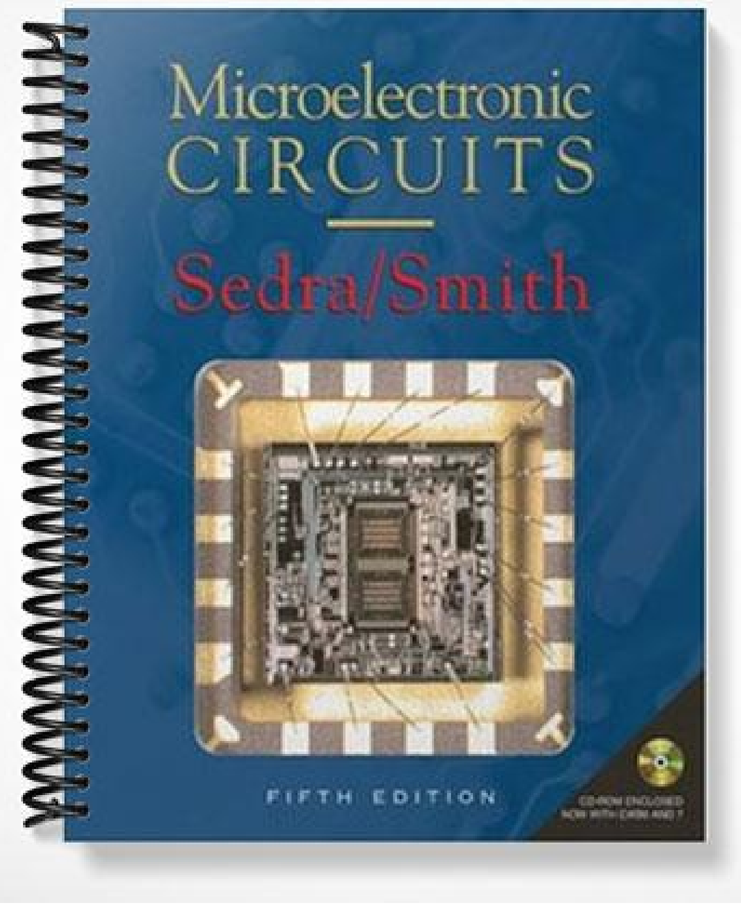
SOLUTIONS MANUAL



CHAPTER 1—PROBLEM SOLUTIONS

1.1 (a) $I = \frac{V}{R} = \frac{10\text{ V}}{1\text{ k}\Omega} = 10\text{ mA}$

(b) $R = \frac{V}{I} = \frac{10\text{ V}}{1\text{ mA}} = 10\text{ k}\Omega$

(c) $V = IR = 10\text{ mA} \times 10\text{ k}\Omega = 100\text{ V}$

(d) $I = \frac{V}{R} = \frac{10\text{ V}}{100\ \Omega} = 0.1\text{ A}$

Note: Volts, milliamps, and kilo-ohms constitute a consistent set of units.

1.2 (a) $P = I^2R = (30 \times 10^{-3})^2 \times 1 \times 10^3 = 0.9\text{ W}$
Thus, R should have a 1-W rating.

(b) $P = I^2R = (40 \times 10^{-3})^2 \times 1 \times 10^3 = 1.6\text{ W}$
Thus, the resistor should have a 2-W rating.

(c) $P = I^2R = (3 \times 10^{-3})^2 \times 10 \times 10^3 = 0.09\text{ W}$
Thus, the resistor should have a $\frac{1}{8}$-W rating.

(d) $P = I^2R = (4 \times 10^{-3})^2 \times 10 \times 10^3 = 0.16\text{ W}$
Thus, the resistor should have a $\frac{1}{4}$-W rating.

(e) $P = V^2/R = 20^2/(1 \times 10^3) = 0.4\text{ W}$
Thus, the resistor should have a $\frac{1}{2}$-W rating.

(f) $P = V^2/R = 11^2/(1 \times 10^3) = 0.121\text{ W}$

Thus, a rating of $\frac{1}{8}$ W should theoretically suffice though $\frac{1}{4}$ W would be prudent to allow for consistent tolerances and measurement errors.

