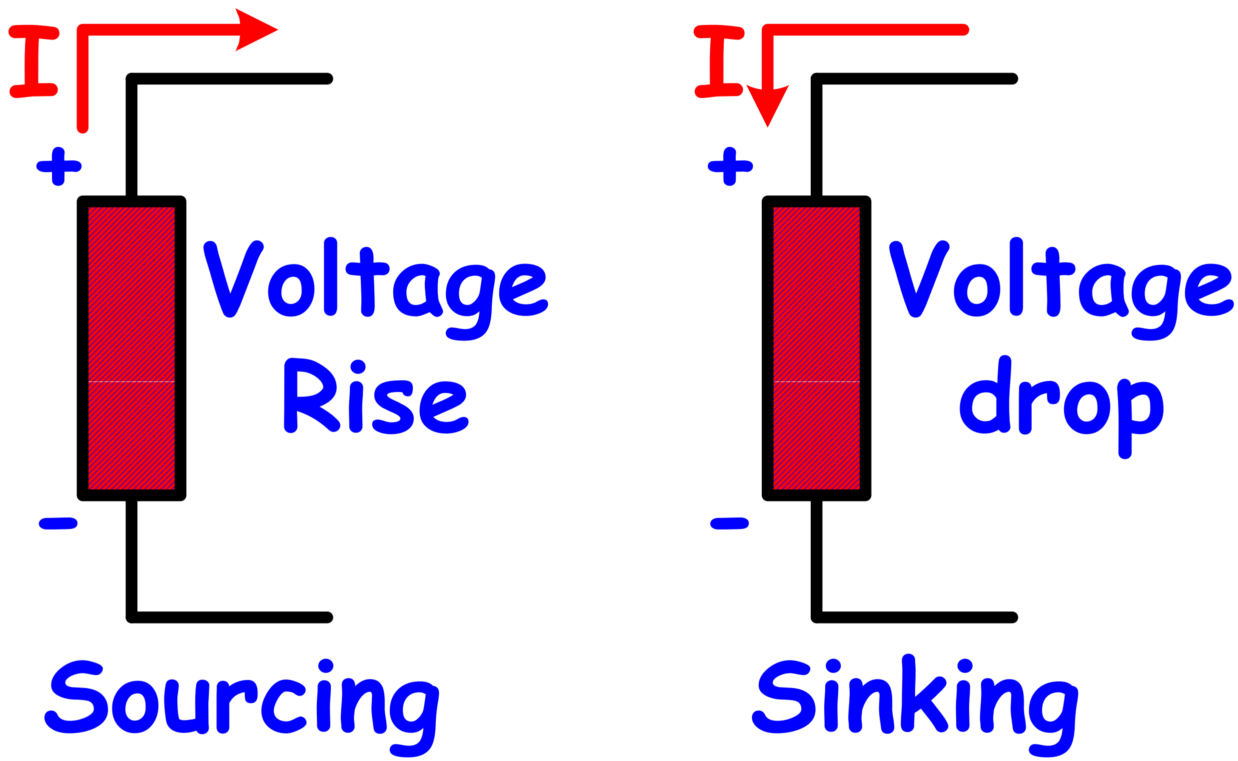
FE Review

ELECTRONICS # 2
DC CIRCUIT ANALYSIS

Source or Sink?



