C - Detector Building - Rickards Invitational Div. C - 12-05-2020

Hello there! Welcome to the Rickards Invitational. You have 50 minutes to complete the following test, good luck! Remember to read instructions for fill in the blank questions carefully.

SECTION 1: RESISTANCE, TEMPERATURE, AND VOLTAGE

1. (3.00 pts)
A conductor has a resistance of 50 ohms at 20° Celsius. At 50° Celsius the same conductor has a resistance of 56.462 ohms. What element is the conductor made of? Put your answer in all lowercase in the blank.

Aluminum

2. (5.00 pts) The thermoelectric effect states that a temperature gradient can cause an electric potential. At an atomic level, why does this happen?

Expected Answer: +2) For noting that charge carriers move when a temperature gradient is applied. (Only give 1 point if they say electron with no mention of either holes or charge carriers) +3) For noting that the movement is caused because the heat makes the carriers diffuse to the other side since the thermal energy causes the charge carriers to move and spread apart from each-other. Full points for any analogy comparing this to a gas scenario.

3. (4.00 pts) All or nothing, arrange the following elements such that they follow their order in the thermoelectric series.

Nickel, Lead, Copper, Iron, Zinc, Bismuth

Expected Answer: Bismuth, Nickel, Copper, Lead, Zinc, Iron

4. (7.00 pts)
Farzan passes a voltage through two different alloy wires connected to each-other at a junction. One alloy has electrons at a higher energy level than the other. Explain what happens to the electrons and the two alloys regarding their temperature and explain why this happens at an atomic level. Also make sure to note the name of the effect that occurs (Be specific)

Expected Answer: +2) For saying that when we pass a voltage the electrons flow from one of the alloys to the other. +2) For saying that when electrons transfer from the alloy with a higher energy level to the lower one, there is a gain in energy in the alloy with the lower energy level. This causes that alloy to heat up and increase the temperature. +2) For saying that when the electrons travel from the alloy with the lower energy level across to the other alloy, they lose energy thus cooling the alloy with the higher energy level. +1) For saying that this is the Peltier Effect; no points for thermoelectric effect.

5. (4.00 pts)
A NTC thermistor has a resistance of 8500 ohms at 25°C. It also has a resistance of 3000 ohms at 45°C. What is the B coefficient for this thermistor? Express your answer as a whol number without units.

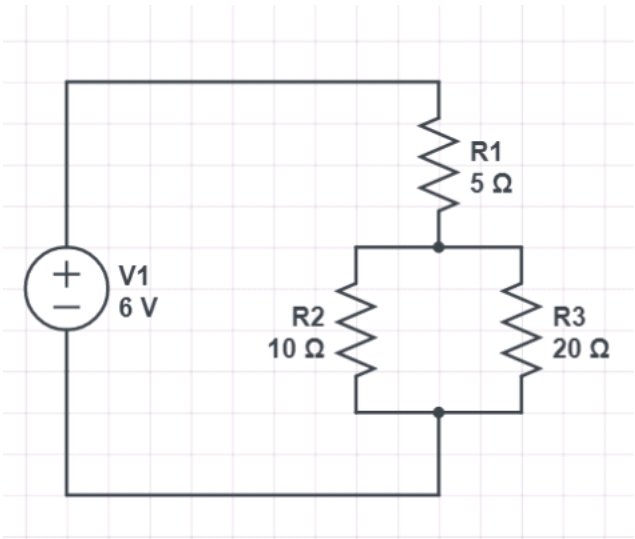
4939

6. (4.00 pts)

A = -0.7401129341 e-3
B = 5.362937835 e-4
C = -10.54966789 e-7

The Steinhart-Hart coefficients of an NTC thermistor are shown in the picture above. Calculate the temperature in °C if the thermistor has a resistance of 9250 ohms. Express your answer to the nearest whole number without units.

25



Use the circuit above for the next 7 questions. Assume that for the first 5 questions that the battery is ideal.