1.3 (a) $V = IR = 10\text{ mA} \times 1\text{ k}\Omega = 10\text{ V}$
$P = I^2R = (10\text{ mA})^2 \times 1\text{ k}\Omega = 100\text{ mW}$

(b) $R = V/I = 10\text{ V}/1\text{ mA} = 10\text{ k}\Omega$
$P = VI = 10\text{ V} \times 1\text{ mA} = 10\text{ mW}$

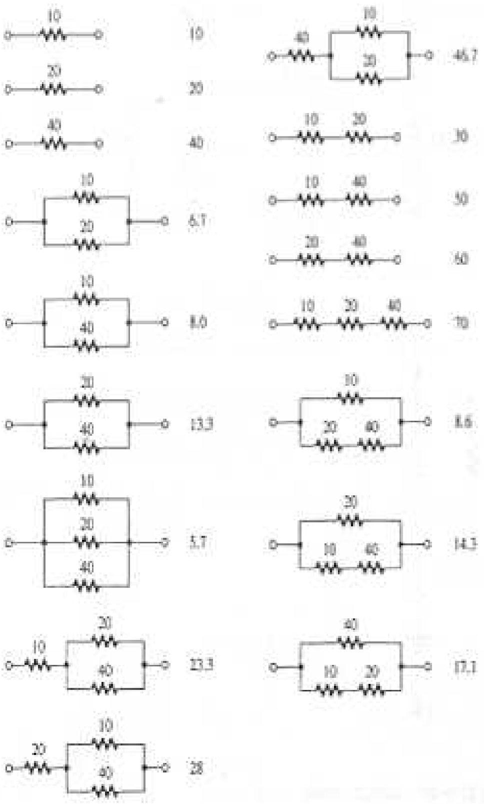
(c) $I = P/V = 1\text{ W}/10\text{ V} = 0.1\text{ A}$
$R = V/I = 10\text{ V}/0.1\text{ A} = 100\ \Omega$

(d) $V = P/I = 0.1\text{ W}/10\text{ mA} = 100\text{ mW}/10\text{ mA} = 10\text{ V}$
$R = V/I = 10\text{ V}/10\text{ mA} = 1\text{ k}\Omega$

(e) $P = I^2R \Rightarrow I = \sqrt{P/R}$
$I = \sqrt{1000\text{ mW}/1\text{ k}\Omega} = 31.6\text{ mA}$
$V = IR = 31.6\text{ mA} \times 1\text{ k}\Omega = 31.6\text{ V}$

Note: V, mA, kΩ, and mW constitute a consistent set of units.

1.4



Thus, there are 17 possible resistance values.

1.5 Shunting the 10 kΩ by a resistor of value R result in the combination having a resistance R_{eq},

$$R_{eq} = \frac{10R}{R+10}$$

Thus, for a 1% reduction,

$$\frac{R}{R+10} = 0.99 \Rightarrow R = 990\text{ k}\Omega$$

For a 5% reduction,

$$\frac{R}{R+10} = 0.95 \Rightarrow R = 190\text{ k}\Omega$$

For a 10% reduction,

$$\frac{R}{R+10} = 0.90 \Rightarrow R = 90\text{ k}\Omega$$

For a 50% reduction,

$$\frac{R}{R+10} = 0.50 \Rightarrow R = 10\text{ k}\Omega$$

Shunting the 10 kΩ by

(a) 1 MΩ result in

$$R_{eq} = \frac{10 \times 1000}{1000+10} = \frac{10}{1.01} = 9.9\text{ k}\Omega\text{, a 1\% reduction;}$$

(b) 100 kΩ results in

$$R_{eq} = \frac{10 \times 100}{100+10} = \frac{10}{1.1} = 9.09\text{ k}\Omega\text{, a 9.1\% reduction;}$$

(c) 10 kΩ results in

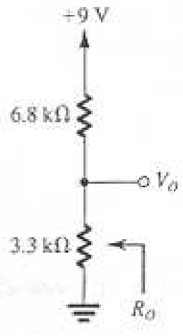
$$R_{eq} = \frac{10}{10+10} = 5\text{ k}\Omega\text{, a 50\% reduction.}$$

1.6 $V_O = V_{DD}\dfrac{R_2}{R_1+R_2}$

To find R_O, we short circuit V_{DD} and look back into node X,

$$R_O = R_2 \,/\!/\, R_1 = \frac{R_1R_2}{R_1+R_2}$$

1.7



$$V_O = 9\frac{3.3}{3.3+6.8}$$
$$= 2.94 \text{ V}$$
$$R_O = 2.22 \text{ k}\Omega$$