Power

$$\text{Power} = P = VI$$

From Ohm's Law we have

$$V = IR \qquad I = \frac{V}{R}$$

From these equations we get

$$P = VI$$
$$= (IR)I$$
$$P = I^2R$$

$$P = VI$$
$$P = V\left(\frac{V}{R}\right)$$
$$P = \frac{V^2}{R}$$

Capacitors and Inductors in DC circuits

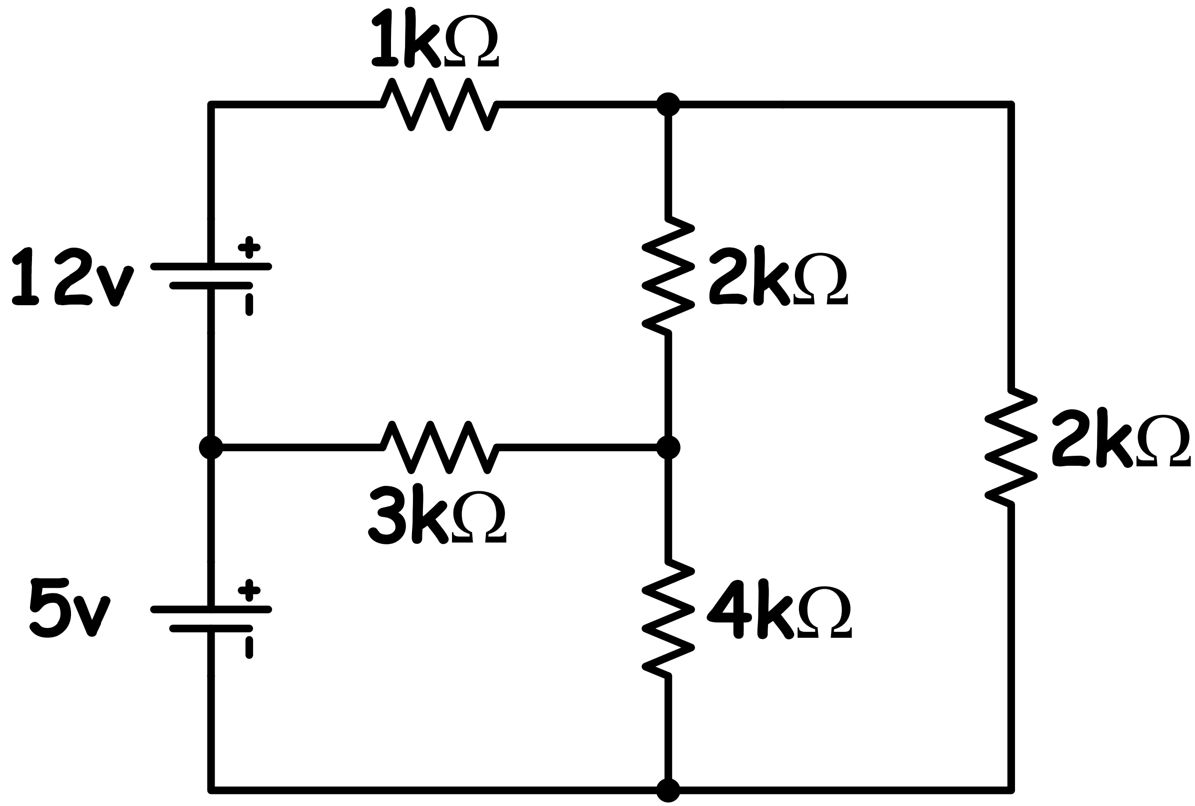
Since V and I don't vary with time in a DC circuit, Capacitors and Inductors don't act the way they would in an AC circuit.

In DC circuits:

Capacitors act like OPEN-CIRCUITS

Inductors act like SHORT-CIRCUITS

DC Circuit Analysis Mesh Example



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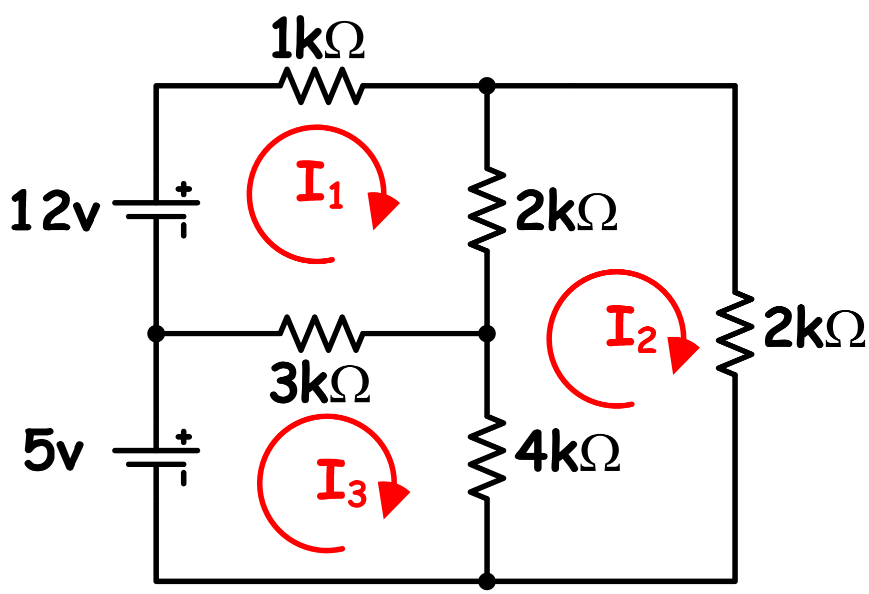
Example (continued)