7. (3.00 pts)
What is the circuit's equivalent resistance in ohms? Express your answer as a number rounded to 3 sig figs **without** units. For example if your answer was 28.834 ohms, in the blank you should put 28.8.

11.7

8. (3.00 pts) How much current passes through the voltage source in amperes? Express your answer to 3 sig figs without units.

0.514

9. (3.00 pts) What is the voltage drop across the 5-ohm resistor in volts? Express your answer as a number rounded to 3 sig figs without units.

2.57

10. (3.00 pts) What is the current across the 10-ohm resistor in amperes? Express your answer to 3 sig figs without units.

0.343

11. (3.00 pts) How much energy does the circuit release every minute in Joules? Express your answer without units and to the nearest whole number.

185

12. (3.00 pts)
It turns out that the battery is actually non-ideal and the current in the circuit is 0.25A. What is the internal resistance of the battery (in ohms), given that its EMF is still 6V? Express your answer without units and rounded to 3 sig figs.

12.3

13. (3.00 pts) What is the terminal voltage of the battery from the previous question in volts? Express your answer without units and rounded to 3 sig figs.

2.92

SECTION 2: LEDS AND DIODES

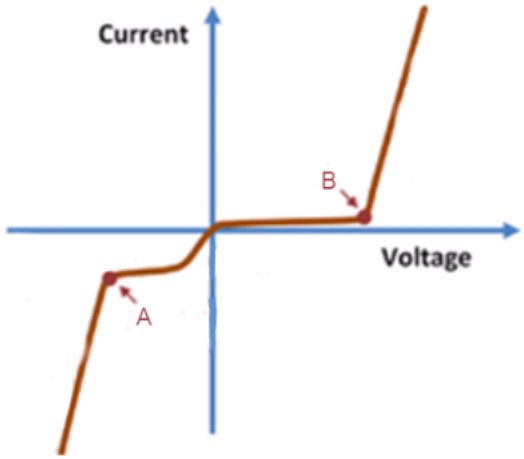
14. (2.00 pts) What is the resistance of an ideal diode in forward bias? What about in reverse bias?

Expected Answer: +1) Ideal Diode is 0 +1) Reverse Bias is infinity

15. (3.00 pts) What happens when a non-ideal diode is reverse-biased with a small voltage? How does this compare to an ideal diode

Expected Answer: +2) For saying that some current will leak through. Full points for mention of leakage or saturation current. +1) In an ideal diode, no current leaks through

Use the following diagram for the next 6 questions.



Shown above is an I-V graph for a particular diode.

16. (2.00 pts) What is the name for the voltage at point A?

Expected Answer: Breakdown Voltage

17. (2.00 pts) What is the name for the voltage at point B?

Expected Answer: Forward Voltage

18. (2.00 pts) If the diode was made of silicon, what would be a good estimate for the voltage at B?

Expected Answer: 0.7 V

19. (3.00 pts) How could you use the graph to calculate the diode's resistance when in forward bias?

Expected Answer: Find the reciprocal of the slope past point B

20. (3.00 pts) In what region of the above graph would a Zener diode be uniquely capable of operating?

Expected Answer: The portion before A (breakdown voltage)

21. (4.00 pts)
It turns out that the particular diode shown in the graph was a red LED. How would the right side of the graph change if the LED was blue instead of red? Explain why.

Expected Answer: +2) For saying that the blue LED has a higher forward voltage than the red LED +2) For saying that point B would shift right. No points awarded for the whole question if they didn't mention forward voltage.

22. (3.00 pts) About what percentage of energy is used by an LED to create visible light? What happens to the rest of the energy?

Expected Answer: +2) For saying 80% +1) For saying the rest of the energy is wasted as heat

23. (3.00 pts) How does the percentage from the previous question compare to that of an incandescent light bulb?

Expected Answer: About 8 times greater since incandescent light bulbs only have a 10% efficiency.

24. (5.00 pts) Which of the following are advantages of LEDs over incandescent light bulbs? There could be more than 1 correct answer.

