Quiz II **ECSE 1010** **Fall 2017**

Name SOLUTIONS

Section 1 or 2: MR 12 noon to 1:50pm or MR 4:00 to 5:50 pm

Part B (80 Points)

1. (10 Pts) ________
2. (15 Pts) ________
3. (10 Pts) ________
4. (25 Pts) ________
5. (10 Pts) ________
6. (10 Pts) ________

Total ________________

For partial credit where appropriate, you can draw circuit diagrams, especially as you simplify the circuits.

For partial credit annotate plots, even when the problem does not ask you to do this. It can help the grader understand where mistakes were made.

Show all of your work.

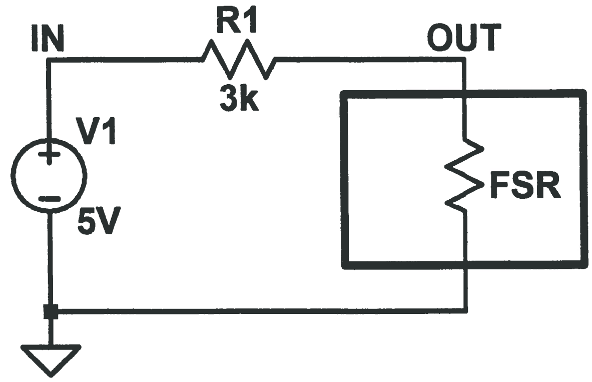
Many problems can be solved using more than one method. Check your answers by using a second method.

At least skim through the entire quiz before you begin and then start with the problems you know best.

The proctor will only answer clarification questions where wording is unclear or where there may be errors/typos. No other questions will be responded to.

Problem 1 (10 Pts) – Experimentally Determining an Input Impedance (Quiz 2 crib sheet)

Nearly all loads can be characterized by some kind of simple input impedance. For example, the two analog input channels on the Analog Discovery board have an input resistance of 1MΩ and an input capacitance of 24pF. The circuit at the right is set up to determine the resistance of a Force Sensitive Resistor (FSR) under two applied force conditions. FSR's are robust polymer thick film devices that exhibit a decrease in resistance with an increase in force applied to the surface of the sensor.



The voltage across FSR is measured using Analog Discovery when 100g and 1000g weights are placed on the FSR. The data for these two measurements are given below.

Trial	Force = m*g [kg*m/s^2]	V(OUT)
1	0.98 N	3.7603V
2	9.8 N	1.667V

a. (~~4~~ 5 Pts) Determine the unknown resistance FSR when the smaller weight is placed on sensor.