Add in three CLOCKWISE loop currents



Step 1:
It is important that the loop currents be drawn in the clock-wise direction

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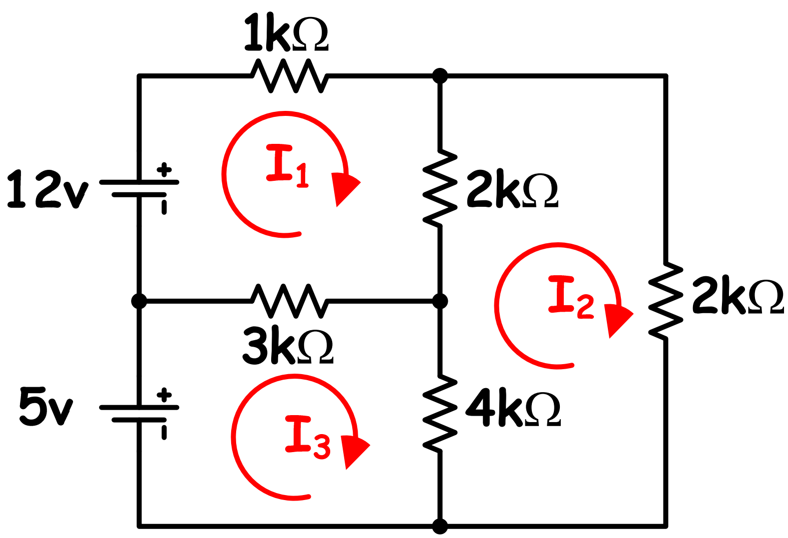
Example (continued)



Call on good old KVL

Step 2:
We will use KVL to write a loop eqn. for each mesh current.

@ I_1

$$0 = -12v + 1k\Omega I_1 + 2k\Omega\left(I_1 - I_2\right) + 3k\Omega\left(I_1 - I_3\right)$$

$$12v = 1k\Omega I_1 + 2k\Omega I_1 - 2k\Omega I_2 + 3k\Omega I_1 - 3k\Omega I_3$$

$$\boxed{12v = 6k\Omega I_1 - 2k\Omega I_2 - 3k\Omega I_3}$$

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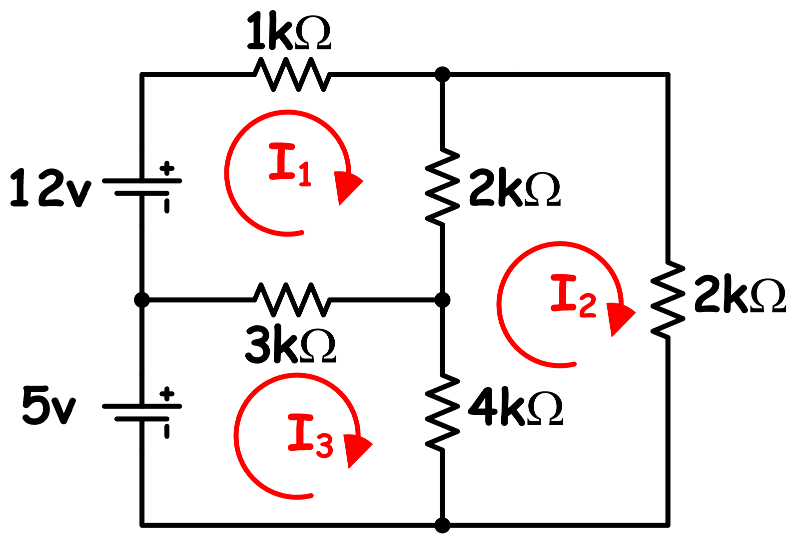
Example (cont.) Call on good old KVL