(Mark **ALL** correct answers)

- [ ] A) Light bulbs have a higher initial price per lumen than LEDs
- [ ] B) Light bulbs have worse light quality than LEDs
- [x] C) LEDs have a better color rendering index than light bulbs
- [ ] D) LEDs cause less light pollution than light bulbs
- [ ] E) Light bulbs have a much greater impact on insect ecosystems than LEDs

- [x] F) LEDs have a lower response time than light bulbs

25. (5.00 pts) Which of the following are disadvantages of LEDs compared to incandescent light bulbs? There could be more than 1 correct answer

(Mark **ALL** correct answers)

- [x] A) LEDs are more sensitive to voltage than light bulbs.
- [x] B) LEDs rely on perfect electrical polarity
- [ ] C) LEDs give off more heat than light bulbs
- [ ] D) LEDs are more likely to burn out over time than an incandescent light bulb.
- [x] E) LEDs can cause blue-light hazard.
- [ ] F) Light bulbs are more rugged and can withstand shock and vibrations.

26. (3.00 pts) Order the following LED semiconductor materials from the least to greatest forward voltage:
Gallium (III) phosphide, Gallium arsenide, Silicon carbide, Diamond.

Expected Answer: All or nothing here, Gallium arsenide, Gallium (III) phosphide, Silicon carbide, Diamond

27. (5.00 pts)
The band gap of a certain semiconductor is 2.61eV. Calculate the emission wavelength of an LED made with this material as well as its color. In the first blank, you should put the wavelength in nm rounded to the nearest whole number without units. In the second blank you should put the color in all lowercase.

476 | blue

28. (3.00 pts) Why do LEDs appear monochromatic even though they are not?

Expected Answer: The spectrum is too narrow for our eyes to perceive the difference

29. (3.00 pts) Haitz's Law estimates that LEDs will be the most efficient light source by what year?

2020

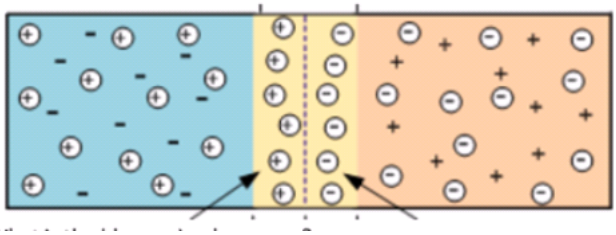
30. (3.00 pts) What type of LED is shown below?

Expected Answer: Surface Mount LED (SMD) or Dual In-Line Package (DIP)

31. (5.00 pts)
Name 3 elements that could be used to dope a semiconductor to make it P-type. Also explain why do these elements make the semiconductor P-type on an atomic level.

Expected Answer: +3 for saying Boron, Aluminum, Gallium +2 for noting that these elements have less electrons (3) than a neutrally charged semiconductor material. This is the reason it is positive.

Use the following diagram of a PN junction for the next 5 questions.



32. (2.00 pts) What is the blue region known as?

Expected Answer: N-region, N-type region

33. (2.00 pts) The orange region (on the right) has an excess of what entity?

Expected Answer: Holes of positive charge NO POINTS FOR PROTONS

34. (2.00 pts) The yellow region in the middle is known as what?

Expected Answer: Depletion region

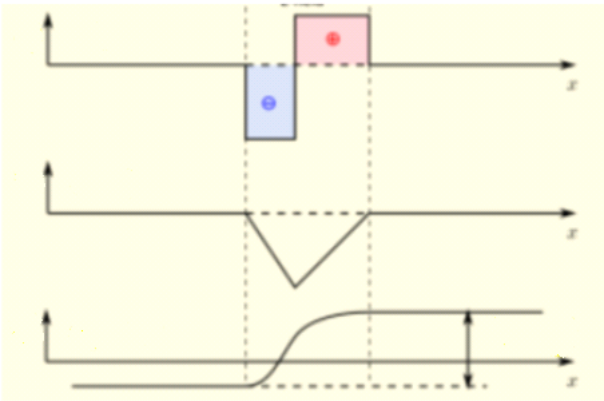
35. (2.00 pts) How does current flow relate to the size of the yellow region?

