EE10

Midterm Exam

Fall 2012

Group 2

Time Limit: 1 hour and 50 minutes

Open Book, Open Notes

Calculators are allowed.

Your Name:

[redacted]

Name of Person to Your Left: [redacted]

Name of Person to Your Right: [redacted]

1. 9
2. 11
3. 8.5
4. 2+1

30.5 + 1 = 31.5

9

$g = R_1$

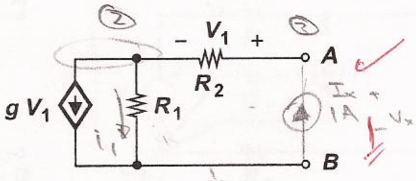
$R_1 I_2 = g I_2$

$I_2 = I_x - I_3$

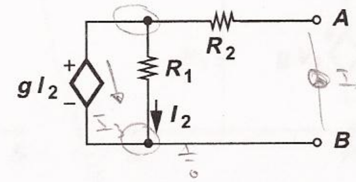
1. (a) Consider the circuit shown in (I) below. Determine the equivalent resistance between terminals A and B.

(b) What happens to the equivalent resistance as g approaches $1/R_2$? Can you explain intuitively why?

(c) Consider the circuit shown in (II) below. Determine the equivalent resistance between terminals A and B.



(I)



(II)

$V_x - I_x R_2 - I_2 R_1 = 0$

$\frac{V_1}{R_2}$

$V_1 = I_x R_2$

$V_x - I_x R_2 - i_1 R_1 = 0$

$\frac{V_x - I_x R_2}{R_1} = i_1$

a) KCL1: $-gV_1 - \frac{V_2}{R_1} + \frac{V_3 - V_2}{R_2} = 0$ $\quad V_3 = V_x$

$I_x = i_1 + gV_1$

KCL 2: $\frac{V_2 - V_3}{R_2} + 1 = 0$

$I_x = i_1 + g I_x R_2$

$I_x = \frac{V_x - I_x R_2}{R_1} + g I_x R_2$

$\frac{I_x + I_x R_2}{R_1} \quad I_x R_2 g$

$\frac{V_3 - V_2}{R_2} = 1$

$V_1 = V_3 - V_2$

$I_x R_1 \left(1 + \frac{R_2}{R_1} - g R_2\right) = V_x$

$R_1 + R_2 - R_1 R_2 g$

$-g(V_3 - V_2) - \frac{V_2}{R_1} + 1 = 0$

$R_{eq} = R_1 + R_2 - g R_2 R_1$

5

$-g(V_3 - V_2) = \frac{V_2}{R_1} - 1$

$V_3 = -\frac{\left(\frac{V_2}{R_1} - 1\right)}{g} + V_2 = R$

$R_1 I_2 = V_x - I_x R_2$

$I_2 = \frac{V_x - I_x R_2}{R_1}$

b) $g \to 1/R_2$

$R_{eq} \to (R_2)$

only current flowing through R_2 resistor. Current flows around R_1 resistor, so it like you only have R_2 resistor in circuit.

4

$I_x = I_2 + I_3$

$V_3 - V_2 = V_1$

$I_x =$

KCL 2: $\frac{V_3 - V_2}{R_2} - \frac{V_1}{R_2} - \frac{V_2}{R_1} = 0$

$I_x = \frac{R_1 I_2}{R_1}$

$\frac{V_1}{R_2} - \frac{V_x}{R_2} - \frac{V_2}{R_1} = 0$ $\quad V_2 = 0$

$i_1 = \frac{V_2}{R_1} = 0$

c) $V_x = I_x R_2 + g I_2$ $\quad V_x = I_x R_2 + I_2 R_1$ $\quad I_x = I_2 + I_3$