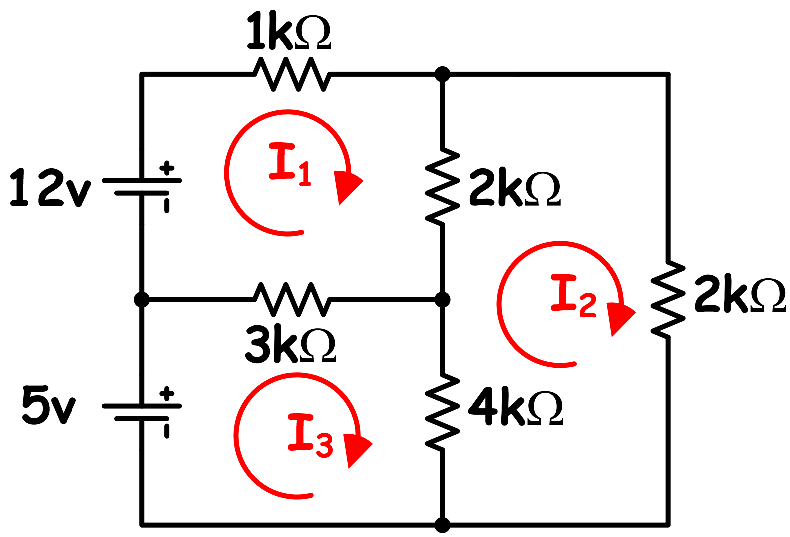


Note that the sign for the current we are working with is + while the signs of both of the others is negative. This is a good 'idiot' check.

@ I_1 $$12v = 6k\Omega I_1 - 2k\Omega I_2 - 3k\Omega I_3$$

Example continued on the next slide.

Example (cont.) Call on good old KVL



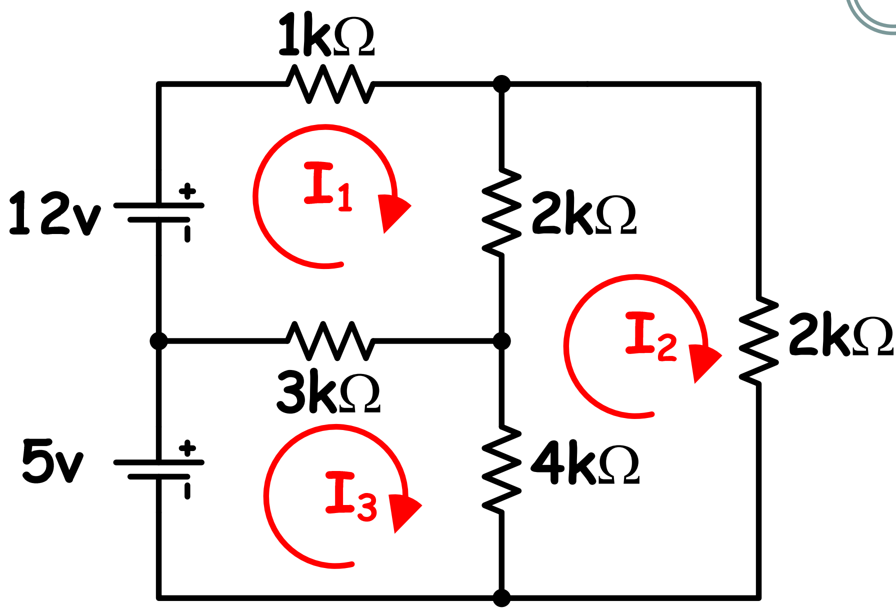
Also note that the sum of the resistors in the I1 loop is 6k just as in the equation. This is another 'idiot' check.

@ I_1

$$12v = 6k\Omega I_1 - 2k\Omega I_2 - 3k\Omega I_3$$

Example continued on the next slide.

Example (cont.) Call on good old KVL



Perform the same idiot checks on the I2 loop equation below.

@ I_2

$$0 = 2kI_2 + 4k\Omega\left(I_2 - I_3\right) + 2k\Omega\left(I_2 - I_1\right)$$

$$0 = 2kI_2 + 4k\Omega I_2 - 4k\Omega I_3 + 2k\Omega I_2 - 2k\Omega I_1$$

$$\boxed{0 = -2k\Omega I_1 + 8k\Omega I_2 - 4k\Omega I_3}$$

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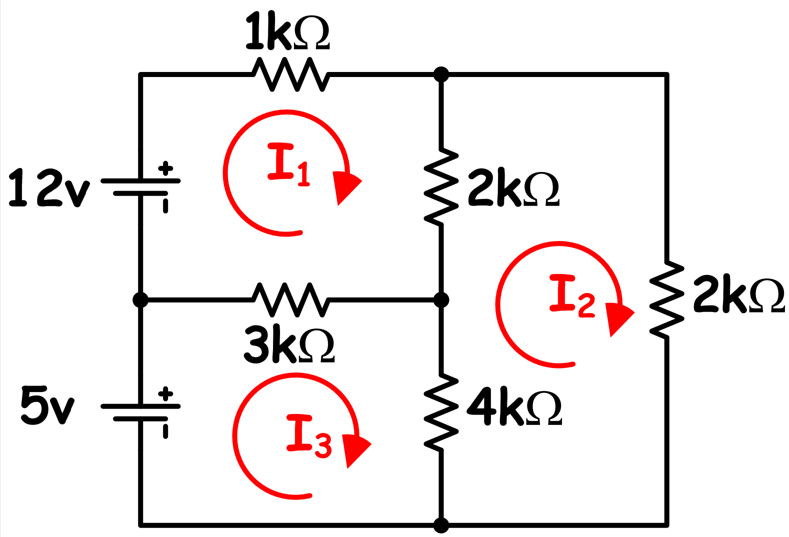
Example (cont) Call on good old KVL