$$V_{out} = V_{in} \frac{FSR}{R1 + FSR}$$

$$3.7603 = 5 \cdot \frac{FSR}{3K + FSR} \Rightarrow FSR = 9.1 K\Omega$$

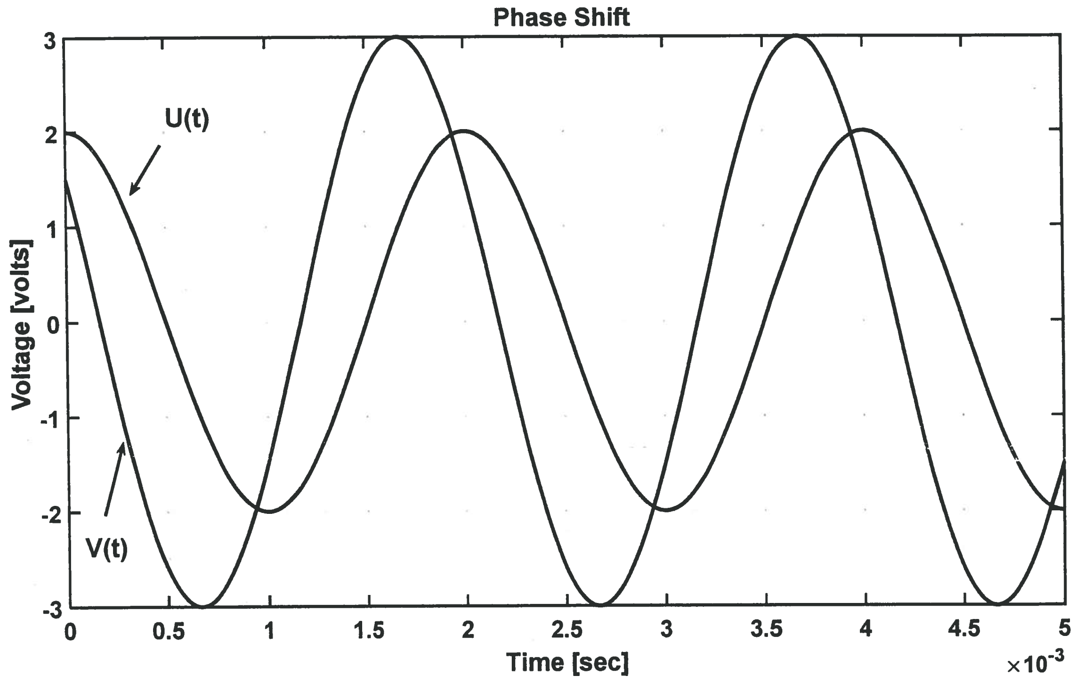
b. (~~4~~ 5 Pts) Determine the unknown resistance FSR when the heavier weight is placed on sensor.

$$V_{out} = 5 \cdot \frac{FSR}{R1 + FSR}$$

$$1.667 = 5 \cdot \frac{FSR}{R1 + FSR} \Rightarrow FSR = 1.5 K\Omega$$

~~c. (2 Pts) Which of the two measurements is more accurate (the closest, in percentage error) to the actual value?~~

Problem 2 (15 Points) – Phase (Quiz 2 crib sheet)
In the Matlab generated plot below, two cosinusoidal voltages are shown vs time. $U(t) = U_o \cos(\omega t + \theta_U)$ and $V(t) = V_o \cos(\omega t + \theta_V)$. The magnitudes of the two voltages are not the same. The vertical scale is 1V/Div and the horizontal scale is 0.5ms/Div



a. (2 Pts) Determine the frequency *f in Hertz* and radial frequency *ω in Radians.*

Time period = 2msec. ⇒ $f = \frac{1}{T}$ = 0.5KHz = 500Hz

$\omega = 2\pi f$ = 1000π rad. = 3141.6 rad.

b. (1 Pt) What is the amplitude, U_o, of *U(t)* in Volts?

2 Volts

c. (2 Pts) Assuming *U(t)* has zero phase, write the voltage as a function of time using the expression $U(t) = U_o \cos(\omega t + \theta_U)$.

$U(t) = 2\cos(1000\pi t + 0^\circ)$ Volts

d. (1 Pt) What is the phasor form of *U(t)*, $\tilde{U} = ?$

$\tilde{U} = 2e^{j0^\circ} = 2$ Volts

e. (2 Pts) Determine the phase of *V(t)* relative to *U(t)* in degrees. *Be sure to specify its sign and remember it can have any value from -360 degrees to +360 degrees.*

$\frac{\Delta t}{T} \times 2\pi = \frac{0.3ms}{2ms} \times 2\pi = 54^\circ$

$= \frac{0.4ms}{2ms} \times 2\pi = 72^\circ$

} Acceptable range of answers

More accurate

Look at V(t) at time 0.

$V(0) = 3\cos(\omega(0) + \theta_V)$

$1.5 = 3\cos(\theta_V)$

$\theta_V = 60^\circ$

f. (1 Pt) What is the amplitude of *V(t)* in Volts?