For ±5% resistor tolerance the extreme values of V_O are

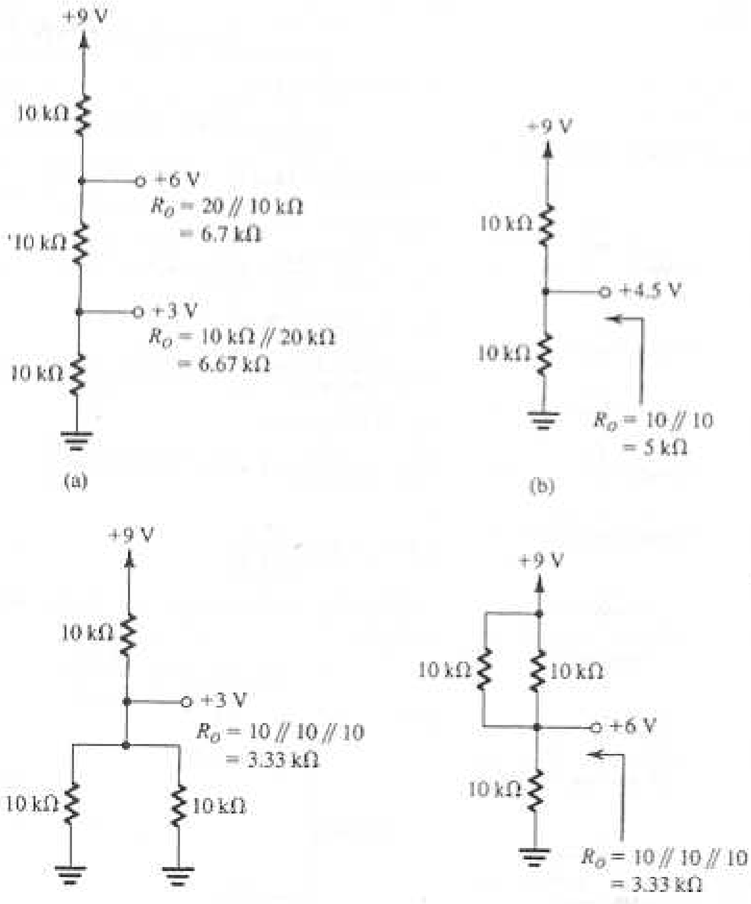
$$V_{O\text{-low}} = 9\frac{3.3(1-0.05)}{3.3(1-0.05)+6.8(1+0.05)}$$
$$= 2.75 \text{ V}$$

$$V_{O\text{-high}} = 9\frac{3.3(1+0.05)}{3(1+0.05)+6.8(1-0.05)}$$
$$= 3.14 \text{ V}$$

The extreme values of R_O are

$$R_{O\text{-low}} = \frac{3.3(1-0.05)\times 6.8(1-0.05)}{3.3(1-0.05)+6.8(1-0.05)}$$
$$= 2.22(1-0.05) = 2.11 \text{ k}\Omega$$
$$R_{O\text{high}} = 2.22(1+0.05) = 2.33 \text{ k}\Omega$$

1.8



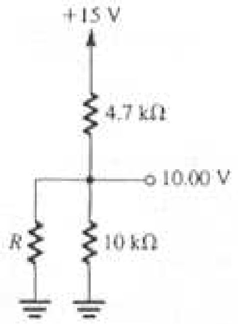
Voltages generated:

+3 V	(two ways: (a) and (c) with (c) having lower output resistance)
+4.5 V	(b)
+6 V	(two ways: (a) and (d) with (d) having a lower output resistance)

1.9

$$V_O = 15\frac{10}{10+4.7} = 10.2 \text{ V}$$

To reduce V_O to 10.00 V we shunt the 10-kΩ resistor by a resistor R whose value is such that $10 \parallel R = 2 \times 4.7$.



Thus

$$\frac{1}{10}+\frac{1}{R}=\frac{1}{9.4}$$

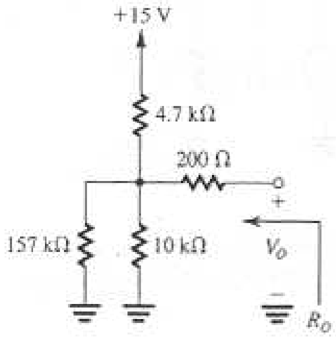
$$\Rightarrow R = 156.7 \simeq 157 \text{ k}\Omega$$

Now,

$$R_O = 10 \text{ k}\Omega \parallel R \parallel 4.7 \text{ k}\Omega$$

$$= 9.4 \parallel 4.7 = \frac{9.4}{3} = 3.133 \text{ k}\Omega$$

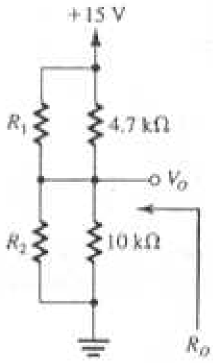
To make $R_O = 3.33$ we add a series resistance of approximately 200 Ω, as shown.



