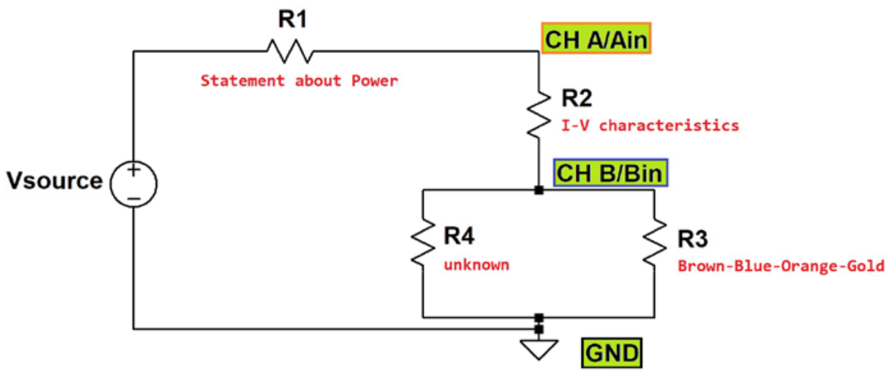
SOLUTIONS

2. Circuit Laws and Resistors (25 points)

Consider the circuit shown below. The DC voltage of the source, Vsource, is unknown. We do know a few details about the resistors that are used in the circuit and the voltages measured using channel A and channel B (both measured with respect to ground) measured at points shown in the circuit to be **10.7635 V** and **5.6526 V** respectively.

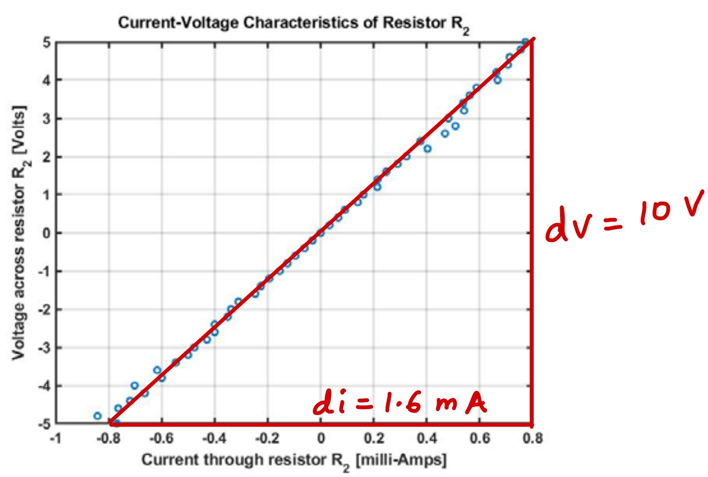


2.1 The power absorbed by resistor R1 is 4.3 mW when 1.693 mA flows through it. Note: 'm' stands for milli. What is the value of R1?

$$R1 = \frac{P1}{I1^2} = \boxed{1.5\ k\Omega}$$

2.2 The current-voltage characteristics of resistor R2 is shown below. Determine the value of R2? Each circle represents one experiment trial. The horizontal axis is current in milli-amps. The vertical axis is voltage in volts.

$$R2 = \frac{dv}{di} = \frac{10}{1.6m} = 6.25\ k\Omega$$



2.3 The color code of resistor R3 is Brown-Blue-Orange-Gold. What is the value of resistor R3?

$R3 = \boxed{16\ k\Omega} \pm 5\%$

2.4 Given the voltages measured using channel A and channel B (both measured with respect to ground) at points shown in the circuit are 10.7635 V and 5.6526 V respectively, and using the answers from the previous questions, determine the value of Vsource? Hint: First find current through R2.

Voltage across R2 = CA V − CB V = 5.111 V

Current through R2 = $\frac{5.111}{R2}$ = 0.8178 mA or 817.8 μA

This is the same current through R1

⇒ Voltage across R1 = (1.5 kΩ)(0.8178 mA) = 1.2267 V

$V_{source} = V_{R1} + CA\ V = 11.99\ V$ $\boxed{12\ V}$

or $= V_{R1} + V_{R2} + CB\ V = 11.99$

2.5 Using all the information you have so far about this circuit, determine how much current flows through resistor R4?

Current through R3 = $\frac{CB\ V}{R_3}$ = 0.3533 mA or 353.3 μA

Current through R4 = Current through R2 − Current through R3

= 817.8 μA − 353.3 μA

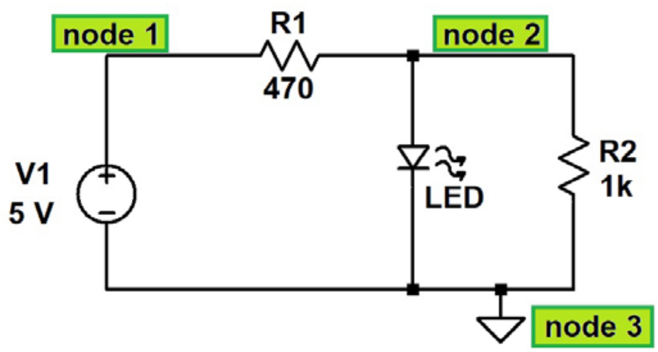
= $\boxed{464.5\ \mu A}$

Optional: $R4 = \frac{CB\ V}{I_{R4}} = 12.17\ k\Omega$

3. DC measurements using M1K board (25 points)

The ADALM1000 (M1K) board is to be used to experimentally determine the voltage across R1, R2, and LED in the circuit below. Later (in question 3.3) these voltages measurements are used to calculate the current through the LED.