$g I_2 = I_2 R_1$ $\quad V_x = I_x R_2 + \frac{V_x - I_x R_2}{R_1} R_1$

$g = R_1$

V_x

$I_x = \frac{V_x}{R_3} + I_2 + I_4 + 1$ $V_x = gV_1 + R_4 I_2$

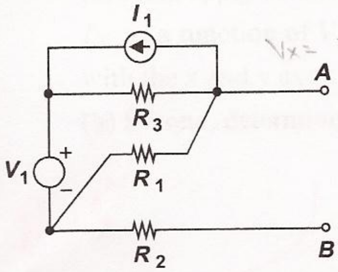
$V_1 = \frac{V_x - R_4 I_2}{g}$ $gR_1 - \frac{1}{R_1} = I_4\left(\frac{1}{R_1} + \frac{1}{R_2} - gR_1\right)$

+11 $V_x = I_3 R_1 + I_4 R_2 + I_2 R_4$ $I_4 = \frac{gR_1 - \frac{1}{R_1}}{\left(\frac{1}{R_1} + \frac{1}{R_2} - gR_1\right)}$

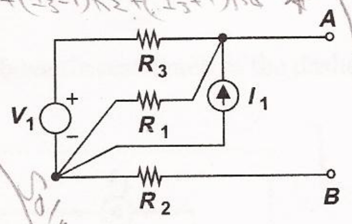
2. Determine the Thevenin equivalent circuit of each circuit shown below.

$I_2 = I_3 + 1$ $I_4 = I_3 - 1$

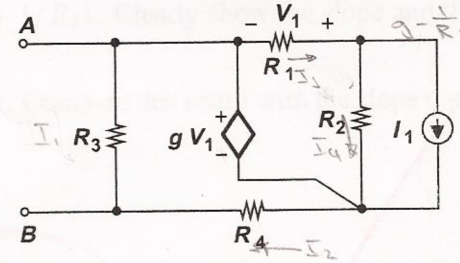
$V_x = I_3 R_1 + (I_3 - 1)R_2 + (I_3 + 1)R_4$



(a)



(b)



(c)

$g(I_4 + 1)R_1 = \frac{I_4 + 1}{R_1} + \frac{I_4}{R_2}$

$g - \frac{1}{R_1} = I_4\left(\frac{1}{R_1} + \frac{1}{R_2} - g\right)$

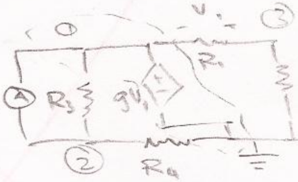
$I_4 = \frac{\left(g - \frac{1}{R_1}\right)}{\left(\frac{1}{R_1} + \frac{1}{R_2} - g\right)}$

Solve for V_x to plug into this eq. Solve for $V_x = V_{th}$

a) $R_{Th} = (R_3 \| R_1) + R_2$

b) $R_{Th} = (R_3 \| R_1) + R_2$

c)



$I_x = 1A$, V_x

KCL 1: $1 + \frac{V_2 - V_1}{R_3} + \frac{V_3 - V_1}{R_1} + \frac{V_3}{R_2} + \frac{V_2}{R_4} = 0$

KCL 2: $-1 + \frac{V_1 - V_2}{R_3} - \frac{V_2}{R_4} = 0$

KCL 3: $\frac{V_1 - V_3}{R_1} - \frac{V_3}{R_2} = 0$

$I = \frac{V_1}{R_3}$

$I = \frac{V_1}{R_3} + I_1$

$V = \left(\frac{V_1}{R_3} + I_1\right)\frac{R_1 R_3}{R_1 + R_3}$

$V_{Th} = \left(\frac{V_1}{R_3} + 1\right)\frac{R_1 R_3}{R_1 + R_3}$ ✓

$R_{Th} = \frac{R_1 R_3}{R_1 + R_3} + R_2$ ✓

+4

$V = V_1 - I_1 R_3$

$I = \frac{V_1 - I_1 R_3}{R_3}$

$V = \frac{V_1 - I_1 R_3}{R_3}\left(\frac{R_1 R_3}{R_1 + R_3}\right)$

$V_{Th} = \frac{(V_1 - I_1 R_3)R_1}{R_1 + R_3}$ ✓

$R_{Th} = \frac{R_1 R_3}{R_1 + R_3} + R_2$ ✓

+5

$I_2 = \frac{V_x - gV_1}{R_4}$

$V_x - gV_1 - R_4 I_2 = 0$

$I_x = I_1 + I_2 + I_3$

$I_x = \frac{V_x}{R_3} + \frac{V_x - g(I_4 + 1)R_1}{R_4} + I_4 + 1$

$I_x = \frac{V_x}{R_3} + \frac{V_x - g\left(\frac{gR_1 - \frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2} - gR_1}\right)R_1}{R_4} +$