Expected Answer: The yellow region becomes smaller when greater current is flowing

36. (4.00 pts) Where is the electric field strongest in the diagram? How does its magnitude relate to the size of the yellow region?

Expected Answer: +2) At the junction between the P and N regions +2) Magnitude increases as size of the depletion region increases

Use the following information for the next 8 questions



The three graphs above show Electric Field, Voltage, and Charge in a PN Junction as a function of position (though not necessarily in that order).

37. (3.00 pts) What side of the junction is more likely to be doped with aluminum (left or right)

right

38. (3.00 pts) Which quantity is most likely represented on the y-axis of the top graph? Your answer should either be Charge, Voltage, or Electric Field.

Charge

39. (3.00 pts) Which quantity is most likely represented on the y-axis of the middle graph? Your answer should be either Charge, Voltage, or Electric Field.

Electric Field

40. (3.00 pts) Which quantity is most likely represented on the y-axis of the bottom graph? Your answer should be either Charge, Voltage, or Electric Field.

Voltage

41. (3.00 pts) What quantity is most represented by the vertical arrow in the bottom graph?

Expected Answer: Built-In Voltage of PN Junction

42. (4.00 pts) How would the graphs change if a current was run through the junction?

Expected Answer: +2) The two vertical dashed lines move close since depletion region shrinks +2) The middle graph becomes flatter because peak electric field decreases

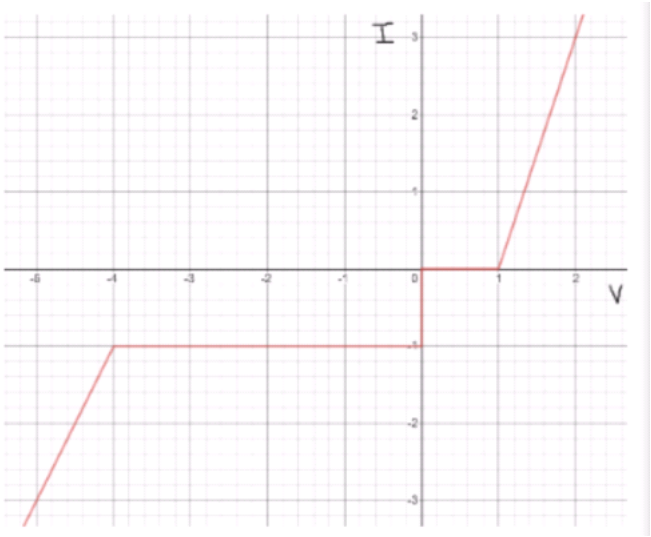
43. (4.00 pts) How would the graphs change if the diode was reverse-biased?

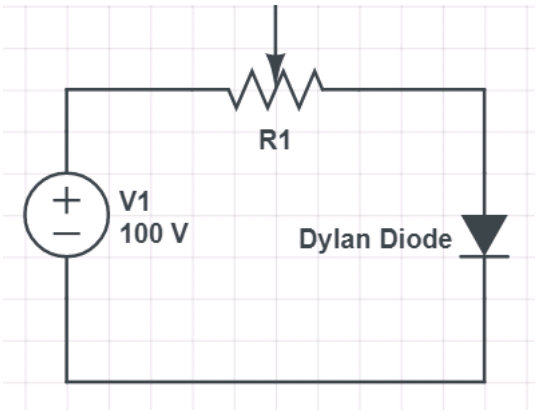
Expected Answer: +2) For saying that the depletion region becomes wider so everything stretches farther apart +2) For saying that the middle graph becomes steeper because the peak electric field increases

44. (4.00 pts) How would the bottom graph change if this red LED was switched to a green one?

Expected Answer: Red LEDs have a smaller forward voltage so the graph would be compressed vertically- the built-in voltage would decrease.

Use the information below for the rest of the LED section.





Consider the following I-V graph of a non-ideal "Dylan Diode" and the accompanying circuit diagram with that diode.