3Volts

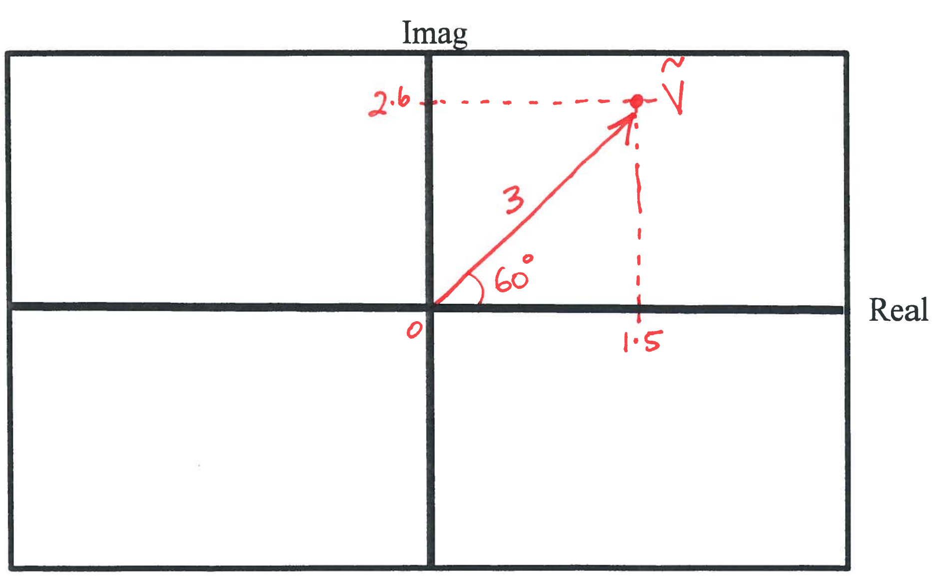
g. (2 Pts) Using your part e and f results, write the voltage, *V(t)*, as a function of time using the expression $V(t) = V_o \cos(\omega t + \theta_V)$

$V(t) = 3\cos(1000\pi t + 60^\circ)$ volts → accept 54° to 72°

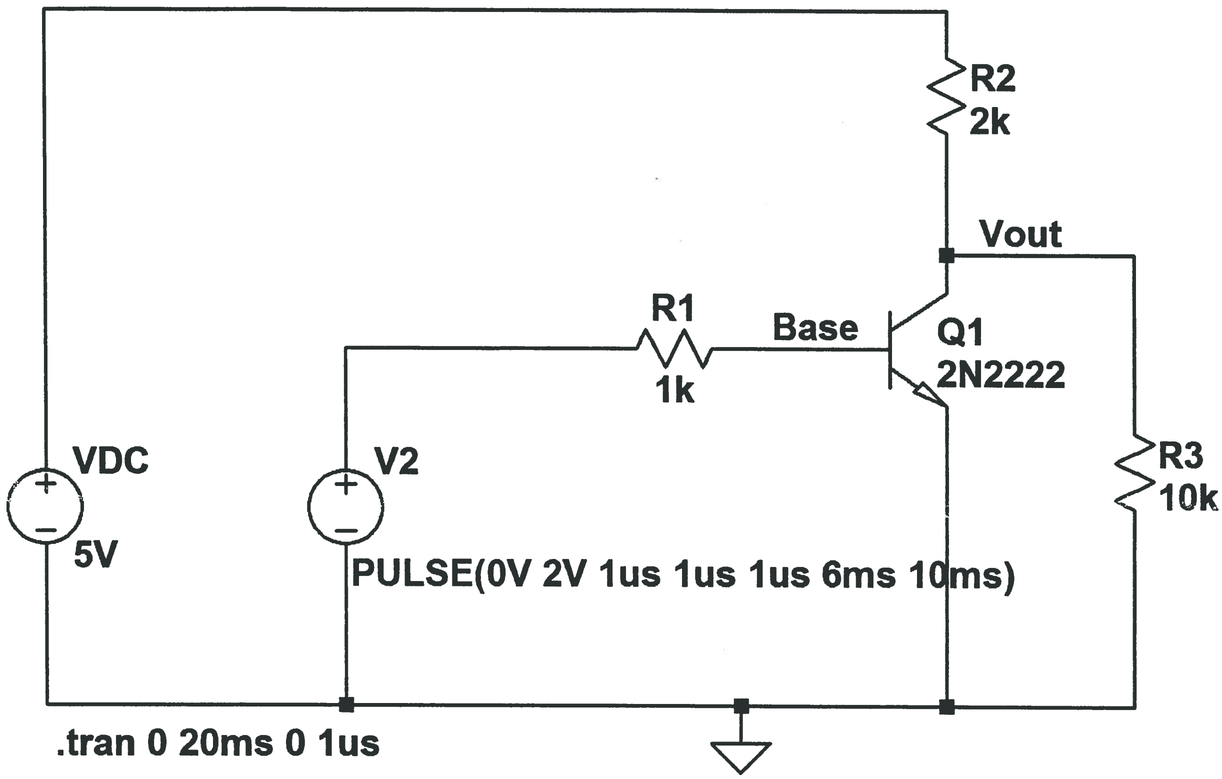
h. (2 Pts) What is the phasor form of *V(t)*, $\tilde{V} = ?$

