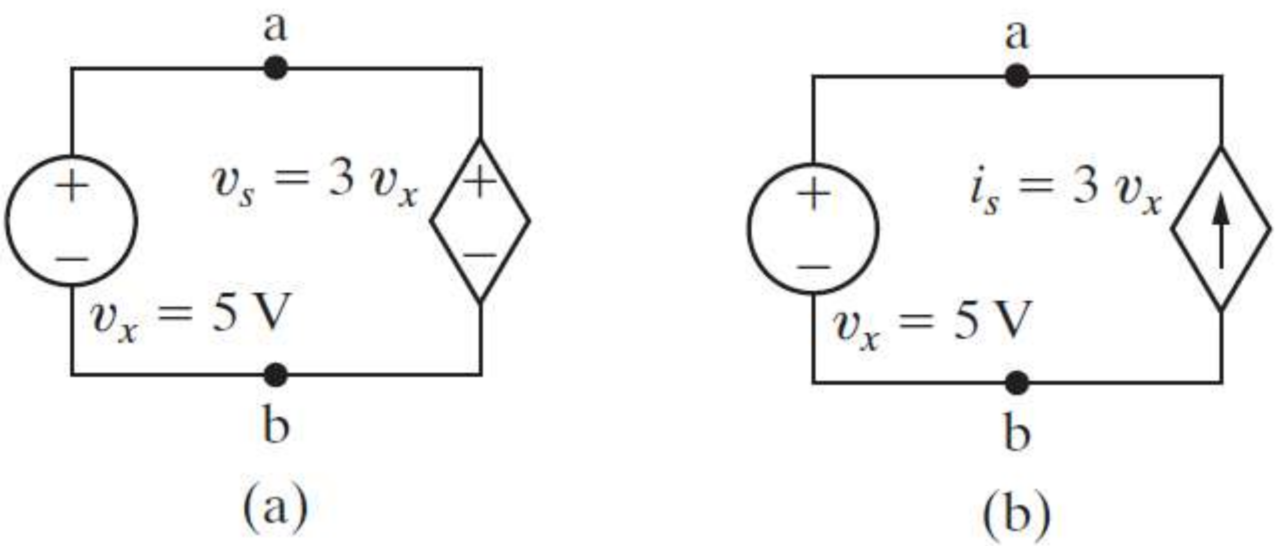


(d)

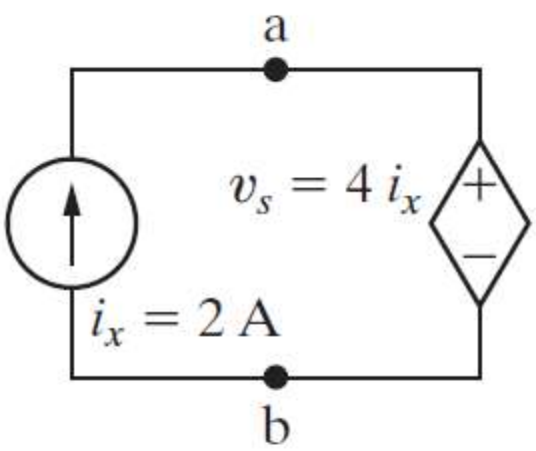


(e)

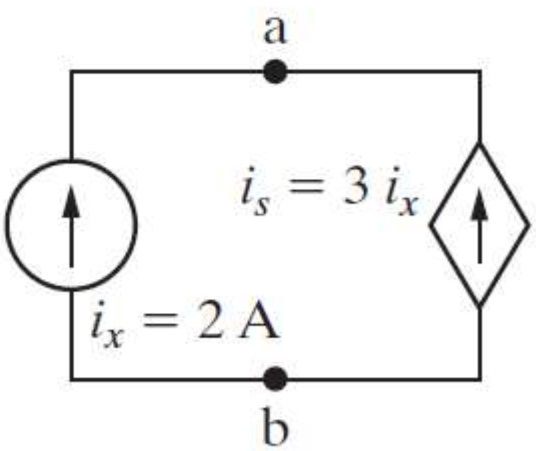
Example 2 (1 of 2)



Example 2 (2 of 2)

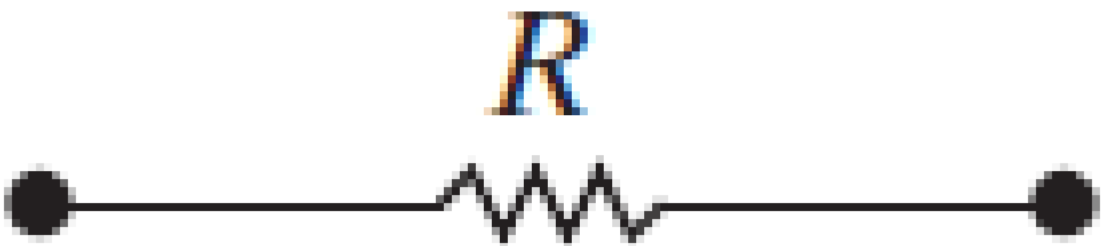


(c)



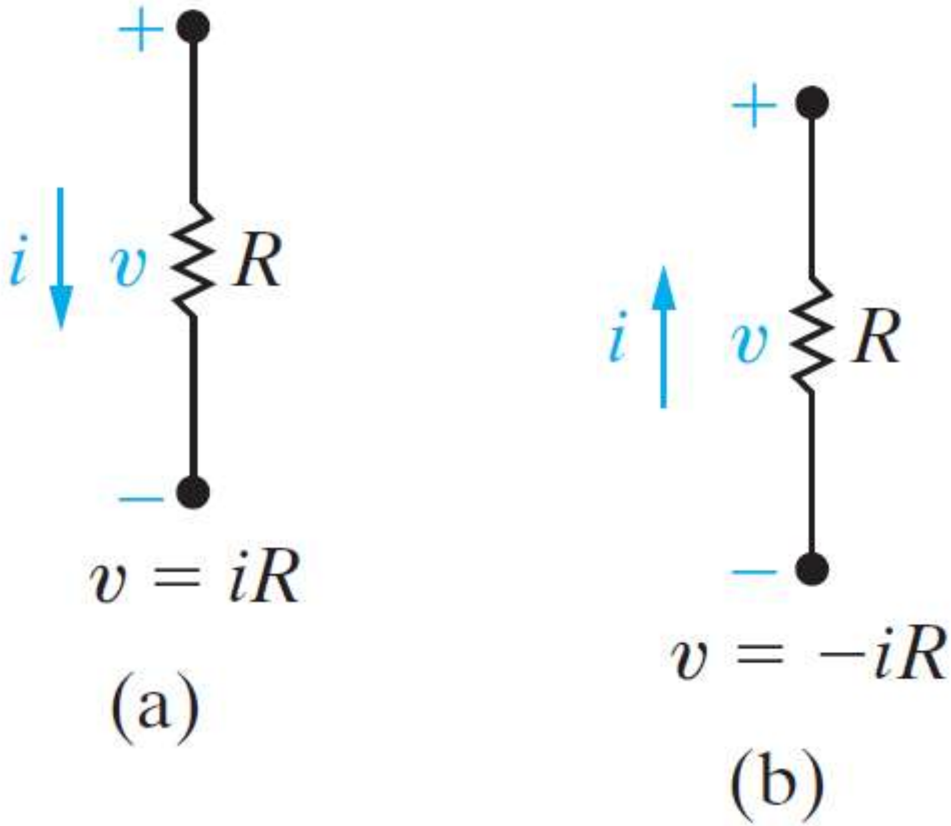
(d)

Electrical Resistance

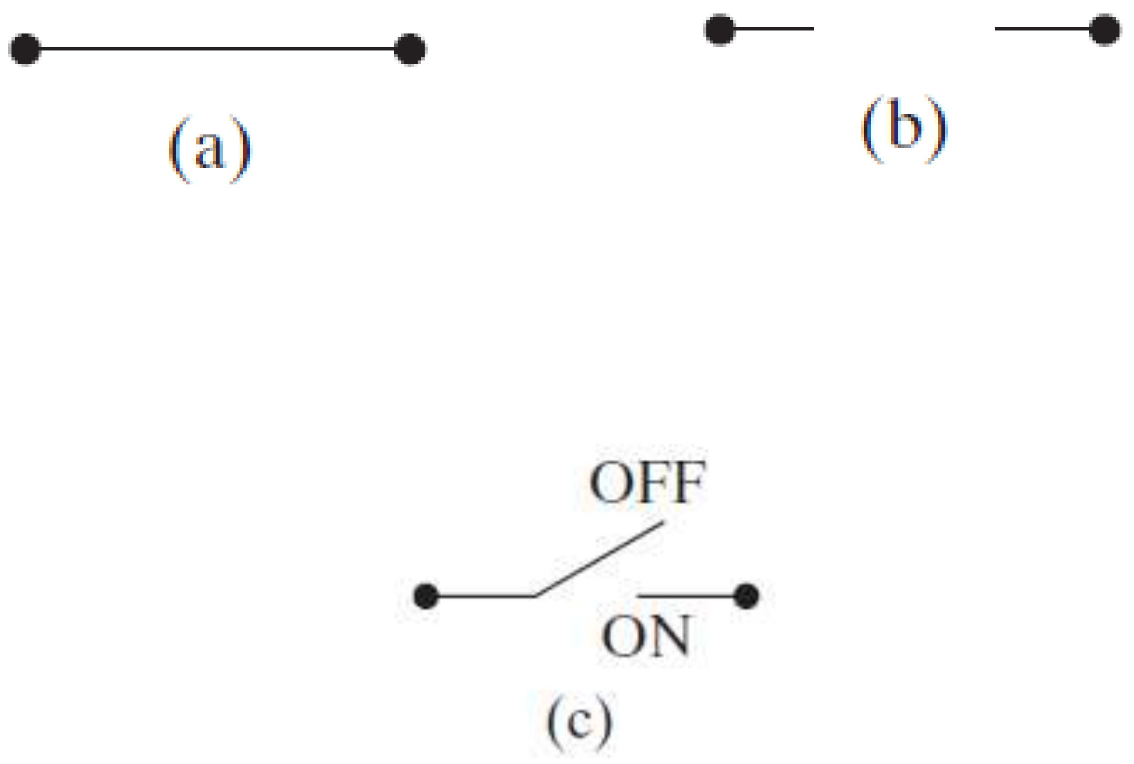


OHM'S LAW

Two possible reference choices for the current and voltage at the terminals of a resistor and the resulting equations.



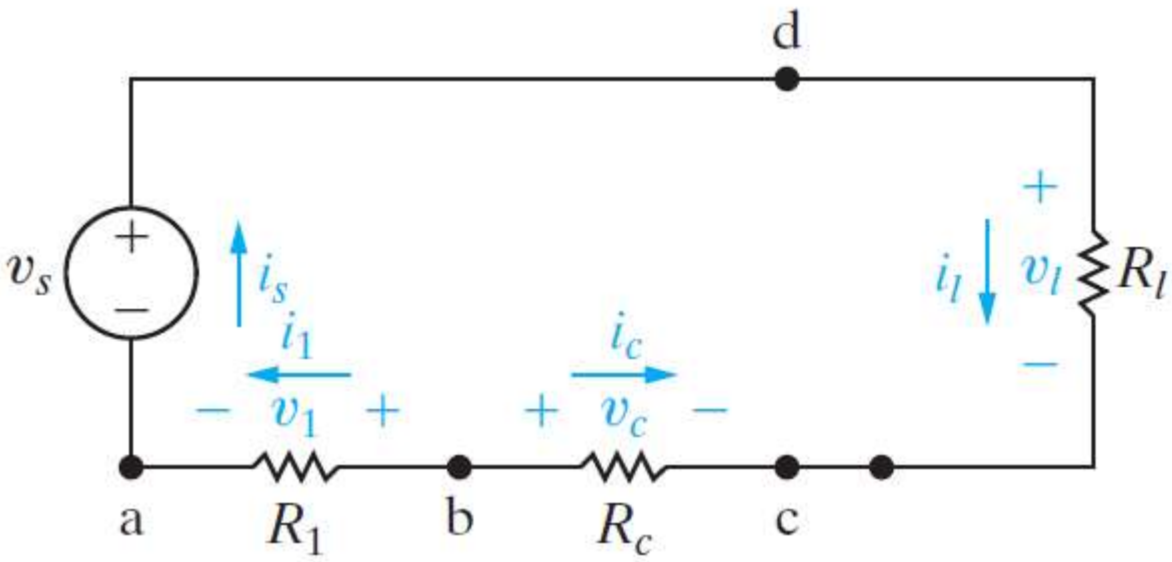
Circuit symbols. (a) Short circuit. (b) Open circuit. (c) Switch.



