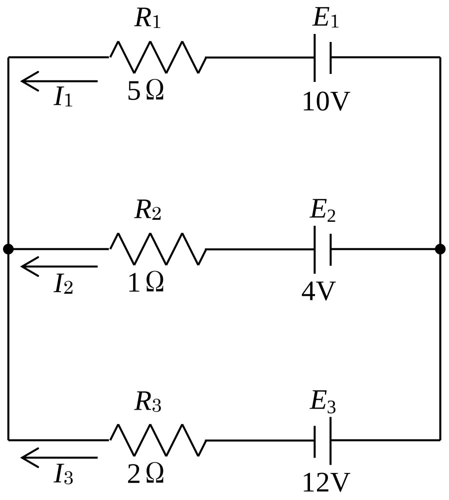
（１）

（枝電流法を用いた開放）



$$\begin{cases} I_1 + I_2 + I_3 = 0 \\ R_1 I_1 - R_2 I_2 = E_1 - E_2 \\ R_2 I_2 - R_3 I_3 = E_2 + E_3 \end{cases}$$

$$\begin{cases} I_1 + I_2 + I_3 = 0 \\ 5I_1 - 1I_2 = 10 - 4 \\ 1I_2 - 2I_3 = 4 + 12 \end{cases}$$

$$\begin{pmatrix} 1 & 1 & 1 \\ 5 & -1 & 0 \\ 0 & 1 & -2 \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \\ I_3 \end{pmatrix} = \begin{pmatrix} 0 \\ 6 \\ 16 \end{pmatrix}$$

$$I_1 = \frac{\begin{vmatrix} 0 & 1 & 1 \\ 6 & -1 & 0 \\ 16 & 1 & -2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 & 1 \\ 5 & -1 & 0 \\ 0 & 1 & -2 \end{vmatrix}} = \frac{\{(0\times -1\times -2)+(6\times 1\times 1)+(16\times 1\times 0)\}-\{(16\times -1\times 1)+(6\times 1\times -2)+(0\times 1\times 0)\}}{\{(1\times -1\times -2)+(5\times 1\times 1)+(0\times 1\times 0)\}-\{(0\times -1\times 1)+(5\times 1\times -2)+(1\times 1\times 0)\}}$$

$$= \frac{(0+6+0)-(-16-12+0)}{(2+5+0)-(0-10+0)} = \frac{(6)-(-28)}{(7)-(-10)} = \frac{34}{17} = 2\text{A}$$

$$I_2 = \frac{\begin{vmatrix} 1 & 0 & 1 \\ 5 & 6 & 0 \\ 0 & 16 & -2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 & 1 \\ 5 & -1 & 0 \\ 0 & 1 & -2 \end{vmatrix}} = \frac{\{(1\times 6\times -2)+(5\times 16\times 1)+(0\times 0\times 0)\}-\{(0\times 6\times 1)+(5\times 0\times -2)+(1\times 16\times 0)\}}{\{(1\times -1\times -2)+(5\times 1\times 1)+(0\times 1\times 0)\}-\{(0\times -1\times 1)+(5\times 1\times -2)+(1\times 1\times 0)\}}$$

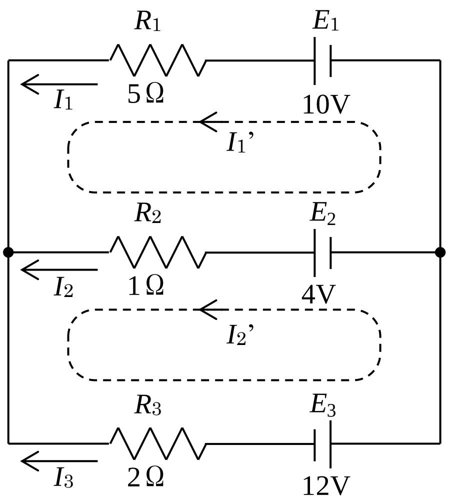
$$= \frac{(-12+80+0)-(0+0+0)}{(2+5+0)-(0-10+0)} = \frac{(68)-(0)}{(7)-(-10)} = \frac{68}{17} = 4\text{A}$$

$$I_2 = \frac{\begin{vmatrix} 1 & 1 & 0 \\ 5 & -1 & 6 \\ 0 & 1 & 16 \end{vmatrix}}{\begin{vmatrix} 1 & 1 & 1 \\ 5 & -1 & 0 \\ 0 & 1 & -2 \end{vmatrix}} = \frac{\{(1\times -1\times 16)+(5\times 1\times 0)+(0\times 1\times 6)\}-\{(0\times -1\times 0)+(5\times 1\times 16)+(1\times 1\times 6)\}}{\{(1\times -1\times -2)+(5\times 1\times 1)+(0\times 1\times 0)\}-\{(0\times -1\times 1)+(5\times 1\times -2)+(1\times 1\times 0)\}}$$

$$= \frac{(-16+0+0)-(0+80+6)}{(2+5+0)-(0-10+0)} = \frac{(-16)-(86)}{(7)-(-10)} = \frac{-102}{17} = -4\text{A}$$

$$\begin{cases} I_1 = 2\text{A} \\ I_2 = 4\text{A} \\ I_3 = -6\text{A} \end{cases}$$

