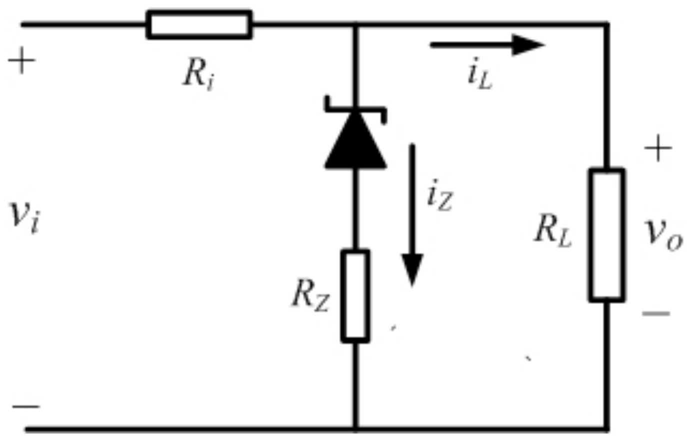
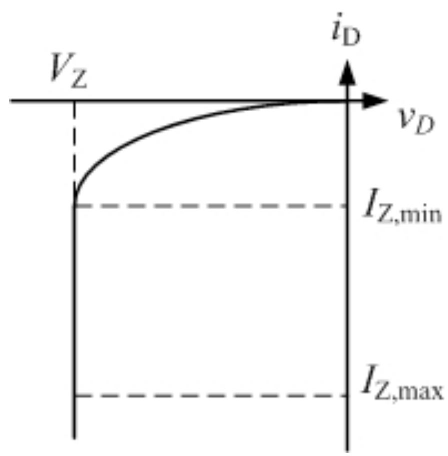
In-Class Exercise 6

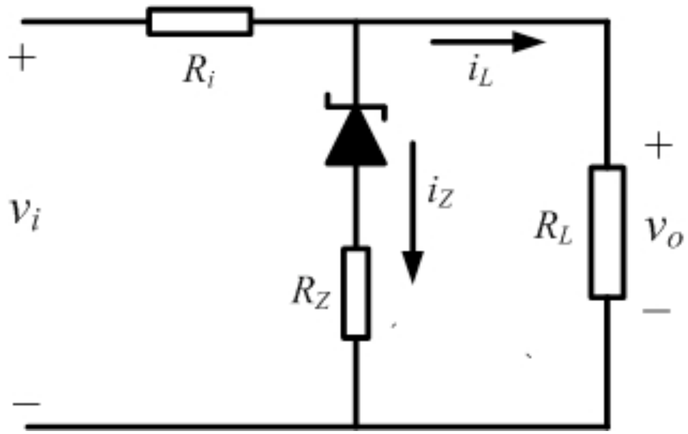
Diode Circuits

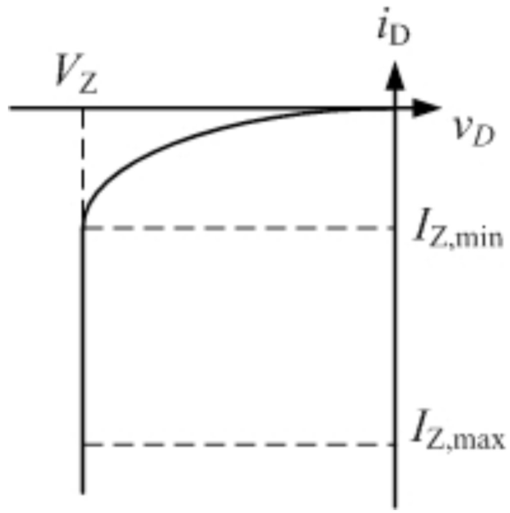
Zener Regulator (1)

1. A zener regulator uses a 9-V zener diode to maintain constant 9 V across the load with the input varying from 18 to 25 V and the output current varying from 400 to 800 mA. Assume R_Z = 0 and the minimum current $I_{Z,min}$ required for the zener diode to operate in the breakdown region, where $I_{Z,min} = 0.1 I_{Z,max}$.
   (a) Select the value for R_i needed and determine its minimum power requirement.
   (b) Determine the power rating of the zener diode.
   (c) Calculate the peak-to-peak output variation if R_Z = 1 Ω.



