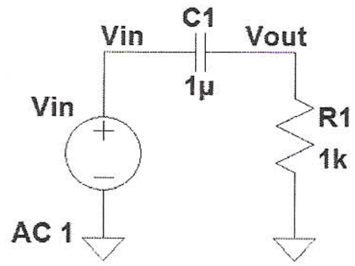
Lecture 13 Spring 2015

Midterm1 EE 320 Electronics, Spring 2015 Name: ______________________

Closed notes, open book, show your work (hand calculations, including algebra) for credit. No scratch paper is allowed.

1. Determine an equation for, and plot, the magnitude and phase response of the following circuit. Using the results from these plots sketch the circuit's input and output on the same plot in the time domain if the input signal is 1 V peak at 92 Hz. (20 points)



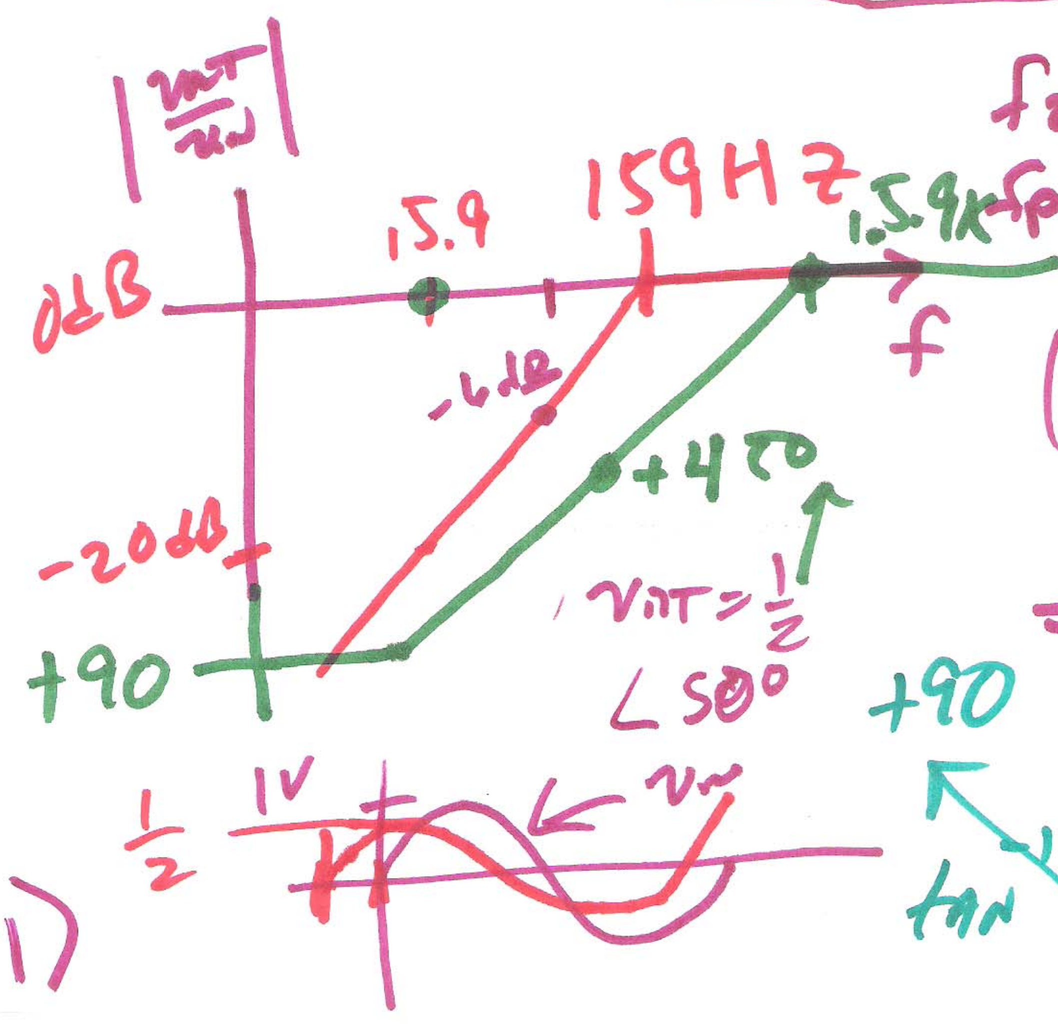
$$\frac{v_{OUT}}{v_{IN}} = \frac{1K}{1K + \frac{1}{j\omega 10^{-6}}}$$

$$\frac{v_{OUT}}{v_{IN}} = \frac{0 + j2\pi f 10^{-3}}{1 + j2\pi f \cdot 10^{-3}}$$

