Diode Tutorial Sheet Solutions

Q1. You are given a large number of identical diodes. You have a DC voltage source whose voltage varies randomly between 9 V to 11 V. Using the diodes available, design a simple circuit whose output voltage is fixed at 4.9 V.

Answer: Connect seven diodes in series. Connect this string of seven diodes to the power supply through a series resistor R_S. As long as the input voltage is in the range (9 V, 11 V), there will be enough current to forward bias the diodes.

Q2. Figure-2 shows the circuit diagram for a bridge rectifier. The mains AC voltage of 220 V and 50 Hz is connected to a transformer whose **primary windings** are N times its **secondary windings**. For such a transformer, the output is an AC voltage, whose amplitude is $1/N$ times the amplitude of the input voltag and whose frequency is the same as the primary frequency. You want this bridge rectifier to provide DC power to your laptop at a DC voltage of 20 V. Assume that your laptop has an effective resistance of 1 kΩ. You are willing to tolerate a **ripple** of 5% in your output voltage. Ripple is defined as

$$\text{Ripple} = \frac{Maximum\ Voltage - Minimum\ Voltage}{Maximum\ Voltage} \times 100.$$

- What is the value of primary winding number N?
- What is the value of the capacitor C?
- What is the maximum reverse bias voltage faced by the diodes?
- What is the peak current through each diode?

Answer: If N = 10, then the peak voltage of the secondary is 22 V. Of this $2 \times 0.7 = 1.4$ V is needed to keep two diodes forward biased. So the capacitor gets charged to a maximum voltage of $V_{max} = 22 - 1.4 = 20.6$ V. From the definition of the ripple, we see that the minimum voltage across the capacitor is $V_{min} = 0.95\ V_{max} = 19.57$ V. Assuming that the exponential discharge of the capacitor can be approximated by a linear function, this minimum voltage is

$$V_{min} = V_{max}\left(1 - \frac{t}{\tau}\right) = V_{max}\left(1 - \frac{T}{2\tau}\right),$$

where $\tau = R_L C$ is the time constant of the discharge and $t = T/2$ is the duration of the discharge for a full wave rectifier. The time period of the AC voltage $T = 1/50 = 0.02$ sec. From the above equation, we get

$$\frac{0.01}{R_L C} = 0.05, \quad C = 200\mu F,$$

for $R_L = 1$ kΩ.

Peak inverse voltage across any diode is -21.3 V. We can see this both from the point of view of positive and negative values of V_S. Suppose $V_S = 22$ V. Then there is a drop of 0.7 V across the top-right diode which is conducting. The bottom-right diode, which is under reverse bias, has a voltage -21.3 V across it. When $V_S = -22$ V, the top-left diode is forward biased with a voltage drop of 0.7 V. Hence, the bottom-left diode experiences a reverse bias voltage of -21.3 V.

Current through the diode is essentially constant and is equal to 20.6/1 kΩ = 20.6 mA.

Q3. For the circuit in Figure-3, the input voltage has the range $0 \leq V_i \leq 5\, V$. Using the second approximation for the diodes, plot V_0 vs V_i for the the given range of V_i.

Answer: We denote the potential at the other end of 20 Ω resistor to be V_A. The current through the 20 Ω resistor is $I = I_1 + I_2$, where I_1 is the current through the 1.5 V battery and I_2 is the current through the 50 Ω resistor.

Case (a): $V_A < 0.7$ V: Then both the diodes are non-conducting. So, $I_1 = 0 = I_2$ leading to $I = 0$ and $V_i = V_A$. As along as $0 < V_i < 0.7$ V, we have $V_A = V_i$ and $V_0 = 0$.

Case (b): 0.7 V $< V_A <$ 2.2 V: In this case, the diode in series with 50 Ω resistor is conducting but the diode in series with 1.5 V battery is non-conductiong. That is, $I_1 = 0$ and $I_2 \neq 0$ with $I = I_2$. We have the following three relations

$$V_i = V_A + 20 I_2, \quad V_0 = 50 I_2 = V_A - 0.7,$$

between the four variables V_i, V_A, V_0 and I_2. Given any one quantitty, all the other quantities can be determined. For V_A in the range (0.7 V, 2.2 V), we get V_i to be in the range (0.7 V, 2.8 V). The corresponding range of V_0 are (0, 1.5 V).

Case (c): $V_A = 2.2$ V: In this case, the diode in series with 1.5 V battery becomes conducting and $I_1 \neq 0$. Since this branch has zero resistance, all it draws all the current and the current through the 50 Ω resistance $I_2 = 0$. In this case, $V_0 = 0$ and $V_A = 2.2$ V are held fixed. The input voltage is given by $V_i = 2.2 + 20 * I_1$ which holds for values of V_i in the range (2.8 V, 5 V).

Q4. For the circuit given in Figure-4, the input voltage varies as

$$V_i = \frac{V_0}{\pi}(\omega t)\sin(\omega t).$$

What is the value of V_{out}, when ωt takes values $\pi/6$, $\pi/2$, π, $3\pi/2$, 2π and $13\pi/6$? What do you think is the purpose of this circuit? What does V_{out} represent?

Answer: This circuit is calledd **peak detector**. Whenever V_i reaches a new peak, the capacitor gets charged to that voltage and remains there until V_i reaches a higher peak.
At $\omega t = \pi/6$, we have $V_{out} = V_0/12$. For $\omega t = \pi/2$, we have $V_{out} = V_0/2$. It remains at this value until $\omega t > 2\pi$ because, in the range $\pi/2 \leq \omega t \leq 2\pi$, the value of V_i is always less than $V_0/2$. At $\omega t = 13\pi/6$, the out voltage $V_{out} = (13/12)V_0$.

