Chapter 2

Textbook questions

Question 2-1

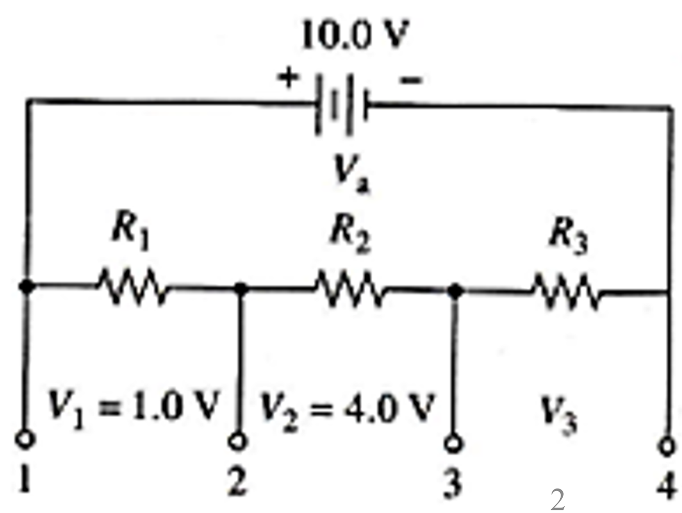
For assembling the voltage divider shown below, two of each of the following resistors are available: 250Ω, 500Ω, 1.0kΩ.

a) Describe a suitable combination of the resistors that would give the indicated voltages.

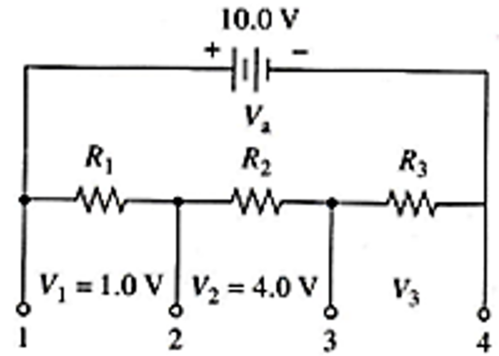
b) What would be the IR drop across R_3? Note: R_3 could be more than one resistor

c) What current would be drawn from the source?

d) What power is dissipated by the circuit?



250Ω, 500Ω, 1.0kΩ



Question 2-1 a)

Voltage divider equation: $\frac{V_1}{V} = \frac{R_1}{R_1 + R_2 + R_3}$

$V_1 = 1.0V$

$V = 10.0V$

$\frac{1}{10} = \frac{R_1}{R_1 + R_2 + R_3}$

$V_2 = 4.0V$ $\quad \frac{4}{10} = \frac{R_2}{R_1 + R_2 + R_3}$

$V_3 = ?$ $\quad V_3 = 10.0V - 1.0\ V - 4.0\ V = 5.0\ V$

$$\frac{5.0}{10} = \frac{R_3}{R_1 + R_2 + R_3}$$

Let R_1 = 250Ω

R_2 = 250 x 4 = 1000Ω = 1.0kΩ

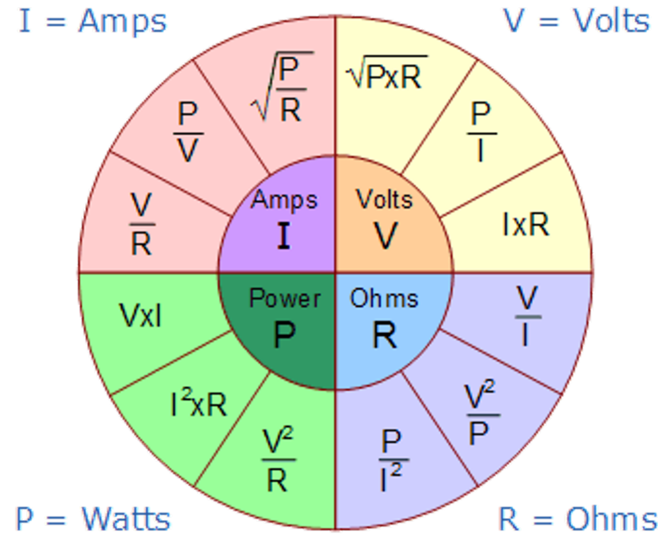
R_3 = 1000 x (5.0/4.0) = 1250Ω = 1.25kΩ

R_1/R_2 = 1.0/4.0

R_2/R_3 = 4.0/ 5.0

Therefore 250Ω and 1.0kΩ resistor are used

Question 2-1 b), c), d)