Perform the same idiot checks on the I3 loop equation below.

$@\, I_3$

$$0 = -5v + 3k\Omega\left(I_3 - I_1\right) + 4k\Omega\left(I_3 - I_2\right)$$

$$5v = 3k\Omega I_3 - 3k\Omega I_1 + 4k\Omega I_3 - 4k\Omega I_2$$

$$\boxed{5v = -3k\Omega I_1 - 4k\Omega I_2 + 7k\Omega I_3}$$

Example continued on the next slide.

Example (continued)

Three eqn's, three unknowns

$$\#1: \quad 12v = 6k\Omega I_1 - 2k\Omega I_2 - 3k\Omega I_3$$

$$\#2: \quad 0 = -2k\Omega I_1 + 8k\Omega I_2 - 4k\Omega I_3$$

$$\#3: \quad 5 = -3k\Omega I_1 - 4k\Omega I_2 + 7k\Omega I_3$$

Example continued on the next slide.

Example (cont) Build that matrix equation

$$\#1: \quad 12v = 6k\Omega I_1 - 2k\Omega I_2 - 3k\Omega I_3$$

$$\#2: \quad 0 = -2k\Omega I_1 + 8k\Omega I_2 - 4k\Omega I_3$$

$$\#3: \quad 5 = -3k\Omega I_1 - 4k\Omega I_2 + 7k\Omega I_3$$

$$\begin{bmatrix} 12v \\ 0 \\ 5v \end{bmatrix} = \begin{bmatrix} 6k & -2k & -3k \\ -2k & 8k & -4k \\ -3k & -4k & 7k \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

Example continued on the next slide.

Example (cont) Cramer's Rule

$$\begin{bmatrix} 12v \\ 0 \\ 5v \end{bmatrix} = \begin{bmatrix} 6k & -2k & -3k \\ -2k & 8k & -4k \\ -3k & -4k & 7k \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$D = \begin{vmatrix} 6k & -2k & -3k \\ -2k & 8k & -4k \\ -3k & -4k & 7k \end{vmatrix} \quad D_1 = \begin{vmatrix} 12 & -2k & -3k \\ 0 & 8k & -4k \\ 5 & -4k & 7k \end{vmatrix}$$

$$D_2 = \begin{vmatrix} 6k & 12 & -3k \\ -2k & 0 & -4k \\ -3k & 5 & 7k \end{vmatrix} \quad D_3 = \begin{vmatrix} 6k & -2k & 12 \\ -2k & 8k & 0 \\ -3k & -4k & 5 \end{vmatrix}$$

By Cramer's Rule,

$$I_1 = \frac{D_1}{D} \quad I_2 = \frac{D_2}{D} \quad I_3 = \frac{D_3}{D}$$

Example continued on the next slide.

Example (cont) Solve for the main determinate (D)

Demonstrating the special method which applies ONLY to 3x3 matrices.

$$D = D = \begin{vmatrix} 6k & -2k & -3k & 6k & -2k \\ -2k & 8k & -4k & -2k & 8k \\ -3k & -4k & 7k & -3k & -4k \end{vmatrix}$$

$$D = \left[(6k)(8k)(7k) + (-2k)(-4k)(-3k) + (-3k)(-2k)(-4k)\right] - \left[(-3k)(8k)(-3k) + (6k)(-4k)(-4k) + (-2k)(-2k)(7k)\right]$$

$$D = \left[288G - 24G - 24G\right] - \left[72G + 96G + 28G\right]$$

$$D = \left[288G\right] - \left[196G\right] = 92G$$

Example continued on the next slide.