45. (6.00 pts) If the potentiometer is set to 20 ohms, what is the voltage across the diode? Express your answer in volts without sig figs and rounded to 2 decimal places.

2.62

46. (6.00 pts) If the potentiometer is set to 99 ohms, what is the current through the circuit? Express your answer in Amperes without units and rounded to 3 decimal places.

0.997

47. (6.00 pts)
Find the minimum potentiometer setting for which no current runs through the circuit, or explain why no such setting exists. If there is a minimum potentiometer setting, express your answer in ohms rounded to the nearest whole number without units.

Expected Answer: No such setting exists: If we assume that the voltage drop across the diode is greater than 1, then we can make the equation V+(3V-3)R=100, which simplifies to V=(100+3R)/(1+3R). As R tends to infinity, V grows infinitely close to 1, but it is never actually less than 1. Since no current will only flow through the circuit when V is less than 1, it never happens!

The polarity of the voltage source is reversed. Use this information for the next 4 questions.

48. (6.00 pts)
If the potentiometer is set to 20 ohms, what is the absolute value of the current through the circuit in amperes. Round your answer to 3 sig figs and don't include units in your final answer.

4.71

49. (6.00 pts)
If the potentiometer is set to 99 ohms, what is the absolute value of the voltage across the diode in volts.? Round your answer to the nearest whole number and don't include units in your final answer.

1

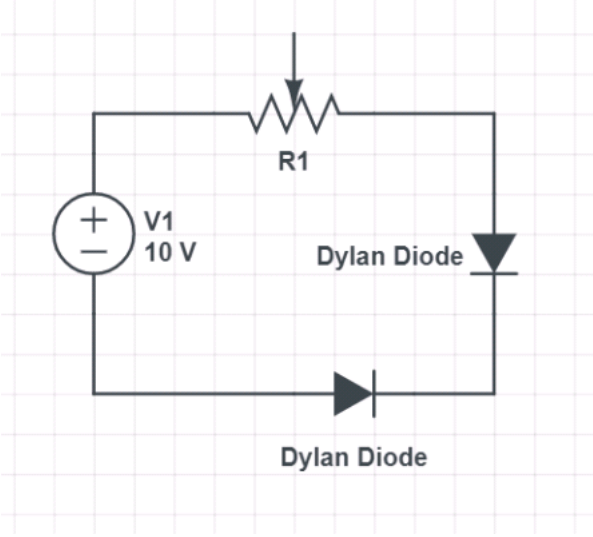
50. (6.00 pts)
A wire with negligible resistance is placed in parallel to the potentiometer. If the potentiometer is set to 75 ohms, what is the power dissipated by the diode in kW? Express your answer without units to 3 sig figs.

19.3

51. (6.00 pts) Find the minimum potentiometer setting for which breakdown does not occur, or explain why no such setting exists

Expected Answer: 96 ohms.

Finally, consider the following modified circuit where both diodes are Dylan Diodes. Use this circuit for the rest of the LED section.



Assume that the potentiometer is set to 2 ohms for the next **3** questions.

52. (6.00 pts) Find the voltage across the forward-biased diode in volts. Express your answer without units and rounded to 3 sig figs.

12.2

53. (6.00 pts) Find the voltage across the reverse-biased diode in volts. Round your answer to 3 sig figs and don't include units.

20.4

54. (6.00 pts) Find the current in the circuit in amperes. Don't include units in your answer and round to 3 sig figs.

33.7

55. (6.00 pts)
Find the potentiometer setting for which the voltage drop across the reverse-biased diode is twice the voltage drop across the forward-biased diode, in ohms. Express your answer without units and rounded to 3 sig figs.

9.78

56. (6.00 pts)
Find the minimum potentiometer setting for which no current flows through the circuit in ohms, or explain why such a setting does not exist. If there is a setting, express your answer to 3 sig figs without units.

Expected Answer: No such setting exists- it is impossible for the current through a reverse-biased Dylan Diode to be 0 because there is always some leakage current for any applie voltage.

