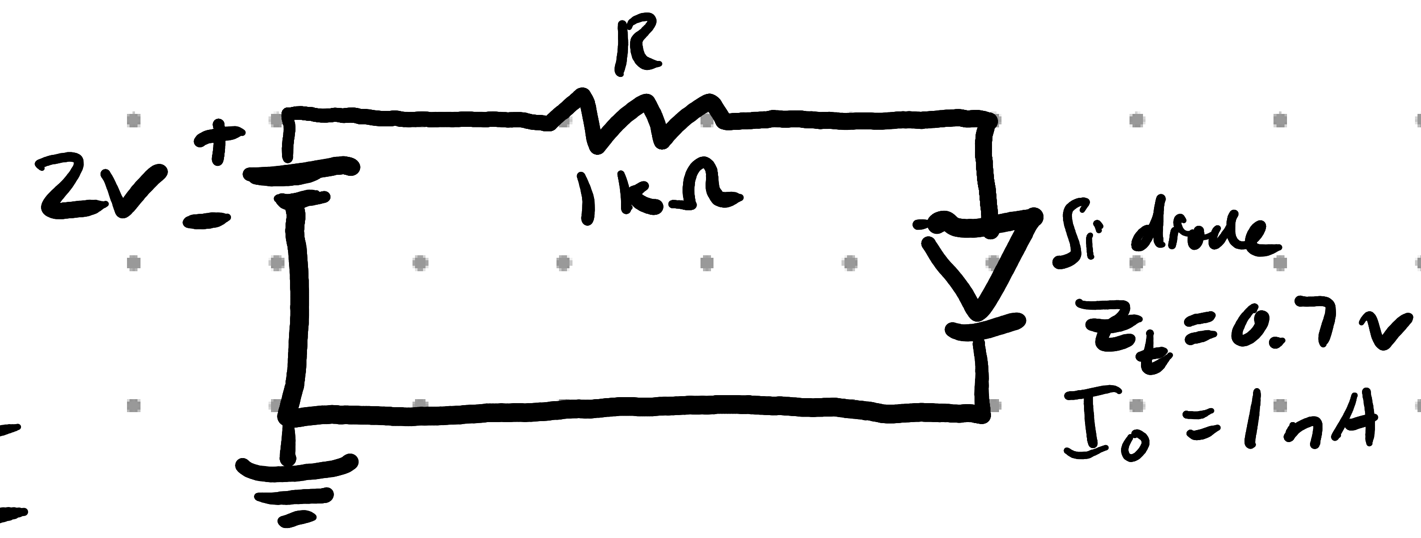
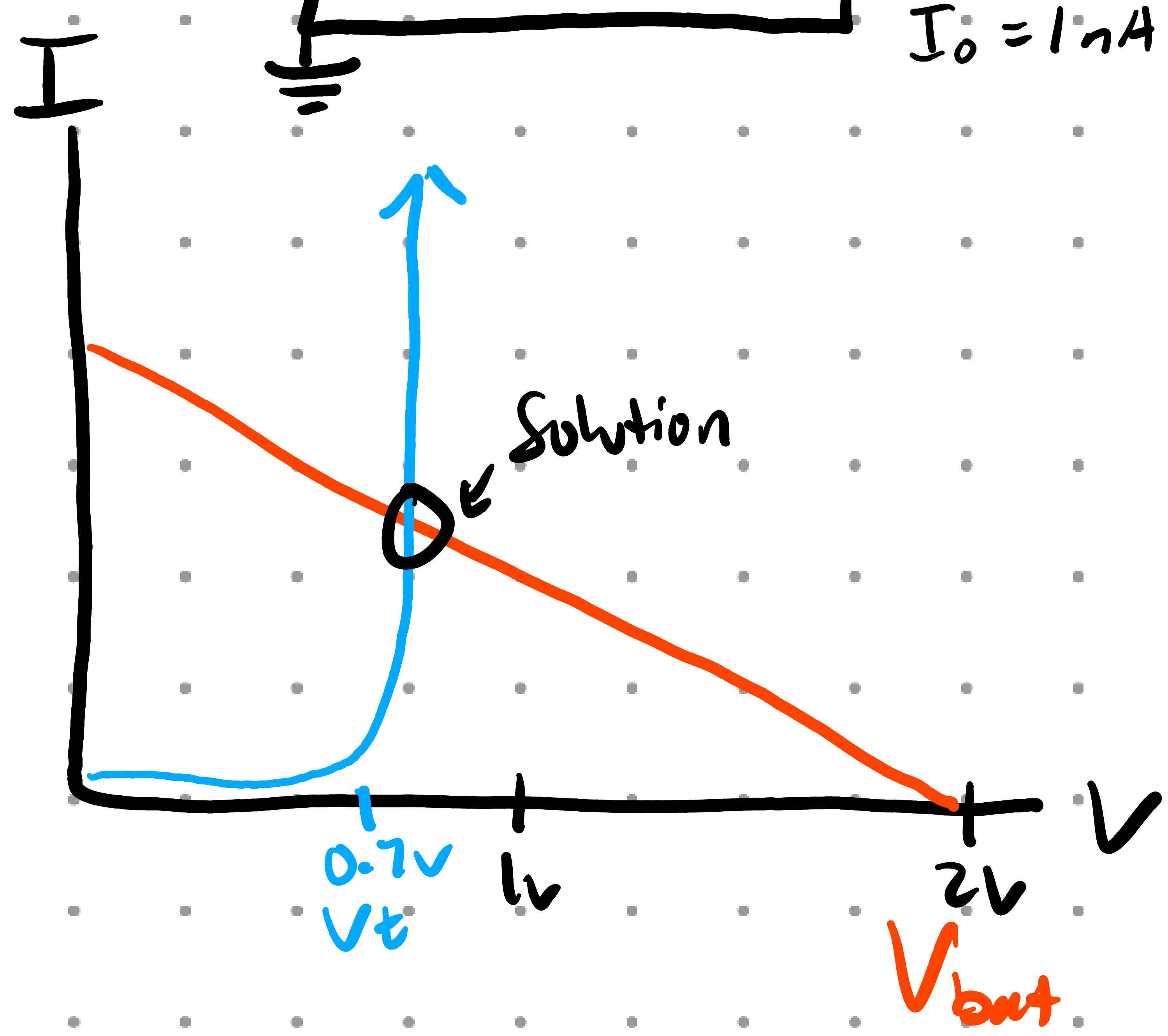
Joseph Hutchinson ITE HWK4 $\boxed{2024\text{-}02\text{-}09}$