$\tilde{V} = 3e^{j\pi/3}$ Volts

i. (2 Pts) Plot the point for the phasor voltage $\tilde{V}$ on the complex plane. *Plot the point that represents its value as a complex number. Be sure to fully label the plot.*



Problem 3 (10 Pts) – Transistor as a Switch (Quiz 2 crib sheet)
In the circuit below, the 2N2222 NPN transistor is being used as a switch. The pulsed source produces a square voltage wave with a 1.0V amplitude and a 1.0V offset. R2 = 2kΩ and R3 = 10kΩ.



a. (3 Pts) Determine the voltage across resistor R3 when the source voltage Vsource (V2) is at or near its maximum value. Is the switch ON or OFF?

Switch is ON

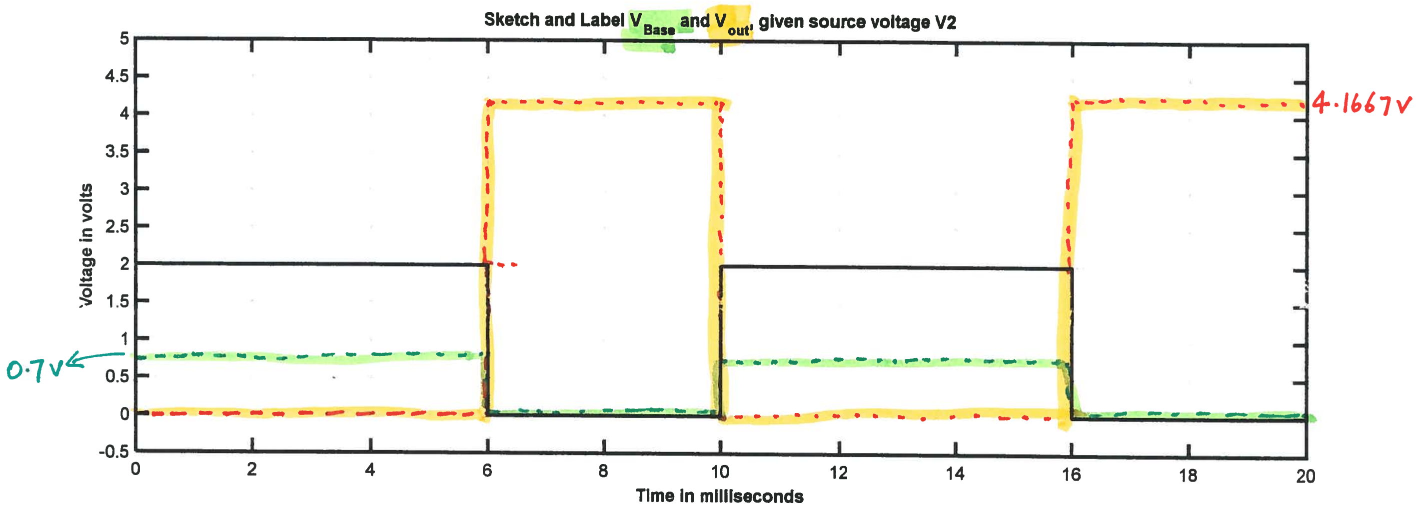
$V_{out} = V_{R3} = 0V$

b. (3 Pts) Determine the voltage across the resistor R3 when the source voltage Vsource (V2) is at or near its minimum value. Is the switch ON or OFF?

Switch is OFF

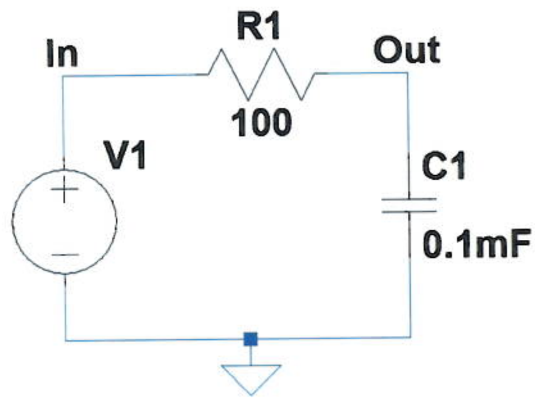
$V_{out} = VDC \times \frac{10K}{2K + 10K} = 4.1667$ Volts

c. (2 Pts) A plot of the input source voltage V2 is shown below. Sketch and label the Base voltage V(Base) and the output voltage V(Out) as functions of time on the same plot. The vertical scale is 0.5V/div and the horizontal scale is 2ms/div.



a. (2 Pts) Based on the plot of source V2 shown above, which of the following is true?
  a. The transistor is ON more than half the time
  b. The transistor is OFF more than half the time
  c. The transistor is ON half the time and OFF half the time