To obtain V_O = 10.00 V and R_O = 3 kΩ we have to shunt both the 4.7-kΩ and the 10-kΩ resistors as shown. To yield an output voltage V_O = 10.00 V we must have

$$\underbrace{(R_2 \parallel 10)}_{R_2'} = 2\underbrace{(R_1 \parallel 4.7)}_{R_1'}$$

$$R_2' = 2R_1' \qquad (1)$$



For R_O = 3 kΩ we must have

$$R_1' \parallel R_2'' = 3 \qquad (2)$$

Solving (1) and (2) yields

$$R_1' = 4.5 \text{ k}\Omega$$

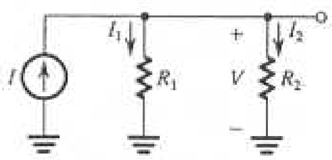
$$R_2' = 9.0 \text{ k}\Omega$$

which can be used to find R_1 and R_2 respectively,

$$R_1 = 157 \text{ k}\Omega$$

$$R_2 = 90 \text{ k}\Omega$$

1.10



$$V = I(R_1 \parallel R_2)$$

$$= I\frac{R_1R_2}{R_1+R_2}$$

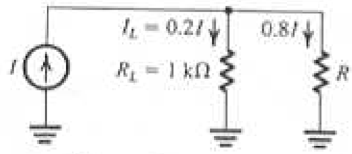
$$I_1 = \frac{V}{R_1} = I\frac{R_2}{R_1+R_2}$$

$$I_2 = \frac{V}{R_2} = I\frac{R_1}{R_1+R_2}$$

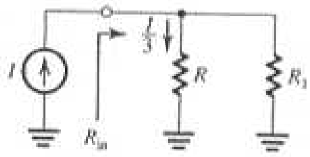
1.11 Connect a resistor R in parallel with R_L. To make $I_L = 0.2I$ (and thus the current through R, $0.8I$), R should be such

$$0.2I \times 1\ \text{k}\Omega = 0.8IR$$

$$\Rightarrow R = 250\ \Omega$$



1.12



To make the current through R equal to $I/3$ we shunt R by a resistance R_1 of value such that the current through it will be $2I/3$; thus

$$\frac{I}{3}R = \frac{2I}{3}R_1 \Rightarrow R_1 = \frac{R}{2}$$

The input resistance of the divider, R_{in}, is

$$R_{in} = R \parallel R_1 = R \parallel \frac{R}{2} = \frac{1}{3}R$$

Now if R_1 is 10% too high, i.e.,

$$R_1 = 1.1\frac{R}{2}$$

the problem can be solved in two ways:

(a) Connect a resistor R_2 across R_1 of value such that $R_1 \parallel R_2 = R/2$, thus

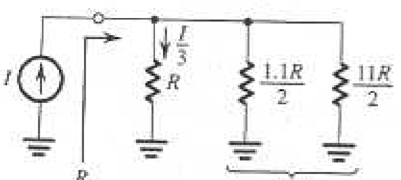
$$\frac{R_2(1.1R/2)}{R_2 + (1.1R/2)} = \frac{R}{2}$$

$$1.1R_2 = R_2 + \frac{1.1R}{2}$$

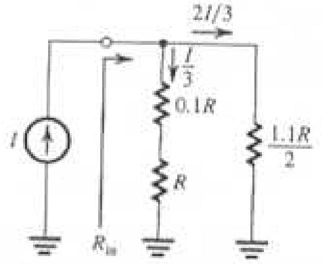
$$\Rightarrow R_2 = \frac{11R}{2} = 5.5R$$

$$R_{in} = R \parallel \frac{1.1R}{2} \parallel \frac{11R}{2}$$

$$= R \parallel \frac{R}{2} = \frac{R}{3}$$



(b) Connect a resistor in series with the load resistor R so as to raise the resistance of the load branch by 10%, thereby restoring the current division ratio to its desired value. The added series resistance must be 10% of R i.e., $0.1R$.

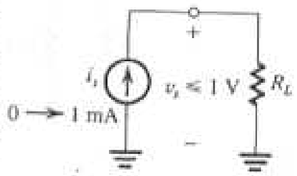


$$R_{in} = 1.1R \parallel \frac{1.1R}{2}$$

$$= \frac{1.1R}{3}$$

i.e., 10% higher than in case (a).