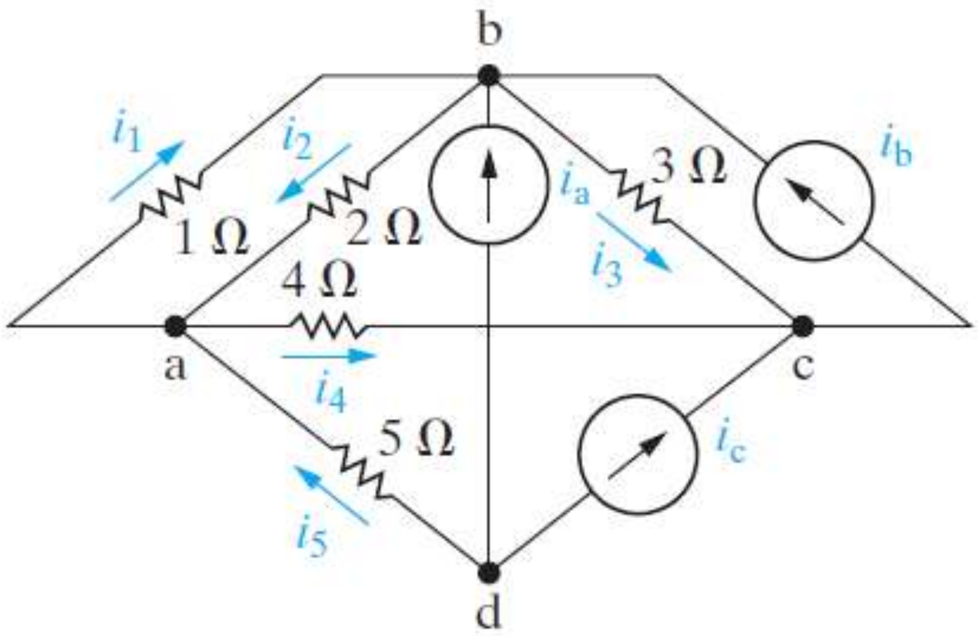
Kirchhoff's current law:

- The algebraic sum of all the currents at any node in a circuit equals zero.

KCL



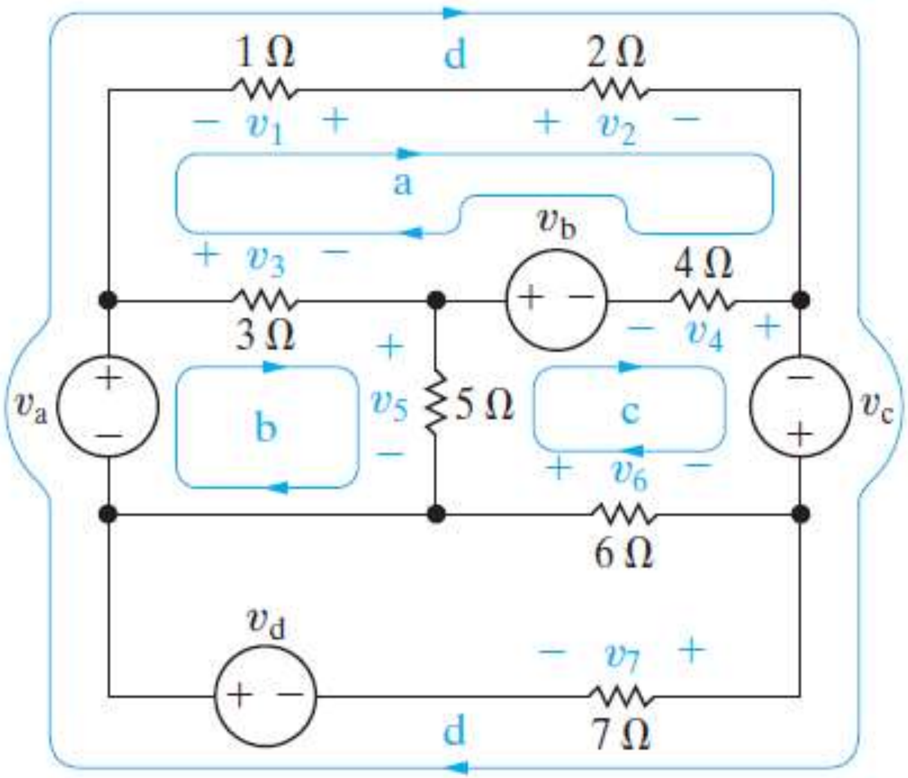
Example (KCL)



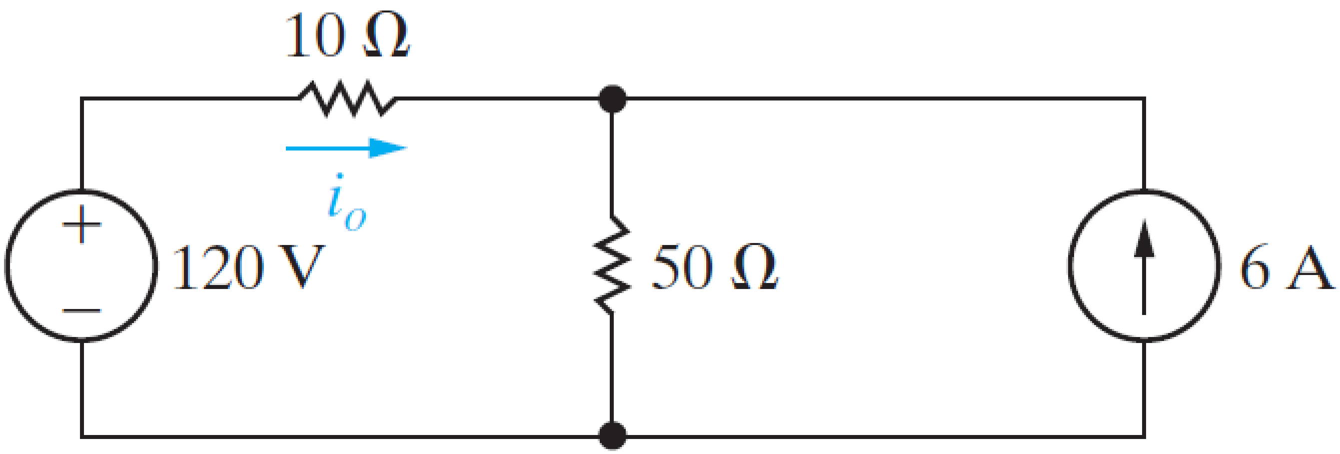
Kirchhoff’s voltage law

- The algebraic sum of all the voltages around any closed path in a circuit equals zero.

Example (KVL)

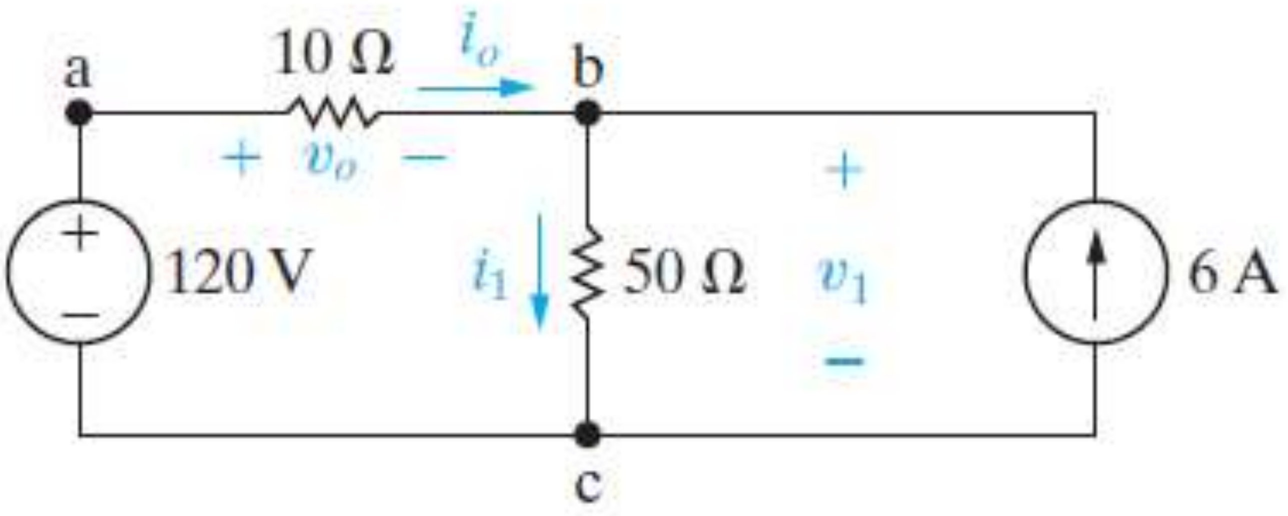


Example



a) Use Kirchhoff’s laws and Ohm’s law to find i0 in the circuit shown in Fig.
b) Test the solution for by verifying that the total power generated equals the total power dissipated.

Solution: The circuit shown in Fig. with the unknowns i_1, v_o, and v_1 defined.



The power dissipated in the 50 Ω resistor is

$$p_{50\Omega} = (3)^2(50) = 450 \text{ W}.$$

The power dissipated in the 10 Ω resistor is

$$p_{10\Omega} = (-3)^2(10) = 90 \text{ W}.$$

The power delivered to the 120 V source is

$$p_{120\text{V}} = -120i_o = -120(-3) = 360 \text{ W}.$$

The power delivered to the 6 A source is

$$p_{6\text{A}} = -v_1(6), \qquad \text{but} \qquad v_1 = 50i_1 = 150 \text{ V}.$$

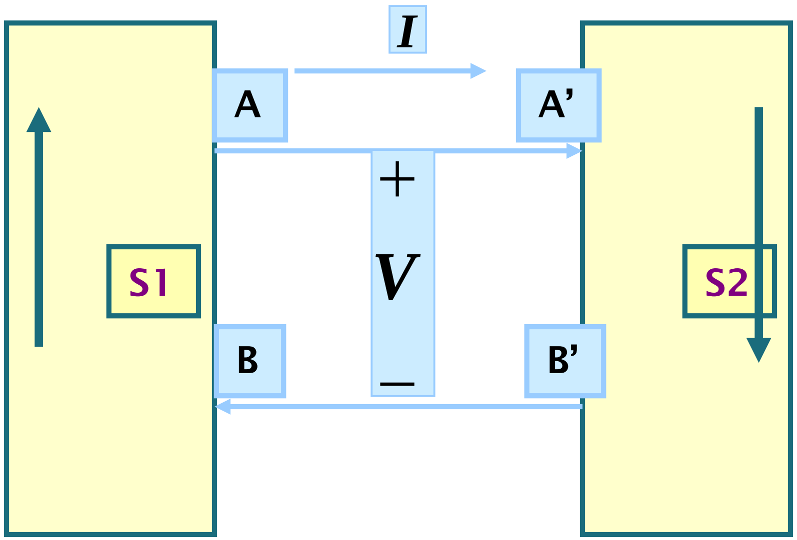
Therefore

$$p_{6\text{A}} = -150(6) = -900 \text{ W}.$$

The 6 A source is delivering 900 W, and the 120 V source is absorbing 360 W. The total power absorbed is $360 + 450 + 90 = 900$ W. Therefore, the solution verifies that the power delivered equals the power absorbed.