$gV_1 = I_3 R_1 + (I_3 - 1)R_2$

$gI_3 R_1 = I_3 R_1 + (I_3 - 1)R_2$

Solve this for I_3

$I_x = \frac{V_x}{R_3} + \frac{V_x - gV_1}{R_4} + \frac{V_x}{R_1 + R_2 + R_4}$

$I_x = \frac{V_x}{R_3} + \frac{V_x - g\left(\frac{V_x}{R_1 + R_2 + R_4}\right)R_1}{R_4} + \frac{V_x}{R_1 + R_2 + R_4}$

+2

$V_x = \frac{V_x - R_4 I_2}{g}R_1 + \left(\frac{V_x - R_4 I_2}{g} - 1\right)R_2 + \left(\frac{V_x - R_4 I_2}{g} + 1\right)R_4$

$R_{Th} = \frac{1}{R_3} + \frac{1 - g\left(\frac{R_1}{R_1 + R_2 + R_4}\right)}{R_4} + \frac{1}{R_1 + R_2 + R_4}$

$V_x = V_x\left(\frac{R_1}{g} + \frac{R_2}{g} + \frac{R_4}{g}\right) - \left(\frac{R_4 I_2}{g}\right)(R_1 + R_2 + R_4) - R_2 + R_4$

$V_x\left(1 + \frac{R_1}{g} + \frac{R_2}{g} + \frac{R_4}{g}\right) = -\frac{R_4 I_2}{g}(R_1 + R_2 + R_4) - R_2 + R_4$

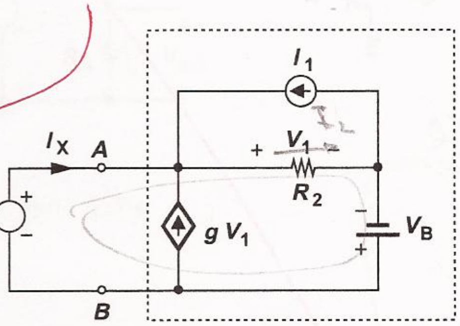
$V_{Th} = \frac{-\frac{R_4 I_2}{g}(R_1 + R_2 + R_4) - R_2 + R_4}{\left(1 + \frac{R_1}{g} + \frac{R_2}{g} + \frac{R_4}{g}\right)}$

3. Consider the circuit shown in the dashed box below. We conduct two experiments.

(a) First, apply an external voltage, V_X, and measure I_X without setting any sources in the dashed box to zero. Plot I_X as a function of V_X. Assume $g < 1/R_2$ and $I_1 > V_B(-g + 1/R_2)$. Clearly show the slope and the intercepts with the x and y axes.

(b) Second, determine the Thevenin resistance of the dashed box. Compare this result with the slope obtained in (a).