$f_z = 0$

$$f_p = \frac{1}{2\pi \cdot 10^{-3}} = 159$$

$$\left|\frac{v_{OUT}}{v_{IN}}\right| = \frac{2\pi f 10^{-3}}{\sqrt{1+(2\pi f 10^{-3})^2}} = \frac{\frac{f}{159}}{\sqrt{1+\left(\frac{f}{159}\right)^2}}$$

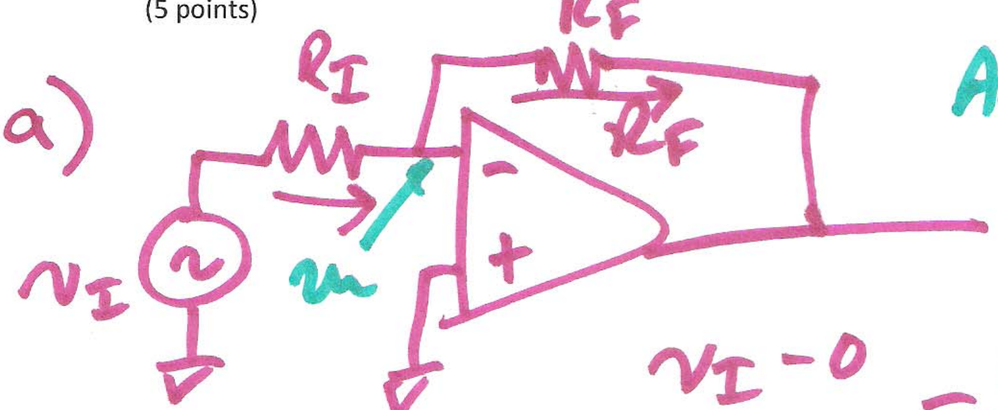


+90

$$\tan^{-1}\frac{2\pi f 10^{-3}}{0} - \tan^{-1}\frac{2\pi f 10^{-3}}{1}$$

2. Suppose an op-amp is used in an inverting amplifier configuration with a feedback resistor, R_F, and an input resistor, R_I. Show how to
   a. calculate the gain, $-R_F/R_I$, of the inverting amplifier configuration if the op-amp is ideal. (5 points)
   b. calculate the gain if the op-amp has an open-loop gain of A_{OL}. (5 points)
   c. calculate the output voltage if the input voltage is 1 V and the op-amp has an offset of 50 mV. (5 points)
   d. calculate the bandwidth of the amplifier if the op-amp's gain-bandwidth product is f_{un}. (5 points)

a)



