# DETECTOR BUILDING C

CAMAS SCIENCE OLYMPIAD INVITATIONAL TOURNAMENT 2021

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| TEAM ______________________ C - ______ | | |
| *example: Science Olympiad High School – Team Blue* | | |
| NAME(S) ______________ ______________ | | SCORE ______ / 132 |

| INSTRUCTIONS | |
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| 1 | You have up to 50 minutes to complete as many questions as you can on this exam. |
| 2 | As specified in the event rules, you are permitted to use, for reference, resources within a single 2-inch or smaller three-ring binder. With the exception of datasheets linked within this test, you may not consult the internet or other people beyond your partner for information. |
| 3 | Your entire score for this event is this Written Test. For this tournament, there are not Design Log or device components to the Total Score. |
| 4 | Please limit short answer responses to 1-4 sentences per question. Full sentences are not required. You will not be penalized for writing a lot, but doing so may take time away from answering other questions. |
| 5 | All tiebreaker questions are included in the test score and in the event of a tie will be used individually in the order specified. |
| 6 | There are no penalties for incorrect answers. Partial credit will be awarded for fill-in-the-blank and multiple answer (i.e. “select all that apply”) questions. |
| 7 | Some questions ask that you input your answer as a rounded number and without units. It is very important that you follow these instructions or the auto-grade function will mark your answer as incorrect!<br><br>For example, if you are instructed to enter your answer 12.3456 V in millivolts (mV) to the nearest millivolt, input “12346” for your answer. Also, Scilympiad checks for exact matches (ignoring upper and lower case) so if rounded to the nearest integer, do not follow your answer with a decimal, i.e. enter “60” and not “60.” |

| NOTES | |
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| 1 | This test was written for the Camas Invitational hosted on December 12, 2020, by Camas High School in Camas, Washington. This tournament was run in *mini SO* format with testing conducted via the Scilympiad platform. As such, many questions of this test were structured and/or worded for the online format. |
| 2 | This test was written by George Sun, a graduate of the University of Washington in Seattle. |

| QUESTIONS | | |
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| **<u>Questions 1-4</u>: At 25˚C, a 2.79 m long nichrome wire resistor with a diameter of 0.1 mm is connected in series with a single 5 mm red LED and a 9.0 V battery such that the red LED turns on. The manufacturer for this particular LED recommends its operation at 2.0 V with a maximum rating of 2.5 V. If needed, assume that the resistivity of nichrome is 1.00 × 10^-6 Ω m at 25˚C and the temperature coefficient of nichrome is 4.0 × 10^-4/°C.** | | |
| 1 | **At 25˚C, what is the resistance of the nichrome wire? Answer in ohms (Ω) rounded to the nearest whole number and input your answer without units.** | ____ / 3 |
| 2 | **At 25˚C, an ammeter measures the current through the resistor to be 20 mA. What is the voltage across the red LED? Answer in volts (V) rounded to the nearest 0.1 V and input your answer without units.** | ____ / 3 |
| 3 | **Does the resistance of the nichrome wire resistor generally increase, decrease, or not change with increasing temperature?**<br>a. The resistance of the nichrome wire resistor should increase with increasing temperature.<br>b. The resistance of the nichrome wire resistor should decrease with increasing temperature.<br>c. The resistance of the nichrome wire resistor should not change with increasing temperature. | ____ / 3 |
| 4 | **A Assuming that the LED and battery are unaffected by temperature changes (i.e. the forward current is temperature independent), what is the most extreme temperature at which the circuit can be operated without exceeding the maximum forward voltage rating of the LED? Answer in degrees Celsius (˚C) rounded to the nearest whole number and input your answer without units.** | ____ / 5 |
| **<u>Questions 5-7</u>: The Steinhart-Hart equation models the resistance of a semiconductor at different temperatures and is given by 1 / T = A + B ln R + C (ln R)^3. For a particular thermistor, the coefficients A, B, and C are 2.22 × 10^-3 K^-1, 8.10 × 10^-5 (K ln Ω)^-1, and 0, respectively.** | | |
| 5 | **At what temperature is the resistance for this particular thermistor 10,000 Ω? Answer in degrees Celsius (˚C) rounded to the nearest whole number and input your answer without units.** | ____ / 3 |
| 6 | **Does this particular thermistor have a positive temperature coefficient (PTC), negative temperature coefficient (NTC), or can this not be determined from the information provided?**<br>a. The temperature coefficient is positive (PTC).<br>b. The temperature coefficient is negative (NTC).<br>c. The sign of the temperature coefficient cannot be determined from the information provided. | ____ / 2 |