1. Consider a series circuit consulting of an ideal DC voltage source (2.0 V), a resistor (1.0 kΩ) and a silicon diode that is biased in the forward direction. A Si diode has a turn-on voltage of 0.7 V and a reverse saturation current of I_0 = 1 nA.
   (a) Sketch the electrical circuit. Make a quantitative plot of the diode forward characteristic and the load line. Determine the diode forward current from the plot.
   (b) Calculate the diode forward current without using the plot. Comment on the agreement / disagreement between graphical solution and analytical solution.
   (c) Next consider that the polarity of the diode is reversed. Sketch the electrical circuit. Make a quantitative plot of the diode reverse characteristic and the load line. Determine the diode current from the plot.
   (d) What is the diode reverse current (without using the plot)? Comment on the agreement / disagreement between graphical solution and analytical solution.

a)





$$V_{bat} - IR = V_{Diode} \rightarrow 2 - IR = 0.7$$

$$I = \frac{1.3}{1K} = 1.3mA$$

$$I = I_0\left(e^{V/26mV}\right) \text{ for } V >> V_t$$

$$I = (1\cdot10^{-9})\left(e^{2/20mV}\right)$$

$$\boxed{I_D = 1.74\cdot10^{-8}A = 17.4\ nA}$$

b) $2v = V_R + V_D$

$2v = (I\cdot1k) + 0.7$

$I = \frac{1.3}{1k} = 0.0013\ A = 1.3\ mA$

$\boxed{\text{calculation gives } I_D = 1.3\ mA}$

$\boxed{\text{Analytical solution is higher current than graphical}}$

c)