Example (cont) Solve for the I_1

$$D = 92G \quad D_1 = \begin{vmatrix} 12v & -2k & -3k \\ 0v & 8k & -4k \\ 5v & -4k & 7k \end{vmatrix} \quad \text{and} \quad I_1 = \frac{D_1}{D}$$

cofactor sign equation: $a^{ij} = (-1)^{i+j}$

$$D_1 = (-1)^{1+1}(12)\begin{vmatrix} 8k & -4k \\ -4k & 7k \end{vmatrix} + (-1)^{2+1}(-2k)\begin{vmatrix} 0 & -4k \\ 5 & 7k \end{vmatrix} + (-1)^{3+1}(-3k)\begin{vmatrix} 0 & 8k \\ 5 & -4k \end{vmatrix}$$

$$D_1 = (1)(12)\begin{vmatrix} 8k & -4k \\ -4k & 7k \end{vmatrix} + (-1)(-2k)\begin{vmatrix} 0 & -4k \\ 5 & 7k \end{vmatrix} + (1)(-3k)\begin{vmatrix} 0 & 8k \\ 5 & -4k \end{vmatrix}$$

$$D_1 = 12\left[8k(7k) - (-4k)(-4k)\right] + 2k\left[0(7k) - (-4k)(5)\right] - 3k\left[0(-4k) - (8k)(5)\right]$$

$$D_1 = 12\left[56M - 16M\right] + 2k\left[0 - (-20k)\right] - 3k\left[0 - 40k\right]$$

$$= 12\left[40M\right] + 2k\left[20k\right] - 3k\left[-40k\right]$$

$$D_1 = 480M + 40M + 120M = \boxed{640M}$$

$$I_1 = \frac{D_1}{D} = \frac{640M}{92G} = \boxed{6.957mA}$$

Example continued on the next slide.

Example (cont) Solve for the I_2

$$D = 92G \quad D_2 = \begin{vmatrix} 6k & 12v & -3k \\ -2k & 0v & -4k \\ -3k & 5v & 7k \end{vmatrix} \quad I_2 = \frac{D_2}{D}$$

$$\text{cofactor sign equation } a^{ij} = (-1)^{i+j}$$

$$D_2 = (-1)^{1+1}(6k)\begin{vmatrix} 0 & -4k \\ 5 & 7k \end{vmatrix} + (-1)^{1+2}(12)\begin{vmatrix} -2k & -4k \\ -3k & 7k \end{vmatrix} + (-1)^{1+3}(-3k)\begin{vmatrix} -2k & 0 \\ -3k & 5 \end{vmatrix}$$

$$= (-1)^2(6k)\left[0(7k) - (-4k)5\right] + (-1)^3(12)\left[-2k(7k) - (-4k)(-3k)\right]$$

$$+ (-1)^4(-3k)\left[-2k(5) - (0)(-3k)\right]$$

$$= (1)(6k)\left[0 - (-20k)\right] + (-1)(12)\left[-14M - (12M)\right] + (1)(-3k)\left[-10k - 0\right]$$

$$= 6k\left[20k\right] + (-12)\left[-26M\right] + (-3k)\left[-10k\right]$$

$$= 120M + 312M + 30M = \boxed{462M}$$

$$I_2 = \frac{D_2}{D} = \frac{462M}{92G} = \boxed{5.022mA}$$

Example continued on the next slide.

Example (cont) Solve for the I_3

$$D = 92G \quad D_3 = \begin{vmatrix} 6k & -2k & 12v \\ -2k & 8k & 0v \\ -3k & -4k & 5v \end{vmatrix} \quad \text{and} \quad I_3 = \frac{D_3}{D}$$

$$\text{cofactor sign equation } a^{ij} = (-1)^{i+j}$$

$$D_3 = (-1)^{1+1}(6k)\begin{vmatrix} 8k & 0 \\ -4k & 5 \end{vmatrix} + (-1)^{1+2}(-2k)\begin{vmatrix} -2k & 0 \\ -3k & 5 \end{vmatrix} + (-1)^{1+3}(12)\begin{vmatrix} -2k & 8k \\ -3k & -4k \end{vmatrix}$$

$$= (-1)^2(6k)\left[(8k)5 - 0(-4k)\right] + (-1)^3(-2k)\left[-2k(5) - (0)(-3k)\right]$$

$$+ (-1)^4(12)\left[-2k(-4k) - (8k)(-3k)\right]$$

$$= (1)(6k)\left[40k - 0\right] + (-1)(-2k)\left[-10k - 0\right] + (1)(12)\left[8M + 24M\right]$$

