EE20005 practice set 5-1

Q1

a) Condition: ideal Op Amp:
   1. Infinity input resistance
   2. Infinity loop gain
   3. Zero output resistance

   $r_1 = \infty\ \Omega, \mu = \infty, r_0 = 0\ \Omega.$

b) $r_1 \to \infty, I_1 = I_2 = 0\ A$
c) $v_0 = v^- = v^+ = 0\ V$

Q2

a) $I_1 = I_2 = 0\ A$
b) $v_1 = v_s \cdot \frac{24}{16+24} = 7.5\ \times \frac{6}{10} = 4.5\ V$
   $v_2 = v^- = v^+ = 4.5\ V$
c) $v_0 = v_2 \cdot \frac{12}{8+12} = 4.5\ \times \frac{3}{5} = 2.7\ V$
   $$I_4 = \frac{v_0}{R_0} = \frac{2.7}{12} = 0.225\ A$$

d) $I_3 = I_4 = 0.225\ A$

Q3

a) $I_1 = I_2 = 0\ A$
b) $v^- = v^+ = 0\ V$
c) $I_s = \frac{v_s}{R_1} = \frac{1}{5k} = 0.2\ mA$
   $I_F = I_s = 0.2\ mA$

d) $v_o = -I_s \times 25k\Omega = -0.2\ mA\ \times 25k\Omega = -5\ V$

Q4

a) Apply KCL on Node V1:
   $$\frac{v_1 - 0.75}{2k} + \frac{v_1 - 0}{4k} + \frac{v_1 - 0}{4k} = 0$$
   $4v_1 - 1.5 = 0$
   $v_1 = 0.375\ V$
b) $I_1 = \frac{v_1}{4k\Omega} = \frac{0.375}{4000} = 93.75\ \mu A$
   $I_2 = 0\ A, I_3 = I_1 = 93.75\ \mu A$

c) $v_o = -I_3 \times 10k\Omega = -93.75\ \mu A\ \times 10000\Omega = -0.9375\ V$

$$i_o = -i_3 + \frac{v_o}{2k\Omega} = -93.75\ \mu A - \frac{0.9735\ V}{2000\ \Omega} = -(93.75\mu A + 0.4688\ mA)$$

$i_o = \ -0.5625\ mA$

d) $i_s = \frac{-v_1+0.75}{2k\Omega} = \frac{0.75-0.375}{2000} = 0.1875\ mA$

$$R_s = \frac{V_s}{i_s} = \frac{0.75\ V}{0.1875\ mA} = 4k\Omega$$

Q5

a) $v^- = v^+ = 1\ V$

b) $I_1 = \frac{3-1}{4k} = \frac{2}{4000} = 0.5\ mA$

$I_2 = 0\ A$

$I_3 = I_1 = 0.5\ mA$

c) $I_3 = \frac{1-v_o}{10k\Omega} \rightarrow v_o = -10k\Omega \times 0.5\ mA + 1 = -5 + 1 = -4\ V$

Q6

a) $I_1 = I_2 = 0\ A$

b) $V^- = V^+ = V_s = 1\ V$

c) $1\ V = V_o \times \frac{10k\Omega}{10k\Omega+10k\Omega} \rightarrow V_o = 2\ V$

$$Gain = \frac{V_o}{V_i} = 2$$

d) $I_3 = \frac{V_O}{20k\Omega} = \frac{2}{20000} = 0.1\ mA$

e) $I_3 = V_o \cdot \frac{\frac{1}{20\times5}}{20+5} k\Omega = 2\ \times \frac{1}{4000} = 0.5\ mA$

f) As there is no input current, thus the input resistance should be infinity.

Q7

a) $V^- = V^+ = 1 \times \frac{90}{10+90} = 0.9\ V$

b) $I_1 = 0\ A$

$$\mathrm{I}_3 = \frac{0.9}{50k\Omega} = 18\ \mu A$$

$\mathrm{I}_2 = -I_3 = -18\ \mu A$

c) $\frac{\mathrm{V_o}-0.9}{100k\Omega} = I_2 \rightarrow V_o = 1.8 + 0.9 = 2.7\ V$

$$\mathrm{I_o} = \frac{V_o}{10k\Omega} - I_2 = 270\mu A + 18\mu A = 288\ \mu A$$

Q8

a) $\mathrm{V}^- = V^+ = 0\,V$
b) $\mathrm{I}_1 = \frac{2\,V}{10k\Omega} = 0.2\,mA$
$\mathrm{I}_2 = \frac{-2V}{20k\Omega} = -0.1mA$
$\mathrm{I}_3 = \frac{-4.5V}{30k\Omega} = -0.15\,mA$
c) $\mathrm{I}_4 = I_1 + I_2 + I_3 = 0.2 - 0.1 - 0.15 = -0.05\,mA$
d) $\mathrm{V}_\mathrm{o} = -I_4 R_o = -0.05\,mA\ \times 30k\Omega = 1.5V$

Q9

a) $\mathrm{I}_1 = \frac{V_1 - 0}{100k\Omega} = \frac{1}{100000} = 10\,\mu A$
$\mathrm{I}_2 = \frac{V_2 - 0}{100k\Omega} = \frac{2}{100000} = 20\,\mu A$
b) $\mathrm{I}_3 = -I_2 = -20\,\mu A$
$I_4 = I_1 - I_3 = 10 - (-20) = 30\,\mu A$
c) $\frac{0-\mathrm{V}}{200\mathrm{k}\Omega} = \mathrm{I}_4 \rightarrow V = -30\,\mu A \times 200k\Omega = -6\,V$
$\mathrm{V}_\mathrm{o} = \frac{40k\Omega}{10k\Omega + 40k\Omega} \cdot V = \frac{4}{5} \times -6V = -4.8V$
$\frac{-6}{50k\Omega} = I_0 + I_4$
$I_o = -0.12mA - 30\mu A = -0.15mA$
d) Same