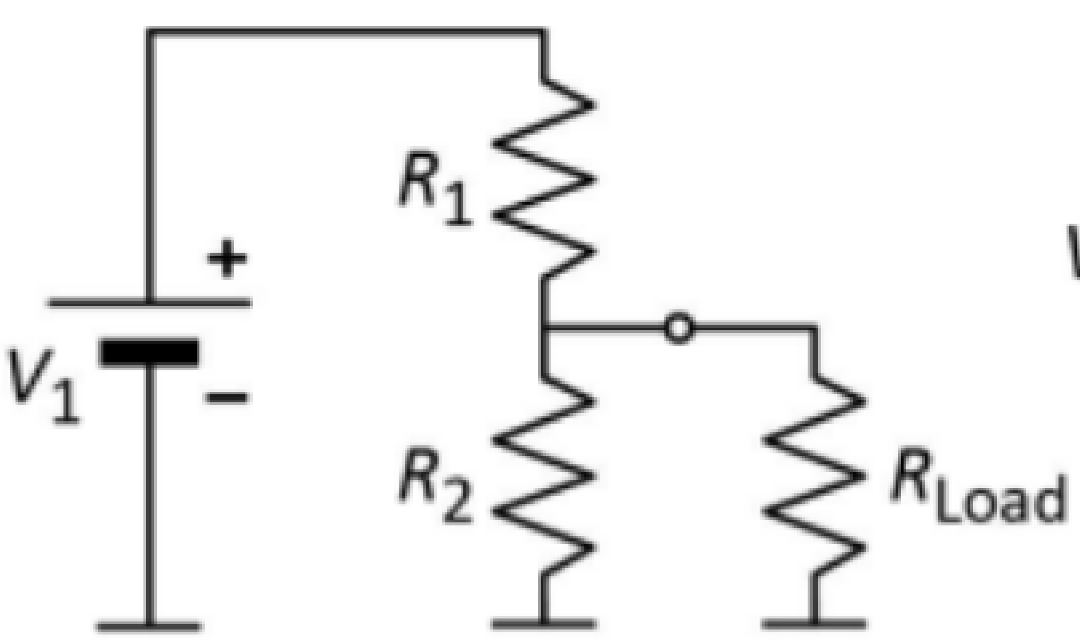
$$I = I_0\left(e^{-2V/0.7V} - 1\right) = -9.4\times10^{-10}\ A$$

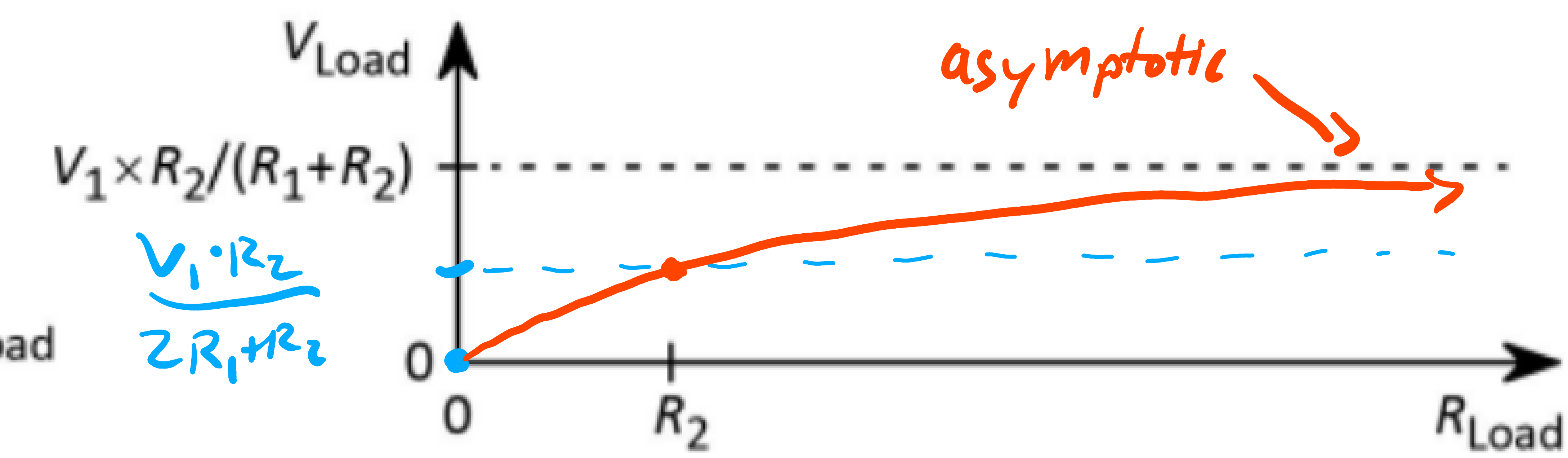
$$\boxed{I_D = -0.9\ nA}$$

d) Analytically, $\boxed{I_D = -1\ nA}$ → these are closer, but the graph value is of lower magnitude