57. (6.00 pts)
Find the minimum potentiometer setting for which breakdown does not occur in the reverse-biased diode in ohms, or explain why such a setting does not exist. If there is a setting, express your answer without units and rounded to 3 sig figs

Expected Answer: 94.7

SECTION 3: CALIBRATION PROCESS

58. (4.00 pts) What is the difference between a primary and a secondary standard?

Expected Answer: A primary standard is the original standard used for measurement. The secondary standard is calibrated using the primary standard.

59. (4.00 pts) What is on the highest tier of the Metrology/Calibration Traceability Pyramid?

Expected Answer: SI units or any International Standard

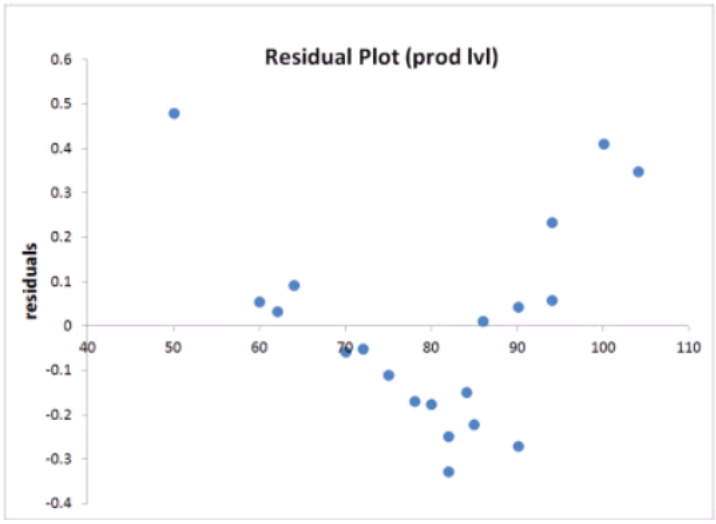
60. (3.00 pts) What is the difference between a systematic and random error? Which one of these errors can be reduced via averaging the data values?

Expected Answer: +1) Random errors are caused by unpredictable changes in an experiment +1) Systematic errors effect the same thing by the same amount every single time. +1 Random Errors can be reduced by averaging data values.

61. (2.00 pts) How many sig figs are in 0.00403800?

6

62. (3.00 pts) Dylan takes his data from an experiment he did and devises an LSRL equation for his data. He then graphs the residuals of his data.



What do these residuals suggest about his equation and data?

Expected Answer: Dylan's equation wasn't perfectly accurate as there is a clear U-shape appearing in the residuals. This means an LSRL is probably not the most accurate equatio to use for his data. Using an exponential or parabolic equation would better fit the data.

63. (4.00 pts)
Farzan does another experiment and gets the values shown in the table below.

X	Y
0.166	0.09
0.43	0.28
0.567	0.402
0.794	0.638
1.017	0.912
1.195	1.161
1.453	1.5682

He uses quadratic regression to devise a best-fit model for the data. If the quadratic equation is in the form ax^2+bx+c, what is a? Put your answer in the blank rounded to 4 sig figs

0.4186

64. (4.00 pts) If Farzan used an LSRL equation instead, what would the coefficient of determination rounded to 3 sig figs?

0.981

65. (3.00 pts) What is an influential point in regards to regression?

Expected Answer: An influential point is a point that when it is deleted, the regression line changes drastically.

SECTION 4: DEVICE COMPONENTS

66. (3.00 pts) What type of thermocouple is most effective at temperatures -150° C? Your answer should be a single capital letter.

T

67. (4.00 pts) What happens when you drop a plugged in toaster into a bathtub full of distilled water? Explain why.

Expected Answer: +2)Pretty much nothing besides a wet toaster. +2)Water's notorious conductivity comes from the ions in the water itself. Without the ions (distilled water), water is actually a very good insulator.

68. (4.00 pts)
Consider the 6 band resistor shown below.

