Captains Tryouts

# Detector Building

Tryout Test – 50 minutes

Interlake High School, WA
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# Detector Building Tryout Score /100

## §1: Resistance, Voltage, and Temperature Subscore /26

1. [3] How does the resistance of a copper wire change as temperature is increased? Why?

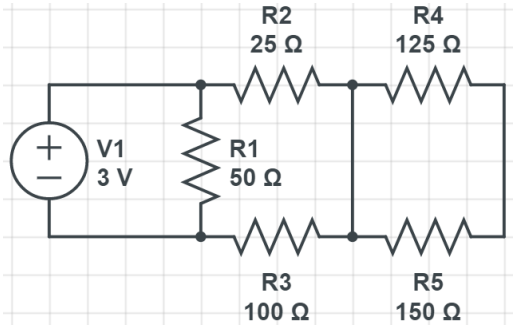
2. [3] How does the resistance of i-type silicon change as temperature is increased? Why?

3. Copper has a resistivity of $1.68 \times 10^{-8}\ \Omega \cdot \text{m}$ at 20 ºC and a temperature coefficient of $0.00404\ \text{K}^{-1}$. A 10 cm long copper wire with diameter 2.588 mm is created and put into a circuit where it passes 1.5 A of current. The wire is kept in thermodynamic equilibrium at a temperature of 45 ºC.
    a. [1] What is the resistivity of the wire?
    b. [2] What is the resistance of the wire?
    c. [1] What is the voltage drop across the wire?

4. [3] Which is a better conductor of electricity: pure water or saltwater? Why?

5. [3] How does the resistance of an AC power line change as AC frequency is increased? Why?

6. Consider the following circuit diagram:




a. [4] Complete the following table:

| Circuit Element | Voltage Drop (V) |
|---|---|
| R1 | |
| R2 | |
| R3 | |
| R4 | |
| R5 | |

b. [2] Suppose the voltage source is running low on battery and the voltage it supplies drops below 3 V. Assuming all other factors stay the same, how does the resistance of the circuit change? Why?

c. [2] What is the power dissipated in resistor R2?

7. [2] Two general classes of thermistors are NTC and PTC. What do these acronyms stand for, and how does this affect the dependence of the resistance of the thermistor on temperature?

## §2: LEDs: Theory and Applications Subscore /27

8. [3] Draw the electronic symbol for a standard LED, and indicate the direction of current:

9. [1] T / F LEDs are only suitable for low-intensity applications such as indicator lights and small light bulbs.
10. [1] T / F The light emitted from a LED, similar to laser light, is monochromatic.
11. [1] T / F The light emitted from a LED, similar to laser light, is spectrally coherent.
12. [1] T / F The light emitted from a LED, similar to laser light, is spatially coherent.
13. [1] What characteristic of the semiconductor in an LED determines its color?
14. [1] What is the optical phenomenon through which LEDs emit light?
15. [1] OLEDs are a relatively new technology with possible applications in thin, high-efficiency, low-cost displays. How do OLEDs differ from regular LEDs?

16. [2] What can an LED connected in reverse-bias mode accomplish?

17. [3] Assuming Shockley diode properties, qualitatively sketch a current-voltage characteristic curve for an LED:

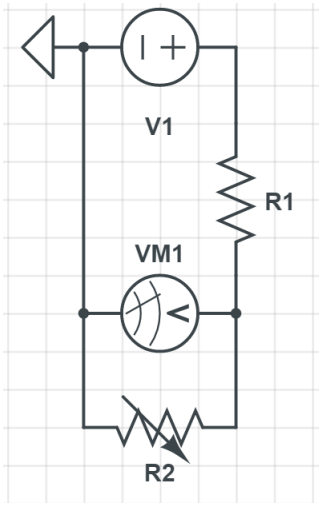
18. [2] Given a standard LED with a long leg and a short leg, which is the cathode, and which is the anode? Which way does current flow?