(b) $V_3 = IR_3 = 10.0\text{ V} - 1.0\text{ V} - 4.0\text{ V} = 5.0\text{ V}$

(c) $I = V/(R_1 + R_2 + R_3) = 10.0\text{ V}/(250\ \Omega + 1000\ \Omega + 1250\ \Omega) = 0.004\text{ A}\ (4.0\text{ mA})$

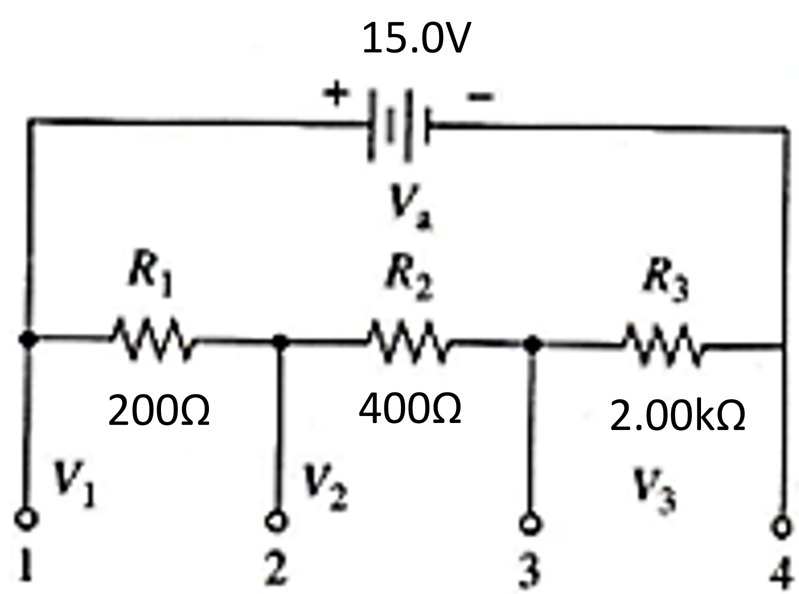
(d) $P = IV = 0.004\text{ A} \times 10.0\text{ V} = 0.04\text{ W}$ (Equation 2-2)

Question 2-2

a) What is voltage V_2?

b) What would be the power loss in resistor R_2?

c) What fraction of the total power lost by the circuit would be dissipated in resistor R_2?



