Project #6 – Introductory Circuit Analysis

Names: ________________________________ Date: ______________________

Class Session (Please check one) ☐ 11AM ☐ 1PM Group & Kit Number: __________

TASK

<u>Instructions</u>: Please complete the following questions to successfully complete this project. Please make sure that all major steps are shown for full credit. If you have any questions, please ask a TA for help. The following equations will be handy in solving some of the problems:

Resistors in Series: $\mathbf{R_T = R_1 + R_2 + R_3 + \ldots..R_N}$

Resistors in Parallel: $\mathbf{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots.. \frac{1}{R_N}} \rightarrow \mathbf{R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots.\frac{1}{R_N}\right)^{-1}}$

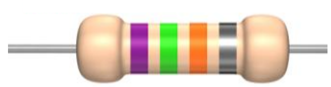
Two resistors in Parallel: $\mathbf{R_{12} = \frac{R_1 R_2}{R_1 + R_2}}$

Voltage Division: $\boldsymbol{V_{out} = V_{in}\left(\frac{R_2}{R_1 + R_2}\right)}$

Ohm's Law: $\mathbf{V = IR}$

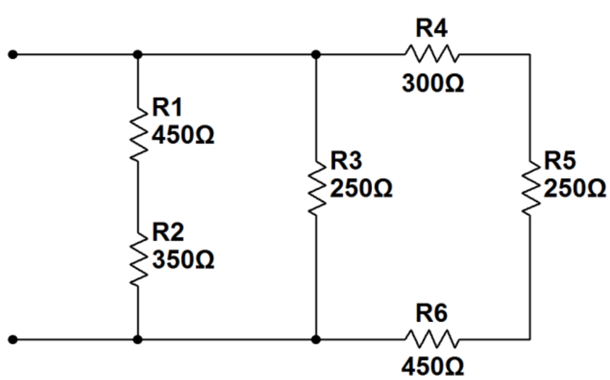
Power: $\mathbf{P = VI} \rightarrow \mathbf{P = \frac{V^2}{R}} \rightarrow \mathbf{P = I^2R}$

1) Determine the resistance value of each resistor shown below (include tolerance):



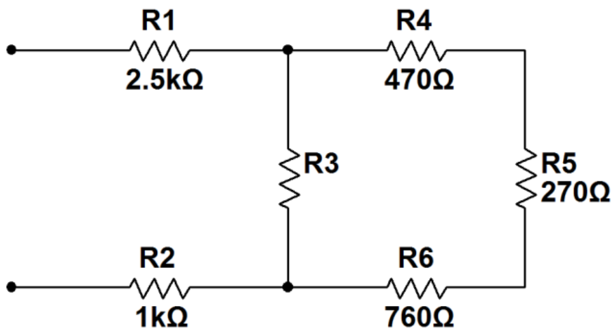
R = __________________ R = __________________ R = ___________________

2) Determine the equivalent resistance in the network shown:



R_{eq} = ____________

3) It has been determined that the equivalent resistance for the following network to be **4.5kΩ**. Determine the resistance value of R3 below:



R3 = ____________________

4) Using your DMM, measure each resistor found in your electrical kit based on the theoretical value given and then compute the percent error between the measured and the theoretical values:

$R1_{meas}$ = ________________ $R1_{theo}$ = ________________ %error = ________________

$R2_{meas}$ = ________________ $R2_{theo}$ = ________________ %error = ________________

$R3_{meas}$ = ________________ $R3_{theo}$ = ________________ %error = ________________

5) Why do resistors have a tolerance band on them? Does this explain why your results are within the expected range? Explain in 1-2 sentences why:

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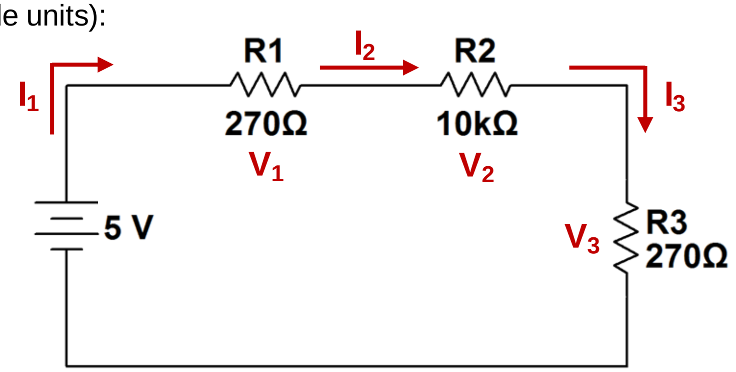
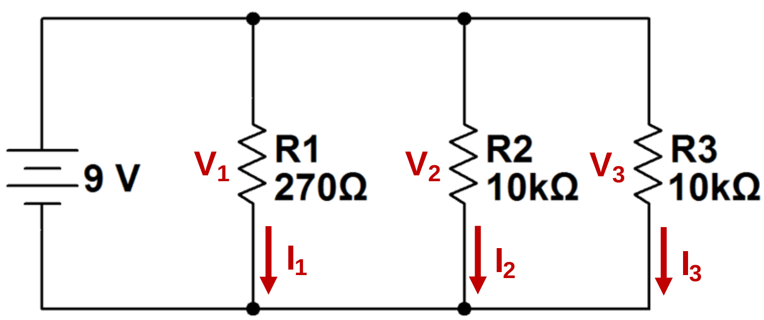
6) Build the circuit as shown on a breadboard and measure the voltage and current flow across each resistor. Use the Arduino for the 5V input. Finally, compute the power dissipated in each resistor (include units):



V_1 = ____________	I_1 = ____________	P_1 = ____________
V_2 = ____________	I_2 = ____________	P_2 = ____________
V_3 = ____________	I_3 = ____________	P_3 = ____________
V_T = ____________	I_T = ____________	P_T = ____________

Does the total voltage drop match the input voltage? What can be said about current in a series circuit?

7) **Repeat** the same step for the following circuit. Use your **9V battery** for the voltage input. Note that the voltage will not be the same for everyone. Therefore, use the DMM to measure the voltage of the battery and indicate its value for V_{batt} below:



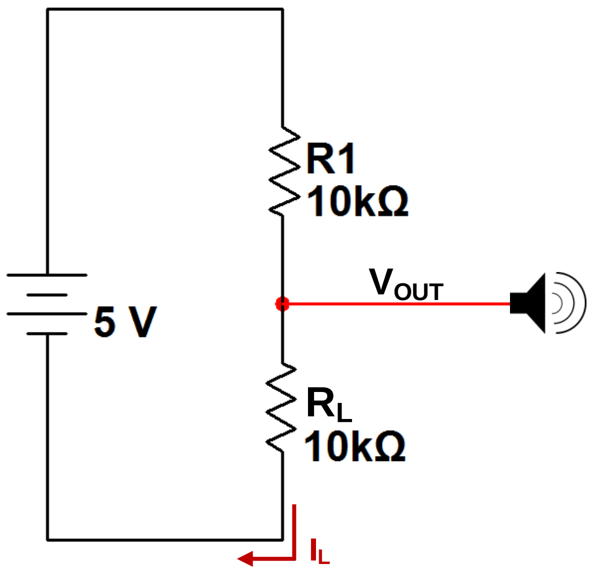
V_{batt} = ____________

V_1 = ____________	I_1 = ____________	P_1 = ____________
V_2 = ____________	I_2 = ____________	P_2 = ____________
V_3 = ____________	I_3 = ____________	P_3 = ____________
	I_T = ____________	

What can be said about current in a parallel circuit? Is the equivalent resistance less than the lowest resistor value observed?

8) In many circuit problems, a **"load resistor"** is used to test for various values such as voltage or current flow. Think of it as a replacement for an actual component to be placed in a design. They are also used to drive a load for an amplifier or speaker based on the power desired. For the following circuit, we require a speaker to activate but it requires a voltage less than 5V. Determine the voltage output for R_1 by manual calculation and the current where indicated. Build the circuit using the resistors you have and determine the voltage output for the load using the DMM.