What is the maximum resistance (ohms) could this resistor have after increasing in temperature by 25°C? Round your answer to the nearest whole number and don't include units.

215204

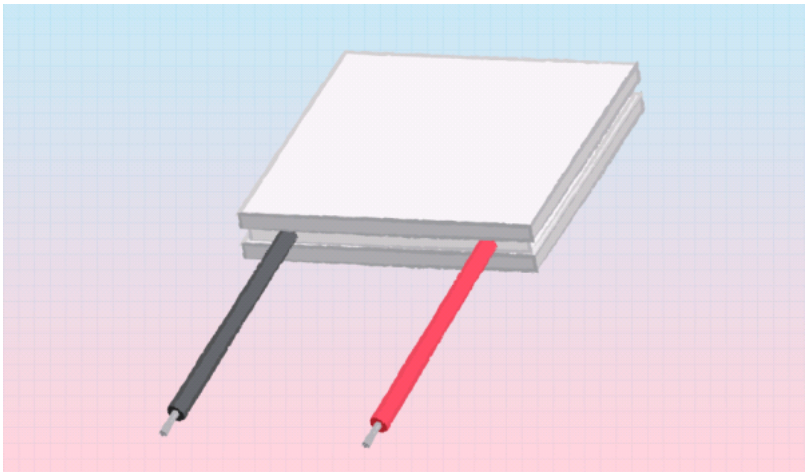
69. (3.00 pts) Visually, what is the difference between an Axial and a Radial thermistor?

Expected Answer: +1.5) Axial thermistors have 1 wire out the top and 1 wire out the bottom going in different directions. +1.5) Radial thermistors have both wires leaving the bead ir the same direction.

70. (4.00 pts) What is a thermopile and what is the purpose of a thermopile?

Expected Answer: +2) A thermopile is a collection of thermocouples, usually connected in series. +2) When the thermopiles are connected in series, they can produce much more electrical energy than a standard thermocouple.

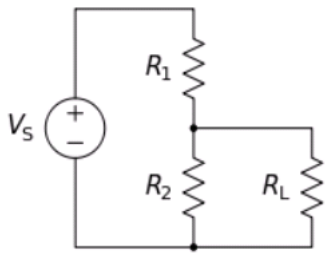
71. (5.00 pts)



What is the name of the device depicted in the image above? What does it do and what is in between the 2 white layers?

Expected Answer: +1) For saying that it is a Peltier Cell/Module. Accept Thermoelectric Cell +2) One side of the cell will be hot, the other side will be cold +2) Dissimilar metals connected to each-other in series will be located in the center of the Peltier cell.

72. (4.00 pts)



The picture above represents a potentiometer with a resistive load. If Vs=5V, R1=220 ohms, R2= 500, and R3=1000000 ohms, calculate the voltage across the load resistor in volts. Don't include units in your answer and round to 2 sig figs.

3.5

73. (3.00 pts) What is the AREF pin in an Arduino used for?

Expected Answer: The AREF pin allows for the Arduino to be fed a reference voltage from an external power supply.

74. (3.00 pts)
If you tried to measure a 5 volt range with a two-bit resolution, and the measured voltage was 4 volts, what would the ADC value return? Express your answer without units.