（閉路電流法を用いた解放）



$$\begin{cases} R_1 I_1' + R_2 (I_1' - I_2') = E_1 - E_2 \\ R_2 (I_2' - I_1') + R_3 I_2' = E_2 + E_3 \end{cases}$$

$$\begin{cases} 5I_1' + 1(I_1' - I_2') = 10 - 4 \\ 1(I_2' - I_1') + 2I_2' = 4 + 12 \end{cases}$$

$$\begin{cases} 6I_1' - I_2' = 6 \\ -I_1' + 3I_2' = 16 \end{cases}$$

$$\begin{pmatrix} 6 & -1 \\ -1 & 3 \end{pmatrix} \begin{pmatrix} I_1' \\ I_2' \end{pmatrix} = \begin{pmatrix} 6 \\ 16 \end{pmatrix}$$

$$I_1' = \frac{\begin{vmatrix} 6 & -1 \\ 16 & 3 \end{vmatrix}}{\begin{vmatrix} 6 & -1 \\ -1 & 3 \end{vmatrix}} = \frac{(6\times3)-(16\times-1)}{(6\times3)-(-1\times-1)} = \frac{(18)-(-16)}{(18)-(1)} = \frac{34}{17} = 2\mathrm{A}$$

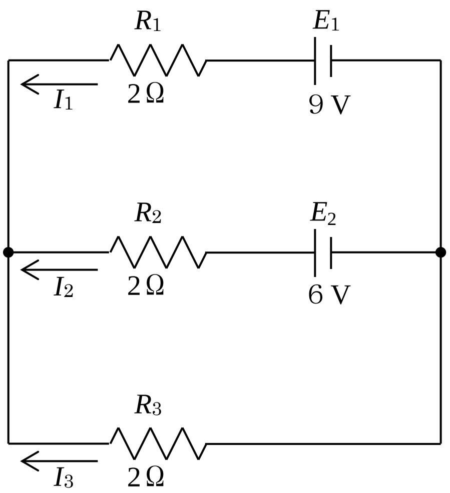
$$I_2' = \frac{\begin{vmatrix} 6 & 6 \\ -1 & 16 \end{vmatrix}}{\begin{vmatrix} 6 & -1 \\ -1 & 3 \end{vmatrix}} = \frac{(6\times16)-(-1\times6)}{(6\times3)-(-1\times-1)} = \frac{(96)-(-6)}{(18)-(1)} = \frac{102}{17} = 6\mathrm{A}$$

$$I_1 = I_1' = 2\mathrm{A}$$
$$I_2 = I_2' - I_1' = 6 - 2 = 4\mathrm{A}$$
$$I_3 = -I_2' = -6\mathrm{A}$$

$$\begin{cases} I_1 = 2\mathrm{A} \\ I_2 = 4\mathrm{A} \\ I_3 = -6\mathrm{A} \end{cases}$$

（２）

（枝電流法を用いた開放）



$$\begin{cases} I_1 + I_2 + I_3 = 0 \\ R_1 I_1 - R_2 I_2 = E_1 - E_2 \\ R_2 I_2 - R_3 I_3 = E_2 \end{cases}$$

$$\begin{cases} I_1 + I_2 + I_3 = 0 \\ 2I_1 - 2I_2 = 9 - 6 \\ 2I_2 - 2I_3 = 6 \end{cases}$$

$$\begin{pmatrix} 1 & 1 & 1 \\ 2 & -2 & 0 \\ 0 & 2 & -2 \end{pmatrix}\begin{pmatrix} I_1 \\ I_2 \\ I_3 \end{pmatrix} = \begin{pmatrix} 0 \\ 3 \\ 6 \end{pmatrix}$$

$$I_1 = \frac{\begin{vmatrix} 0 & 1 & 1 \\ 3 & -2 & 0 \\ 6 & 2 & -2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 & 1 \\ 2 & -2 & 0 \\ 0 & 2 & -2 \end{vmatrix}} = \frac{\{(0\times-2\times-2)+(3\times2\times1)+(6\times1\times0)\}-\{(6\times-2\times1)+(3\times1\times-2)+(0\times2\times0)\}}{\{(1\times-2\times-2)+(2\times2\times1)+(0\times1\times0)\}-\{(0\times-2\times1)+(2\times1\times-2)+(1\times2\times0)\}}$$

$$= \frac{(0+6+0)-(-12-6+0)}{(4+4+0)-(0-4+0)} = \frac{(6)-(-18)}{(8)-(-4)} = \frac{24}{12} = 2\text{A}$$

$$I_2 = \frac{\begin{vmatrix} 1 & 0 & 1 \\ 2 & 3 & 0 \\ 0 & 6 & -2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 & 1 \\ 2 & -2 & 0 \\ 0 & 2 & -2 \end{vmatrix}} = \frac{\{(1\times3\times-2)+(2\times6\times1)+(0\times0\times0)\}-\{(0\times3\times1)+(2\times0\times-2)+(1\times6\times0)\}}{\{(1\times-2\times-2)+(2\times2\times1)+(0\times1\times0)\}-\{(0\times-2\times1)+(2\times1\times-2)+(1\times2\times0)\}}$$