Compute the percent error and determine what principle is being applied here. Are the experimental results within acceptable range? (Percentage error below 10% is acceptable). Based on the results, what is the input voltage for the speaker as shown? Finally, determine the power absorbed by the load.



$V(R_1)$ = ________________

$V(R_{load})$ = ________________

I_L (calculated) = ________________

I_L (DMM) = ________________

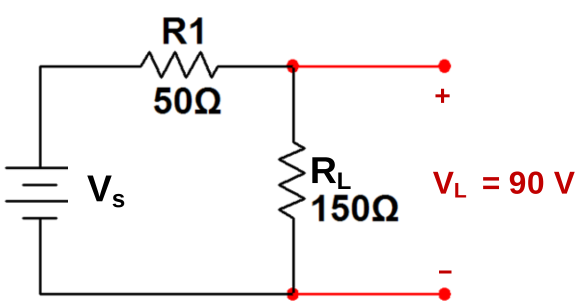
V_{out} (calculated) = ________________

V_{out} (DMM) = ________________

% error (V_{out}) = ________________

P_L = ________________

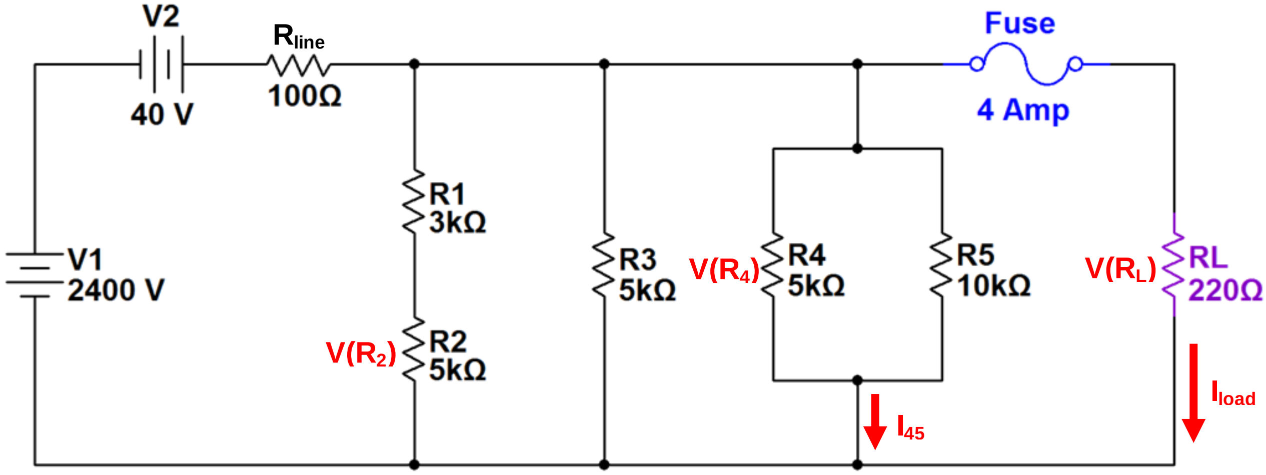
9) Determine V_S based on the given information from the circuit below:



V_s = ________________

10) In almost all electrical applications, it is important to monitor the amount of current flowing in the system. Many systems have a **fuse** installed to limit the amount of current entering the circuit. A fuse is nothing more than a short length of wire designed to melt and separate in the event of excess current. If the input current is **higher** than the tolerance of the fuse, the fuse will blow which will stop the flow of current coming in to the circuit.

In the circuit below, a load resistor is used as a replacement for a backup generator, in which it requires 3.5A to begin charging. A **4 amp fuse** is placed before the load as protection, in case the current exceeds the maximum tolerance of 3.76 Amps. Based on the circuit below, will the fuse be intact and what will the current and voltage be for the load resistor? Also, determine the total current for the entire circuit, as well as the indicated voltages and current shown in red. Note that the DC voltage is from an electromechanical generator in which there is a line resistance of 100Ω after the 2nd generator.

