# ENGR 212: Laboratory Experiment 2

Answer Guide & TA Notes

Teaching Assistant Reference

## Overview

This guide outlines the theoretical values and expected behaviors for **Lab Experiment 2**. Use this to verify student results and explain discrepancies during the lab session.

## 1 Part 1: Voltage Divider Circuit Calculations

### Problem Statement

Students must calculate $v_{out}$, $i$, and $P_{R_2}$ for the circuit in Figure 1(a) with a fixed source of 10V and $R_1 = 10\text{k}\Omega$. The value of $R_2$ varies across five specific resistance values.

### Formulas Used

The circuit is a standard unloaded voltage divider.

1. **Current ($i$):**

$$i = \frac{V_{source}}{R_{eq}} = \frac{10\text{V}}{R_1 + R_2}$$

2. **Output Voltage ($v_{out}$):**

$$v_{out} = i \times R_2 = 10\text{V} \times \left(\frac{R_2}{R_1 + R_2}\right)$$

3. **Power Dissipated by $R_2$ ($P_{R_2}$):**

$$P_{R_2} = i^2 \times R_2 = \frac{(v_{out})^2}{R_2}$$

### Answer Key (Theoretical Values)

Use the table below to check the "Calculation" columns in student reports. Note that power is calculated in milliwatts (mW).

| $\mathbf{R_2}$ **Value** | **Total R** $(\mathbf{R_1 + R_2})$ | **Current i** | **Voltage** $\mathbf{v_{out}}$ | **Power** $\mathbf{P_{R_2}}$ |
|---|---|---|---|---|
| $2.2\,\mathrm{k}\Omega$ | $12.2\,\mathrm{k}\Omega$ | **0.820 mA** | **1.80 V** | **1.48 mW** |
| $4.7\,\mathrm{k}\Omega$ | $14.7\,\mathrm{k}\Omega$ | **0.680 mA** | **3.20 V** | **2.18 mW** |
| $10\,\mathrm{k}\Omega$ | $20.0\,\mathrm{k}\Omega$ | **0.500 mA** | **5.00 V** | **2.50 mW** |
| $20\,\mathrm{k}\Omega$ | $30.0\,\mathrm{k}\Omega$ | **0.333 mA** | **6.67 V** | **2.22 mW** |
| $33\,\mathrm{k}\Omega$ | $43.0\,\mathrm{k}\Omega$ | **0.233 mA** | **7.67 V** | **1.78 mW** |

Table 1: Theoretical values for Table 1. Measured values should be within resistor tolerance ($\approx 5\%$).

# 2 Part 2: LED Circuit Analysis

## Theoretical Expectations

### 1. Forward Bias Behavior (Steps a–c)

- **Threshold:** An LED is a non-linear device. Current will remain near zero until the voltage across the LED reaches its **turn-on voltage** ($V_{turn-on}$).
- **Typical** $V_{turn-on}$**:** For a standard red LED, this is typically **1.8V − 2.0V**.
- **Behavior:**
  - **Input 1V:** Source < Turn-on. LED is OFF. $I \approx 0$mA. $V_{LED} \approx 1$V (Open circuit behavior).
  - **Input 2V $\sim$ 5V:** Source > Turn-on. LED turns ON. $V_{LED}$ clamps near the forward voltage ($\approx 2$V) and rises very slowly. Current increases linearly with the remaining voltage drop across the resistors.

### 2. Effect of Varying $R_1$ (Step d)

Increasing $R_1$ increases the total series resistance ($R_{total} = R_1 + R_2$).

- **Impact:** For the same input voltage, a higher $R_1$ results in **lower current** flowing through the LED, making it dimmer.
- The voltage across the LED ($V_{LED}$) will remain relatively stable (characteristic of a diode), but the voltage drop across the resistors will change significantly.

### 3. Estimating Turn-on Voltage (Step f)

When students plot $I$ ($y$-axis) vs $V_{LED}$ ($x$-axis), they should observe a "knee" in the graph.

- The curve should be flat (at $I = 0$) until roughly **1.8V** (for Red LED), after which current shoots up steeply.

### Sample Calculation

*Assuming a Red LED ($V_{turn-on} \approx 1.9V$), Input = 5V, and $R_1 = 0\Omega$:*

$$\begin{aligned} V_R &= 5\text{V} - 1.9\text{V} = 3.1\text{V} \\ R_{tot} &= 3.9\text{k}\Omega \\ I &= \frac{3.1\text{V}}{3.9\text{k}\Omega} \approx 0.79\text{mA} \end{aligned}$$

## Supplementary Note: Loading Effect

Although "loading effect" is listed in the objectives, it is not explicitly calculated in the numbered steps.

- **Concept:** The loading effect occurs when a load resistor $R_L$ is attached in parallel to $R_2$ (Figure 1b). This reduces the effective resistance of the bottom branch to $R_{eq} = R_2 \parallel R_L$.
- **Result:** The measured $v_{out}$ will be **lower** than the calculated unloaded $v_{out}$ from Table 1.