$A_{OL}(0 - v_{in}) = v_{OUT}$

$$\frac{v_I - 0}{R_I} = \frac{0 - v_{OUT}}{R_F}$$

$$\frac{v_{OUT}}{v_{IN}} = \frac{-R_F}{R_I}$$

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b) A_{OL} = finite

$v_{OUT} = A_{OL}(-v_{in})$

$$\frac{v_I - v_{in}}{R_I} = \frac{v_{in} - v_{OUT}}{R_F}$$

$v_{in} = \frac{-v_{OUT}}{A_{OL}}$

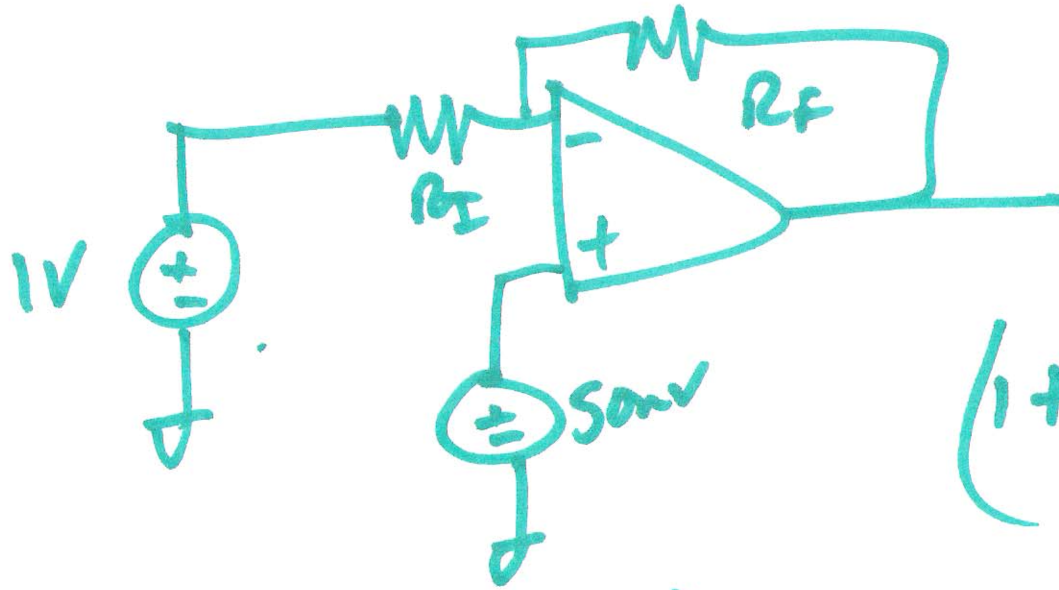
$$v_I - \left(-\frac{v_{OUT}}{A_{OL}}\right) = \frac{R_I}{R_F}\left(-\frac{v_{OUT}}{A_{OL}} - v_{OUT}\right)$$

$$v_I \cdot \frac{R_I}{R_F} = -v_{OUT}\left(\frac{R_I}{A_{OL} R_F} + \frac{1}{A_{OL}} + 1\right)$$

$$\boxed{-\frac{v_{OUT}}{v_I} = \frac{1}{A_{OL}} + \frac{R_F}{R_I} \cdot \frac{1}{A_{OL}} + \frac{R_F}{R_I}}$$

2)

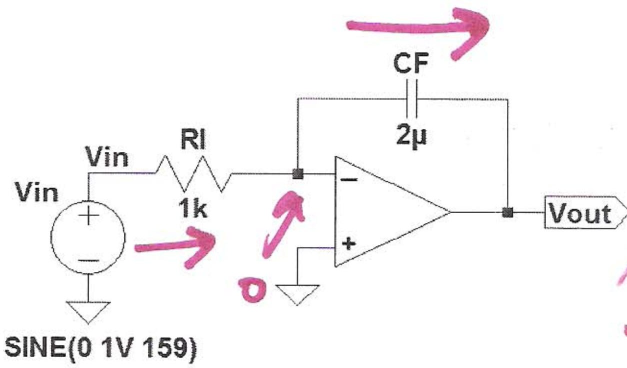
c)



$-\frac{R_F}{R_I} \cdot 1 + \left(1 + \frac{R_F}{R_I}\right) \cdot 50\,mV$

d) $f_{un} = f_{3dB} \cdot \left(\frac{R_F}{R_I}\right)$

3. The input to the integrator seen below is a sinusoid with a peak amplitude of 1 V and a frequency of 159 Hz. Calculate the amplitude and phase shift of the output voltage assuming an ideal op-amp is used. Sketch the circuits' input and output voltage on the same plot in the time domain. (20 points)



$$\frac{V_{in} - 0}{1K} = \frac{0 - V_{out}}{1/j\omega C}$$

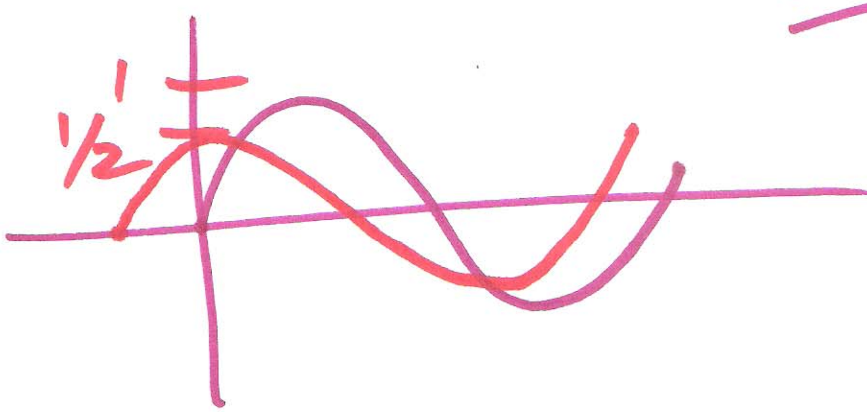
$$\frac{V_{out}}{V_{in}} = -\frac{1}{j\omega CR}$$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{2\pi \cdot 159 \cdot 2\mu \cdot 1K}$$

$$= \frac{1}{2}$$

$$\angle \frac{V_{out}}{V_{in}} = 180 - \tan^{-1}\frac{1/j\omega C}{0} \quad (90)$$

$$= +90^\circ$$



4)