  d. There is not enough information to select an answer from the choices above

Problem 4 (25 Points) – Filters and Transfer Functions (Quiz 1 and Quiz 2 crib sheets)
A simple filter is configured with a capacitor and a resistor, as shown. For parts a-f of this problem, you are asked for the general questions (i.e. in terms of ω, R, C, V1, V(OUT), V(IN)). ***Do not plug in numbers until you are asked to do so.***



a. (2 Pt) When the output voltage is measured across the capacitor, is this a high pass or a low pass filter?

Lowpass

b. (2 Pt) Based on your part a answer, if the source frequency is *very small*, is the voltage across the capacitor **much less than** the source voltage or **about equal to** the source voltage?

about equal to

c. (2 Pt) Based on your part a answer, if the source frequency is *very large*, is the voltage across the capacitor **much less than** the source voltage or **about equal to** the source voltage?

much less than

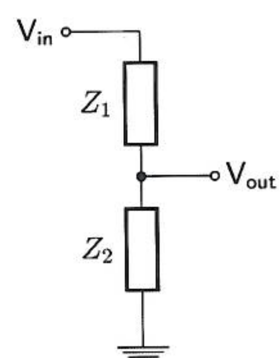
d. (2 Pts) As frequency increases, does the impedance of the resistor, Z_R, **increase**, **decrease**, or **stay the same**?

stay the same

e. (2 Pts) As frequency increases, does the impedance of the capacitor, Z_C, **increase**, **decrease**, or **stay the same**?

decrease

f. (3 Pts) This circuit is of the general form shown to the right, which is a voltage divider built with two general impedances rather than resistors. Write the general expression for V_{out} in terms of V_{in}, Z_1 and Z_2.