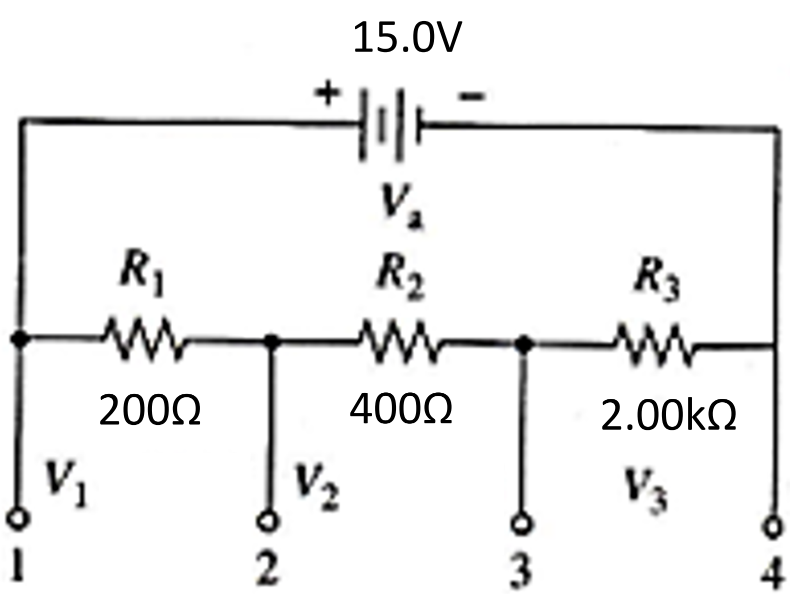
Question 2-2

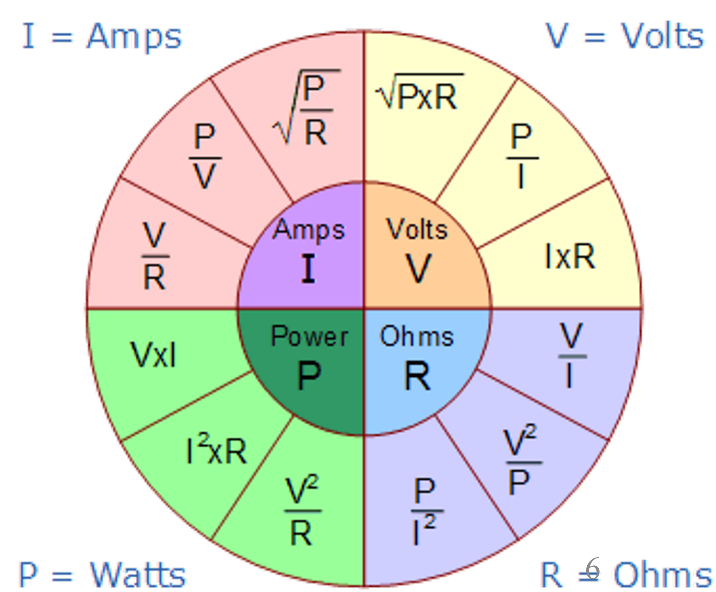
(a) From Equation 2-10, $V_2 = 15 \times 400/(200 + 400 + 2000) = 2.31$ V

(b) $P = V_2^2/R_2 = (2.31)^2/400 = 0.013$ W

(c) Total $P = V^2/R_s = (15)^2/2600 = 0.087$ W

Percentage loss in $R_2 = (0.013/0.087) \times 100 = 15\%$





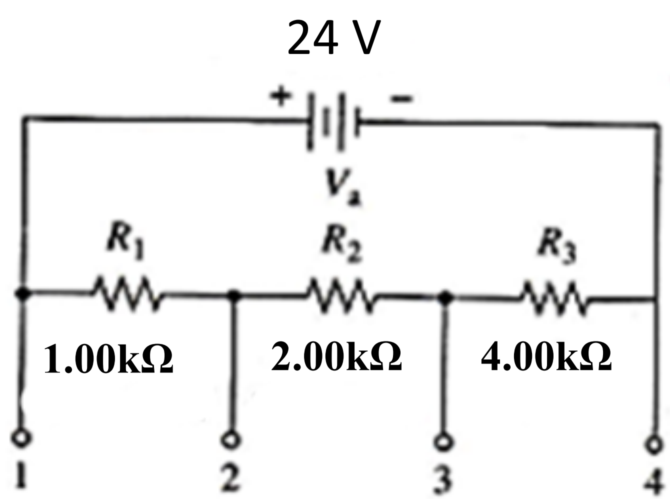
Question 2-3

For a circuit similar to the one shown in Problem 2-1, $R_1 = 1.00\ k\Omega$, $R_2 = 2.00\ k\Omega$, $R_3 = 4.00 k\Omega$, and $V_a = 24.0\ V$. A voltmeter was placed across contacts 2 and 4. Calculate the relative error in the voltage reading if the internal resistance of the voltmeter was:

a) $4000\ \Omega$

b) $80.0\ k\Omega$

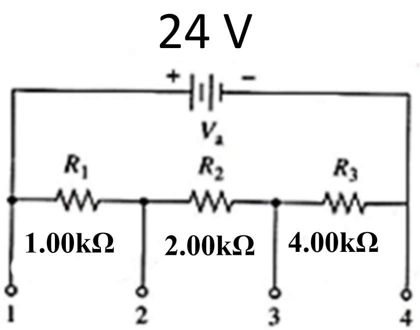
c) $1.00\ M\Omega$



Question 2-3

$$\text{Relative error} = \frac{V_{measure} - V_{Theo}}{V_{Theo}} \times 100\%$$

$$V_{2,4} = 24.0 \times [(2.0 + 4.0) \times 10^3]/[(1.0 + 2.0 + 4.0) \times 10^3] = 20.6\text{ V}$$