4. A bar of Silicon with a thickness of 5 um, a length of 500 um, and width of 5 um is doped with 10^{16} Phosphorous atoms/cm^3. Assuming the mobility of an electron is 600 cm^2/Vs and that the intrinsic carrier concentration is 10^{11} carriers/cm^3 answer the following: (20 points)

a) What type, n or p, of semiconductor is this?

b) What are both the electron and hole concentrations?

c) What is the resistivity, ρ, of the semiconductor?

d) What is the resistance of the semiconductor bar?

e) If 1 V is applied across the piece of Si how much current flows?

f) In part e) what is the electric field throughout the Silicon bar?

a) N-type

b) $N = N_D = 10^{16} \frac{\text{electrons}}{cm^3}$, $P = \frac{N_i^2}{N} = \frac{10^{22}}{10^{16}}$

$P = 10^{6} \frac{\text{holes}}{cm^3}$

c) $\rho = \frac{1}{q(\mu_N \cdot N + \mu_P \cdot P)}$

$\rho \approx \frac{1}{q\mu_N \cdot N} = \frac{1}{1.6\times10^{-19} \cdot 600 \cdot 10^{16}}$

$= \frac{1}{1.6 \cdot .6} = 1.02\ \Omega\cdot cm$

d) $R = \frac{\rho}{t} \cdot \frac{L}{W} = \frac{1}{0.0005cm} \cdot \frac{500\mu}{5\mu}$

$= \frac{100}{.0005} = \frac{100}{5} \cdot 10^4$

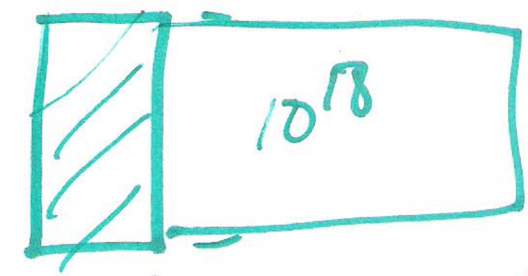
200K

e) $I = \frac{1}{200K} = 5\mu A$

f) $E = \frac{1V}{0.5\ cm} = 2\ \frac{V}{cm}$

5)

5. Work problem 3.14 on page 172 of the book. (10 points)



0.1μ

$A = 10\mu \times 10\mu$

$Q = q\,10^{18}\,cm^{-3} \cdot 10\mu \times 10\mu \times 0.1\mu$

$$Q = \frac{1.6\times10^{-19} \cdot 10^{18} \cdot 0.0001 \cdot 0.0001 \cdot 0.000001}{}$$

$$Q = 1.6\times10^{-19} \cdot \frac{10^{18}}{10^{-6}\,m} \cdot 10^{-5} \cdot 10^{-5} \cdot 10^{-7}$$