Note: Don't perform any experiments to answer this or any other question on this quiz. Answer questions based on information provided.



3.1 The voltage drop across R1, R2, and LED can be measured using the M1K board by making wire connections between the circuit and M1K board pinouts.

In the following table, indicate what wire connections should be made between the M1K board and the circuit. Three nodes have been highlighted in the circuit diagram for you to use them as reference points in the table below. One of the rows has been answered already. There are more rows in the table than you need.

Node on circuit diagram	Pinout of M1K board
node 1	5 V
node 1	CH A or Ain
node 1	—
node 2	CH B or Bin
node 2	—
node 2	—
node 3	GND

Alternate solution: Use Channel A (or B) in split I/o mode. Alice meter - source tool.

3.2 After making the connections based on your table for 3.1, explain in a few sentences how you would determine the voltage drop across R1, R2, and LED. You would need to specify the software tool you would use, and where/which channel voltage you would be looking at for the voltage across each of the three components.

Software tool: Alice Voltmeter

Use channel A to measure voltage at node 1, with respect to ground. (CA-V)

Use channel B to measure voltage at node 2, with respect to ground. (CB-V)

V_{R1} = CA V − CB V

V_{R2} = CB V

$V_{LED} = V_{R2}$ = CB V

3.3 Assume that the voltage at node 1 (with respect to ground) was measured to be 5 V and node 2 (with respect to ground) was measured to be 3 V. Determine the current flowing through the LED? Express your answer in milli-amps.

$V_{node\,1} = 5\,V$, $V_{node\,2} = 3\,V$

$V_{R1} = V_{node1} - V_{node\,2} = 2\,V$

$I_{R1} = \frac{V_{R1}}{R_1} = \frac{2\,V}{470\,\Omega} = 4.255\,mA$

$V_{R2} = V_{node\,2} = 3\,V$

$I_{R2} = \frac{V_{R2}}{R_2} = \frac{3\,V}{1K\,\Omega} = 3\,mA$

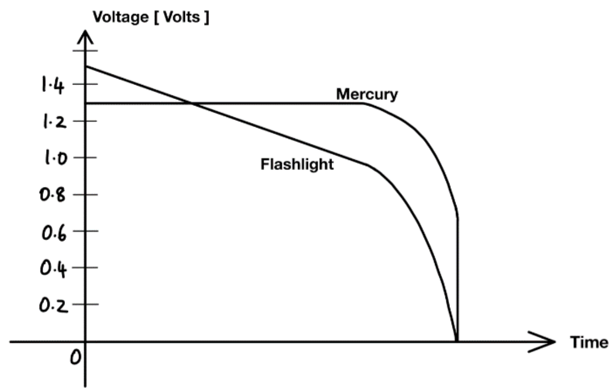
$I_{LED} = I_{R1} - I_{R2} = $ **1.255 mA**

4. Voltage Dividers and Battery Characteristics (25 points)

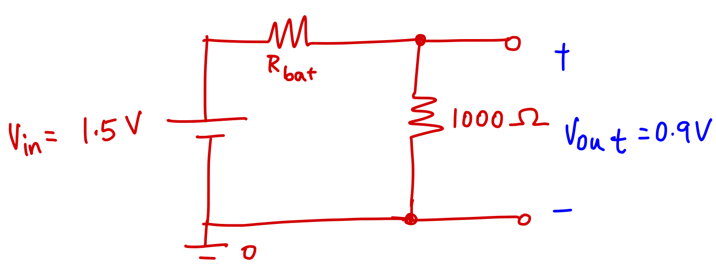
4.1 The voltage-time curves for two types of batteries, flashlight (Vbat = 1.5 V) and Mercury (Vbat = 1.3 V), are shown below. The voltage on the vertical axis is measured using a voltmeter. Interpret the behavior in terms of the respective internal resistances. For this, you need to specifically comment about how their internal resistances (Rbat) change over time.

Initially, the internal resistance of flashlight battery increases rapidly - at a much faster rate compared to that of the Mercury battery.

As time increases, just before the batteries are completely dead, the internal resistance of Mercury battery increases sharply.



4.2 A new voltmeter whose internal resistance is 1000 ohms measures the voltage of a worn-out 1.5 V flashlight battery (same one used in the previous part) as 0.9 V. What is the internal resistance of the battery?

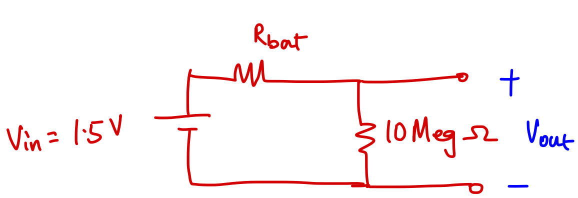


$$V_{out} = V_{in}\left(\frac{1000}{1000 + R_{bat}}\right)$$

$$\Rightarrow 900 + 0.9\,R_{bat} = 1500$$

$$\Rightarrow \boxed{R_{bat} = 666.67\ \Omega}$$

4.3 If the flashlight battery from the previous part had been measured using a vacuum tube voltmeter with a internal resistance of 10 Mega-ohms, what voltage would have been read? Assume that Rbat << 10 Mega ohms.



$$R_{bat} << 10\ \text{Meg}\ \Omega$$

$$\Rightarrow \boxed{V_{out} \approx V_{in} = 1.5\ V}$$