2. A voltage divider is intended to provide a stable voltage to a load. A Zener diode circuit is also intended to provide a stable voltage to a load. This problem compares the two methods.

(a) The circuit below is a voltage divider that is connected to a load resistance (R_{Load}). Draw the right-hand-side (RHS) diagram and complete it.





(b) What do we learn from the diagram? Which condition must the load resistance satisfy, so that a voltage divider works as intended?

R_L can range from $0 \rightarrow R_2 \rightarrow$ infinite value

→ At $R_L = 0$, the measured voltage is tied directly to GND, so V_{Load} becomes = $\boxed{0V}$

→ At $R_L = R_2$, the resistance of R_{2+L} is "halved" via parallel resistance

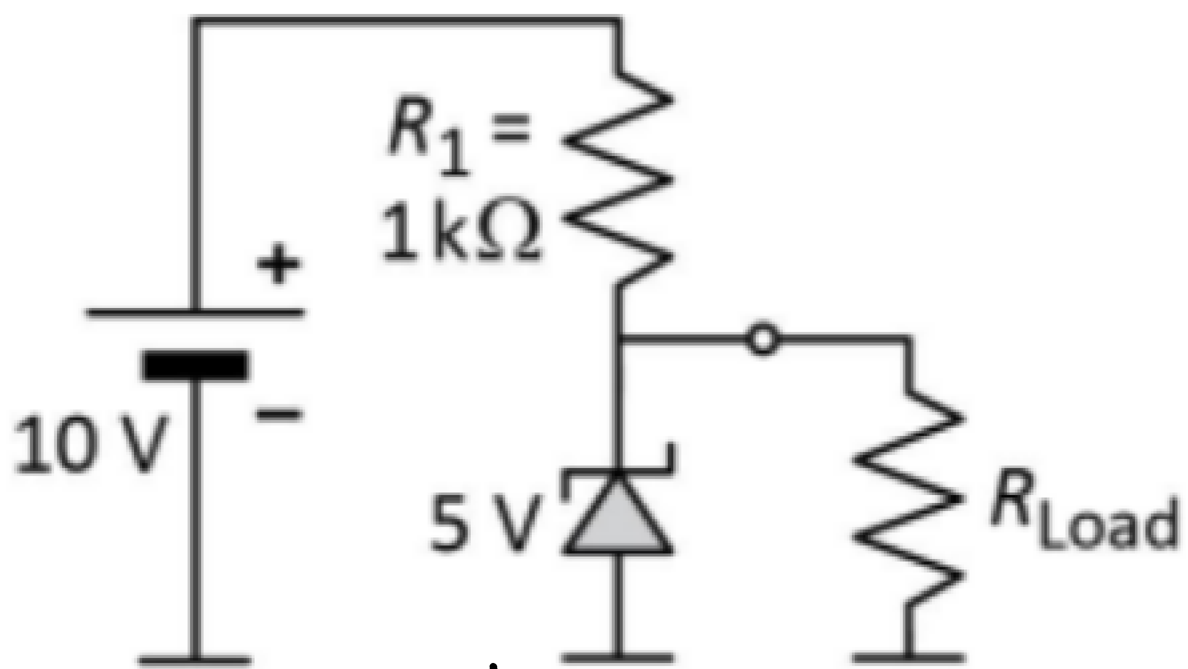
$$V_L = \frac{V_1 \cdot \frac{R_2}{2}}{R_1 + \frac{R_2}{2}} = \boxed{\frac{V_1 \cdot R_2}{2R_1 + R_2}} \text{ for } R_L = R_2$$