$$= 1.6\times10^{-12}\,C$$

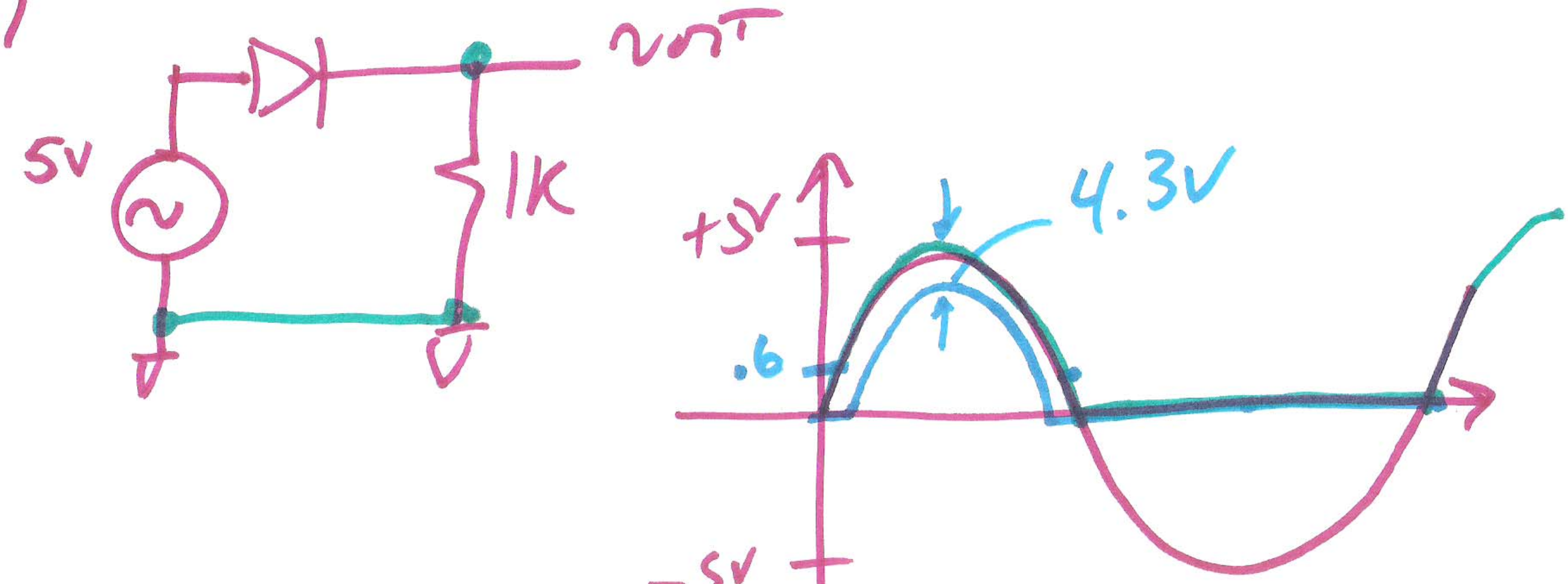
6. Work problem 3.27 on page 173 of the book. (10 points)

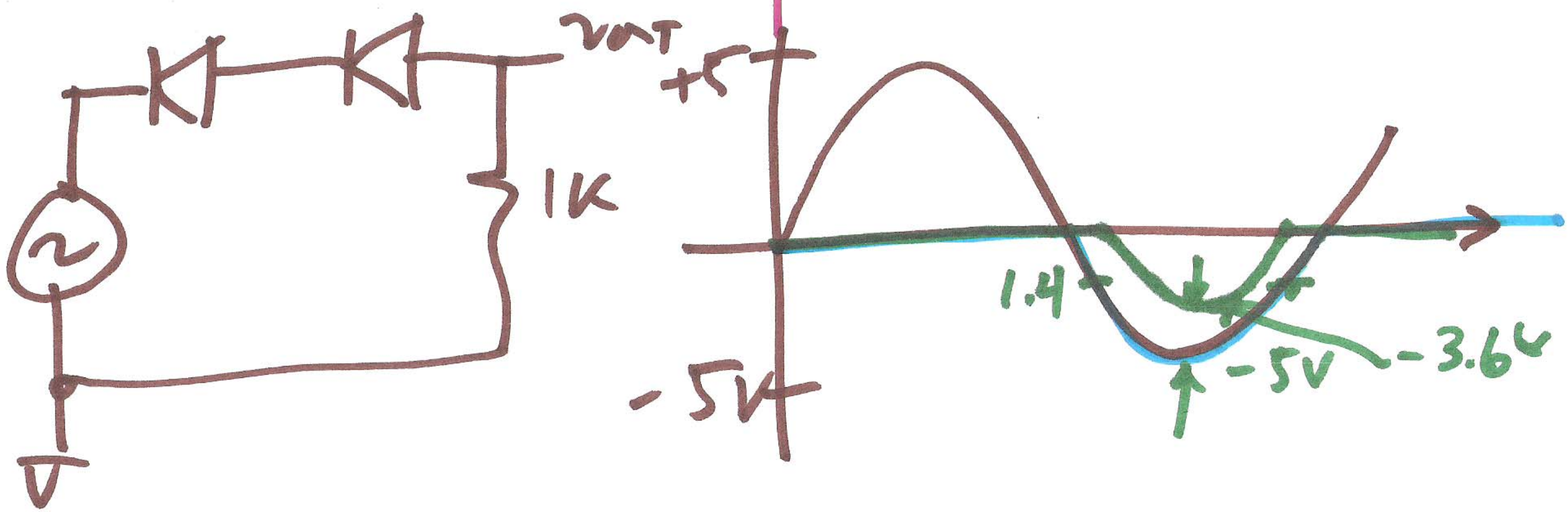
$$\tau_T = C_d \cdot \frac{V_T}{I} = 5p \cdot \frac{25mV}{1mA} = \underline{125ps}$$