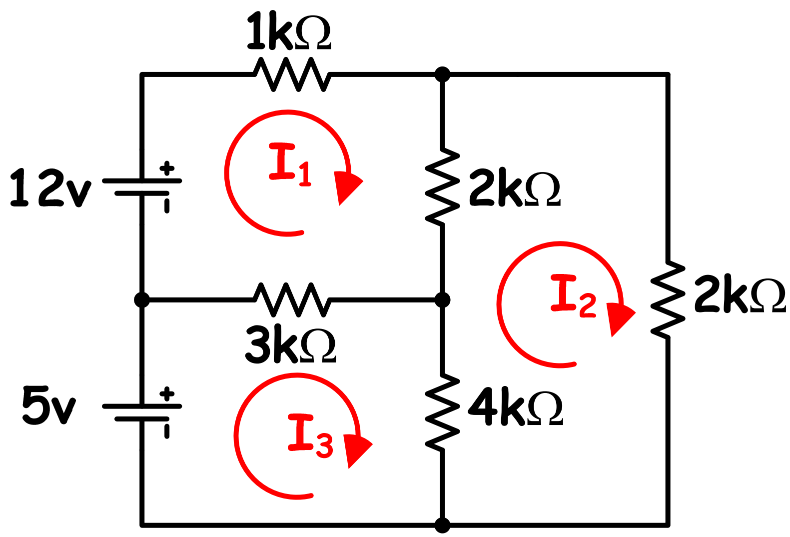
$$= 6k\left[40k\right] + 2k\left[-10k\right] + 12\left[32M\right]$$

$$= 240M - 20M + 384M = \boxed{604M}$$

$$I_3 = \frac{D_3}{D} = \frac{604M}{92G} = \boxed{6.565mA}$$

Example continued on the next slide.

Example (cont) Intermediate results



Results

$I_1 = 6.957mA$

$I_2 = 5.022mA$

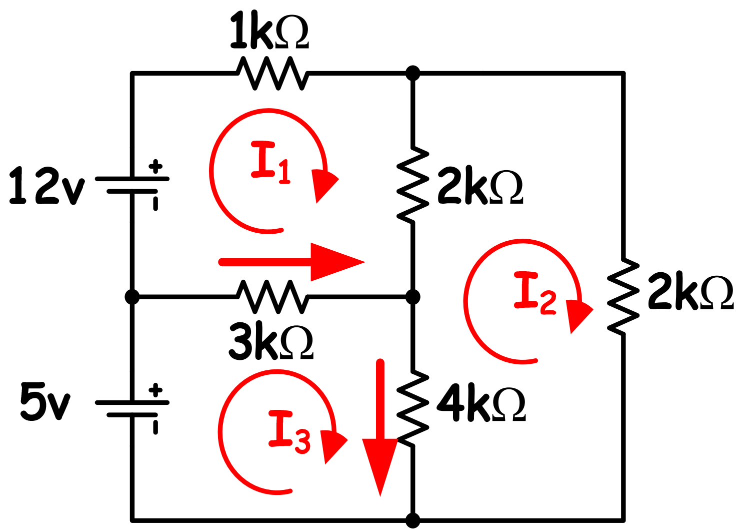
$I_3 = 6.565mA$

Using these values you can calculate the rest of the unknowns. For this set of notes, we will Only calculate two: I_{3k} and I_{4k}.

Example continued on the next slide.

Example (continued)

Add in the currents in random directions



Results

$I_1 = 6.957mA$

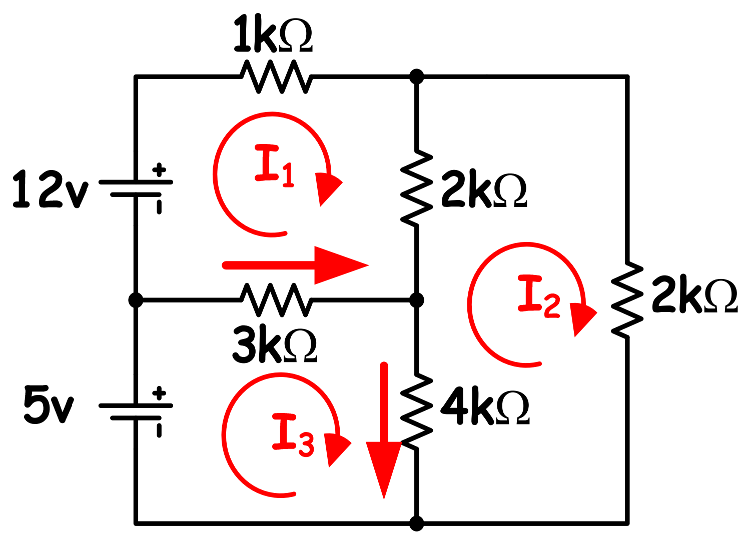
$I_2 = 5.022mA$

$I_3 = 6.565mA$

Current directions have been added to the circuit. Since at this point we don't know the actual directions, we will just guess.