UNDERSTANDING PASSIVE SIGN CONVENTION

We must examine the voltage across the component and the current through it



$$P_{S1} = V_{AB} I_{AB}$$
$$P_{S2} = V_{A'B'} I_{A'B'}$$

Voltage(V)	Current A - A'	S1	S2
positive	positive	supplies	receives
positive	negative	receives	supplies
negative	positive	receives	supplies
negative	negative	supplies	receives

ON S_1

$V_{AB} > 0, I_{AB} < 0$

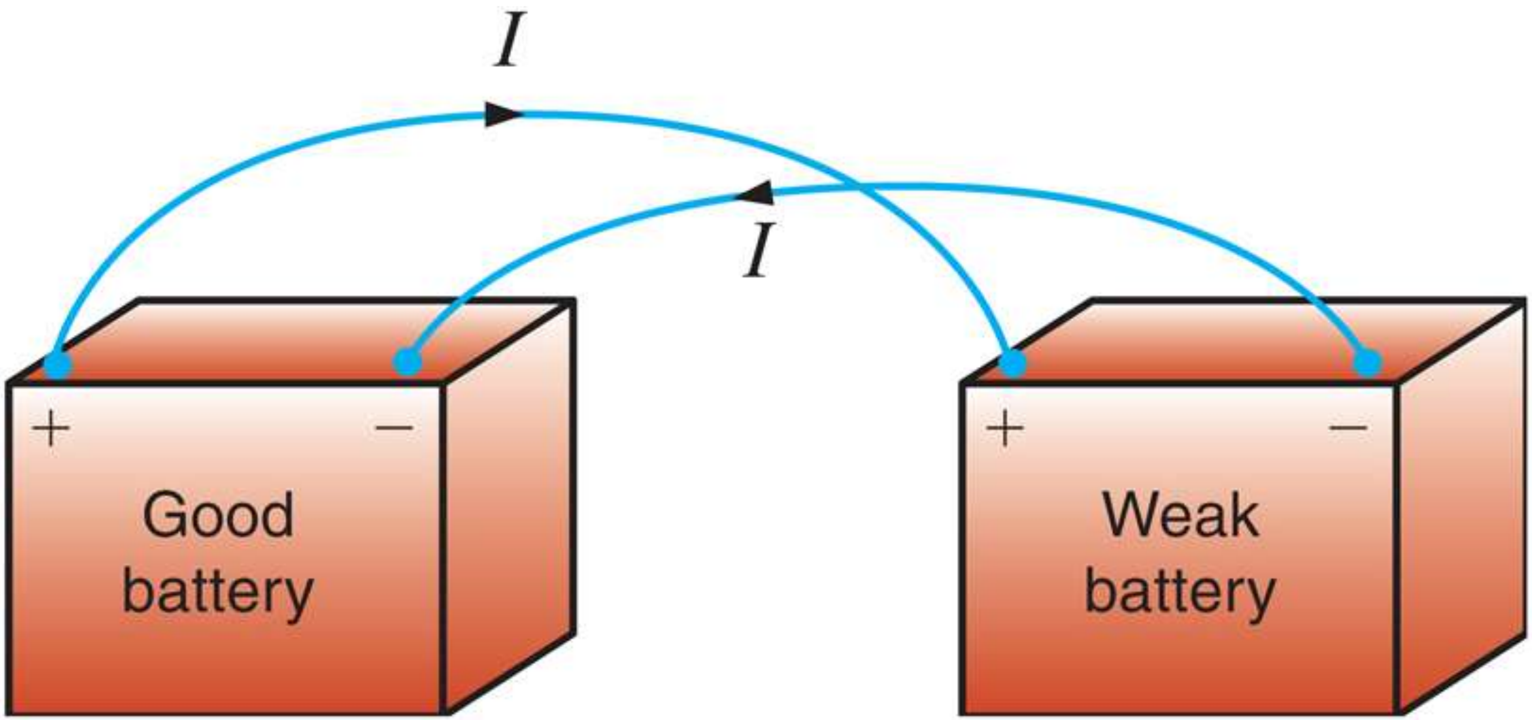
ON S_2

$V_{A'B'} > 0, \; I_{A'B'} > 0$

ON S2

$V_{A'B'} < 0, \; I_{A'B'} > 0$

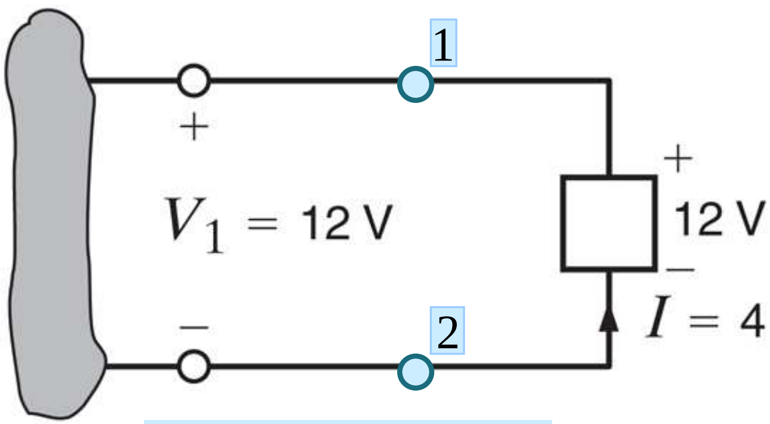
GEAUX



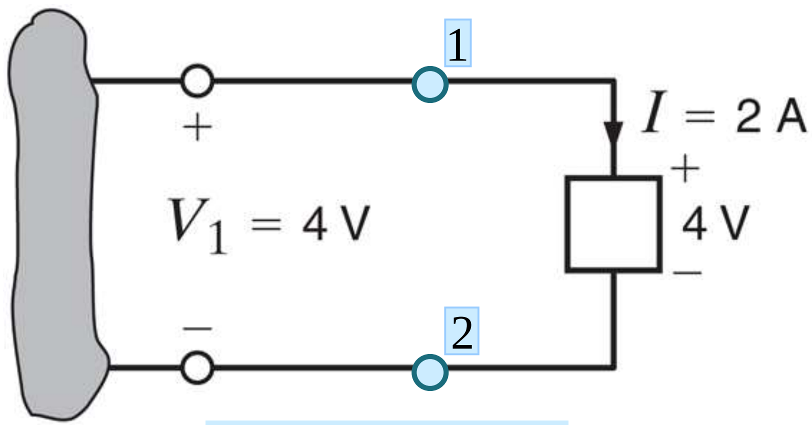
CHARGES RECEIVE ENERGY.
THIS BATTERY SUPPLIES ENERGY

CHARGES LOSE ENERGY.
THIS BATTERY RECEIVES THE ENERGY

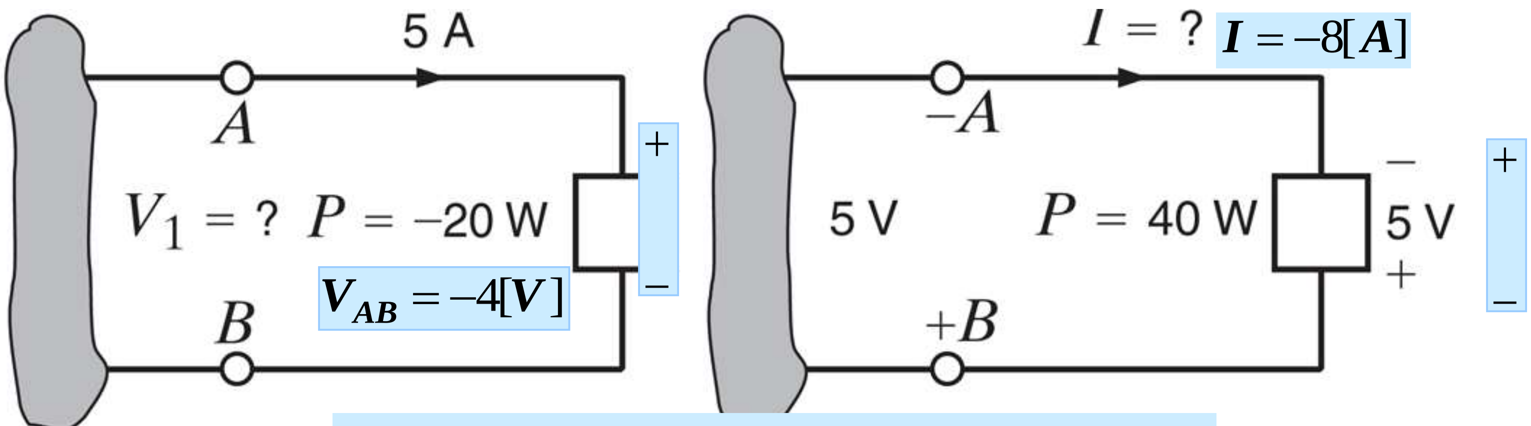
WHEN IN DOUBT LABEL THE TERMINALS OF THE COMPONENT



$V_{12} = 12V,\ I_{12} = -4A$



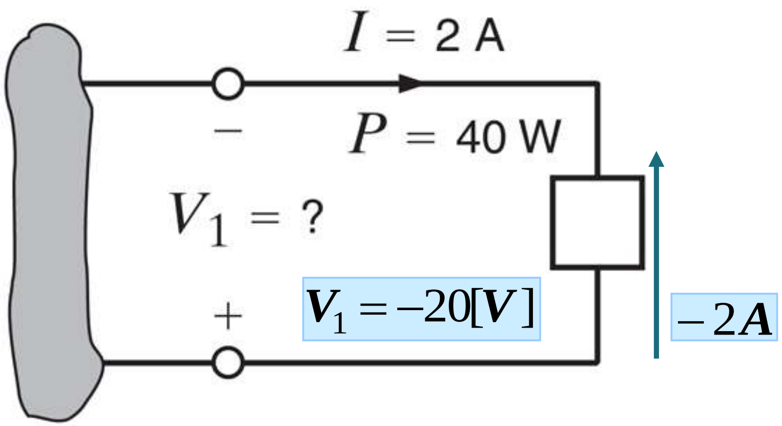
$V_{12} = 4V,\ I_{12} = 2A$

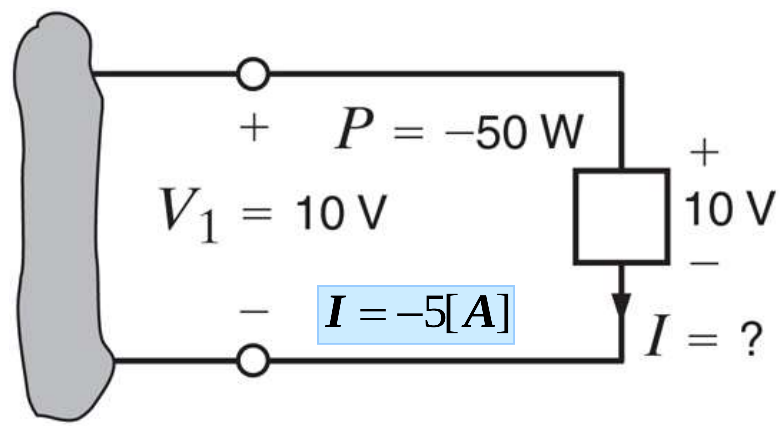


$-20[W] = V_{AB} \times (5A)$

SELECT VOLTAGE REFERENCE POLARITY BASED ON CURRENT REFERENCE DIRECTION

$40[W] = (-5V) \times I$





$40[W] = V_1 \times (-2A)$

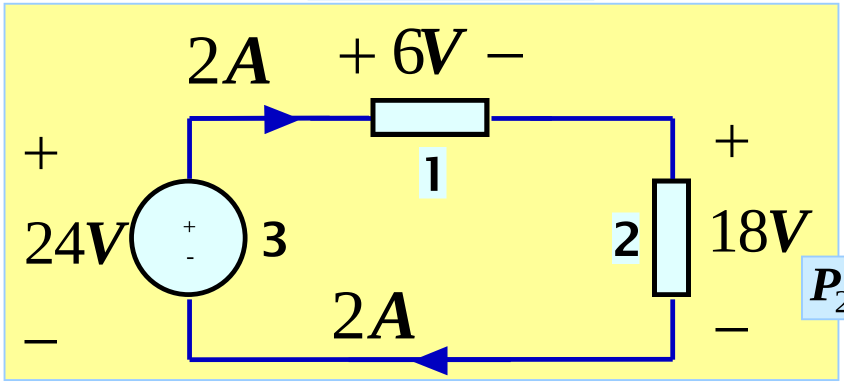
SELECT HERE THE CURRENT REFERENCE DIRECTION BASED ON VOLTAGE REFERENCE POLARITY

$-50[W] = (10[V]) \times I$

WHICH TERMINAL HAS HIGHER VOLTAGE AND WHICH IS THE CURRENT FLOW DIRECTION