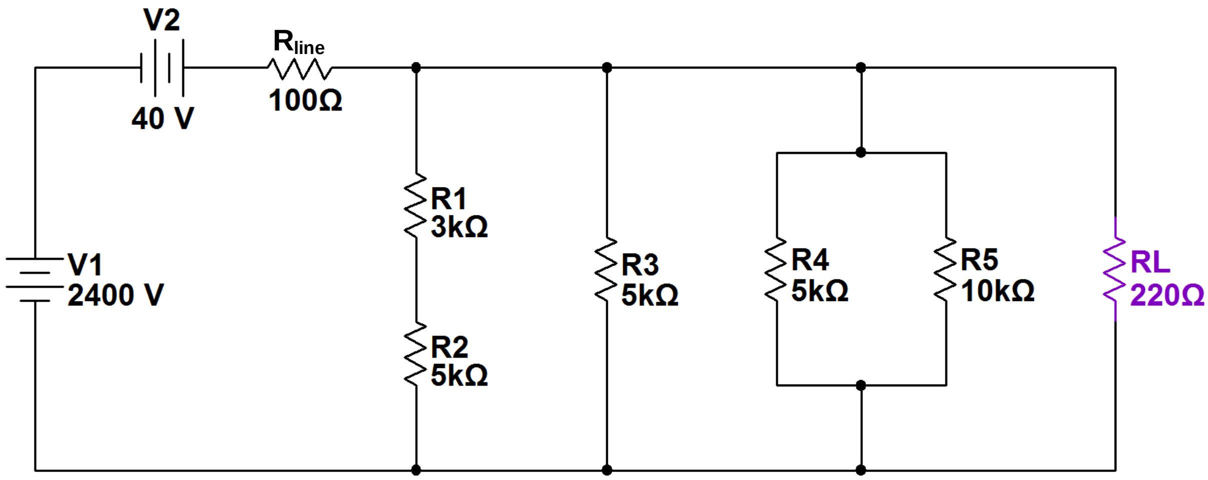


Voltage and Current across R_{load}: ____________ Total Current in Circuit: __________

Voltage at R4: ________ R2: __________ Current flow for I_{45}: ____________

11) Let's recall the same circuit used in Question 3 provided below. The fuse is no longer necessary and is removed. Can the circuit be redesigned so that the input voltage to the **load resistor is 1.50 kV**? Describe or show some manual calculation to prove your design. All ideas will be accepted given it's an open ended design problem given you can prove your design theory and why it may work.

Note: The input voltage and the resistor values **cannot** be altered. You can add voltage sources, add resistors, or remove any. Think critically – there's an easy and hard way to obtain the desired voltage!



12) Using the intuition learned from previous Arduino projects, describe what the code is doing and what electrical components are being used. For starters, a DC motor fan is being used and so is a transistor (Project #2). Note that that the photoresistor and resistor arrangement is in the same orientation as in Project #6, supplied with 5V:

```
int lightPin = 0;  //Analog A0 is being used for the photoresistor and 10K resistor (voltage division)
int transistorPin = 3; // PWM Pin 3 connected to the transistor
int ledred = 13; // Pin 13 will be the red LED
int ledgreen = 12; // Pin 12 will be the green LED
int photovalue = 0;  //initial value set at 0 which will store the value from pin A0 (Analog pin)
int regulator = 0;  //regulator will be used to regulate the PWM signal for the transistor when supplying
                    //voltage to the attached DC Motor fan (9V is used for the power)
void setup() {
   // set the transistor pin as output:
  pinMode(transistorPin, OUTPUT);
  pinMode(ledred, OUTPUT); pinMode(ledgreen, OUTPUT);
  Serial.begin(9600);  Serial.print("Values detected by Photoresistor");
}

void loop(){

  photovalue = analogRead(lightPin);
  Serial.println(photovalue);

  photovalue = photovalue / 4;  // value needs to be divided by 4 for transistor since 255 is max value
  regulator = 255 - photovalue;
  analogWrite(transistorPin, regulator);

  if (photovalue >= 70)
  {
   digitalWrite(ledred, HIGH); delay(photovalue); digitalWrite(ledred, LOW); delay(photovalue);
  }

  else
  {
   digitalWrite(ledgreen, HIGH); digitalWrite(ledred, LOW);
  }
}
```

