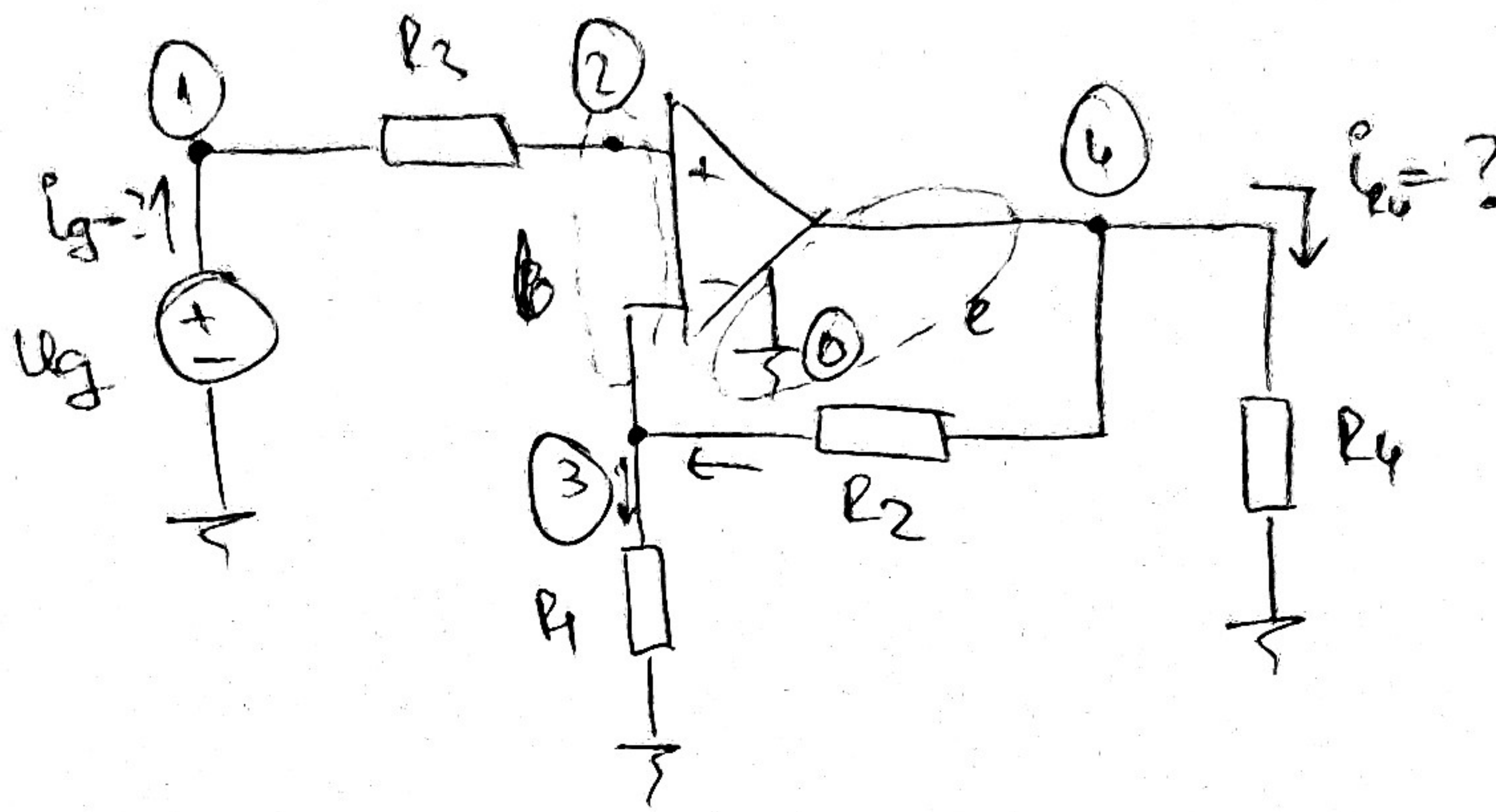
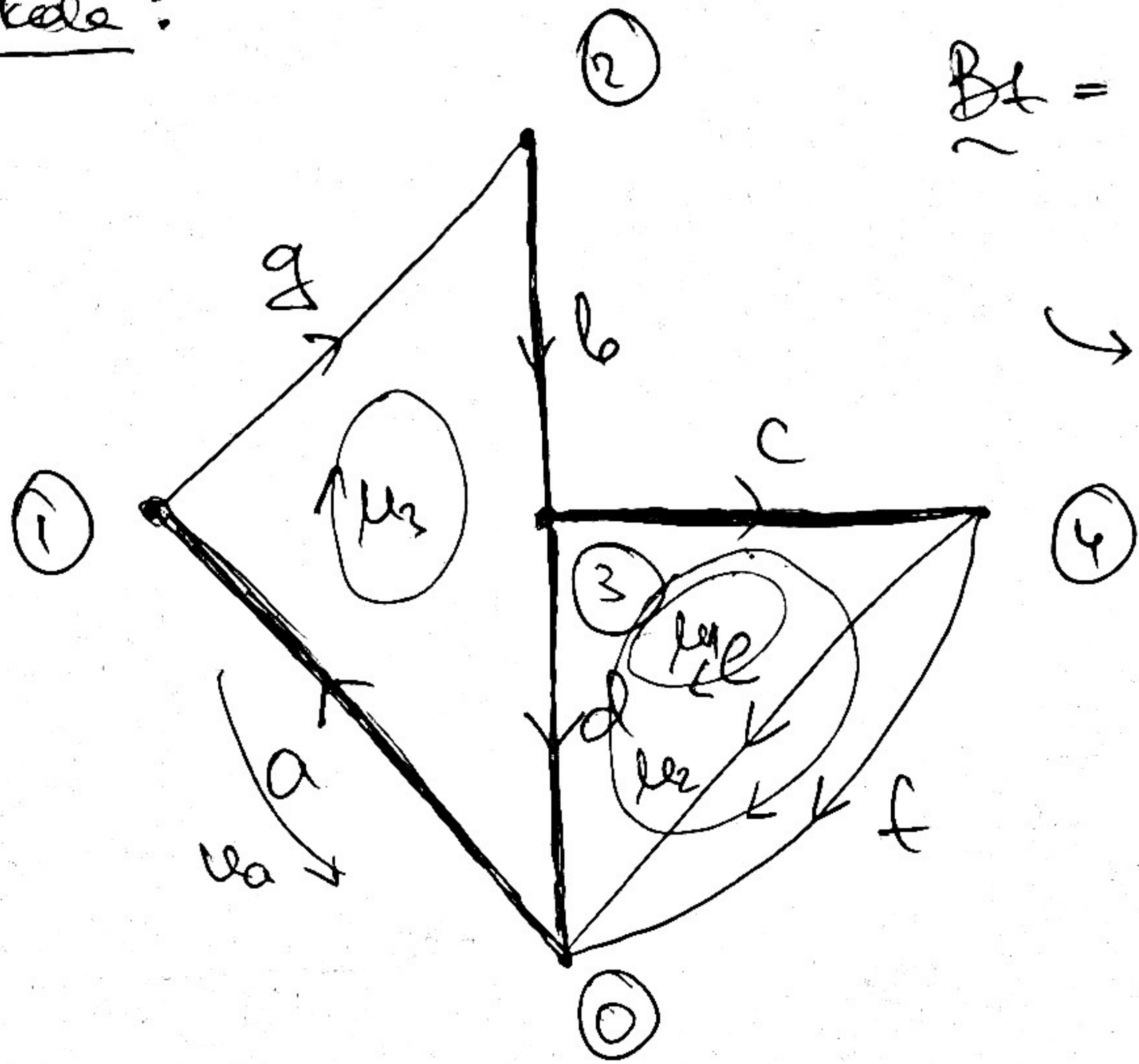