COMPUTE POWER ABDORBED OR SUPPLIED BY EACH ELEMENT

$P_1 = (6V)(2A)$



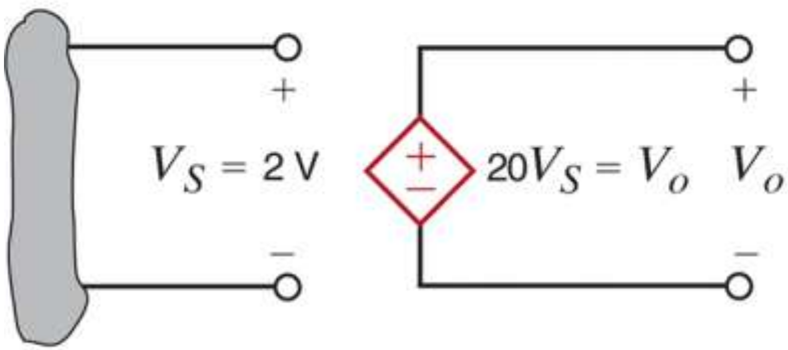
$P_2 = (18V)(2A)$

$P_3 = (24V)(-2A) = (-24V)(2A)$

P1 = 12W
P2 = 36W
P3 = -48W

IMPORTANT: NOTICE THE POWER BALANCE IN THE CIRCUIT

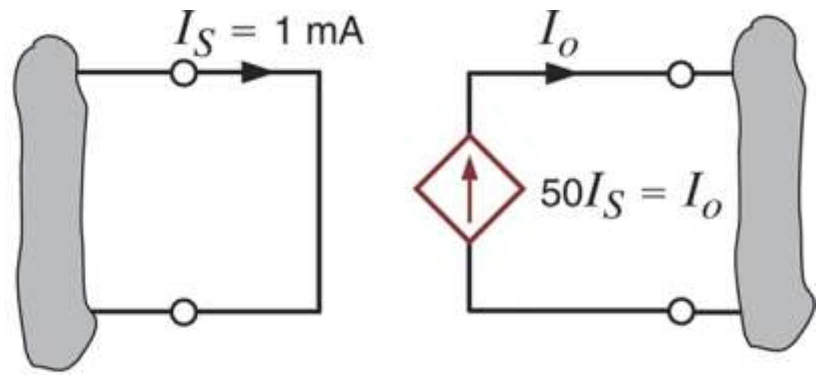
EXERCISES WITH DEPENDENT SOURCES



FIND V_O

(a)

$V_O = 40[V]$



FIND I_O

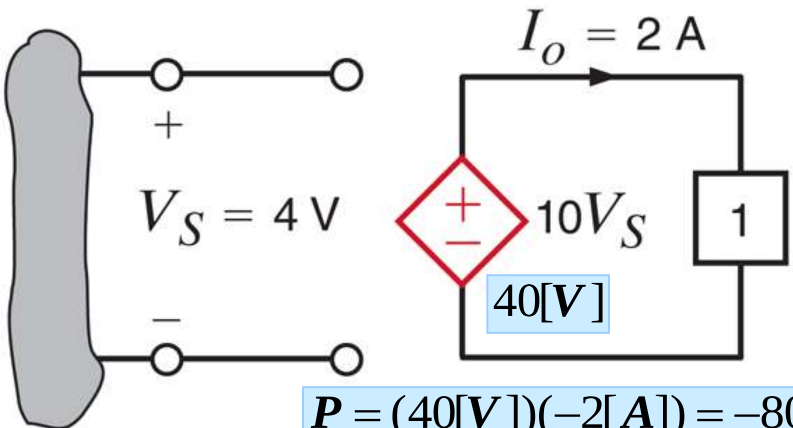
(b)

$I_O = 50mA$

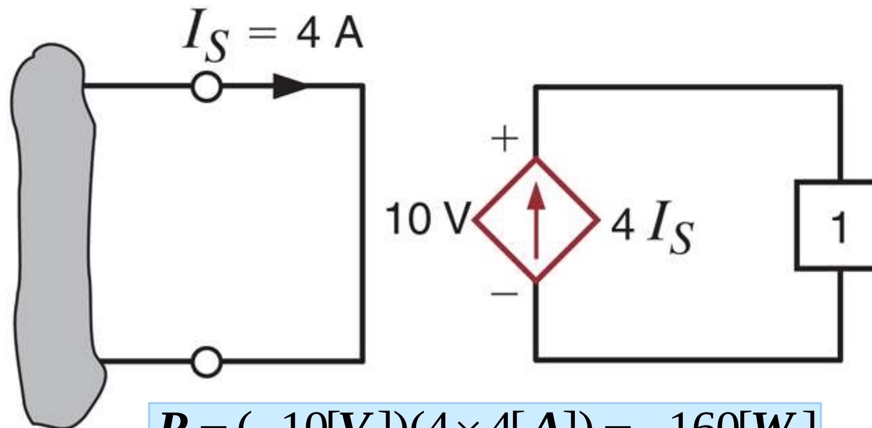
Pearson

GEAUX

DETERMINE THE POWER SUPPLIED BY THE DEPENDENT SOURCES



$$P = (40[V])(-2[A]) = -80[W]$$

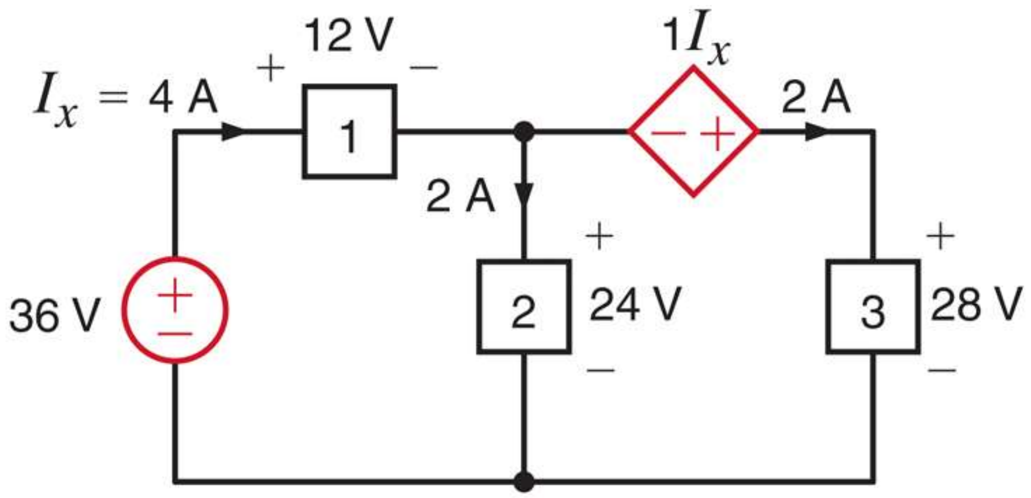


$$P = (-10[V])(4 \times 4[A]) = -160[W]$$

TAKE VOLTAGE POLARITY REFERENCE

TAKE CURRENT REFERENCE DIRECTION

POWER ABSORBED OR SUPPLIED BY EACH ELEMENT



$$P_1 = (12V)(4A) = 48[W]$$

$$P_2 = (24V)(2A) = 48[W]$$

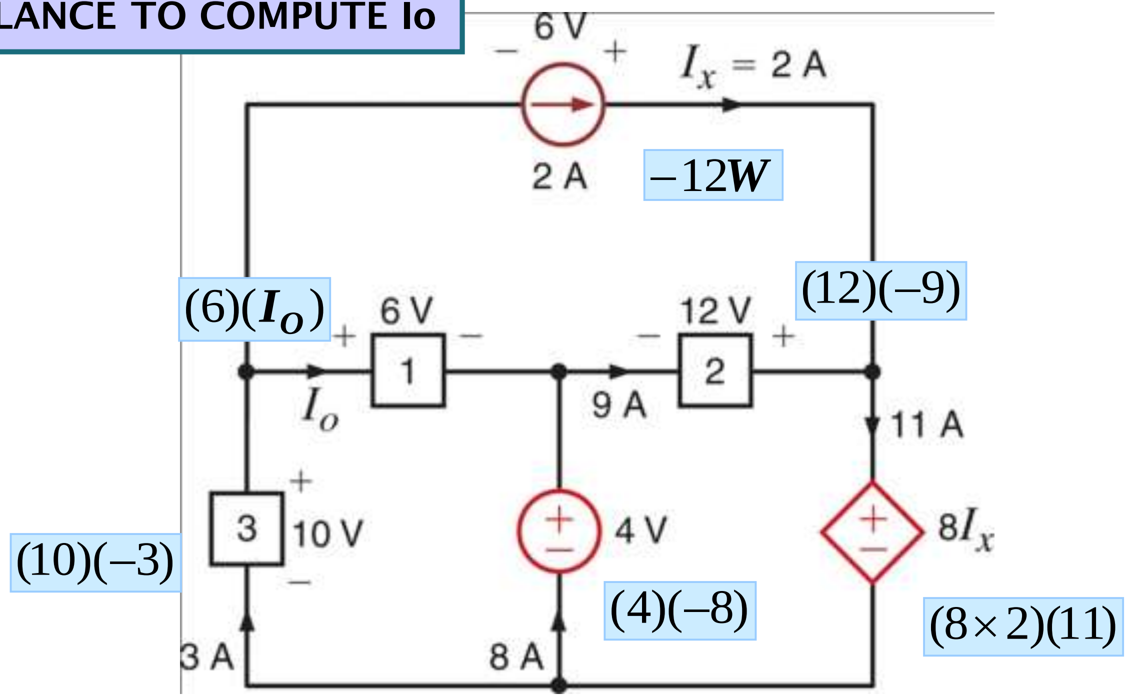
$$P_3 = (28V)(2A) = 56[W]$$

$$P_{DS} = (1I_x)(-2A) = (4V)(-2A) = -8[W]$$

$$P_{36V} = (36V)(-4A) = -144[W]$$

NOTICE THE POWER BALANCE

USE POWER BALANCE TO COMPUTE Io



$$P_{2\,\text{A}} = (6)(-2) = -12 \text{ W}$$
$$P_1 = (6)(I_o) = 6I_o \text{ W}$$
$$P_2 = (12)(-9) = -108 \text{ W}$$
$$P_3 = (10)(-3) = -30 \text{ W}$$
$$P_{4\,\text{V}} = (4)(-8) = -32 \text{ W}$$
$$P_{DS} = (8I_x)(11) = (16)(11) = 176 \text{ W}$$