Example continued on the next slide.

Example (cont) Calculate I_{3k}



Results

$I_1 = 6.957mA$

$I_2 = 5.022mA$

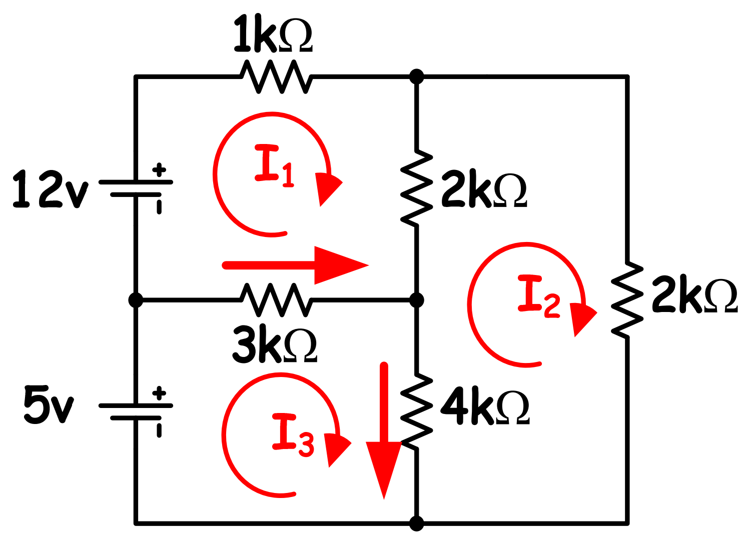
$I_3 = 6.565mA$

I_{3k} consists of I_1 and I_3. Since the drawn direction is in the direction of I_3, the calc will be:

$$I_{3k} = I_3 - I_1$$

Example continued on the next slide.

Example (cont) Calculate I_{3k}



Results

$I_1 = 6.957mA$

$I_2 = 5.022mA$

$I_3 = 6.565mA$

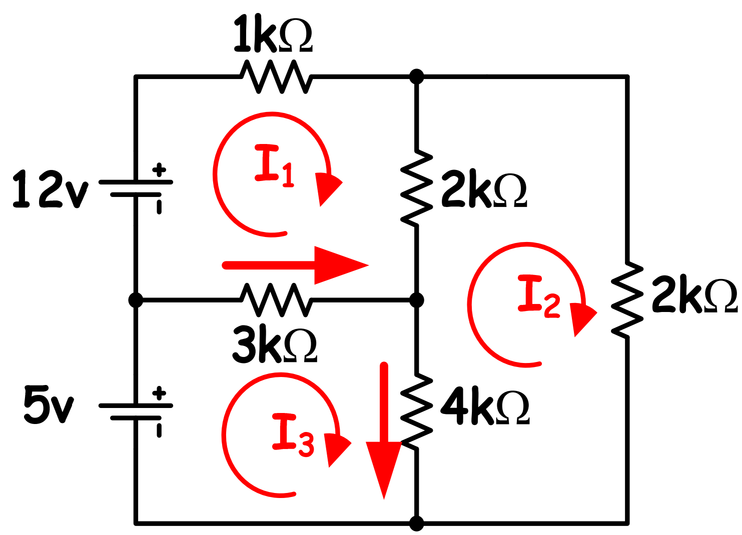
$$I_{3k} = I_3 - I_1$$

$$I_{3k} = 6.565mA - 6.957mA$$

$$= \boxed{-392.0\mu A}$$

Example continued on the next slide.

Example (cont) Calculate I_{4k}



Results

$I_1 = 6.957mA$

$I_2 = 5.022mA$

$I_3 = 6.565mA$

$$I_{4k} = I_3 - I_2$$

$$I_{4k} = 6.565mA - 5.022mA$$

$$= \boxed{1.543mA}$$

Example continued on the next slide.