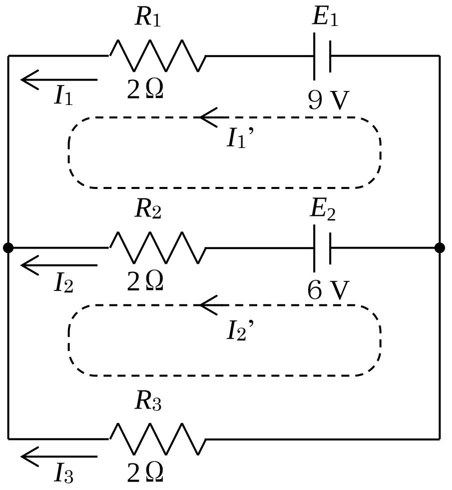
$$= \frac{(-6+12+0)-(0+0+0)}{(4+4+0)-(0-4+0)} = \frac{(6)-(0)}{(8)-(-4)} = \frac{6}{12} = 0.5\text{A}$$

$$I_3 = \frac{\begin{vmatrix} 1 & 1 & 0 \\ 2 & -2 & 3 \\ 0 & 2 & 6 \end{vmatrix}}{\begin{vmatrix} 1 & 1 & 1 \\ 2 & -2 & 0 \\ 0 & 2 & -2 \end{vmatrix}} = \frac{\{(1\times-2\times6)+(2\times2\times0)+(0\times1\times3)\}-\{(0\times-2\times0)+(2\times1\times6)+(1\times2\times3)\}}{\{(1\times-2\times-2)+(2\times2\times1)+(0\times1\times0)\}-\{(0\times-2\times1)+(2\times1\times-2)+(1\times2\times0)\}}$$

$$= \frac{(-12+0+0)-(0+12+6)}{(4+4+0)-(0-4+0)} = \frac{(-12)-(18)}{(8)-(-4)} = \frac{-30}{12} = -2.5\text{A}$$

$$\begin{cases} I_1 = 2\text{A} \\ I_2 = 0.5\text{A} \\ I_3 = -2.5\text{A} \end{cases}$$

（閉路電流法を用いた解放）



$$\begin{cases} R_1 I_1' + R_2 (I_1' - I_2') = E_1 - E_2 \\ R_2 (I_2' - I_1') + R_3 I_2' = E_2 \end{cases}$$

$$\begin{cases} 2I_1' + 2(I_1' - I_2') = 9 - 6 \\ 2(I_2' - I_1') + 2I_2' = 6 \end{cases}$$

$$\begin{cases} 4I_1' - 2I_2' = 3 \\ -2I_1' + 4I_2' = 6 \end{cases}$$

$$\begin{pmatrix} 4 & -2 \\ -2 & 4 \end{pmatrix} \begin{pmatrix} I_1' \\ I_2' \end{pmatrix} = \begin{pmatrix} 3 \\ 6 \end{pmatrix}$$

$$I_1' = \frac{\begin{vmatrix} 3 & -2 \\ 6 & 4 \end{vmatrix}}{\begin{vmatrix} 4 & -2 \\ -2 & 4 \end{vmatrix}} = \frac{(3 \times 4) - (6 \times -2)}{(4 \times 4) - (-2 \times -2)} = \frac{(12) - (-12)}{(16) - (4)} = \frac{24}{12} = 2\mathrm{A}$$

$$I_2' = \frac{\begin{vmatrix} 4 & 3 \\ -2 & 6 \end{vmatrix}}{\begin{vmatrix} 4 & -2 \\ -2 & 4 \end{vmatrix}} \frac{(4 \times 6) - (-2 \times 3)}{(4 \times 4) - (-2 \times -2)} = \frac{(24) - (-6)}{(16) - (4)} = \frac{30}{12} = 2.5\mathrm{A}$$

$$I_1 = I_1' = 2\mathrm{A}$$
$$I_2 = I_2' - I_1' = 2.5 - 2 = 0.5\mathrm{A}$$
$$I_3 = -I_2' = -2.5\mathrm{A}$$

$$\begin{cases} I_1 = 2\mathrm{A} \\ I_2 = 0.5\mathrm{A} \\ I_3 = -2.5\mathrm{A} \end{cases}$$