19. Shuji Nakamura, Hiroshi Amano, and Isamu Akasaki received the Nobel Prize in Physics in 2014.
    a. [1] For what discovery was this Nobel Prize awarded?
    b. [2] What is a possible application of this discovery?

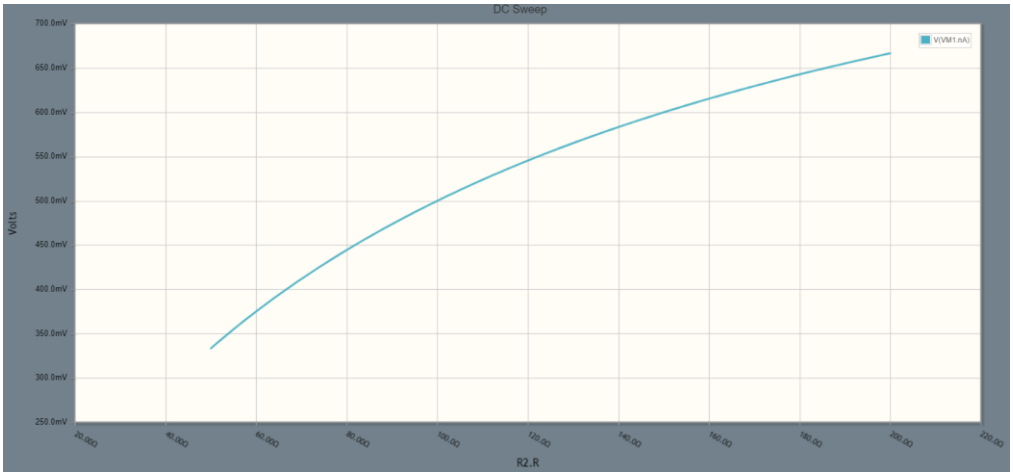
20. This question concerns various type of semiconductor materials used in producing different colors of LEDs.
    a. For each question, give an example of a semiconductor material that can be used to produce an LED of the given color.
        i. [1] Red
        ii. [1] Green
        iii. [1] Blue
    b. What color can the given semiconductor material produce in electroluminescence?
        i. [1] Gallium arsenide
        ii. [1] Diamond
        iii. [1] Aluminum gallium phosphide
        iv. [1] Aluminum gallium nitride

## §3: Calibration Subscore /32

21. Consider the following circuit diagram




And graph




a. [2] Write an equation relating V, the voltage measured by the voltmeter, $V_1$, the voltage supplied by the battery, $R_1$, the resistance of the resistor, and $R_2$, the resistance of the thermistor. Assume the battery has negligible internal resistance.

b. [4] What is the value of $V_1$?

c. [4] What is the value of $R_1$?

d. [2] What will V be if $R_2$ is 500 Ω?

22. The Steinhart-Hart equation for resistance of a semiconductor is given by

$$\frac{1}{T} = A + B\,ln\,R + C(ln\,R)^3$$

a. [5] Let $x = \frac{1}{2C}\left(A - \frac{1}{T}\right)$ and $y = \sqrt{\left(\frac{B}{3C}\right)^3 + x^2}$. Find R in terms of x and y.

b. Given the following data table:

| Resistance (kΩ) | Temperature (ºC) |
|---|---|
| 25 | 5 |
| 10 | 25 |
| 6.5 | 35 |

