

**Detector Building 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.

**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?**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

**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)

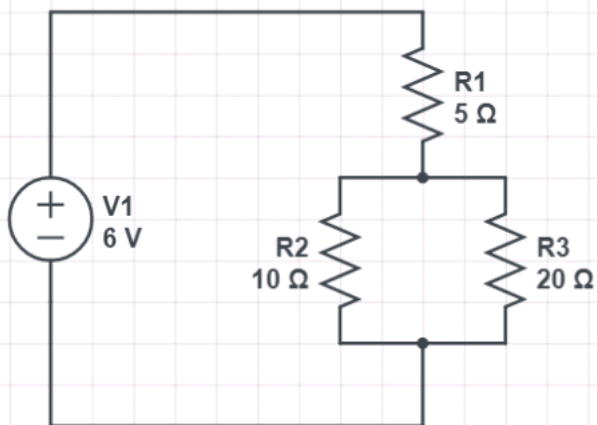
**5. (4.00 pts)**

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 whole number without units.

**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.



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.

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

**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.

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

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.

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.

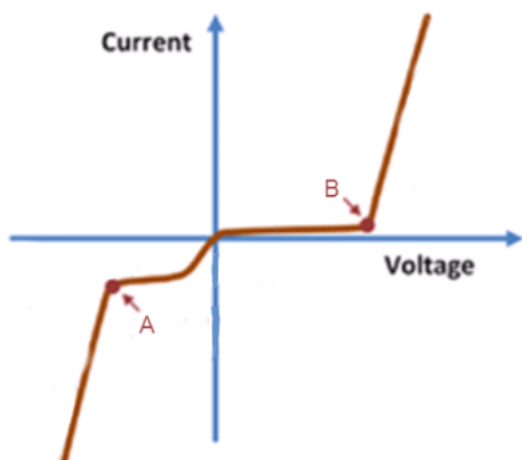
13. (3.00 pts) What is the terminal voltage of the battery from the previous question in volts? Express your answer without units and rounded to 3 sig figs.

## 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?

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

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?

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

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

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

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

**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.

**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?

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

**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
- ☐ 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
- ☐ 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)

- ☐ A) LEDs are more sensitive to voltage than light bulbs.
- ☐ 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.
- ☐ 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.

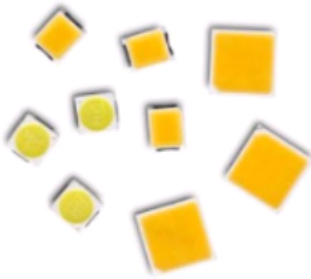
**27. (5.00 pts)**

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.

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

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

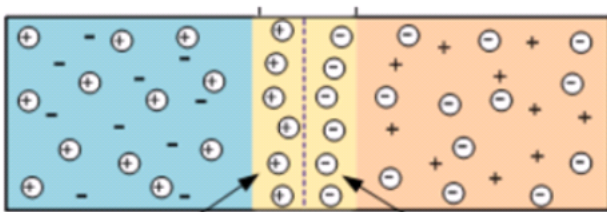
30. (3.00 pts) What type of LED is shown below?



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.

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



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

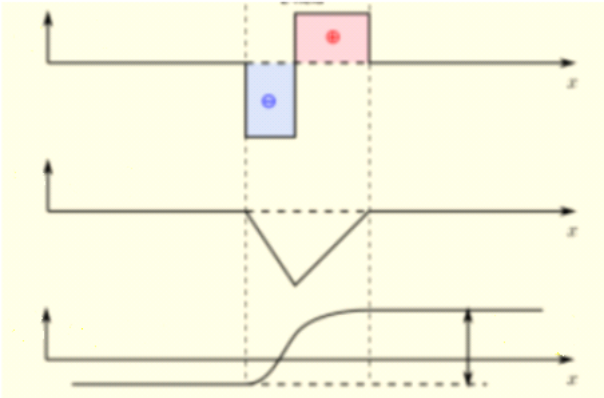
33. (2.00 pts) The orange region (on the right) has an excess of what entity?

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

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

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?

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)

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.

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.

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.