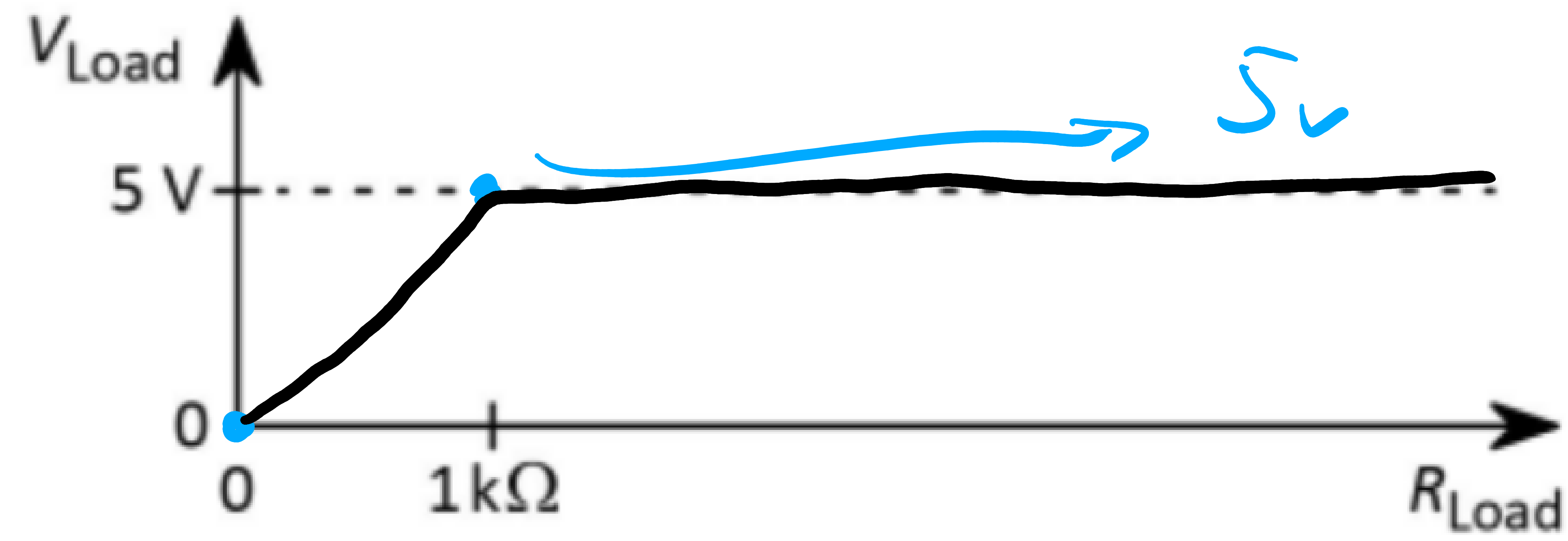
→ At $R_L = \infty$, the voltage divider acts as normal with an open circuit to GND at V_L. So;

$$V_L = \frac{V_1 \cdot R_2}{(R_1 + R_2)} \text{ for } R_L = \infty$$ → this will be <u>asymptotic</u>!

b) From the diagram, we can tell that the load condition must be $R_L = \infty$ for the divider to function as normal.

(c) The circuit below is a Zener-diode-voltage-stabilization circuit that a load is connected to. Draw the RHS diagram and complete it.





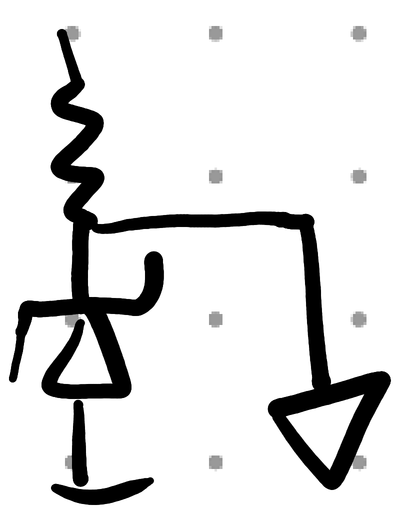
off for V<5v

(d) What do we learn from the diagram? Which condition must the load resistance satisfy, so that a voltage stabilization circuit provides a stable voltage?