POWER BALANCE

$$-12 + 6I_o - 108 - 30 - 32 + 176 = 0$$

$$I_O = 1[A]$$

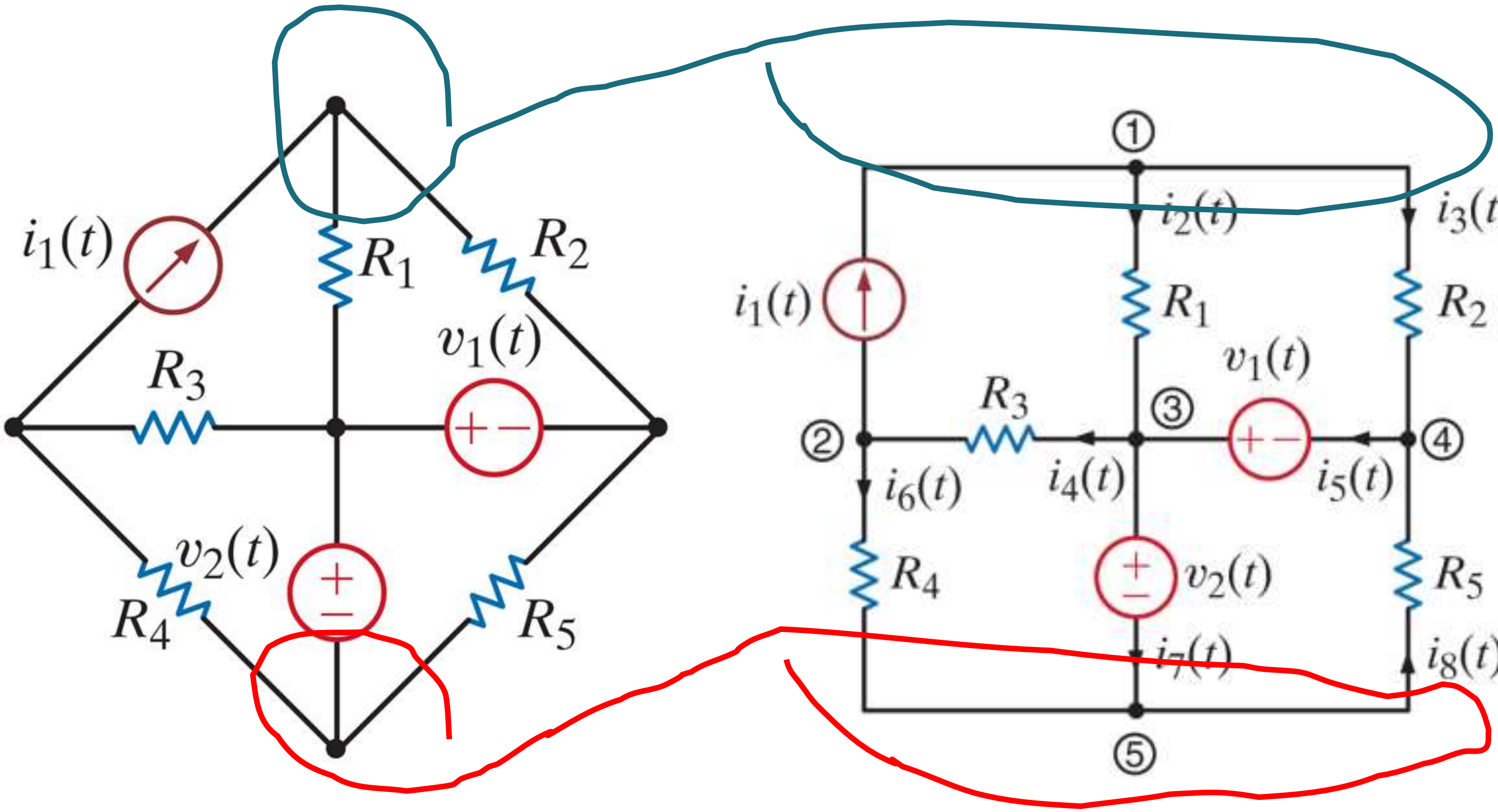
Pearson

STOP

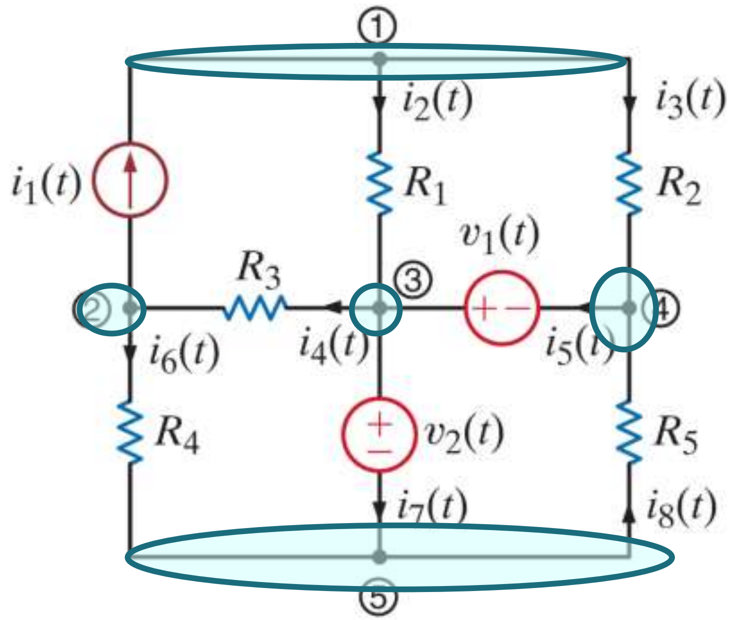
KCL

- SUM OF CURRENTS FLOWING INTO A NODE IS EQUAL TO SUM OF CURRENTS FLOWING OUT OF THE NODE

A node is a point of connection of two or more circuit elements.
It may be stretched out or compressed for visual purposes…
But it is still a node



WRITE ALL KCL EQUATIONS



$$-i_1(t)+i_2(t)+i_3(t)=0$$

$$i_1(t)-i_4(t)+i_6(t)=0$$

$$-i_2(t)+i_4(t)-i_5(t)+i_7(t)=0$$

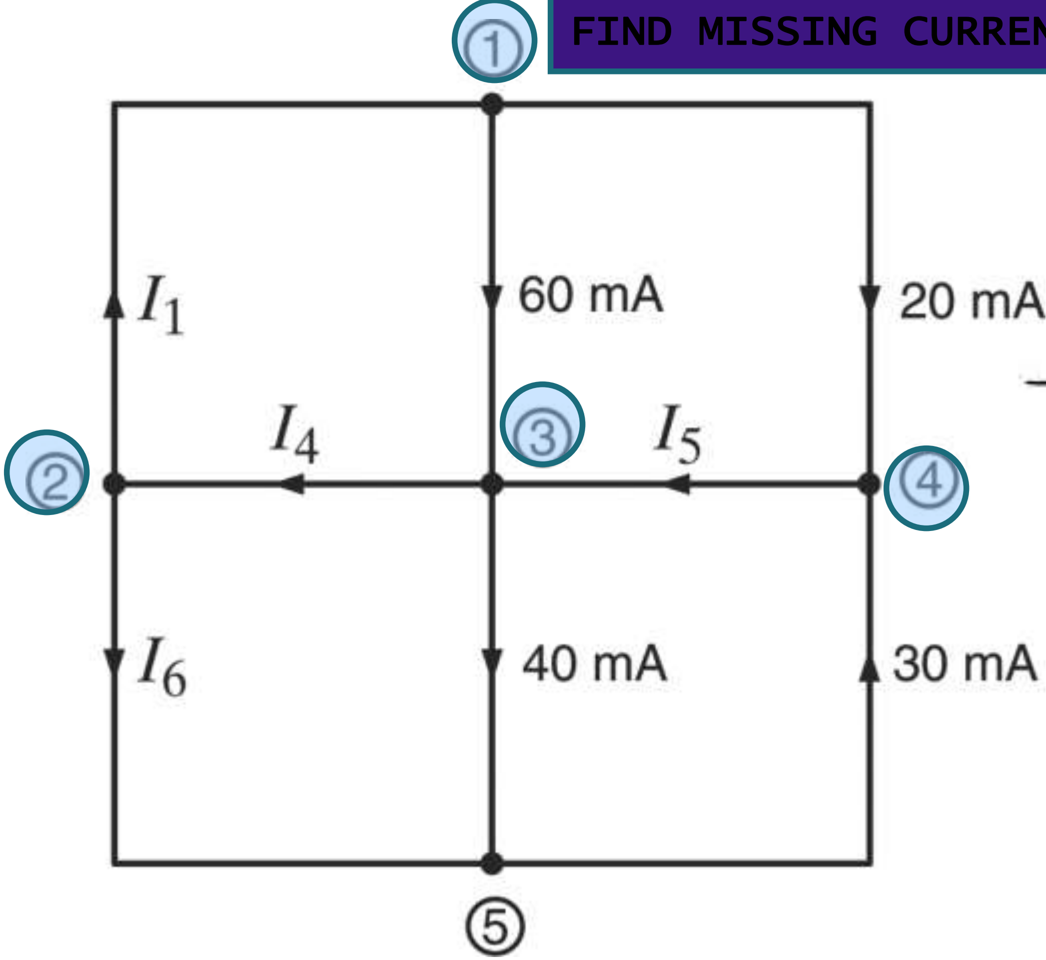
$$-i_3(t)+i_5(t)-i_8(t)=0$$

$$-i_6(t)-i_7(t)+i_8(t)=0$$

THE FIFTH EQUATION IS THE SUM OF THE FIRST FOUR... IT IS REDUNDANT!!!