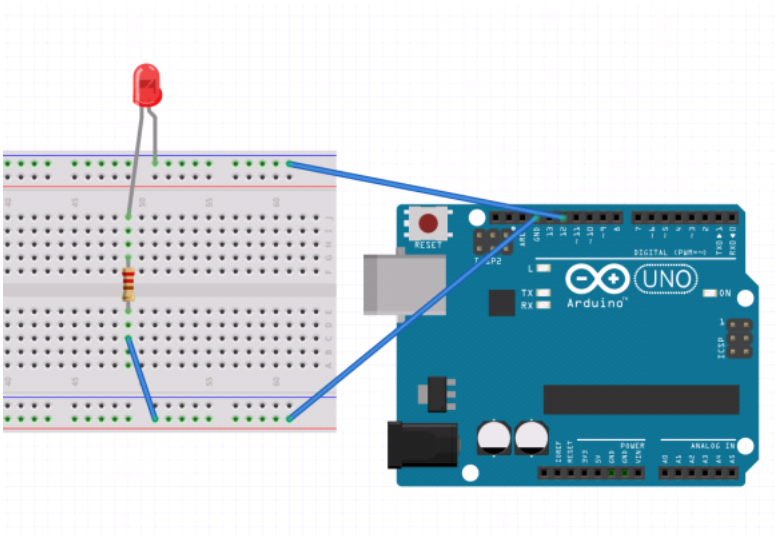
3

75. (4.00 pts)
You are trying to measure the resistance of a 100k resistor with your multimeter. You are on the resistance setting, and everything is plugged in correctly. You try measuring the resistor, but the multimeter only displays the number one. What is the **most likely** cause of this happening and what can you do to fix it?

Expected Answer: +2) Your setting on the multimeter is too low and is not high enough to read the resistor +2) Increase the resistor setting on the multimeter to over 100k

SECTION 5: LAB PORTION

76. (12.00 pts)
Farzan constructs the setup shown in the diagram below and runs the code also shown below. Assume that the Arduino is connected to a computer running the code. For this question, also ignore the built-in LED that is on the Arduino.



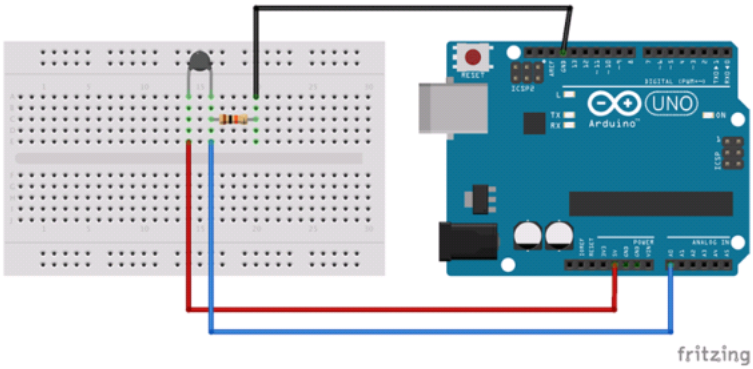
```
void setup() {
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(LED_BUILTIN, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalwrite(LED_BUILTIN, HIGH);
  delay(1000);
  digitalwrite(LED_BUILTIN, LOW);
  delay(1000);
}
```

There are 3 major mistakes with the setup and code that Farzan has made. First identify what is the intended purpose of the setup that Farzan has built. Then list the 3 mistakes that Farzan has made and explain how you would change them to make the circuit work as intended.

Expected Answer: +2 For saying that the intended purpose is making an LED turn on and off (blink). Award 0 points if they say low brightness/current instead of off. +1 For saying that the LED is on/off for intervals of 1 second. +2 For noting that the LED is hooked backwards +1 For saying to fix this by either swapping the direction of the LED or reversing the rest of the circuit +2 For noting that the input pin is 13 instead of 12 +1 For noting that all you have to do is switch the input from 12 to 13, or change the code to spit voltage out of the 12 pin instead of the LED_BUILTIN pin (13). +2 For noting that digitalwrite is not a function +1 For noting that the correct function is digitalWrite

77. (6.00 pts)

Farzan finally constructs his temperature detector for his new event. A diagram is shown below. Assume the Arduino is connected to a computer with code running. (Black wire is connected to GND, Red is connected to 5V and blue is connected to A0). Also shown below are the Steinhart-Hart coefficients for the thermistor.



A = -0.5041690807 e-3
B = 5.156554865 e-4
C = -10.96976239 e-7

If analogRead(0)=272.8, find the temperature that the thermistor is detecting in Fahrenheit. Round your answer to the nearest whole number and don't include units.

41

Congratulations on finishing! Don't forget to check your answers. Once you do, feel free to submit. Good luck on your other events! If you have any questions, feel free to contact me at farzanshiju1@gmail.com or on Discord at fds#7731