(e) Compare the two circuits above. Advantages? Disadvantages?

c) Consider another 3 conditions for R_L:

→ For $R_L = 0$:



$\boxed{V_L = 0\,v}$

→ to GND

→ for $R_L = R_1 = 1k$

divider formed which gives 5v at V_L, so $\boxed{V_L = 5v}$

→ for $R_L \to \infty$

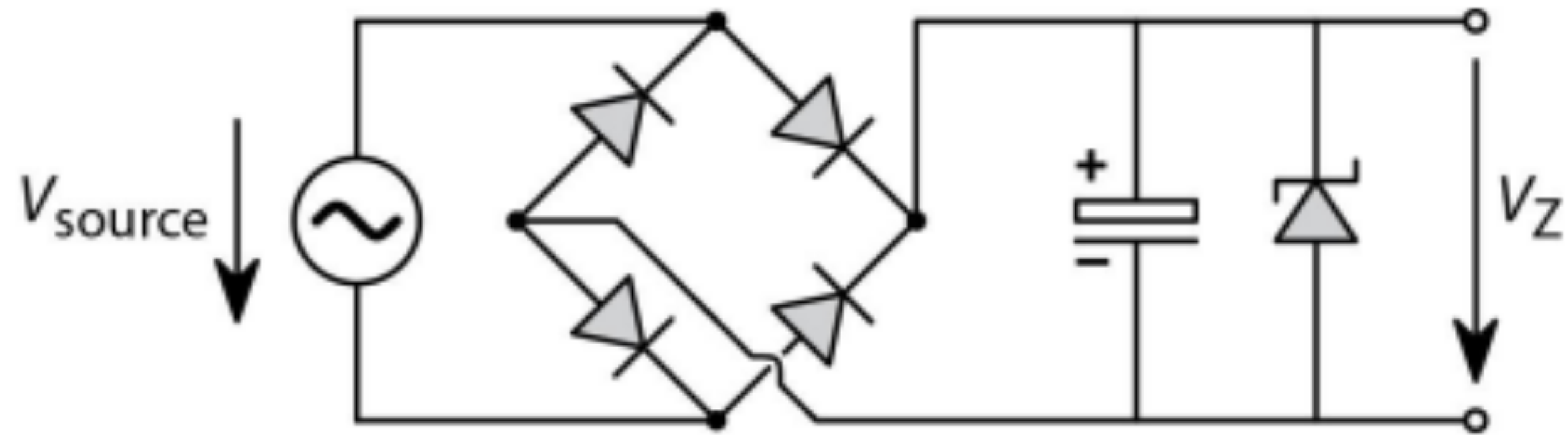
Zener will receive > 5v but will breakdown and stabilize V_L to be = 5v again

$\boxed{V_L = 5v}$

d) Diagram shows stability of Zener diode!
R_L must be $\geq R_1$ in this case to give stable voltage

e) First circuit is "simpler" in that it only has resistors, but Second circuit has a stable output and works for reasonable values of R_L! 2nd only works for $V > V_Z$

3. Consider the voltage-stabilization circuit below.



(a) Explain the purpose of the Zener diode.

(b) What is the major disadvantage of the circuit?