Pearson

FIND MISSING CURRENTS



$$-I_1 + 0.06 + 0.02 = 0$$

$$I_1 - I_4 + I_6 = 0$$

$$-0.06 + I_4 - I_5 + 0.04 = 0$$

$$-0.02 + I_5 - 0.03 = 0$$

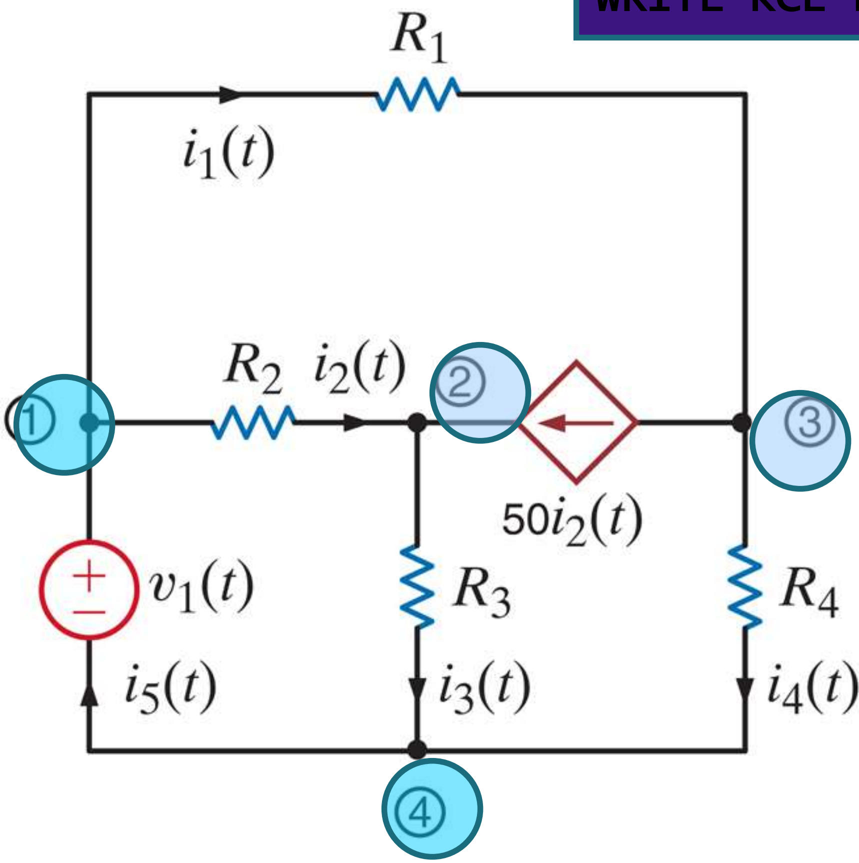
KCL DEPENDS ONLY ON THE INTERCONNECTION.
THE TYPE OF COMPONENT IS IRRELEVANT

KCL DEPENDS ONLY ON THE TOPOLOGY OF THE CIRCUIT

Pearson

GEAUX

WRITE KCL EQUATIONS FOR THIS CIRCUIT



$$i_1(t) + i_2(t) - i_5(t) = 0$$

$$-i_2(t) + i_3(t) - 50i_2(t) = 0$$

$$-i_1(t) + 50i_2(t) + i_4(t) = 0$$

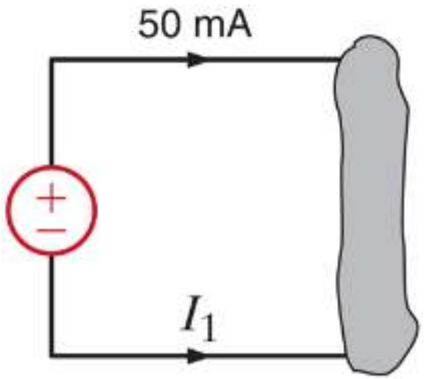
$$i_5(t) - i_3(t) - i_4(t) = 0$$

- THE LAST EQUATION IS AGAIN LINEARLY DEPENDENT OF THE PREVIOUS THREE

- THE PRESENCE OF A DEPENDENT SOURCE DOES NOT AFFECT APPLICATION OF KCL
  KCL DEPENDS ONLY ON THE TOPOLOGY

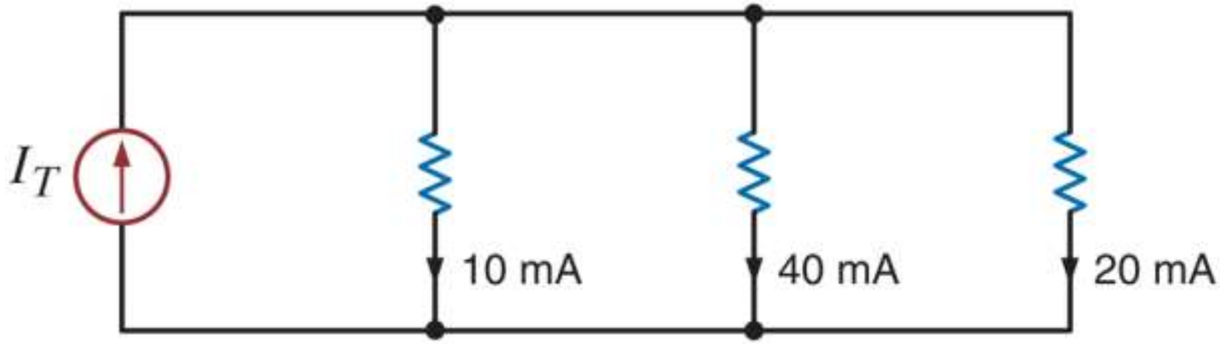
GEAUX

Find I_1



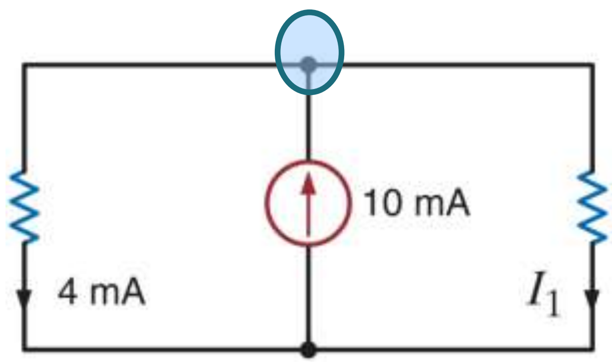
$$I_1 = -50mA$$

Find I_T



$$I_T = 10mA + 40mA + 20mA$$

Find I_1

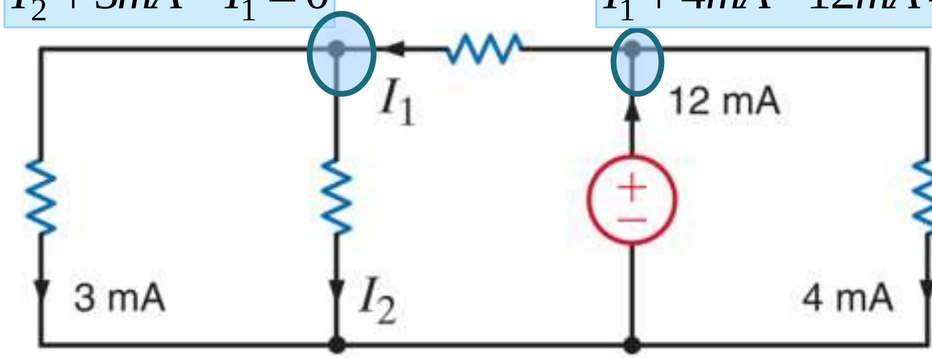


$$10mA - 4mA - I_1 = 0$$

Find I_1 and I_2

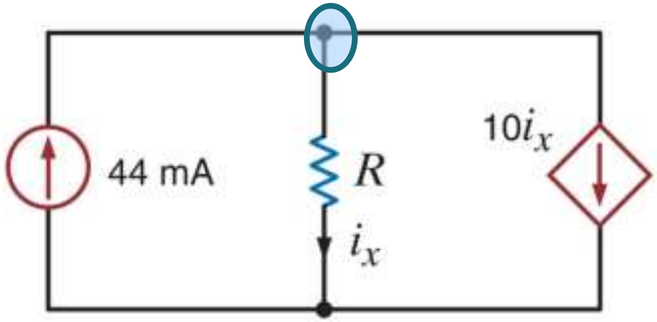
$$I_2 + 3mA - I_1 = 0$$

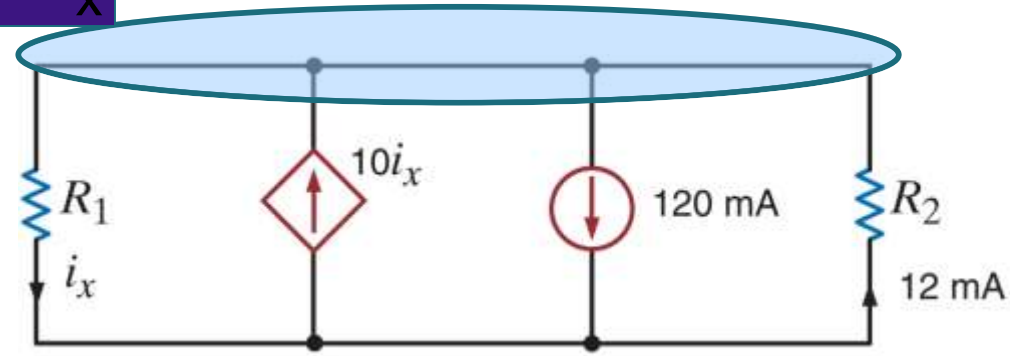
$$I_1 + 4mA - 12mA = 0$$



GEAUX

Find i_x



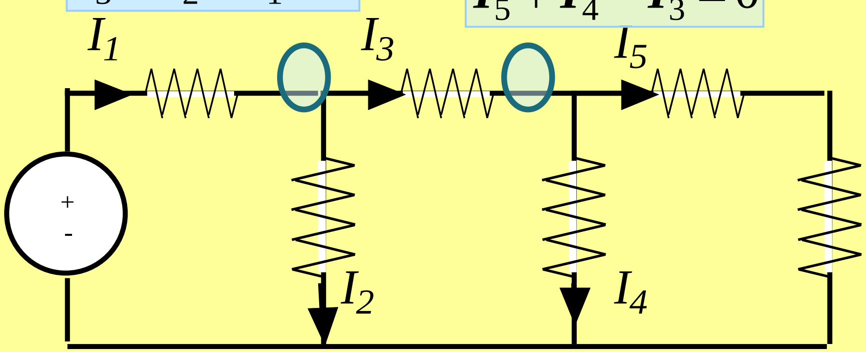


$$10\boldsymbol{i}_x + \boldsymbol{i}_x - 44\boldsymbol{mA} = 0$$
$$\boldsymbol{i}_x = 4\boldsymbol{mA}$$

$$\boldsymbol{i}_x - 10\boldsymbol{i}_x + 120\boldsymbol{mA} - 12\boldsymbol{mA} = 0$$