With the meter in parallel across contacts 2 and 4,

$$\frac{1}{R_{2,4}} = \frac{1}{(2.0 + 4.0)\text{ k}\Omega} + \frac{1}{R_M} = \frac{R_M + 6.0\text{ k}\Omega}{R_M \times 6.0\text{ k}\Omega}$$

$$R_{2,4} = (R_M \times 6.0\text{ k}\Omega)/(R_M + 6.0\text{ k}\Omega)$$

(a) $R_{2,4} = (4.0\text{ k}\Omega \times 6.0\text{ k}\Omega)/(4.0\text{ k}\Omega + 6.0\text{ k}\Omega) = 2.40\text{ k}\Omega$

$$V_M = (24.0\text{ V} \times 2.40\text{ k}\Omega)/(1.00\text{ k}\Omega + 2.40\text{ k}\Omega) = 16.9\text{ V}$$

$$\text{rel error} = \frac{16.9\text{ V} - 20.6\text{ V}}{20.6\text{ V}} \times 100\% = -18\%$$

(b) -1.2% (c) -0.2%

Question 2-4

A voltmeter was used to measure the voltage of a cell with an internal resistance of 1.00kΩ. What must the internal resistance of the meter be if the relative error in the measurement is to be less than

a) -1.0%

b) -0.10%

Question 2-4

$$E_r = \frac{-R_S}{R_M + R_S} \times 100\%$$

(a) $$-1.0\% = -\frac{1000\ \Omega}{(R_M + 1000\ \Omega)} \times 100\%$$

$$R_M = (1000 \times 100 - 1000)\ \Omega = 99000\ \Omega \text{ or } 99\ \text{k}\Omega$$

(b) $$-0.1\% = -\frac{1000\ \Omega}{(R_M + 1000\ \Omega)} \times 100\%$$

$$R_M = 999\ \text{k}\Omega$$

Chapter 3

Textbook questions

Question 3-1

An operational amplifier has output voltage limits of +13V and -14V when used with a $\pm$15V power supply. If the amplifier is used as comparator, by what amount does v+ have to exceed v- and v- have to exceed v+ for the amplifier to be at limit if the open-loop gain A is

a) 100000

b) 600000

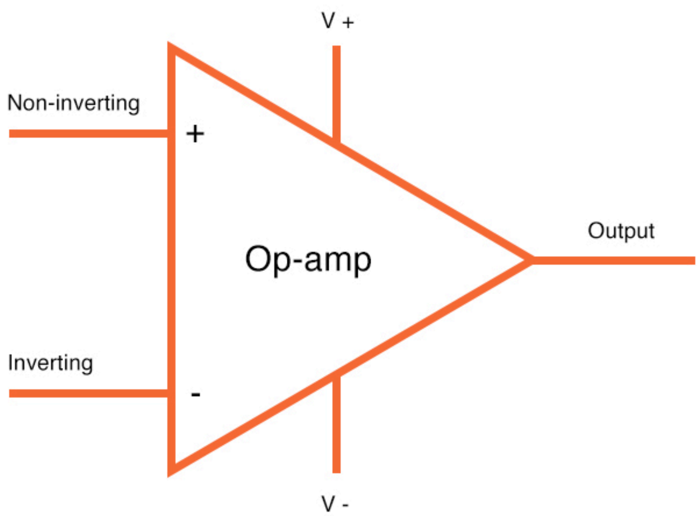
c) 2.6 x 10^6

$$v_o = Av_s$$

V_s = input difference voltage

$v_s = (v_+ - v_-)$

$$v_o = Av_s = A(v_+ - v_-)$$



https://www.allaboutcircuits.com/textbook/semiconductors/chpt-8/introduction-operational-amplifiers/

Question 3-1

$v_o = Av_s = A(v_+ - v_-)$ For + limit, $+13\text{ V} = A(v_+ - v_-)$. For – limit, $-14\text{ V} = A(v_+ - v_-)$.

(a) If $A = 100{,}000$, for + limit, $(v_+ - v_-) = 13\text{ V}/100{,}000 = 130\ \mu\text{V}$. So v_+ must exceed v_- by 130 μV for + limit to be reached.