8.5



$I_2 = \frac{V_1}{R_2}$

a) $I_x + I_1 - I_2 + g I_2 R_2 = 0$

$V_x - I_2 R_2 + V_B = 0$

$I_x = -I_1 + I_2 - g I_2 R_2$ 2

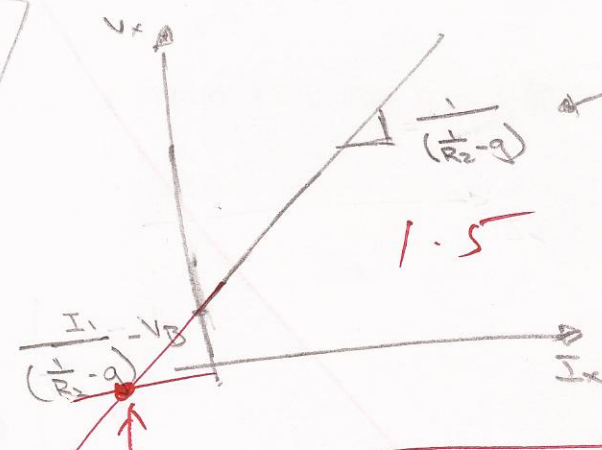
$I_2 = \frac{V_x + V_B}{R_2}$

$I_x = -I_1 + \frac{V_x + V_B}{R_2} - g\frac{(V_x + V_B)}{R_2} R_2$

$g < 1/R_2$

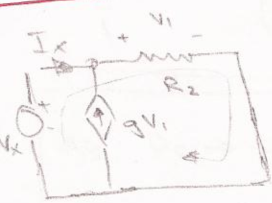
$I_x = -I_1 + V_x\left(\frac{1}{R_2} - g\right) + V_B\left(\frac{1}{R_2} - g\right)$

$$\frac{I_x + I_1}{\left(\frac{1}{R_2} - g\right)} - V_B = V_x$$



1.5

b.



$I_x + gV_1 - \frac{V_1}{R_2} = 0$ 1

KVL $V_x - V_1 = 0$

$V_x = V_1$

$I_x = \frac{V_x}{R_2} - gV_x$

$V = IR$ $R_{Th} = \frac{V_x}{V_x\left(\frac{1}{R_2} - g\right)} = \frac{1}{\frac{1}{R_2} - g} = R_{th}$ 2

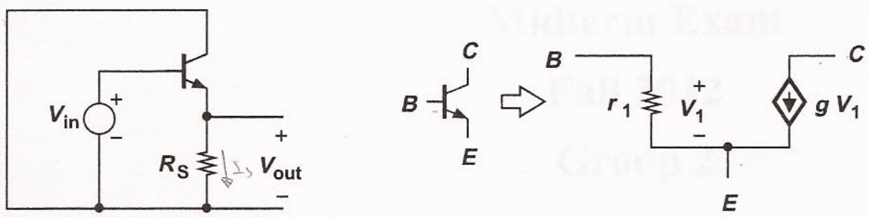
$R = \frac{V}{I}$

Compare ?

(2) +1

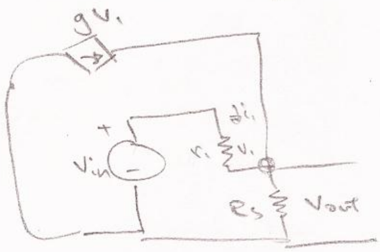
4. (a) Shown below is an amplifier incorporating a transistor. Using the circuit model shown for the transistor, determine V_{out} in terms of V_{in}.

(b) What happens as $R_S \to \infty$?



a)

$V_{out} = I_S R_S$



$V_{in} - V_1 - V_{out} = 0$

$gV_1 + \frac{V_1}{R_1} - \frac{V_{out}}{R_S} = 0$

$V_1 = I_1 R_1$

$gI_1R_1 + I_1 - \frac{V_{out}}{R_S} = 0$

$V_{in} - I_1R_1 - V_{out} = 0$

1 +1

$I_1(gR_1 + 1) = \frac{V_{out}}{R_S}$

$V_{in} - \frac{V_{out}}{R_S(gR_1+1)} - V_{out} = 0$

$I_1 = \frac{V_{out}}{R_S(gR_1+1)}$

$V_{in} = V_{out}\left(\frac{1}{R_S(gR_1+1)} + 1\right)$

$V_{out} = \frac{V_{in}}{\left(\frac{1}{R_S(gR_1+1)} + 1\right)}$

b) As $R_S \to \infty$

$V_{out} = V_{in} \leftarrow V_{out} = \frac{V_{in}}{(0+1)}$

1