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| 7 | **<u>Tiebreaker 5</u>: What is the β parameter for this particular thermistor? Answer in Kelvin rounded to the nearest 10 K and input your answer without units.** | ___ / 5 |
| 8 | **<u>Tiebreaker 6</u>: Which of the following phenomena enables light emission by LEDs? Select all that apply.**<br>a. Recombination of electron carriers and electron holes<br>b. A growing depletion region releasing electrons as light<br>c. A forward voltage causing protons to displace electrons<br>d. Electron migration from the P-type region to the N-type region<br>e. None of the above. | ___ / 5 |
| 9 | **Event rules for Detector Building require that your temperature-sensing device have three LEDs in the colors red, green, and blue. Rank the band gap energies of these three colors of LEDs from greatest to least.** | ___ / 3 |
| 10 | **While building your temperature-sensing device, your partner realizes that they only have two-leaded 5 mm round red LEDs. Which of the following can be done to the red LEDs to produce light that is blue or green? Select all that apply.**<br>a. Use a potentiometer with the LED and change its resistance until the LED displays the correct color.<br>b. Change the voltage of the power source for the LED until the LED displays the correct color.<br>c. Apply a blue or green color filter to the red LED to change the observed color.<br>d. Use a power supply that outputs a sinusoidal waveform with frequency corresponding to the wavelength for the color of interest.<br>e. None of the above. | ___ / 5 |
| 11 | **Which of the following statements about LEDs and conventional lighting sources is/are true? Select all that apply.**<br>a. Both LED lighting and conventional lighting sources are inherently directional.<br>b. LED thermal path is accomplished by conduction, whereas in incandescent lighting it is not effectively managed.<br>c. While compact fluorescent light (CFL) bulbs generally have lifespans longer than LED bulbs, they are less favored because they contain mercury vapors.<br>d. Compared to conventional lighting, LEDs generate less waste on the consumer end. | ___ / 4 |
| 12 | **Which of the following answer choice(s) describe difficulties of engineering LEDs? Select all that apply.**<br>a. Designing electronics of lights so they match the color characteristics of natural lighting<br>b. Compact thermal management for larger lights<br>c. Preventing color change over the lifespan of a device<br>d. Engineering lights so they are responsive and can response within fractions of seconds to changes<br>e. None of the above. | ___ / 5 |
| 13 | **Which of the following comparisons of through-hole and surface-mount LEDs is/are correct? Select all that apply.**<br>a. Surface-mount LEDs are better suited for breadboard prototyping of circuit designs.<br>b. Surface-mount technology allows using LEDs that are both brighter and more energy efficient.<br>c. Surface-mount technology produces circuits that are more reliable and physically robust.<br>d. Surface-mount technology allows circuit designs that are more space efficient.<br>e. Surface-mount and through-hole components are incompatible together. | ___ / 5 |

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| 14 | **Which of the following answer choice(s) correctly pairs a property and a possible metric used for its measurement? Select all that apply.**<br>a. Electrical characteristics, measured by input voltage or current<br>b. Light output, measured by luminous flux<br>c. Thermal efficiency, measured by maximum rate of temperature change without failure<br>d. Lighting efficiency, measured by wattage<br>e. Product lifespan, measured by hours of continuous operation until failure<br>f. Color accuracy, measured by correlated color temperature | ____ / 6 |
| 15 | **Which of the following change(s) to your temperature-sensing device would require recalibration of your device? Select all that apply.**<br>a. Replacing the material used to waterproof your sensor (i.e. resealing your sensor)<br>b. Changing the thermistor used for your sensor<br>c. Changing the length of your temperature-sensing probe<br>d. Changing the sampling frequency of your microcontroller<br>e. Changing the resistance of a resistor used to keep input current of your temperature sensor within operating limits<br>f. None of the above. | ____ / 6 |
| **<u>Questions 16-20</u>: The following questions reference the datasheet for the Everlight "Opto Interrupter" (https://www.endrich.com/fm/2/ITR-8105.pdf).** | | |
| 16 | **Which of the following statements about the Everlight "Opto Interrupter" is/are correct? Select all that apply.**<br>a. Forward current and forward voltage exhibit a linear relationship.<br>b. The smallest possible dimension for the gap between the light emitter and detector is 2.4 mm.<br>c. The sensor can be used either indoors or outdoors without additional considerations.<br>d. The sensor has been tested for its ability to withstand sudden and drastic changes in ambient temperature.<br>e. The sensor can be operated by making only two connections.<br>f. The sensor produces a different response to partial interruptions vs. full interruptions. | ____ / 6 |
| 17 | **<u>Tiebreaker 2</u>: The manufacturer lists copiers, printers, and ticket vending machines as possible applications for the "Opto Interrupter" sensor. Describe in detail how the sensor could be used in one of these three applications and how the sensor serves its purpose in your described function.** | ____ / 6 |
| 18 | **The infrared emitting diode of the Everlight "Opto Interrupter" uses gallium arsenide (GaAs) which has a band gap of 1.441 eV. What wavelength in nanometers does this correspond to? Answer in nanometers (nm) with two significant figures and input your answer without units.** | ____ / 3 |
| 19 | **Two AA batteries with nominal voltage 1.5 V each are connected in series with a resistor to power the input of the Everlight "Opto Interrupter." What resistance in ohms should be used for the resistor such that the device is operating at its recommended specifications? Answer in ohms (Ω) rounded to the nearest ohm and input your answer without units.** | ____ / 3 |

