Detector Builder-C2020-Regional-Answer Key Team #: Team Name:
score: /16 Member:
Member:

Points are based on the number of steps that must be shown to complete the problem, not the difficulty. For example, a one step problem is worth $\boxed{1}$ point, a two step problem is worth $\boxed{2}$ points, etc. There is a reference section at the end which includes useful formulas and tables.

1 Relationships between Resistance, Voltage, and Temperature

1.1 The relationship between a thermistor's temperature and its resistance is linear. $\boxed{1}$

False, the relationship is non-linear.

1.2 The relationship between a thermistor's resistance and its voltage is $\boxed{1}$

linear

1.3 When current passes through a thermistor, power is dissipated in the form of what? $\boxed{1}$

Heat

1.4 When a temperature difference exists across a thermocouple, a voltage is produced between the two ends of it. What is the name of this effect? $\boxed{1}$

Seebeck Effect

2 Theory of LEDs, Working Principles, and Applications

2.1 Given an LED with a forward voltage of 2.15V, theoretically, what color is the light released from the LED, based on table 1 in the reference section? $\boxed{2}$

- 1 point for using the equation that relates the LEDs forward voltage to its wavelength
- 1 point for writing the correct color

In an LED, an electron will drop the full length of the band gap. So, the forward voltage across the LED corresponds to the value of the band gap energy.

$$E_g = 2.15\text{V} \cdot 1\text{e} = 2.15\text{eV}$$

$$\lambda = \frac{hc}{E_g}$$
$$= \frac{4.136 \times 10^{-15}\text{eVs} \cdot 3 \times 10^8\text{m/s}}{2.15\text{eV}}$$
$$= 577 \text{ nm}$$

The color of the LED, based on table 1, is **yellow**

2.2 Explain why photons are released from an LED when it is powered. Use keywords such as *electrons* and *holes*, or, *conduction band* and *valence band*. $\boxed{1}$

Will accept any of these answers:

Free electrons in the semiconductor recombine with empty holes.

Electrons jump from the conduction band to the valence band.

2.3 We have an LED that we don't want to blow out. Our LED can safely handle a current of 20mA, I_{LED}, and has a forward voltage of 2V, V_{LED}. The circuit is supplied a voltage of 4V, V_{source}. Find the resistance, R. $\boxed{3}$

- 1 point for writing the current through the resistor
- 1 point for writing the voltage drop across the resistor
- 1 point for writing the resistance

$$I_R = I_{LED} = 20\text{mA}$$
$$V_R = V_{source} - V_{LED} = 2\text{V}$$
$$R = \frac{V_R}{I_R} = \boxed{100\Omega}$$

3 The Process of Calibration

3.1 You are given a Negative Temperature Coefficient (NTC) thermistor. You take two resistance measurements across the thermistor at different temperatures (see table below). Find the material constant, β. *(Use the model given in the reference section)* $\boxed{1}$

Temperature	Resistance Measurement
$100°C$	950Ω
$20°C$	$12\text{k}\Omega$

From the β equation in the reference section:

$$\boxed{\beta = 3468}$$

3.2 Using the β value calculated above, estimate the temperature, given a resistance measurement of $R_{test} = 10\text{k}\Omega$. *(Answer in units of **Celsius**)* $\boxed{1}$

Using the T_2 equation in the reference section:

$$\boxed{T_{test} = 24.6°C}$$

3.3 Which mathematical model **is the most accurate**, of the four choices below, for finding a precise temperature of a thermistor throughout the thermistor's entire working temperature range? $\boxed{1}$

Steinhart-Hart Equation

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4 Operational Knowledge of Basic Device Components

4.1 What is the purpose of this component? *(It is not an axial inductor, though it looks like one)* $\boxed{1}$

To limit current passing through it.

4.2 A **thermistor** acts similarly to which component? $\boxed{1}$

Resistor

4.3 What circuit component does a microcontroller use, internally, to convert an analog input voltage, connected to one of the microcontroller's GPIO pins, to a value that can be stored in memory? $\boxed{1}$

Analog-to-Digital Converter

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5 Reference

Table 1: Approximate Color with Respect to Wavelength

LED Color	Wavelength (nm)
Red	635-700
Orange	590-635
Yellow	560-590
Green	520-560
Cyan	490-520
Blue	450-490
Violet	400-450

Table 2: Constants and Equations

Symbol	Definition	Meaning
c	3×10^8m/s	Speed of Light
h	4.136×10^{-15}eVs	Planck's Constant
f	c/λ	Frequency of Light
E	$h \cdot f$	Photon Energy

Temperature is in **Kelvin** for the below equations.

$$\beta = \frac{\ln \frac{R_{T1}}{R_{T2}}}{\frac{1}{T_1} - \frac{1}{T_2}} \qquad T = \frac{\beta}{\ln\left(\frac{R}{R_0 e^{-\beta/T_0}}\right)}$$