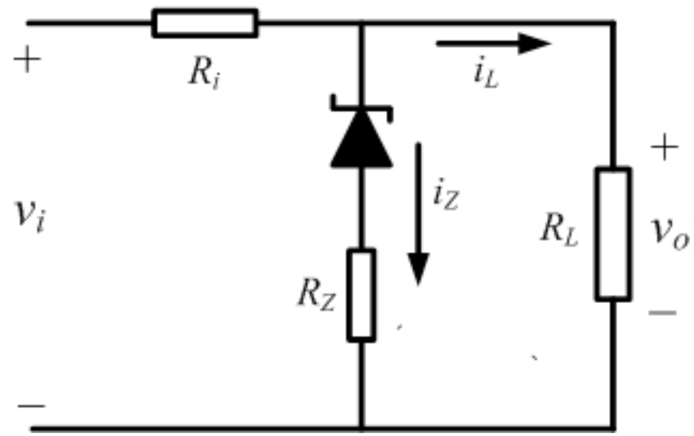






Two extreme conditions:

1. The current through the zener diode must be less than its maximum allowable current. This occurs when i_{Ri} is largest and i_L is smallest.
2. The current must be greater than $I_{z,min}$ in order to have a constant output voltage V_z. This occurs when i_{Ri} is smallest and i_L is largest.



Condition 1:

$$I_{Ri,\min} = I_{z,\min} + I_{L,\max}$$

$$\Rightarrow \frac{18-9}{R_i} = I_{z,\min} + 0.8 = 0.1 I_{z,\max} + 0.8$$

Condition 2:

$$I_{Ri,\max} = I_{z,\max} + I_{L,\min}$$

$$\Rightarrow \frac{25-9}{R_i} = I_{z,\max} + 0.4$$

$$\Rightarrow R_i = 9.74\ \Omega \text{ and } I_{z,\max} = 1.24\ \text{A}$$

$$P_{Ri} = \frac{(25-9)^2}{9.74} = 26.28\ \text{W}$$

$$P_Z = 9 \times 1.24 = 11.2\ \text{W}$$

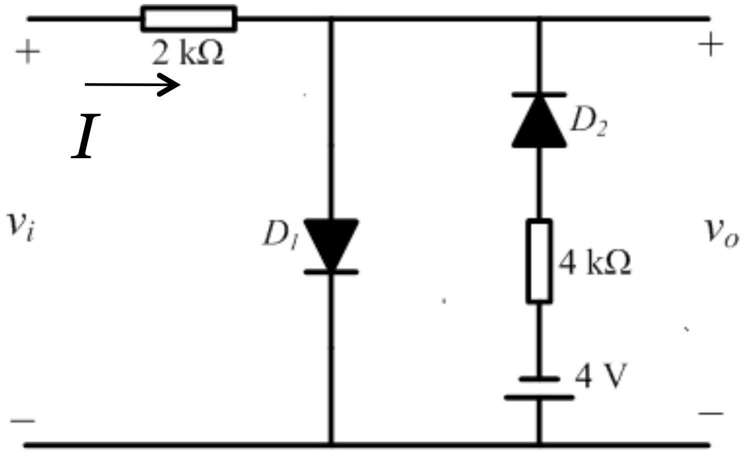
The voltage across R_z varies from $I_{z,\min} \times 1$ to $I_{z,\max} \times 1$ or 0.124 V to 1.24 V

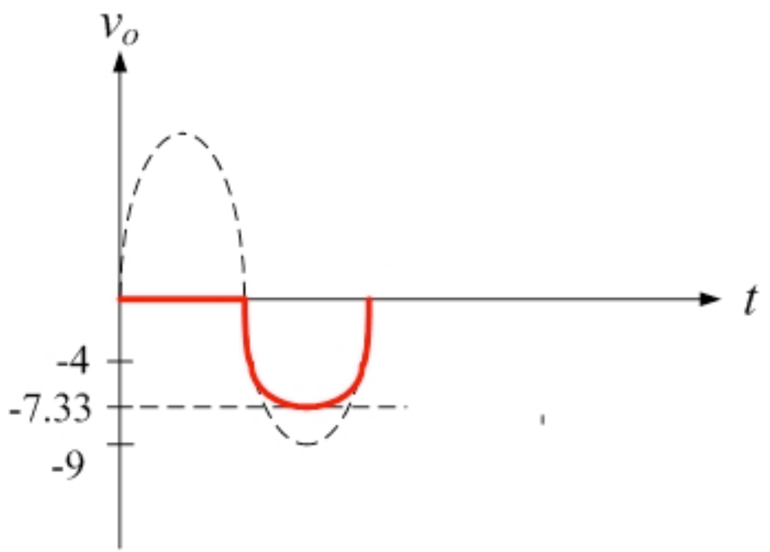
The output voltage is then:

$$V_{L,\min} = 9 + 0.124 = 9.124\ \text{V}$$

$$V_{L,\max} = 9 + 1.24 = 10.24\ \text{V}$$

2. Sketch the output waveform when v_i = 9 sin 1000t V. Show the maximum and minimum values on the sketch. Assume the diode is ideal.





i. v_i positive $v_o = 0$ as D_1 conducts

ii. v_i negative $v_i = v_o$ when $v_i \geq$ -4 V

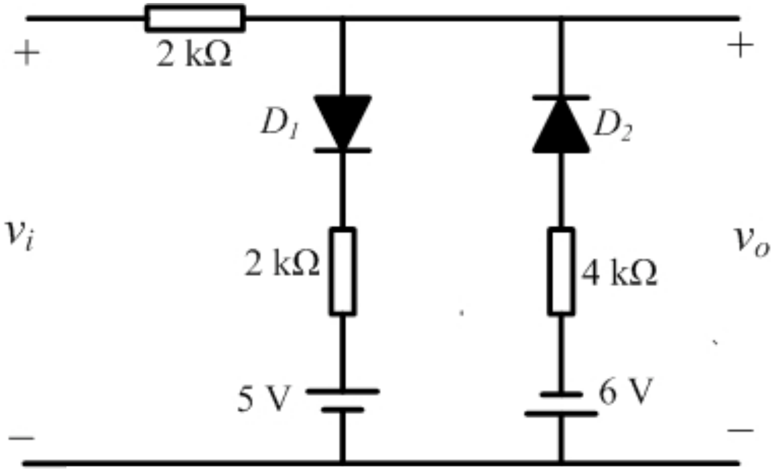
iii. v_i negative and $v_i \leq$ -4 V

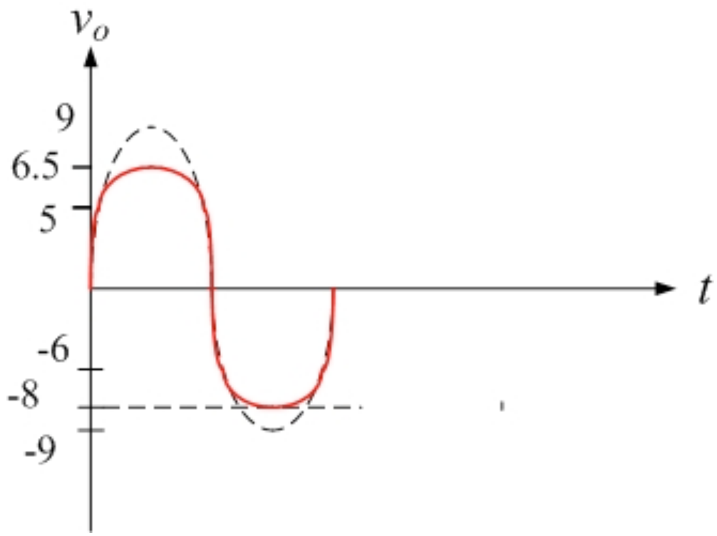
$$I = \frac{v_i - (-4)}{2\text{k} + 4\text{k}} = \frac{v_i + 4}{6\text{k}}$$

$$v_o = -4 + 4\text{k}\left(\frac{v_i + 4}{6\text{k}}\right) = -1.33 + 0.667 v_i$$

$$v_o(-9) = -7.33 \text{ V}$$

3. Sketch the output waveform when v_i = 9 sin 1000t V. Show the maximum and minimum values on the sketch. Assume the diode is ideal.