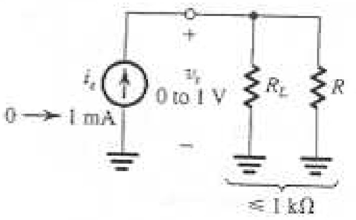
1.13 If $R_L = 10\ \text{k}\Omega$ then a voltage of 0 to 10 V may develop across the source. To limit the voltage to the specified maximum of 1 V, we have to shunt R_L with a resistor R whose value is such that the parallel combination of R_L and R is $\leq 1\ \text{k}\Omega$. Thus,



$$\frac{RR_L}{R + R_L} \leq 1$$

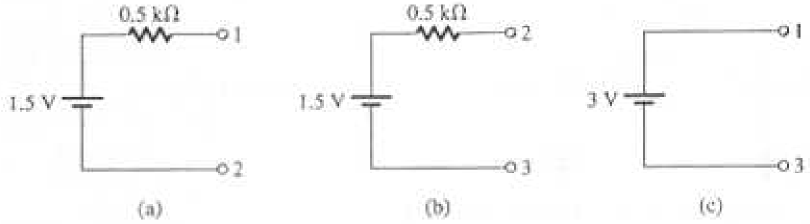
$$R \leq 1.111\ \text{k}\Omega$$

$$\Rightarrow R = 1.1\ \text{k}\Omega$$

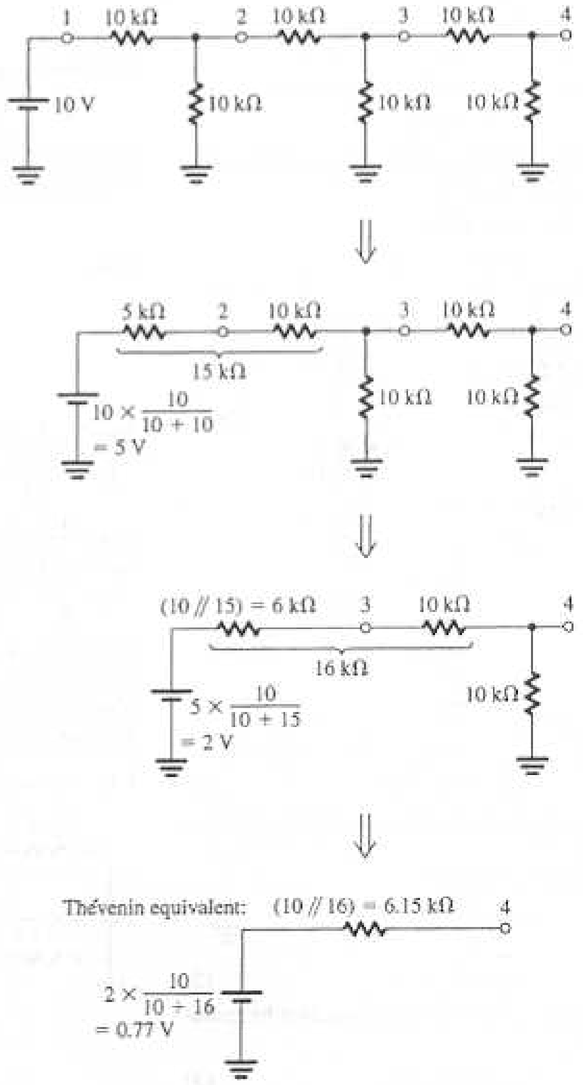


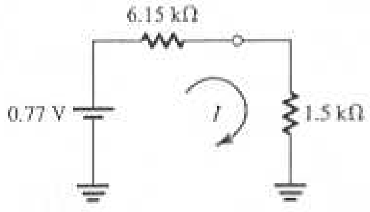
The resulting circuit, utilizing only one additional resistor of value 1.1 kΩ creates a current divider across the source.