$$\boldsymbol{I}_3 + \boldsymbol{I}_2 - \boldsymbol{I}_1 = 0$$

$$\boldsymbol{I}_5 + \boldsymbol{I}_4 - \boldsymbol{I}_3 = 0$$



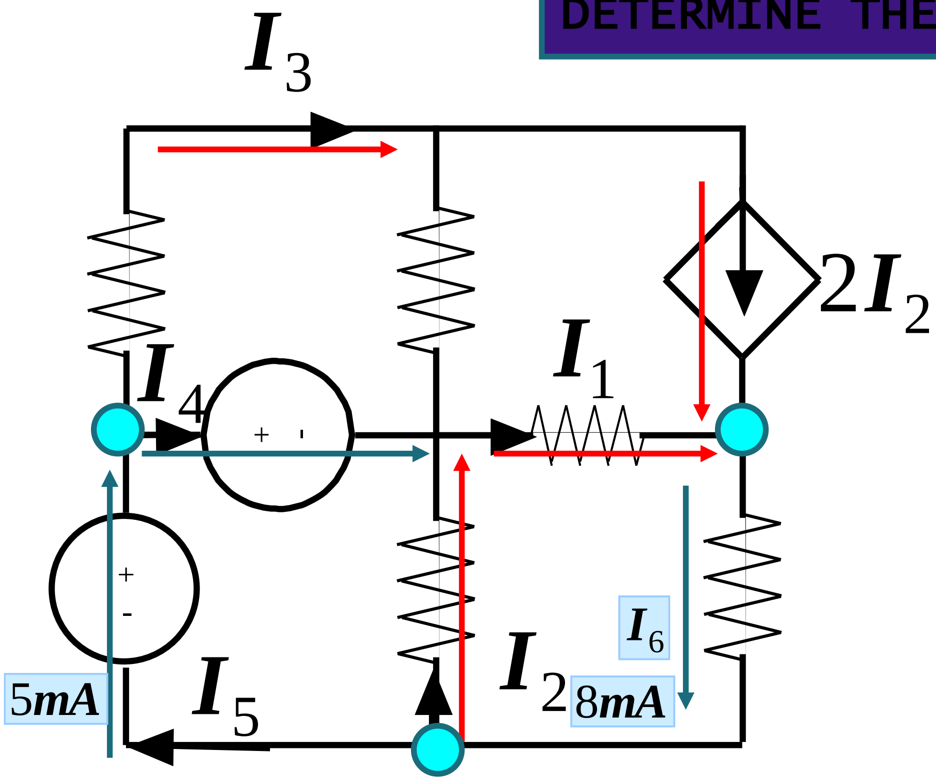
I_1 = ________

I_5 = ________

I_2 = 6mA, I_3 = 8mA, I_4 = 4mA

GEAUX

DETERMINE THE CURRENTS INDICATED



$$I_1 = 2mA,\ I_2 = 3mA, I_3 = 5mA$$

$I_4 = 2mA$

$I_5 = 5mA$

$$I_6 - I_1 - 2I_2 = 0 \Rightarrow I_6 = 8mA$$

$$I_5 + I_2 - I_6 = 0$$

$$I_4 + I_3 - I_5 = 0$$

THE PLAN

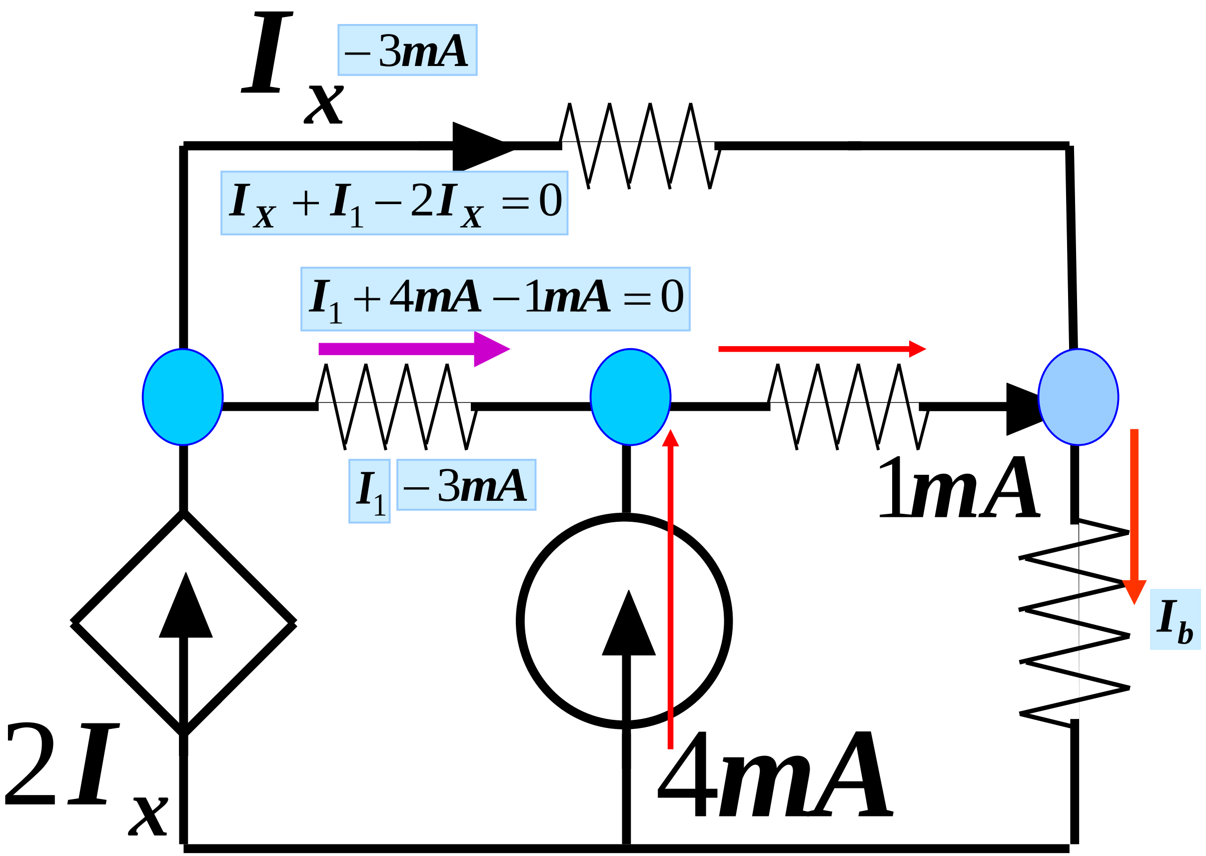
MARK ALL THE KNOWN CURRENTS

FIND NODES WHERE ALL BUT ONE CURRENT ARE KNOWN

Pearson

GEAUX

FIND I_x



VERIFICATION

$I_b = 1mA + I_X = -2mA$

$2I_X + 4mA = I_b$

Pearson

GEAUX

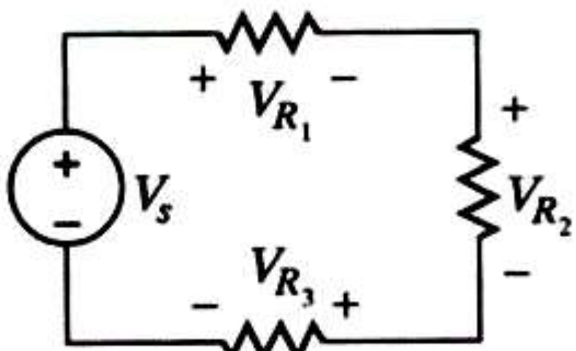
KVL

KVL: THE ALGEBRAIC SUM OF VOLTAGE DROPS AROUND ANY LOOP MUST BE ZERO

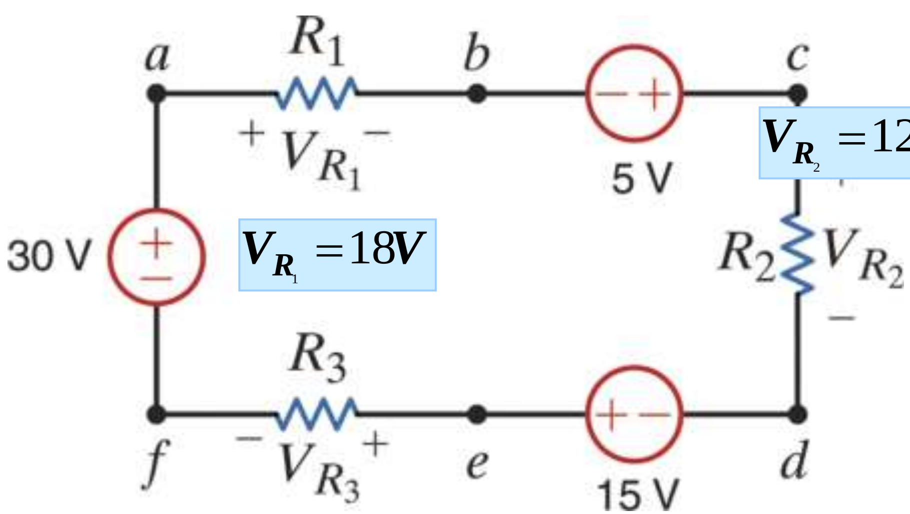
$$\underset{A}{\circ}\ \boxed{-\ V\ +}\ \underset{B}{\circ} \quad \equiv \quad \underset{A}{\circ}\ \boxed{+(-V)-}\ \underset{B}{\circ}$$

A VOLTAGE RISE IS
A NEGATIVE DROP

Write the KVL equation for the following loop, traveling clockwise:



$$-V_S + V_{R_1} + V_{R_2} + V_{R_3} = 0$$



$V_{R_2} = 12V$

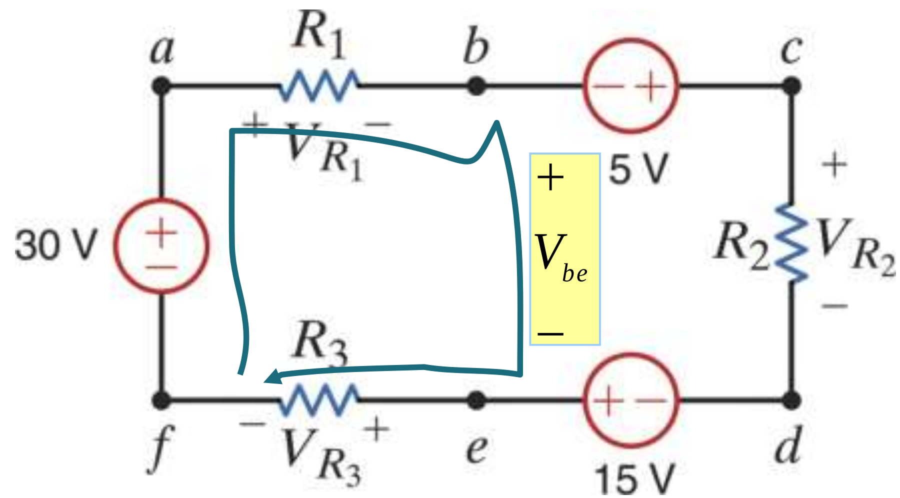
$V_{R_1} = 18V$

LOOP *abcdefa*

$$+V_{R_1} - 5 + V_{R_2} - 15 + \boxed{V_{R_3}} - 30 = 0$$

PROBLEM SOLVING TIP: KVL IS USEFUL TO DETERMINE A VOLTAGE - FIND A LOOP INCLUDING THE UNKNOWN VOLTAGE

THE LOOP DOES NOT HAVE TO BE PHYSICAL

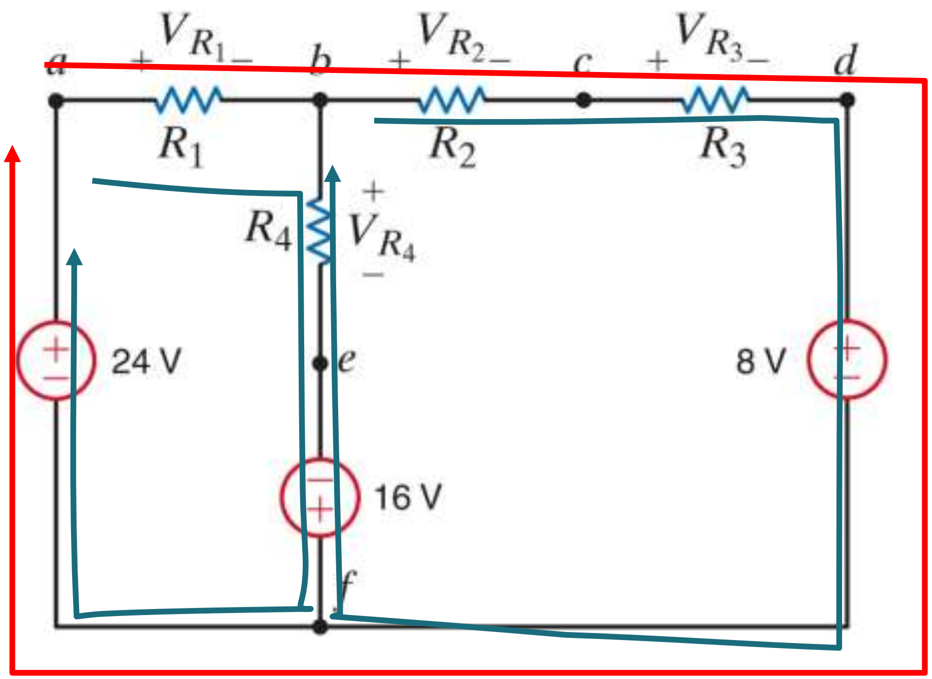


EXAMPLE: V_{R1}, V_{R3} ARE KNOWN
DETERMINE THE VOLTAGE V_{be}

$$V_{R_1} + V_{be} + V_{R_3} - 30[V] = 0$$

GEAUX

BACKGROUND: WHEN DISCUSSING KCL WE SAW THAT NOT ALL POSSIBLE KCL EQUATIONS ARE INDEPENDENT. WE SHALL SEE THAT THE SAME SITUATION ARISES WHEN USING KVL



$$V_{R_1} + V_{R_4} - 16 - 24 = 0$$

$$V_{R_2} + V_{R_3} + 8 + 16 - V_{R_4} = 0$$

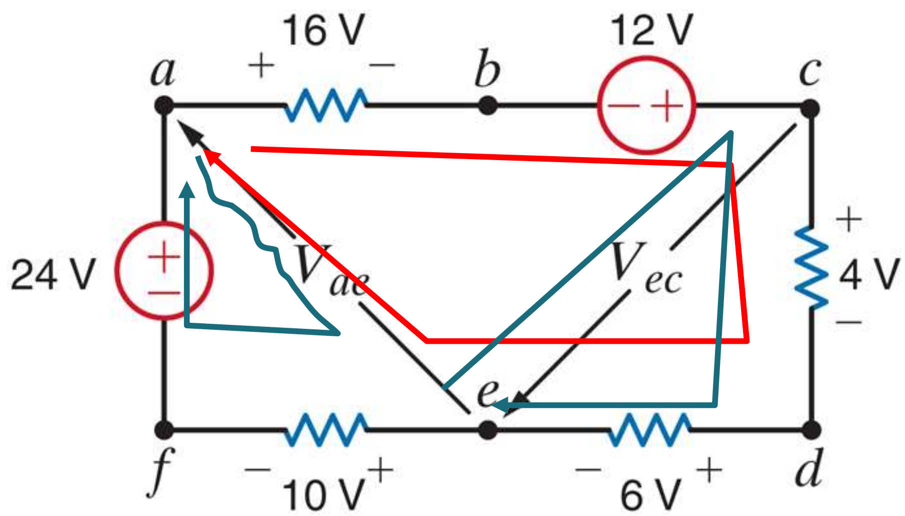
$$\boxed{V_{R_1} + V_{R_2} + V_{R_3} + 8 - 24 = 0}$$

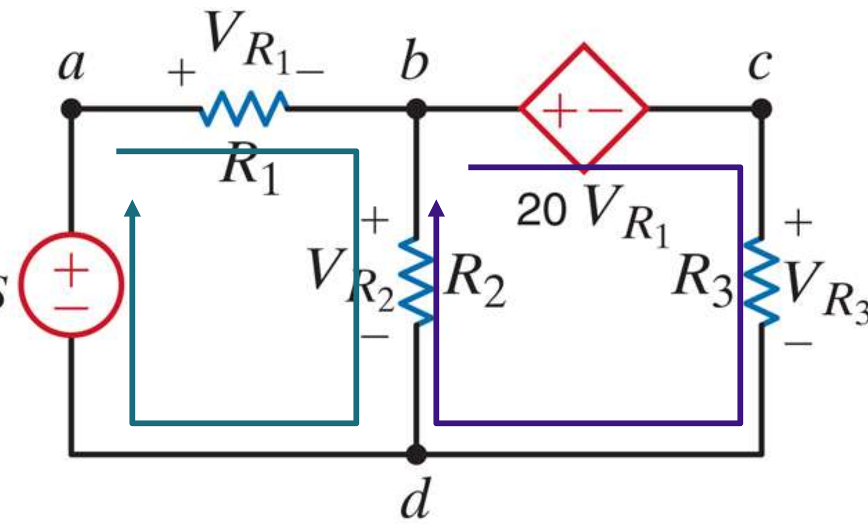
THE THIRD EQUATION IS THE SUM OF THE OTHER TWO!!