$$C_d\Big|_{:1mA} = \underline{0.5pF}$$

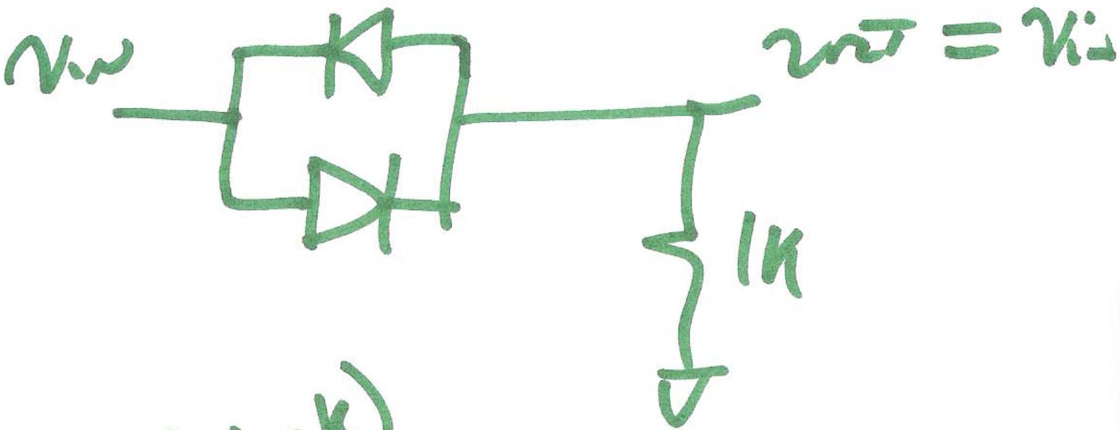
6)

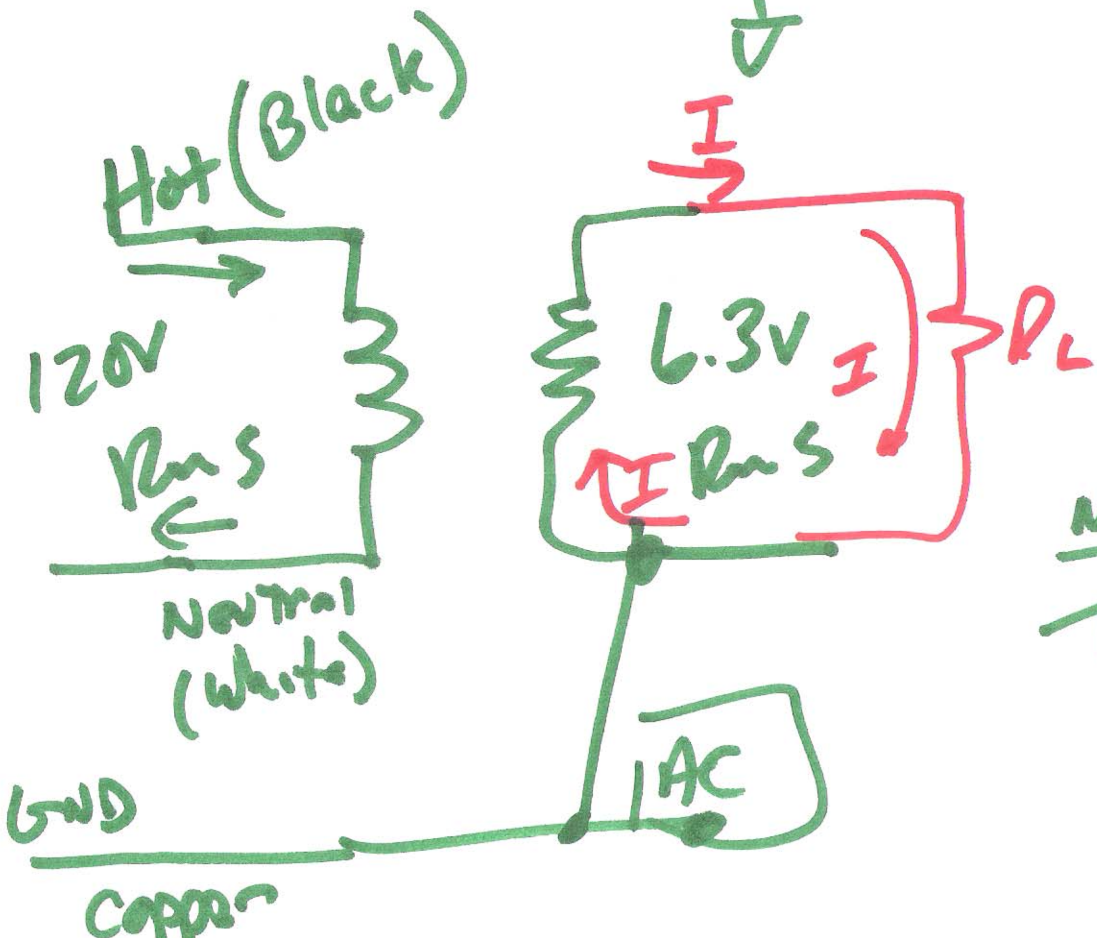
4.4)