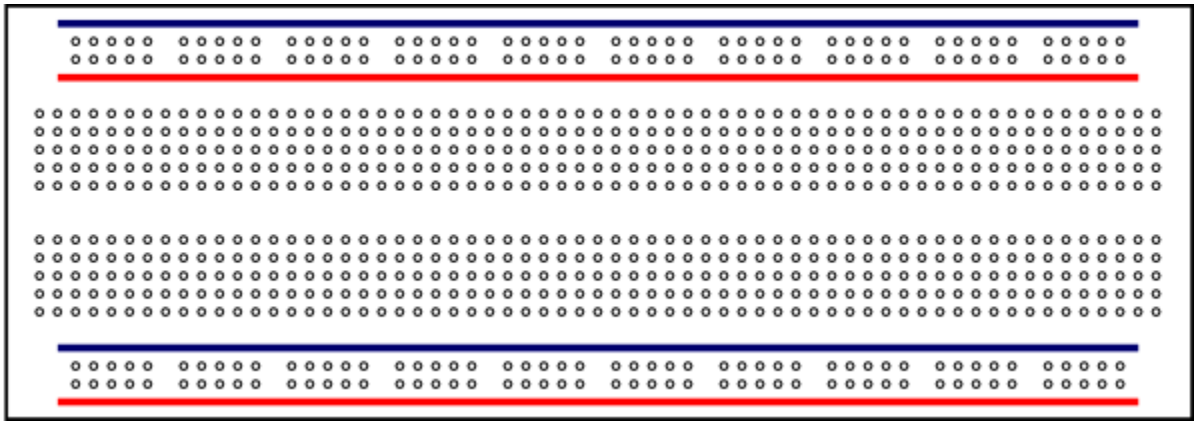
i. [5] Solve for the Steinhart-Hart coefficients A, B, and C.

ii. [5] What is the temperature if the measured resistance is 2.5 kΩ?

iii. [5] What will the measured resistance be at a temperature of 70 ºC?

## §4: Device Components Subscore /15

23. Refer to the following diagram of a breadboard:



a. [2] How many distinct metal strips are in this breadboard?

b. [4] Suppose you had a battery, two wires attached to the positive and negative terminals of the battery respectively, and an LED. Indicate on the breadboard how you would light the LED, including polarities of all circuit elements, if applicable.

24. Refer to the following image of a multimeter:

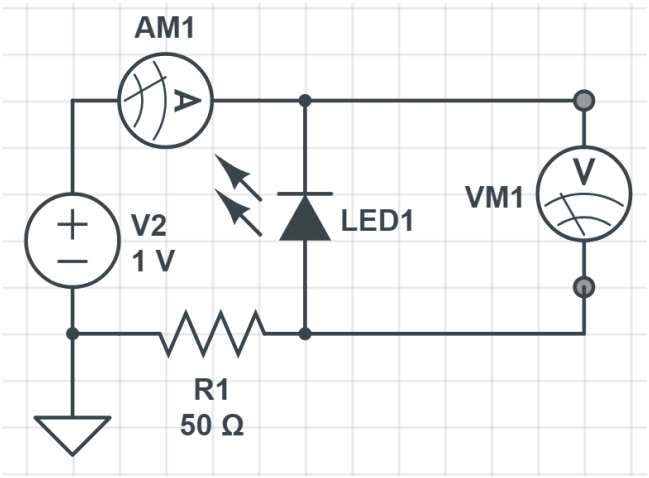

a. [1] What is the most appropriate setting of the dial for measuring a voltage drop of 11 V?

b. [2] How should the voltmeter be connected to the circuit element in question?

c. [1] What is the most appropriate setting of the dial for measuring a current of 2746 μA?

d. [2] How should the ammeter be connected to the circuit element in question?

25. Consider the following circuit diagram:




a. You note that the ammeter reading is very low. Thinking that your voltage isn't high enough to drive the LED, you decide to increase the voltage supplied by your power source (perhaps by adding a few batteries). The ammeter reading persists to be low, until you increase the voltage more and the current suddenly increases and appreciable current flows around your circuit.

i. [1] Will the LED light in this configuration?

ii. [1] Assume that now, the LED is flipped around and the voltage is reduced back to a more reasonable level. Will the LED light?

b. [1] You note that during this debacle, your resistor has heated up considerably. Assuming this particular resistor displays PTC characteristics, how does its resistance change?