Q5. Figure-5 shows a circuit with two Zener diodes back to back. Plot the graph of V_0 vs V_i for V_i in the range $-10\ V \leq V_i \leq 10\ V$.

Answer: We have two Zener diodes back to back. Given the way they are connected, if there is current in them, then one Zener diode should have Zener breakdown and the other should be forward biased. Thus the potential difference across both the diodes together will have magnitude 5.7 V, if there is current in the diodes. If there is no current in them. then $V_0 = V_i$. This no current condition holds when V_i is in the range (-5.7 V, 5.7 V). For values of V_i outside this range, there will be current through the diodes and $V_0 = 5.7$ V for $V_i \geq 5.7$ V and $V_0 = -5.7$ V for $V_i \leq -5.7$ V.

Q6. For the circuit in Figure-6, we have $V_Z = 10\ V$ and $R_S = 100\ \Omega$. The minimum Zener current is 10 mA and the maximum Zener current is 90 mA. The minimum load resistance is 200 Ω and the maximum load resistance is 500 Ω. Given these parameters, determine the minimum and the maximum values of V_i for which the Zener diode will have Zener breakdown.

Answer: We have the inputs $V_Z = 10$ V, $I^Z_{min} = 10$ mA, $I^Z_{max} = 90$ mA, $R_{L\ min} = 200\ \Omega$, $R_{L\ max} = 500\ \Omega$. The minimum and maximum load values imply the load currents $I^L_{min} = 20$ mA and $I^L_{max} = 50$ mA, assuming the Zener breakdown takes place. So the minimum current that will be drawn by the circuit, when the Zener breakdown takes place, is $I_{min} = I^Z_{min} + I^L_{min} = 30$ mA. Similarly the maximum current is $I_{max} = I^Z_{max} + I^L_{max} = 140$ mA. From these we calculate $V_{i\ min} = 10 + 0.1 * 30 = 13$ V and $V_{i\ max} = 10 + 0.1 * 140 = 24$ V. For input voltages $< V_{i\ min}$, the Zener breakdown will not take place. For input voltages $> V_{i\ max}$, the current through the Zener diode will exceed 90 mA and the diode will get damaged.

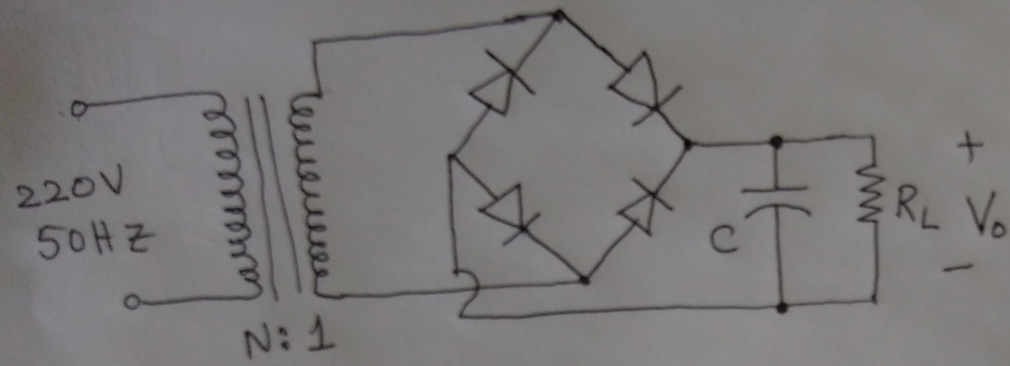

Figure – 2

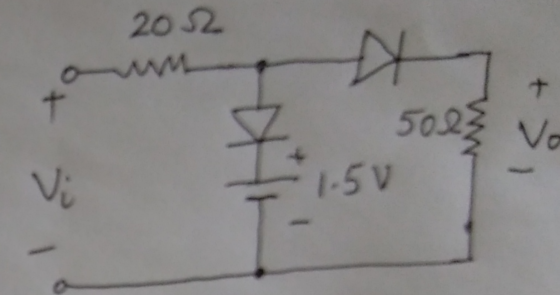

Figure – 3

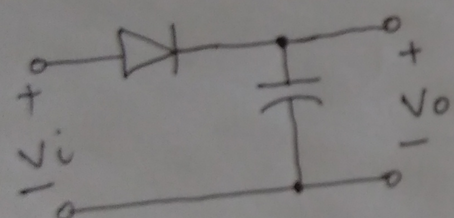

Figure – 4

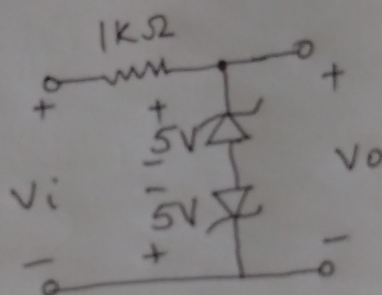

Figure – 5

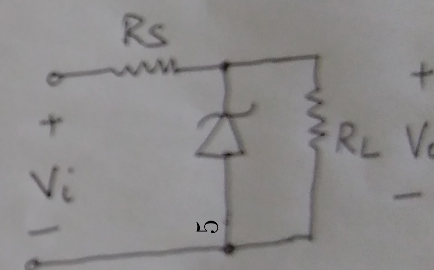

Figure – 6.