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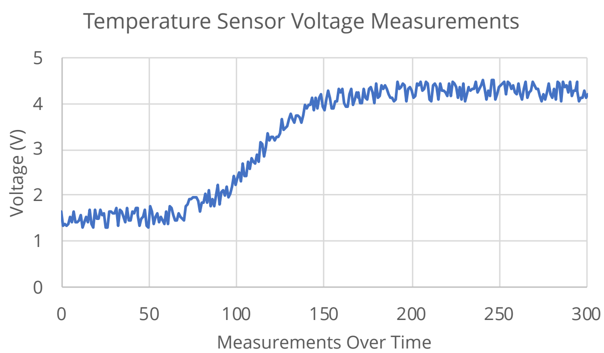
| 20 | **<u>Tiebreaker 3</u>: Figures 1 and 2 on page 5 show device response for shielding/interruption in different dimensions. The trend observed is one common to sensors in general. Explain why such a response curve is expected in sensors in general, discussing each of the three parts of the curve.** | ____ / 6 |
| 21 | **<u>Tiebreaker 1</u>: Your partner has decided to modify your temperature-sensing device such that it displays a temperature measurement only after readings have stabilized. Write code that processes an array of real-time voltage measurements and prints the calculated temperature if voltage readings have stabilized or otherwise prints "UNSTABLE." (To help you understand the objective of this question, think about what happens when you place a thermometer in boiling water. The temperature reading does not immediately change from 25˚C to 100˚C; rather, it gradually increases from 25˚C to 100˚C, then stabilizes at 100˚C and may fluctuate within a few degrees.)**<br><br>**You may write your code in any language of your choice. To calculate temperatures from voltages, you may use the mathematical model from your actual device, or you may make up one. Your code will be scored on implementation and clarity, so you are encouraged to comment your code and name variables appropriately. You will not be penalized for minor errors such as missing semicolons, etc.**<br><br> | ____ / 12 |

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| 21 | *You may use the space on this page to continue writing your code.* |
| 22 | **In what programming language did you write your code for the previous question?** ____ / 0 |

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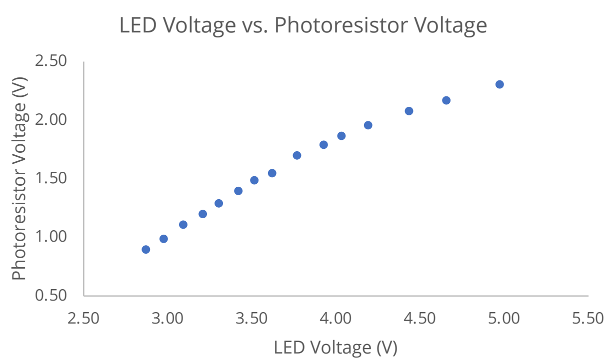
| 23 | **Which of the following is/are appropriate methods for minimizing noise in your detected signal? Select all that apply.**<br>a. Passing your signal through a low-pass filter prior to analog-to-digital conversion.<br>b. Passing your signal through an exponential moving average filter.<br>c. Passing your signal through a proportional-integral-derivative (PID) controller.<br>d. Positionally stabilizing your temperature-sensor during data collection.<br>e. Recalibrating your temperature-sensing device against a trusted thermometer.<br>f. Increasing your sampling frequency to avoid aliasing. | ____ / 6 |
| 24 | **Analog input for Arduino Uno microcontrollers reads voltages between 0 and 5 V as integer values between 0 and 1023, inclusive. How many bits does this correspond to? Round your answer to the nearest whole number.** | ____ / 2 |
| 25 | **The number of bits in the analog-to-digital converter (ADC) of the Arduino Uno is hypothetically increased by two bits. What is the analog input voltage resolution of this hypothetical device? Answer in millivolts (mV) rounded to the nearest 0.1 mV and input your answer without units.** | ____ / 3 |