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

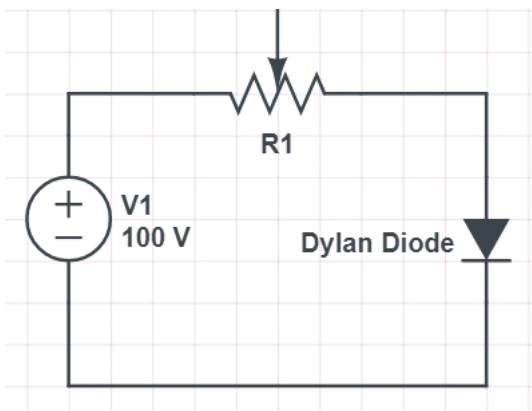
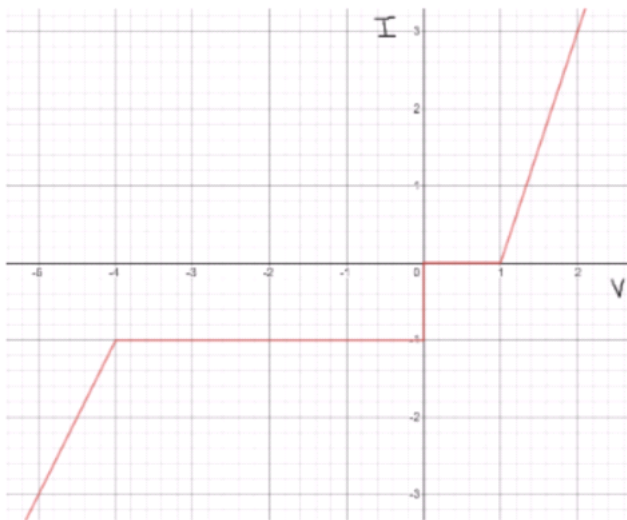
42. (4.00 pts) How would the graphs change if a current was run through the junction?

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

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

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.

- 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.

- 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.

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.

**49. (6.00 pts)**

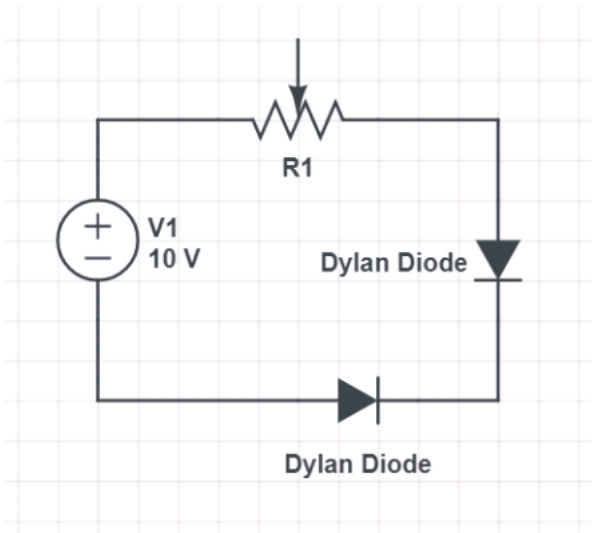
If the potentiometer is set to 99 ohms, what is the absolute value of the voltage across the diode in volts.? Round your answer to the nearest whole number and don't include units in your final answer.

**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.

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

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.

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.

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.

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.

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.

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

SECTION 3: CALIBRATION PROCESS

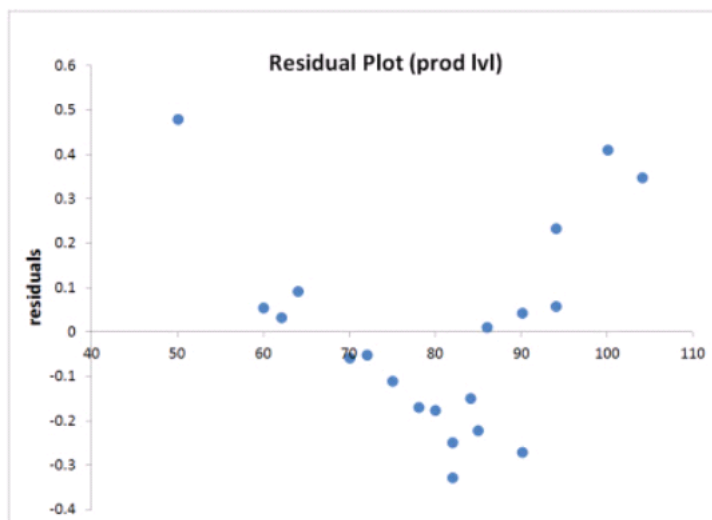
58. (4.00 pts) What is the difference between a primary and a secondary standard?

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

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?

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

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?

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

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

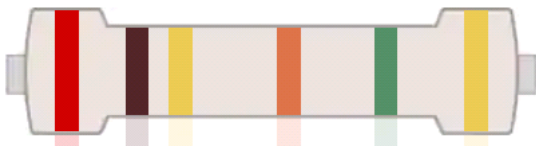
65. (3.00 pts) What is an influential point in regards to regression?

#### SECTION 4: DEVICE COMPONENTS

66. (3.00 pts) What type of thermocouple is most effective at temperatures  $-150^{\circ}\text{C}$ ? Your answer should be a single capital letter.