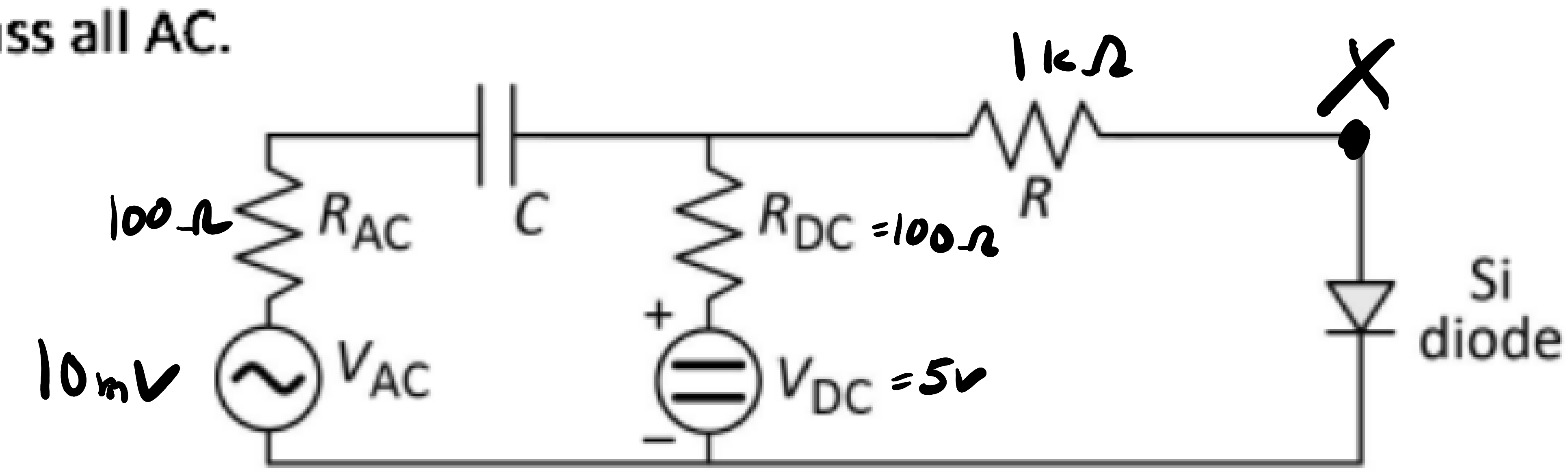
a) The Zener diode here acts as a stabilizer of the rectifier's output voltage. It will reduce the magnitude of "voltage ripples" seen on the output wave (which SHOULD be DC).

The Zener is acting to mitigate a "bad" signal!

b) There will inevitably be some amount of lost power in the Zener diode, due to the current passing through it when it must stabilize the voltage. The Zener will have some real resistance, which will thus convert a portion of the output power to thermal energy (heat).

The circuit is also best suited for input Vsource voltages that are high enough so that voltage drop across the rectifier diodes is not an issue. If Vsource is too low, then the Zener may lead to issues and the output would be VERY low.

4. Consider the following diode circuit containing a silicon pn-junction diode with V_{AC} = 10 mV, R_{AC} = 100 Ω, V_{DC} = 5 V, R_{DC} = 100 Ω, and R = 1 kΩ. Assume that the capacitor C blocks all DC but lets pass all AC.