$$V_{out} = \frac{Z_2}{Z_2 + Z_1} V_{in}$$

or

$$V_{out} = \frac{Z_C}{Z_C + Z_R} V_{in}$$

g. (3 Pts) Using the expressions for resistor and capacitor impedances, rewrite your part f voltage divider as the transfer function, $H(j\omega)=\dfrac{\tilde{V}_{OUT}}{\tilde{V}_{IN}}=?$

$$H(j\omega)=\frac{\frac{1}{j\omega C}}{\frac{1}{j\omega C}+R} \underset{or}{=} \frac{\frac{1}{RC}}{j\omega+\frac{1}{RC}} \underset{or}{=} \frac{1}{1+j\omega RC}=\frac{1}{1+j\omega 10^{-3}}$$

h. (3 Pts) For this filter, what is the corner frequency in radians, ω_c?

$$\omega_c=\frac{1}{RC}=10^3 \text{ rad/s}$$

i. (3 pts) Find the real and imaginary parts of the transfer function when the source frequency is at the corner frequency, $\omega = \omega_c$.

$\text{Re}\{H(j\omega)\}=?$ $\frac{1}{2}$ $\text{Im}\{H(j\omega)\}=?$ $-\frac{1}{2}$

$$H(j\omega_c)=\frac{1}{1+j}$$

~~$H(j\omega_c)=\frac{1}{\sqrt{2}}$~~

$$=\frac{1-j}{(1+j)(1-j)}=\frac{1-j}{2}=\frac{1}{2}-\frac{j}{2}$$

j. (3 Pts) Using your answers to part i, write the transfer function in polar form. That is find the magnitude and phase (in radians and degrees). *Hint: The phase should be near π/n where n is some integer from 1 to 12.*

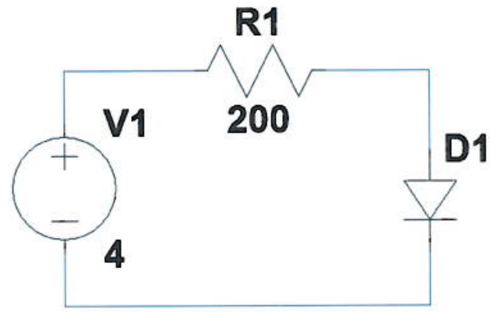
$$H(j\omega)=|H(j\omega)|e^{j\theta_H}=? \quad = \frac{1}{\sqrt{2}}e^{-j\frac{\pi}{4}}$$

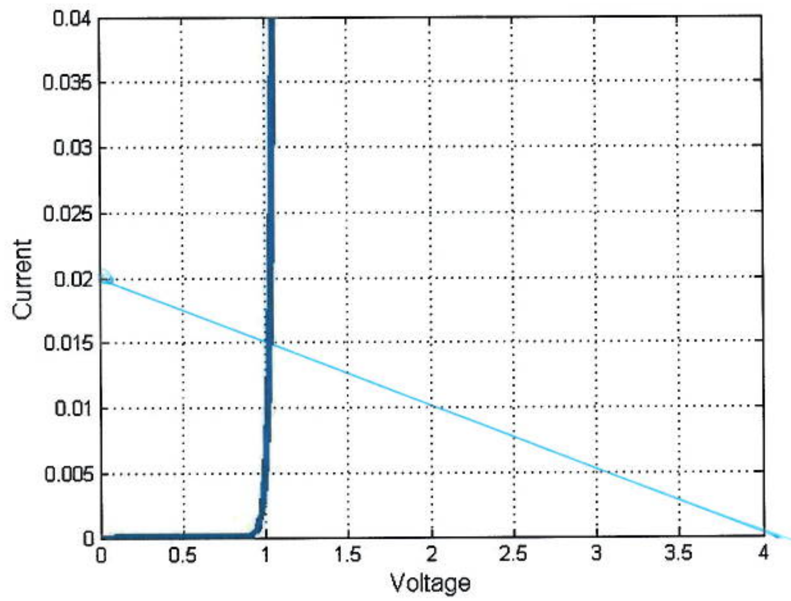
$$|H(j\omega_c)|=\left[\left(\frac{1}{2}\right)^2+\left(\frac{1}{2}\right)^2\right]^{\frac{1}{2}}=\frac{1}{\sqrt{2}}$$

$$\angle H(j\omega_c)=\tan^{-1}\left(\frac{-\frac{1}{2}}{\frac{1}{2}}\right)=-45^\circ \text{ or } -\frac{\pi}{4}$$