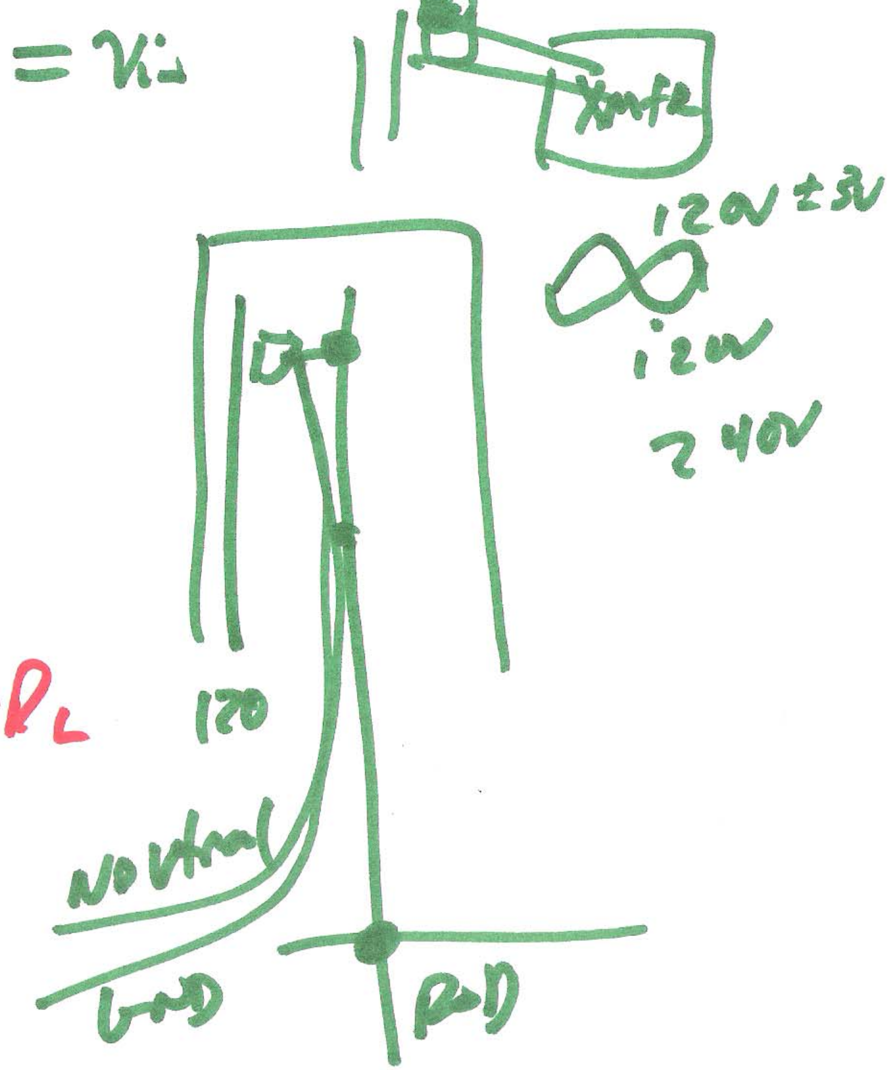




7)


Vin
1K


Hot (Black)
120V
Rms
Neutral (white)
I
6.3V
Rms
I
RL
AC
GND
copper


Xmfr
120V
240V
120
Neutral
GND
Rod