WORK SHEET HERE:			
Supply Voltage	Channel VoltageResistor	Channel 2 VoltageLED	CurrentLED ($V_{resistor}$ / 220)
0 V[6]	0.002 V	0.002 V	9×10^{-6} A
0.5 V	0.005V	0.487 V	2.3×10^{-5} A
1.0 V	0.006 V	0.486V	1.7×10^{-5} A
1.5 V	0.039 V	1.45 V	1.77×10^{-4} A
2.0 V	0.421V	1.57 V	0.0019 A
2.5 V	0.887V	1.61 V	0.004A
5.0 V	3.32V	1.68 V	0.0145 A

0.025 A

At approximately what LED voltage does the LED start to glow?

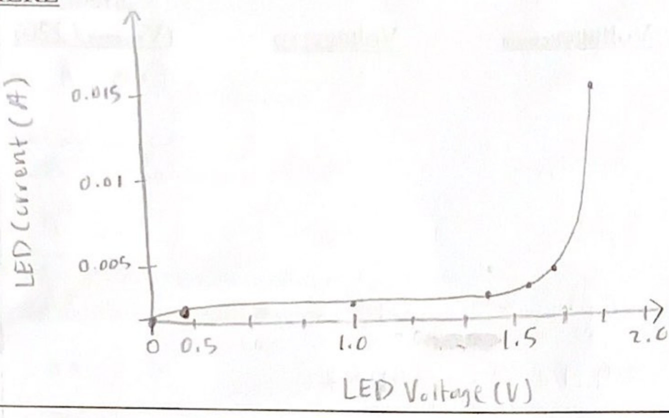
1.61V

It starts glowing very dimly at 1.61V, but is significantly brighter at 1.68 V.

[6] Turn the voltage supply off to achieve this. Note that you may see a non-zero reading on the voltmeter. The power supply has an absolute accuracy of ±10 mV and the voltmeter has an absolute accuracy of ±5 mV (for voltages < 0.5 V). Convince yourself whether or not this non-zero reading is unreasonable.

Plot LED current vs. LED voltage in the given space below.

ANSWER HERE



When choosing the resistor value for this circuit, we placed an upper bound on the diode current (25 mA) and used the max power supply voltage (5 V) to calculate a minimum resistance (5 V/25 mA = 200 ohm) to prevent damage to the LED. In the lab, you actually found that the diode current at a 5 V supply voltage was less than 25 mA! Explain why this is the case. (Note that this reduction in current is **not only** from rounding 200 ohms to 220 ohms)

ANSWER HERE

The LED itself uses somes of the voltage so it isn't actually 5V when we measure it, it was closer to 3.32 V.

In circuit theory, we sometimes make the simplification that once a diode is forward biased or "on", the voltage across a diode does not change[7]. Using the Vd you measured at a 5 V supply voltage, calculate the resistor value to place the diode current at exactly 25 mA. Show your work:

1.68 V

$V_d = 1.68\,V$ $\qquad \frac{1.68\,V}{0.025A} \rightarrow \boxed{67.2\,\Omega \text{ resistor}}$

[7] This is called the Constant-Voltage Drop model for a diode (covered in ECE 115A).

ANSWER HERE

Answer on previous page

Phototransistors

In order to understand how phototransistors work, we will first look at a regular transistor. Transistors are three terminal devices that act as linear amplifiers, or, on a basic level, as switches. In this class, we will primarily be working with *Bipolar Junction Transistors*, or BJTs, shown in the figure below. BJTs have three terminals labeled base (B), collector (C), and emitter (E). The direction of the arrow points in the direction of current flow. (The symbol and operation listed in Figure 3-9 is for an NPN BJT. You may work with PNP BJTs later for your project, which have a different symbol and operation.)

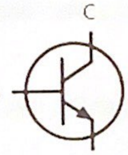


FIGURE 3-9: NPN BJT Symbol

In an NPN BJT, when a high voltage with respect to the emitter is applied to the base, current is allowed to flow from the collector to the emitter. When a low voltage with respect to the emitter is applied to the base, current is no longer allowed to flow from the collector to the emitter. This allows the transistor to act as an electrically controlled switch.

In this portion of the lab, we will work with BJT-based phototransistors. BJT-based phototransistors have an *exposed base* that is sensitive to light. When light shines on the base, the phototransistor allows current to flow from the collector to the emitter. **Within the scope of this course,** in general we can think of **phototransistors as variable resistors with its resistance depending on the incoming light intensity. The higher the incoming light intensity (brighter), the less effective resistance the phototransistors will have.**

In this course we will introduce one way of "reading" light intensity information from phototransistors. Namely, reading the change in the "RC measurement time". This is essentially the general strategy used for collecting inputs from the phototransistor array in your actual line-following car, and we will be qualitatively examining this strategy using discrete circuit components on a breadboard today.

(1) Calculate and tabulate your experimental results in the chart below:

WORK SHEET HERE:			
Condition	Start Time	Measurement Time	Phototransistor Resistance[9]
High Bright	X	499.9 μs	190, 319.96 Ω
Medium Bright	X	X	X
Dark	X	2.956 ms	1,125,396.66 Ω

(2) Use any plotting software/programming language (e.g., C++, Excel, Matlab, Python…) of your choice, plot the three experimental curves on the same plot (we give **NO** credit for hand-drawn curves). [9]

Please include your plot (screen shot is also ok) on the following page.

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[9] See note below. See also Equation 12, above.

Calculating R_{pt}

In lecture, we discussed the equation describing the behavior of a capacitor discharging into a resistor.

$$v_C(t) = V_S e^{-\frac{t}{RC}}$$

$\ln\left(\frac{V_c}{V_s}\right) = \frac{-t}{RC}$

$C \cdot \ln\left(\frac{V_c}{V_s}\right) = \frac{-t}{R}$ $\quad R = \frac{-t}{C \cdot \ln\left(\frac{V_c}{V_s}\right)}$

In this equation, we know V_S, C, t (measured by the oscilloscope), and the voltage $v_C(t)$ at t's value. IOW, we know everything but R. All we need to do is solve for R.

$V_c(t) = 1V$ $\quad V_s = 3.3V$

$t = 870.2 \mu s$ $\quad R = ?$ $\quad C = 2.2nF$

Voltage in Capacitor Over Time