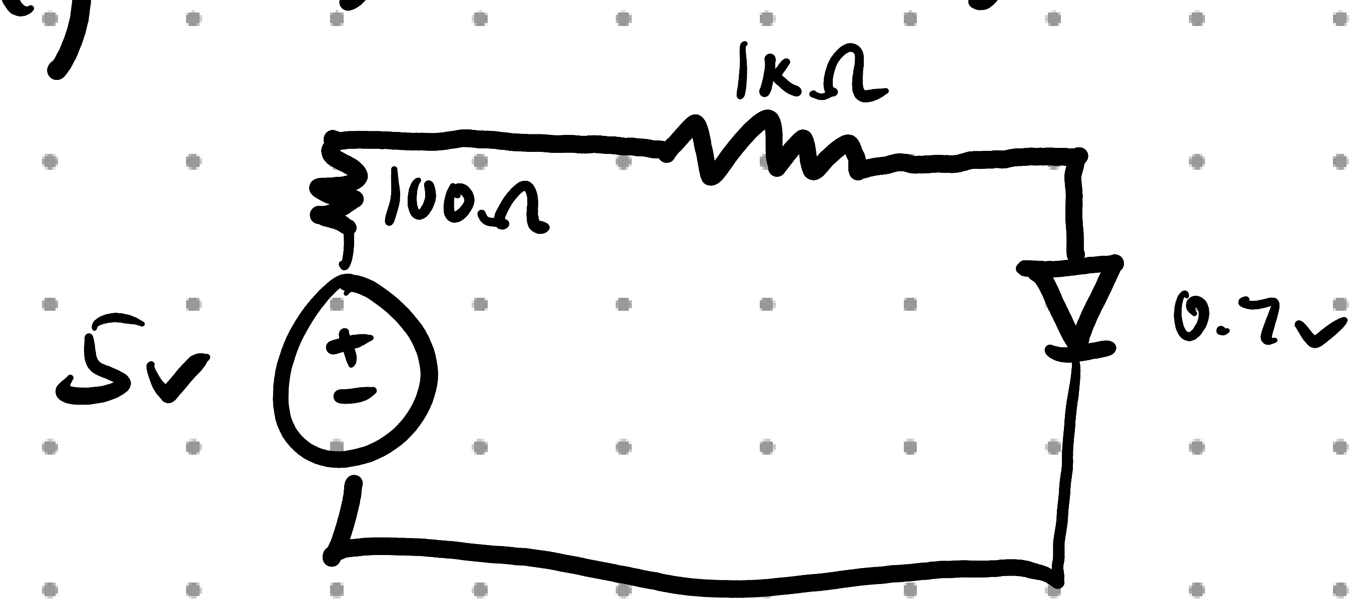
= Voltage of $V_D = 0.7v$

(a) Determine the steady-state voltage and current (DC values) of the diode (numerical values). The steady-state values may be called quiescent-point (Q-point) values.

(b) Draw an AC small-signal equivalent circuit of the diode circuit. Determine the Si-diode's differential resistance (numerical value).

(c) Determine the AC voltage across and current through the diode (numerical values).

a) For DC source being considered:



$V_D = 0.7v$ for silicon

$5v = (I \cdot 100) + (I \cdot 1000) + 0.7v$

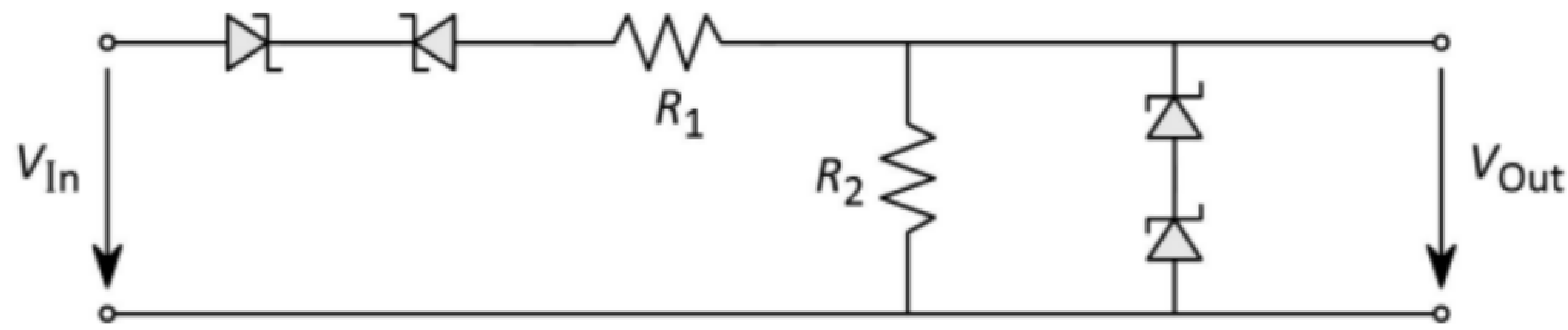
$I = \frac{4.3}{1100} = \boxed{3.90909\,mA}$

Steady-state / quiesent values of Diode are: $\boxed{\begin{matrix} V_D = 0.7v \\ I_D = 3.909\,mA \end{matrix}}$

b) $r_D = \frac{V_t}{I_d} = \frac{26\,mV}{3.909\,mA} = 6.67\,\Omega$

c)

5. Consider the following Si Zener-diode circuit. Assume that the Zener voltage of all four Zener diodes is $V_{Zener} = 5$ V. Assume that $R_1 = R_2 = 1$ kΩ.



(a) Define the diode threshold voltage (in your own words) and give its numerical value for the above circuit. Define the Zener voltage (in your own words) and give its numerical value for the above circuit.

(b) Draw the output-voltage-versus-input-voltage diagram of the circuit. Use the abscissa (horizontal axis) for the input voltage and the ordinate (vertical axis) for the output voltage. Mark all significant points of the diagram with numerical voltage values.

(c) Explain the diagram that you drew under the previous question.

(d) What is the output voltage for $V_{In} = 10$ V? What is the current value through R_1?

(e) What is the output voltage for $V_{In} = 30$ V? What is the current value through R_1?