- Prvi stepen teorije grafova u OP naliku :



Operativni postupak se
izvodi u dvije grane:
e → grana između čvorova
i relevantnog čvora
b → grana između
izvornih čvorova
već ugrađenih u skema

- Graf kola :



$$\tilde{B}_t = \begin{matrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{matrix} \begin{bmatrix} 0 & 0 & 1 & -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix}$$

→ vektore čvorovih potencijala

- Prvi stepen IIKZ :

$$\tilde{i} = \tilde{B}_t^T \tilde{u} \rightarrow \begin{bmatrix} i_a \\ i_b \\ i_c \\ i_d \\ i_e \\ i_f \\ i_g \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_e \\ u_f \\ u_g \end{bmatrix} \rightarrow$$

$$\begin{aligned} i_a &= i_g \dots (1) \\ i_b &= i_g \dots (2) \\ i_c &= i_e + i_f \dots (3) \\ i_d &= -i_e - i_f + i_g \dots (4) \end{aligned}$$

Kako je ulazni otpor idealnog operativnog pojačavača beskonačan, to je :

$$i_b = 0 \dots (5)$$

Premade dvije relacije se određuju pomoću III Z:

$$\underline{\mu_1}: U_a + \cancel{U_b} + U_d + U_g = 0$$

$$-U_s + 0 + R_1 i_d + R_3 i_g = 0 \dots (6)$$

↑
jer je razlika napona u
istom grana nula!

$$\underline{\mu_2}: U_c + U_f + U_d = 0$$

$$R_2 i_c + R_4 i_f - R_1 i_d = 0 \dots (7)$$

Rješavajući sistem jednačina:

$$\textcircled{1} \rightarrow i_b = 0$$

$$\textcircled{2} \rightarrow i_g = 0$$

$$\textcircled{3} \rightarrow i_a = 0$$

$$\textcircled{4} \rightarrow i_d = -i_e - i_f$$

$$\textcircled{5} \quad i_c = i_e + i_f \rightarrow i_c = i_e + \frac{U_s}{R_4} - \frac{R_2}{R_4} i_c \rightarrow i_e = -\frac{U_s}{R_4} + \frac{R_2 + R_4}{R_4} i_c$$

$$\textcircled{6} \rightarrow U_s = R_1 i_d \rightarrow i_d = \frac{U_s}{R_1}$$

$$\textcircled{7} \rightarrow R_2 i_c + R_4 i_f = R_1 i_d = R_1 \frac{U_s}{R_1} = U_s \rightarrow i_f = \frac{U_s - R_2 i_c}{R_4}$$

$$\textcircled{9} \rightarrow \frac{U_s}{R_1} = \frac{U_s}{R_4} - \frac{R_2 + R_4}{R_4} i_c - \frac{U_s}{R_4} + \frac{R_2}{R_4} i_c$$

$$\frac{U_s}{R_1} = -i_c \Rightarrow \boxed{i_c = -\frac{U_s}{R_1}}$$

$$i_f = \frac{U_s}{R_4} + \frac{R_2}{R_4 R_1} U_s = \boxed{\frac{R_2 + R_1}{R_1 R_4} U_s}$$

$$i_e = -\frac{U_s}{R_4} + \frac{R_1 + R_2}{R_4} \frac{U_s}{R_1} = \boxed{-\left(\frac{2R_1 + R_2}{R_1 R_4}\right) U_s}$$