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13) Solve for x and y below. These are the type of questions that are asked in C programming courses, so practice them! Use the "for-loop" guide on Blackboard and the "for-loop" guide on the Arduino reference page online as to how a "for-loop" functions. (**Hint**: It's not as hard as it looks - just take it a step at a time!)

```
void loop()
{
  int x=0;
  for (int i=0; i<4; i++)
  {
    x = (i+1)*2 + x;
  }

  int y=0;
  for (int k=0; k<3, k++)
  {
    y = (k/2)*(x-y);
  }

  y = 15 + y;
}
```

x = ______________   y = ________________

Tip: Notice how all the mathematical (arithmetic) operators in C++ programming are being used. What are all the mathematical operators present in the above code? (There is something called the *modulo*, %, but will be ignored for this question.)

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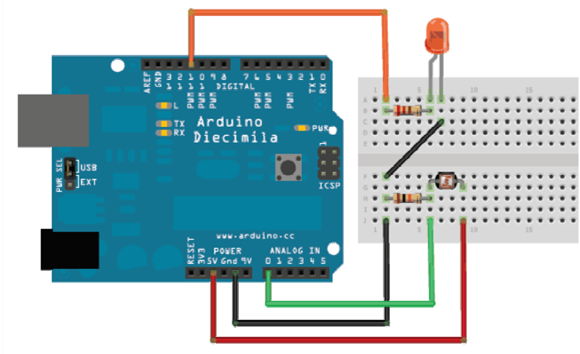
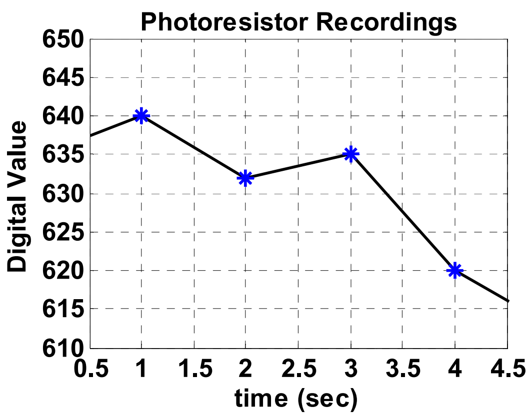
14) In the photoresistor project, we observed the digital values in the serial monitor based on the voltage division between the 10K resistor and the photoresistor in series formation as shown below:



But how are these digital values being actually calculated? This conversion follows a principal called Analog to Digital conversion (AD). An Arduino supplies 5V, whose corresponding digital value is 1023. If the voltage is 0, the digital value will be 0. If the input voltage into the Arduino was 2.5V, the digital value would be 512.

Data from a photoresistor was recorded from a random 4 second window, in which the graph below shows the digital value for each second recorded. Based on the given information, determine the input voltage into the Arduino based on the way they are connected above. What is the voltage across the photoresistor at the time? Can the resistance value of the photoresistor be determined for this problem? What can be said about the surrounding environment of the setup: do you think it was super bright, bright, semi-dark, dark etc.