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

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

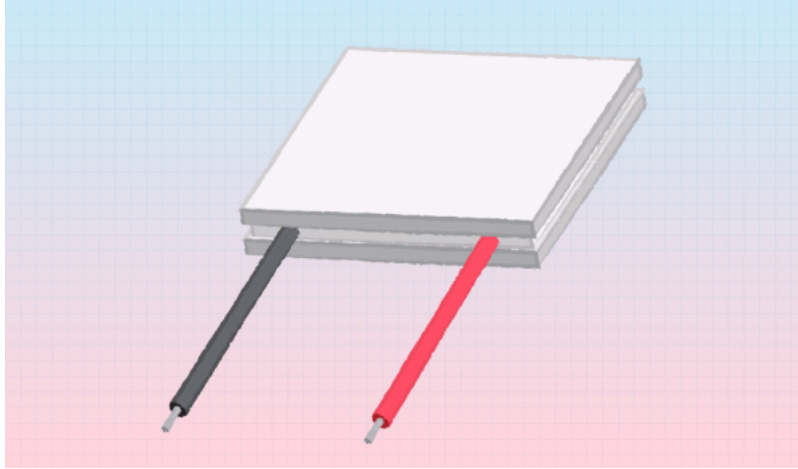


What is the maximum resistance (ohms) could this resistor have after increasing in temperature by  $25^{\circ}\text{C}$ ? Round your answer to the nearest whole number and don't include units.

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

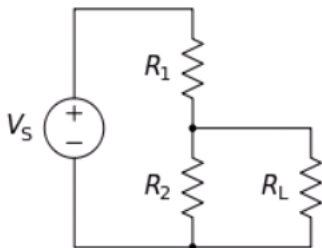
70. (4.00 pts) What is a thermopile and what is the purpose of a thermopile?

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?

72. (4.00 pts)



The picture above represents a potentiometer with a resistive load. If  $V_S=5V$ ,  $R_1=220$  ohms,  $R_2= 500$ , and  $R_3=1000000$  ohms, calculate the voltage across the load resistor in volts. Don't include units in your answer and round to 2 sig figs.

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

**74. (3.00 pts)**

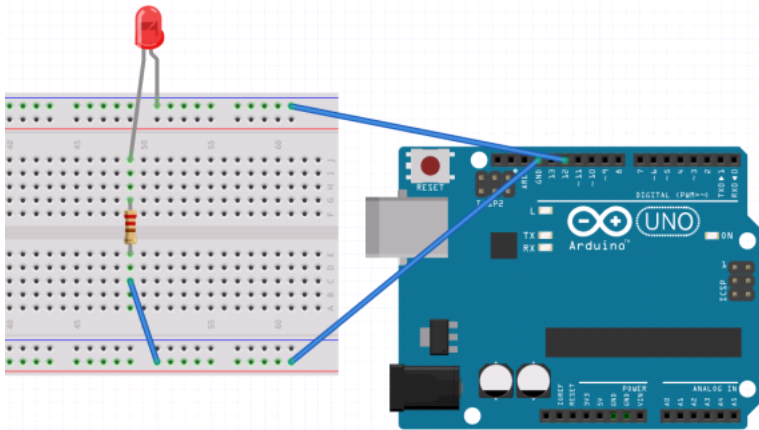
If you tried to measure a 5 volt range with a two-bit resolution, and the measured voltage was 4 volts, what would the ADC value return? Express your answer without units.

**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?

**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.

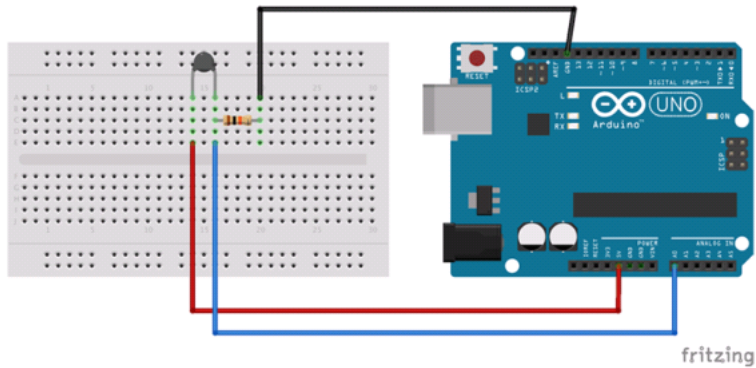


```
void setup() {  
  // initialize digital pin LED_BUILTIN as an output.  
  pinMode(LED_BUILTIN, OUTPUT);  
}  
  
// the loop function runs over and over again forever  
void loop() {  
  digitalWrite(LED_BUILTIN, HIGH);  
  delay(1000);  
  digitalWrite(LED_BUILTIN, LOW);  
  delay(1000);  
}
```

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.

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

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](mailto:farzanshiju1@gmail.com) or on Discord at [fds#7731](#)