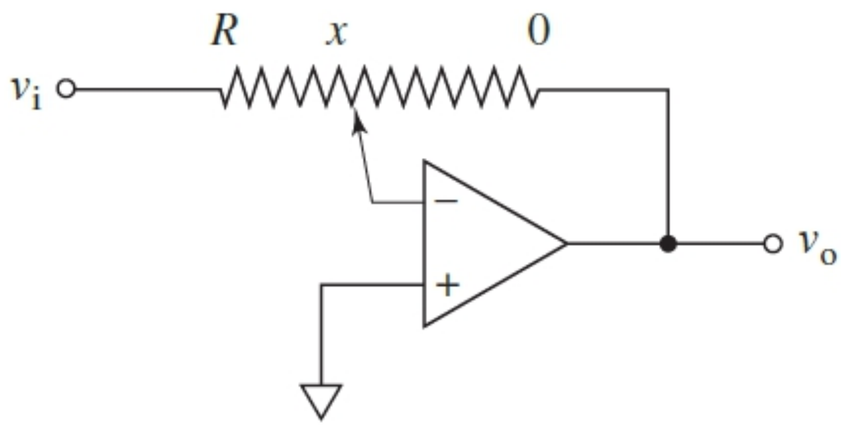
For – limit, $(v_+ - v_-) = -14\text{ V}/100{,}000 = -140\ \mu\text{V}$, v_- must exceed v_+ by 140 μV.

(b) For + limit $(v_+ - v_-) = 13\text{ V}/600{,}000 = 21.7\ \mu\text{V}$. For – limit $(v_+ - v_-) = -14\text{ V}/600{,}000 = -23.3\ \mu\text{V}$.

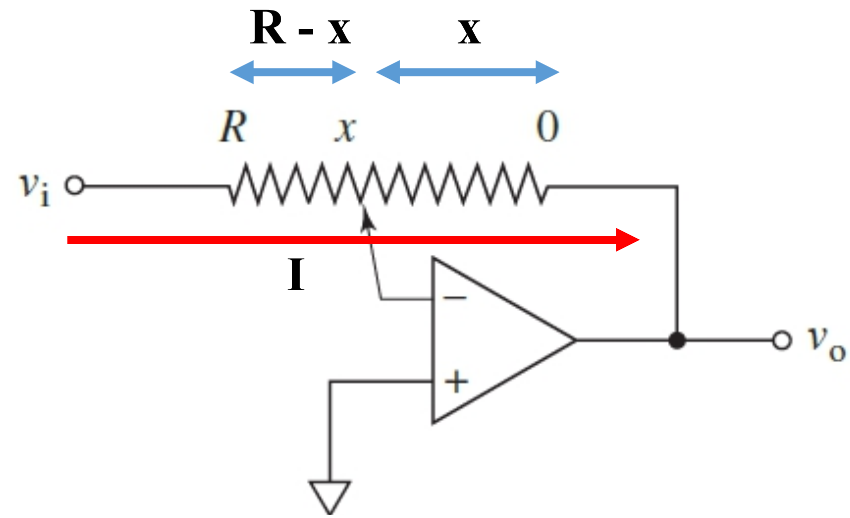
(c) + limit, $(v_+ - v_-) = 13\text{ V}/2.6 \times 10^6 = 5.0\ \mu\text{V}$; – limit, $(v_+ - v_-) = -14\text{ V}/2.6 \times 10^6 = -5.4\ \mu\text{V}$

Question 3-7

In the following circuit, R is a variable resistor. Derive an equation that describes v_o as a function of v_i and the position x of the movable contact of the voltage divider. Perform the derivation such that x is zero if there is zero resistance in the feedback loop.



Question 3-7



$$v_o = -ix$$

$$v_i = i(R - x)$$

$$\frac{v_o}{v_i} = \frac{-ix}{i(R-x)} = -\frac{x}{R-x}$$

$$v_o = -\left(\frac{x}{R-x}\right)v_i$$

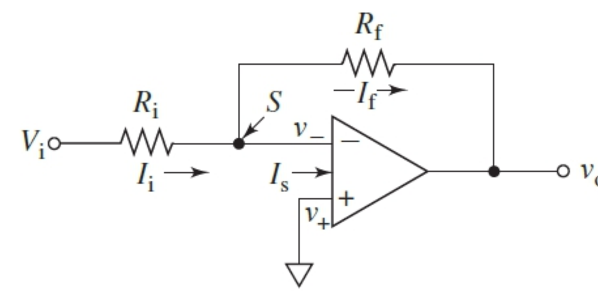


Figure 3-7