Estimated Input Voltage = ____________

V(Photoresistor) = _______________

R(Photoresistor) = _______________

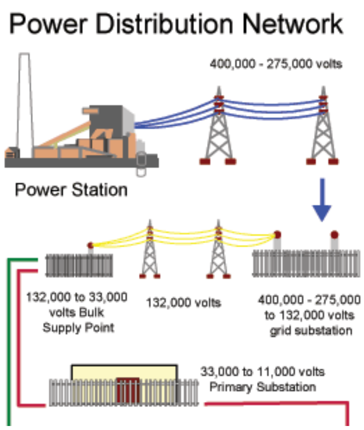
Extra Credit – Critical Analysis

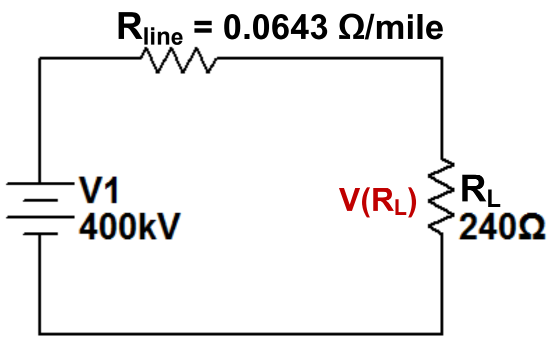
The following problems are not required to complete this assignment, but can be completed for extra credit with points rewarded for each question. You must show all major steps to receive credit for the 2 questions asked. A maximum score of 14 can be achieved in this assignment, with 2 extra points for the extra credit.

Question 1 (1 point):

Here's a real life application problem: You're a power engineer and you want to assess a transmission line that is connected between a power station and a county substation. The transmission line (basically a specialized cable carrying current and voltage between two locations) is carrying a high voltage level of **400 kV DC** (the nominal voltage all American energy companies output from their stations). A load has been placed **350 miles away** from the power company and they want to determine the power delivered to the load to see if the transmission line is working properly.

Unfortunately, there is always some resistance in transmission lines which prohibits a lossless power transmission between the two stations. In this case, the line resistance has been determined to be **0.0643 Ω/mile**. The load is determined to be **240 Ω**. For your convenience, an example of a power distribution network is shown as well as the equivalent network for the system described:



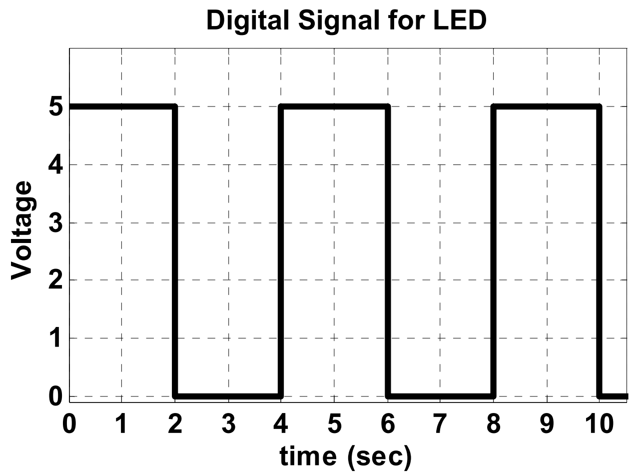


350-mile transmission line

Determine the voltage across the load, the power absorbed by the load, and the power loss in the transmission line. (Power loss = $P_{input} - P_{load}$)

Question 2 (1 point):

For the Arduino projects, we only made the LED either turn on or turn off, or blink based on a delay argument that was specified. For example, if we wanted an LED to blink **every 2 seconds**, the digital pins would output this characteristic:



Whenever "HIGH" was specified in the code, **5V** was applied to the LED; conversely, "LOW" meant **0V**. Suppose the code below was uploaded to the Arduino board with an LED attached to Pin 11 (PWM). What behavior would the LED show? (**Hint**: "float" is a data type in which the numbers contain decimals as opposed to just integer values).

```
int led = 11;
float sinValue;
int ledValue;

void setup() {
pinMode(led, OUTPUT);
}

void loop() {
for (int x=0; x<180; x++)
  {
   // convert degrees to radians then obtain sin value
   sinValue = (sin(x*(3.1412/180)));
   ledValue = int(sinValue*255);
   analogWrite(led, ledValue);
   delay(25);
   }
}
```