Problem 5 (10 Pts) – Load Lines (Quiz 2 crib sheet)

The I-V (current-voltage) characteristics of the diode in the circuit to the right are shown below. The circuit has a 4V source and a 200Ω resistor.





a. (3 Pts) Determine the expression for the load line, I = ?

$$I_D = \frac{V - V_{Diode}}{R_1} = \frac{4 - V_{Diode}}{200}$$

b. (3 Pts) Draw the load line on the same graph with the diode I-V plot. (as above)

c. (2 Pts) Based on your part b graph, approximately determine the diode voltage and diode current for this circuit.

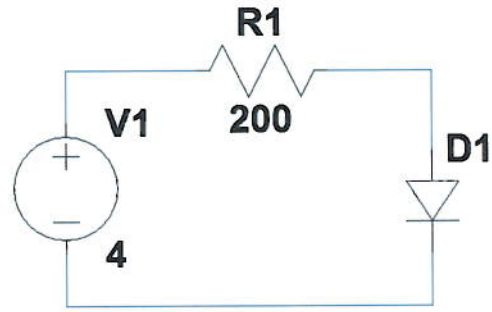
V_D = 1 V I_D = 0.015 A or 15 mA

d. (2 Pts) The diode I–V plot was generated using the expression $I_D = I_S\left(e^{V_D / nVthermal} - 1\right)$. If I_S increases, will the diode I–V plot shift to the 'left' or to the 'right'?

As I_S increases the curve shifts to the left

Problem 6 (10 Pts) – Diodes, Current, Voltage and Power (Quiz 1 crib sheet)

The voltage source is DC and equal to 4V. The resistor R1 is 200Ω. The diode model is a simplified model, as seen in the Quiz 1 crib sheet.



a. (1 Pt) If the diode model is ideal, what is the voltage across the resistor, R1?

$V_D = 0V$

$\Rightarrow V_R = 4V$

b. (2 pts) If the diode model is ideal (as in part a), what is the current through the diode?

$I_D = I_R = \frac{V_R}{R} = \frac{4}{200} = 0.02A$ or $20mA$

c. (1 Pts) If the diode is a green LED with an on voltage of 1.8V, what is the voltage across the resistor, R1?

$V_{R1} = V_1 - V_{D1} = 4 - 1.8 = \underline{2.2V}$

d. (2 Pts) For the same green LED (as in part c), what is the current through the diode?

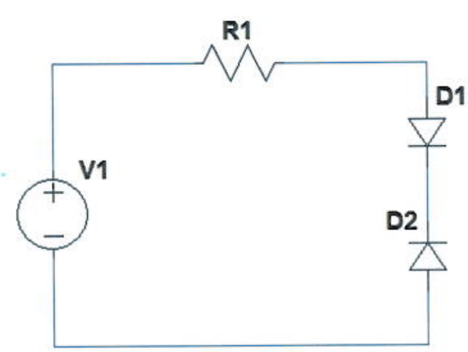
$I_D = I_R = \frac{V_R}{R} = \frac{2.2}{200} = 0.011A$ or $1.1mA$

e. (1 pt) For the same green LED, if the source voltage increases, will the diode get brighter or dimmer?

Current increases, so the LED will get brighter

For the two diode circuit shown to the right.

f. (3 Pt) Briefly explain why no current flows.



Current flows from the anode to the cathode only. In this case one diode will always 'block' the current, no matter what the source voltage is.