1.14


0.5 kΩ
1
1.5 V
2
(a)
0.5 kΩ
2
1.5 V
3
(b)
1
3 V
3
(c)

1.15


1
10 kΩ
2
10 kΩ
3
10 kΩ
4
10 V
10 kΩ
10 kΩ
10 kΩ
⇓
5 kΩ
2
10 kΩ
3
10 kΩ
4
15 kΩ
10 × 10/(10 + 10) = 5 V
10 kΩ
10 kΩ
⇓
(10 // 15) = 6 kΩ
3
10 kΩ
4
16 kΩ
5 × 10/(10 + 15) = 2 V
10 kΩ
⇓
Thévenin equivalent:
(10 // 16) = 6.15 kΩ
4
2 × 10/(10 + 16) = 0.77 V



Now, when a resistance of 1.5 kΩ is connected between 4 and ground,

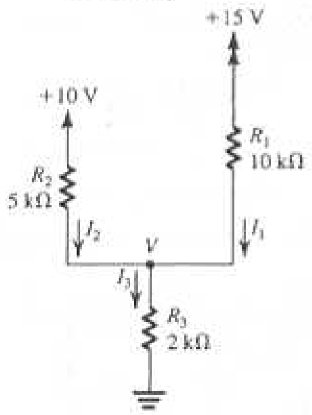
$$I = \frac{0.77}{6.15 + 1.5}$$
$$= 0.1 \text{ mA}$$

1.16 (a) Node equation at the common node yields

$$I_3 = I_1 + I_2$$

Using the fact that the sum of the voltage drops across R_1 and R_3 equals 15 V, we write

$$15 = I_1R_1 + I_3R_3$$
$$= 10I_1 + (I_1 + I_2) \times 2$$
$$= 12I_1 + 2I_2$$



That is,

$$12I_1 + 2I_2 = 15 \qquad (1)$$

Similarly, the voltage drops across R_2 and R_3 add up to 10 V, thus

$$10 = I_2R_2 + I_3R_3$$
$$= 5I_2 + (I_1 + I_2) \times 2$$

which yields

$$2I_1 + 7I_2 = 10 \qquad (2)$$

Equations (1) and (2) can be solved together by multiplying (2) by 6,

$$12I_1 + 42I_2 = 60 \qquad (3)$$

Now, subtracting (1) from (3) yields

$$40I_2 = 45$$
$$\Rightarrow I_2 = 1.125 \text{ mA}$$

Substituting in (2) gives

$$2I_1 = 10 - 7 \times 1.125 \text{ mA}$$
$$\Rightarrow I_1 = 1.0625 \text{ mA}$$
$$I_3 = I_1 + I_2$$
$$= 1.0625 + 1.1250$$
$$= 1.1875 \text{ mA}$$
$$V = I_3R_3$$
$$= 1.1875 \times 2 = 2.3750 \text{ V}$$

To summarize:

$$I_1 \simeq 1.06 \text{ mA} \qquad I_2 \simeq 1.13 \text{ mA}$$
$$I_3 \simeq 1.19 \text{ mA} \qquad V \simeq 2.38 \text{ V}$$

(b) A node equation at the common node can be written in terms of V as

$$\frac{15 - V}{R_1} + \frac{10 - V}{R_2} = \frac{V}{R_3}$$

Thus,

$$\frac{15 - V}{10} + \frac{10 - V}{5} = \frac{V}{2}$$
$$\Rightarrow 0.8V = 3.5$$
$$\Rightarrow V = 2.375 \text{ V}$$

Now, I_1, I_2, and I_3 can be easily found as

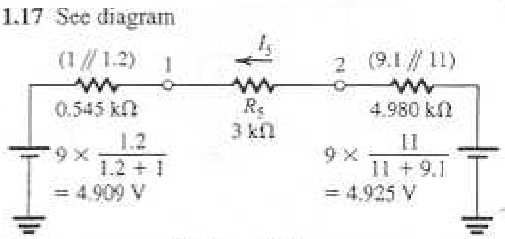
$$I_1 = \frac{15 - V}{10} = \frac{15 - 2.375}{10} = 1.0625 \text{ mA} \simeq 1.06 \text{ mA}$$

$$I_2 = \frac{10 - V}{5} = \frac{10 - 2.375}{5} = 1.125 \text{ mA} = 1.13 \text{ mA}$$

$$I_3 = \frac{V}{R_3} = \frac{2.375}{2} = 1.1875 \text{ mA} = 1.19 \text{ mA}$$

Method (b) is much preferred; faster, more insightful and less prone to errors. In general, one attempts to identify the least possible number of variables and write the corresponding minimum number of equations.

1.17 See diagram



$$I_5 = \frac{4.925 - 4.909}{4.98 + 3 + 0.545} = 1.88 \ \mu\text{A}$$

$$V_5 = 1.88 \ \mu\text{A} \times 3 \text{ k}\Omega = 5.64 \text{ mV}$$