GEAUX

FIND THE VOLTAGES V_{ae}, V_{ec}

DEPENDENT SOURCES ARE HANDLED WITH THE SAME EASE





$$V_{ae} + 10 - 24 = 0$$

$$16 - 12 + 4 + 6 - V_{ae} = 0$$

GIVEN THE CHOICE USE THE SIMPLEST LOOP

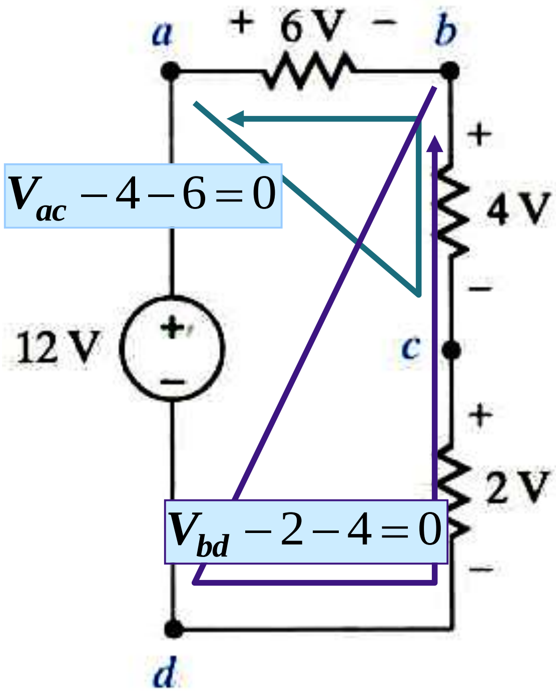
$$4 + 6 + V_{ec} = 0$$

$$V_{R_1} + V_{R_2} - V_S = 0$$

$$20V_{R_1} + V_{R_3} - V_{R_2} = 0$$

Pearson

GEAUX



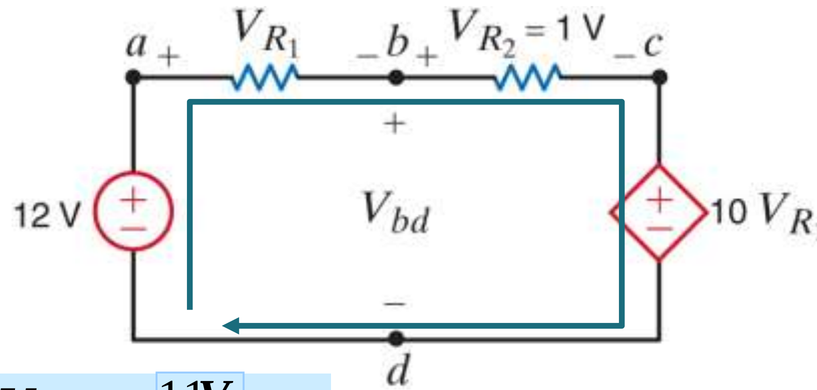
$V_{ac} - 4 - 6 = 0$

$V_{bd} - 2 - 4 = 0$

$V_{ad} = \_\_\_\_\_\_$

$V_{ac} = \underline{10V}$

$V_{bd} = \underline{6V}$



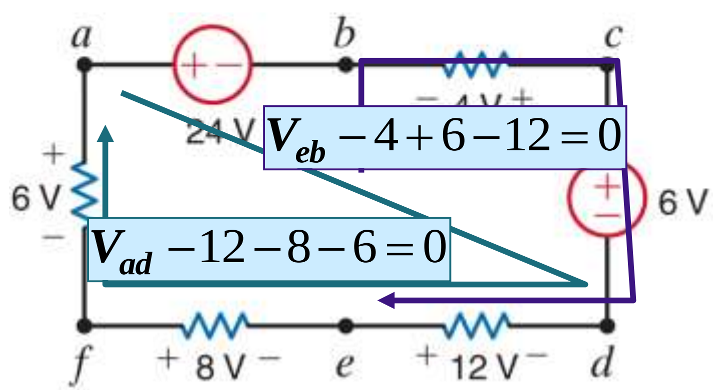
$V_{bd} = \underline{11V}$

MUST FIND V_{R_1} FIRST

$-12 + V_{R_1} + 1 + 10V_{R_1} = 0 \Rightarrow V_{R_1} = 1V$

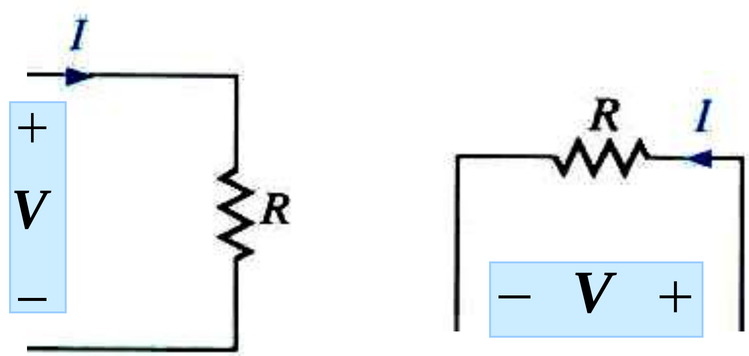
DEPENDENT SOURCES ARE NOT REALLY DIFFICULT TO ANALYZE

REMINDER: IN A RESISTOR THE VOLTAGE AND CURRENT DIRECTIONS MUST SATISFY THE PASSIVE SIGN CONVENTION



$V_{eb} - 4 + 6 - 12 = 0$

$V_{ad} - 12 - 8 - 6 = 0$

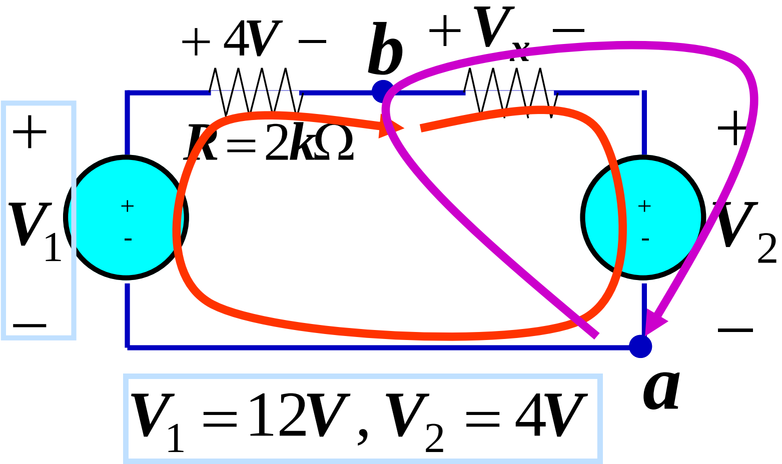


$V_{ad} = \_\_\_\_\_\_, \quad V_{eb} = \_\_\_\_\_\_$

Pearson

GEAUX

SAMPLE PROBLEM



DETERMINE

$V_x = $ **4V**

$V_{ab} = $ **-8V**

Power disipated on the 2k resistor

$P_{2k} =$

Remember past topics

We need to find a closed path where only one voltage is unknown

$$FOR\ V_X$$

$$V_X + V_2 - V_1 + 4 = 0$$

$$V_X + 4 - 12 + 4 = 0$$

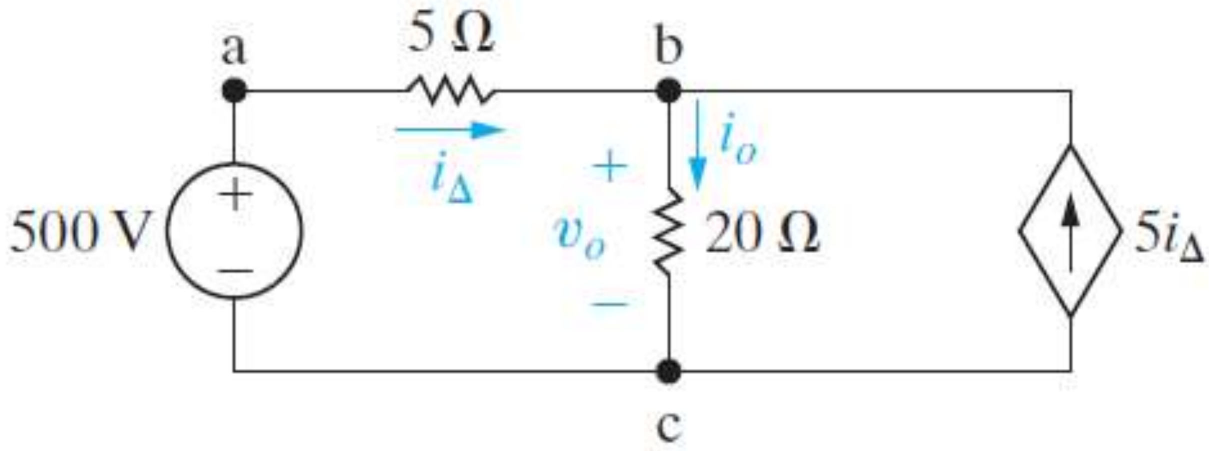
$$V_X + V_2 + V_{ab} = 0$$

$$V_{ab} = -V_X - V_2$$

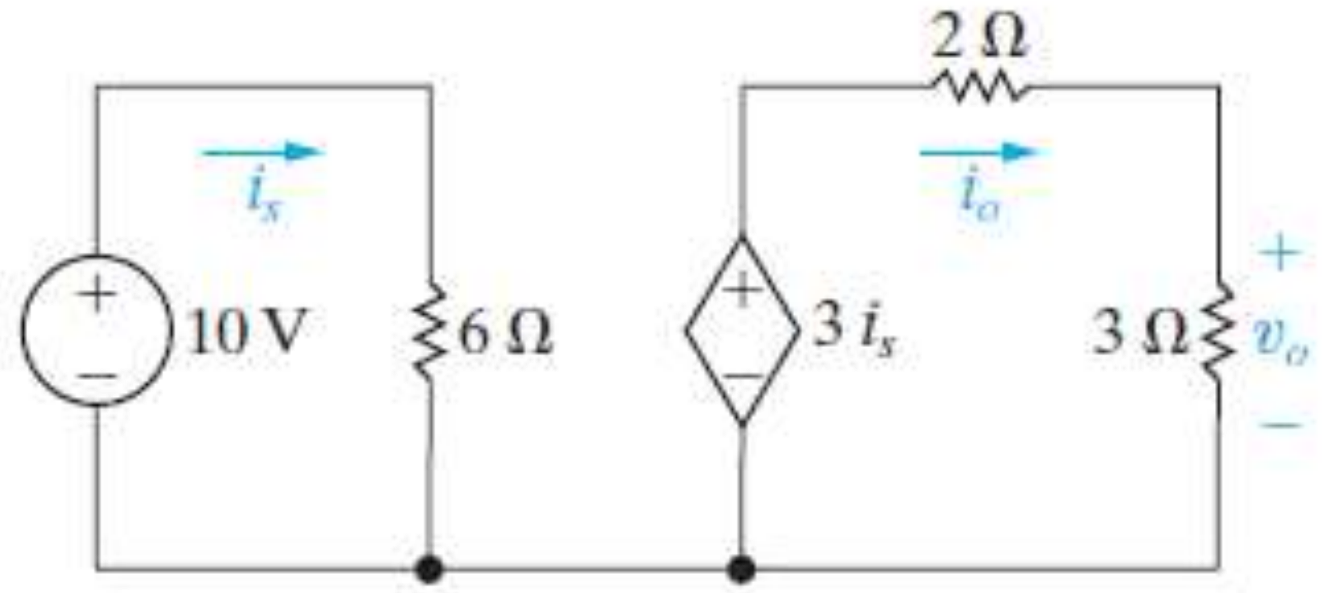
Pearson

GEAUX

Example: A circuit with a dependent source.



Example:



Example