i. v_i positive

$v_i = v_o$ when $v_i \le 5$ V

when $v_i > 5$ V

$$I = \frac{v_i - (5)}{2k + 2k} = \frac{v_i - 5}{4k}$$

$$v_o = 5 + 2k\left(\frac{v_i - 5}{4k}\right) = 2.5 + 0.5 v_i$$

$$v_o(+9) = 6.5 \text{ V}$$

ii. v_i negative

$v_i = v_o$ when $v_i \ge -6$ V

when $v_i < -6$ V

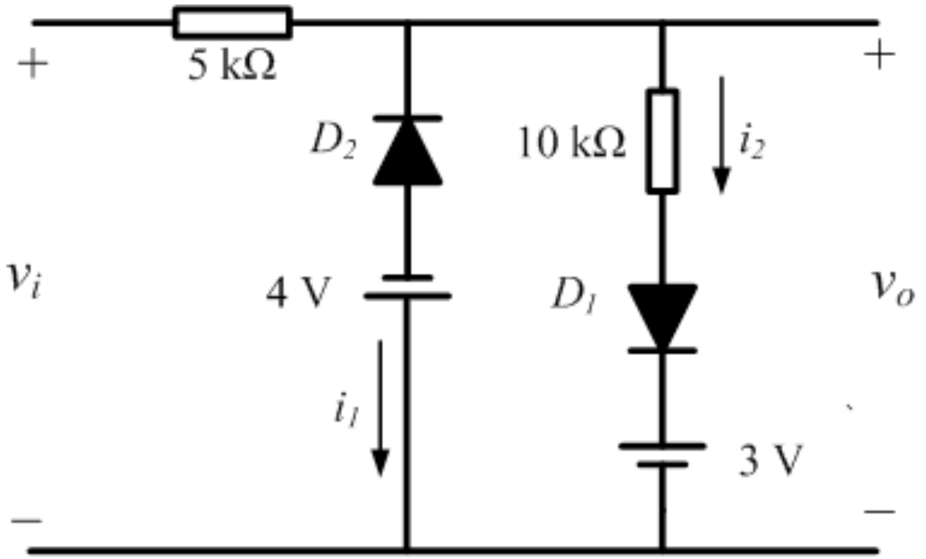
$$I = \frac{v_i - (-6)}{2k + 4k} = \frac{v_i + 6}{6k}$$

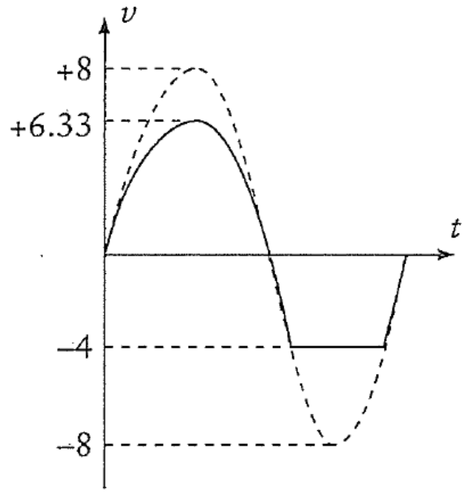
$$v_o = -6 + 4k\left(\frac{v_i + 6}{6k}\right) = -2 + 0.667 v_i$$

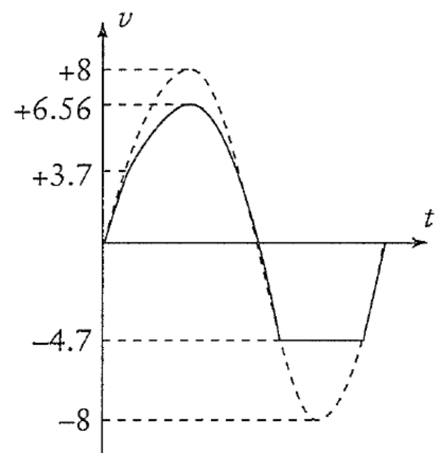
$$v_o(-9) = -8 \text{ V}$$

Self-study:

1. Find the output of the clipping circuit for vi = 8 sin 1000t V, assuming that the diode has a forward voltage of (a) 0 V and (b) 0.7 V.







2. For the circuits below, sketch the output waveform when v_i varies linearly from 0 to 150 V. Assume ideal diodes.