**<u>Questions 26-31</u>: In medicine, a device called a pulse oximeter measures oxygen saturation (the percentage of hemoglobin molecules that are oxygen-bound) using two LEDs of different wavelengths and a photodetector. A student creates a functioning low-cost battery-powered pulse oximeter using a single red LED and a photoresistor.**

**Realizing that the voltage supplied to the LED and therefore its brightness will vary as the battery powering the pulse oximeter is drained, the student decides to characterize the relationship between LED voltage and the voltage measured across the photodiode. The student positions the LED directly opposite to the photodiode in a dark room and measures the voltage across the photodiode as the voltage across the LED is adjusted.**

**The student's measurements are shown in the table to the right below**




| LED Voltage (V) | Photoresistor Voltage (V) |
|---|---|
| 2.88 | 0.87 |
| 2.99 | 0.97 |
| 3.10 | 1.09 |
| 3.22 | 1.18 |
| 3.32 | 1.27 |
| 3.43 | 1.37 |
| 3.53 | 1.47 |
| 3.63 | 1.53 |
| 3.78 | 1.67 |
| 3.94 | 1.77 |
| 4.05 | 1.84 |
| 4.20 | 1.93 |
| 4.45 | 2.06 |
| 4.67 | 2.15 |
| 4.99 | 2.28 |

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| 26 | **Which of the following circuit arrangements is most likely how the student wired their pulse oximetry device?**<br>a. The LED and photoresistor in series<br>b. The LED and photoresistor in parallel<br>c. The LED and photoresistor in separate circuits<br>d. The LED and photoresistor connected by a relay<br>e. The photoresistor connected to the base of an NPN transistor with the LED at the emitter | ____ / 2 |
| 27 | **What conclusion can be made from the student's data?** | ____ / 2 |
| 28 | **How would the student's model change if it had been performed in a room that was not dark?**<br>a. The photoresistor voltage values would all be higher.<br>b. The LED voltage values would all be lower.<br>c. There would be no change in the student's model.<br>d. LED voltage and photoresistor voltage would follow an exponential trend. | ____ / 3 |

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| 29 | **<u>Tiebreaker 4</u>: Linearize the student's voltage/voltage data. Clearly describe what operation(s) you performed and on which variable(s) to linearize the data.** | ____ / 2 |
| 30 | **<u>Tiebreaker 4</u>: Determine an equation that describes your linearized data. Include units and define any variables you use.** | ____ / 3 |
| 31 | **The student is dissatisfied with the line of best fit and decides to take repeated measurements for a greater range of values. What will happen to the R-squared value?**<br>a. The R-squared value must increase.<br>b. The R-squared value must decrease.<br>c. The R-squared value must stay the same.<br>d. The R-squared value must approach a limit.<br>e. None of the above. | ____ / 3 |
| 32 | **<u>Tiebreaker 7</u>: Which of the following statements about working with data is/are true? Select all that apply.**<br>a. Any dataset can be linearized to produce a linear trend.<br>b. Adding a new datapoint to a dataset for which a regression has been performed will not change the regression if the new datapoint lies on the original regression curve.<br>c. A negative correlation indicates that two variables are not related.<br>d. A high R squared value indicates that two variables are strongly correlated.<br>e. None of the above. | ____ / 5 |
| 33 | **A student models the temperature-voltage relationship for their temperature-sensing device with the equation T = 63.56 [UNITS] * ln (V_Th) + 254.15 K, where T represents temperature in Kelvin and V_Th represents voltage in volts across the temperature sensor. What are the correct units for the slope?**<br>a. K V<br>b. K V^-1<br>c. K ln (V)<br>d. K (ln V)^-1<br>e. K e^-V | ____ / 2 |