Q1

a) $NO\ current\ flow\ in\ or\ out\ of\ input\ terminals.\ I_1 = I_2 = 0\ A$

b) $Apply\ voltage\ divider\ rule\ to\ find\ out.\ V_b = V_2 \cdot \frac{R_4}{R_3+R_4} = 2 \cdot \frac{90}{10+90} = 1.8\ V;$

$The\ voltage\ of\ two\ input\ terminals\ are\ SAME.\ V_a = V_b = 1.8\ V$

c) $Find\ I_3: Apply\ Mesh\ Analysis: I_3 = \frac{(V_1 - V_a)}{R_1} = \frac{1-1.8}{10k} = -0.08\ mA$

$Find\ I_F: I_F = I_3 = -0.08 mA$

$Find\ V_o: Mash\ Analysis:$

$V_a - V_o = I_F \cdot R_2 \rightarrow V_o = V_a - I_F \cdot R_2 = 1.8V + 0.08mA \cdot 90k\Omega = 9\ V$

Q2

a) $As\ the\ requirement\ of\ the\ question, using\ nodal\ analysis:$

$$\frac{V_s - V^+}{4k\Omega} + \frac{0 - V^+}{6k\Omega} + \frac{(0 - V^+)}{12k\Omega} = 0 \rightarrow \frac{V_s}{4k\Omega} = V^+\left(\frac{1}{4k\Omega} + \frac{1}{6k\Omega} + \frac{1}{12k\Omega}\right) \rightarrow V^+ = \frac{10mV}{(1 + \frac{2}{3} + \frac{1}{3})} = 5\ mV$$

$Acturaly, there\ is\ a\ simple\ method\ to\ find\ out\ the\ voltage\ of\ input\ teminals:$

$$Apply\ voltage\ divider\ rule: V^- = V^+ = V_S \cdot \frac{Z_1}{4 + Z_1} = 10\ mV \cdot \frac{\frac{6 \cdot 12}{6 + 12}}{4 + \frac{6 \cdot 12}{6 + 12}} = 10mV \cdot \frac{1}{2} = 5\ mV$$

b) $Apply\ nodel\ analysis\ at\ Node\ V^-:$

$$\frac{(V_o - V^-)}{12k\Omega} + \frac{10mV - V^-}{6k\Omega} + \frac{0 - V^-}{4k\Omega} = 0 \rightarrow V_o = 12k\Omega \cdot [V^-\left(\frac{1}{12k\Omega} + \frac{1}{6k\Omega} + \frac{1}{4k\Omega}\right) - \frac{10mV}{6k\Omega}]$$

$V_o = [5mV \cdot (1 + 2 + 3) - 20\ mV] = 10\ mV$

Q3

a) $Find\ i_1: Mesh\ Analysis: i_1 = \frac{V_{s1} - 0}{25k\Omega} = \frac{1}{25000} = 0.04\ mA$

$Find\ i_2: i_2 = i_1 = 0.04\ mA$

$Find\ v_{o1}: Mesh\ Analysis: \frac{0 - v_{o1}}{50k\Omega} = i_2 \rightarrow v_{o1} = -i_2 \cdot 50k\Omega = -2\ V$

b) $Find\ i_3: Mesh\ Analysis: i_3 = \frac{V_{s2} - 0}{50k\Omega} = \frac{2}{50k\Omega} = 0.04\ mA$

$Find\ i_4: Node\ Analysis: i_4 = \frac{v_{o1} - 0}{100k\Omega} + i_3 = -0.02\ mA + 0.04\ mA = 0.02\ mA$

$Find\ v_{o2}: Mesh\ Analysis: \frac{0 - v_{o2}}{100k\Omega} = i_4 \rightarrow V_{o2} = -i_4 \cdot 100k\Omega = -2\ V$

c) $Find\ i_5: Mash\ Analysis: i_5 = \frac{v_{o2} - 0}{50k\Omega} = -\frac{2}{50k\Omega} = -0.04\ mA$

d) $Find\ v_o: Mesh\ Analysis: \frac{v_o - 0}{100k\Omega + 50k} = i_5 \rightarrow v_o = -0.04\ mA \cdot 150k\Omega = -6\ V$

Q4 $Asking\ to\ find\ out\ the\ voltage\ gain\ of\ this\ circuit.$

$Point\ is\ that\ building\ the\ equation\ has\ both\ v_i\ and\ v_o$

$Assuming\ the\ Right\ Amp\ is\ P2, the\ input\ terminals\ are\ V_2^+\ and\ V_2^-. Also\ assuming\ the\ Left\ Amp\ is\ P1,$
$the\ input\ terminals\ are\ V_1^+\ and\ V_1^-. From\ the\ circuit, we\ get:$

$V_1^- = V_1^+ = 0\ V.$

$$V_2^+ = V_2^- = v_o \cdot \frac{10k\Omega}{10k\Omega + 2k\Omega} = \frac{5}{6} v_o$$

$Then\ apply\ Node\ Analysis\ (KCL)\ on\ Node\ V_1^-:$

$$\frac{v_i - 0}{5k\Omega} + \frac{v_o - 0}{4k\Omega} + \frac{V_2^+ - 0}{10k\Omega} = 0$$

$$4v_i + 5v_o + \frac{5}{3} v_o = 0$$

$$\frac{20}{3} v_o = -4v_i$$

$$\frac{v_o}{v_i} = -4 \times \frac{3}{20} = -\frac{6}{10} = -0.6$$

Q5

a) $\frac{v_s}{R_S} + \frac{v_{out}}{R_F} = 0 \rightarrow v_{out} = -v_s \cdot \frac{R_S}{R_F} = -1.2 \times 5 = -6\ V$

$However, as\ this\ is\ an\ active\ Amp, there\ is\ limitation\ of\ v_{out}\ due\ to\ the\ power\ supply.$

$V_s^+ < v_{out} < V_s^- \rightarrow v_{out} = -5V$

$$H(j\omega) = -\frac{R_S}{R_F} = -5$$