Homework 2 - Solutions
Problems (not review questions) :
4.2, 4.3, 4.16, 4.19, 4.41, 4.56, 4.60, 4.61
Extra problem (not graded): 4.66

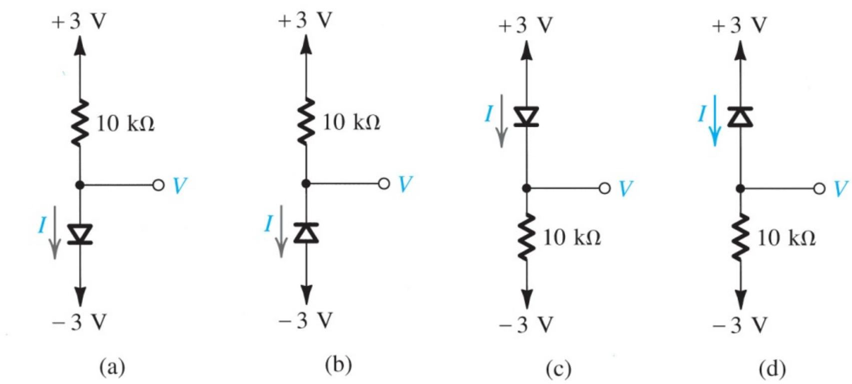



**Figure P4.2**

**4.2** Refer to Fig. P4.2.

(a) Diode is conducting, thus

$V = -3$ V

$$I = \frac{+3 - (-3)}{10\ \text{k}\Omega} = 0.6\ \text{mA}$$

(b) Diode is reverse biased, thus

$I = 0$

$V = +3$ V

(c) Diode is conducting, thus

$V = +3$ V

$$I = \frac{+3 - (-3)}{10\ \text{k}\Omega} = 0.6\ \text{mA}$$

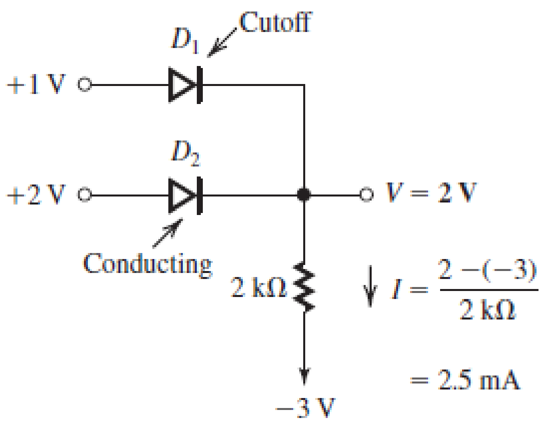
(d) Diode is reverse biased, thus

$I = 0$

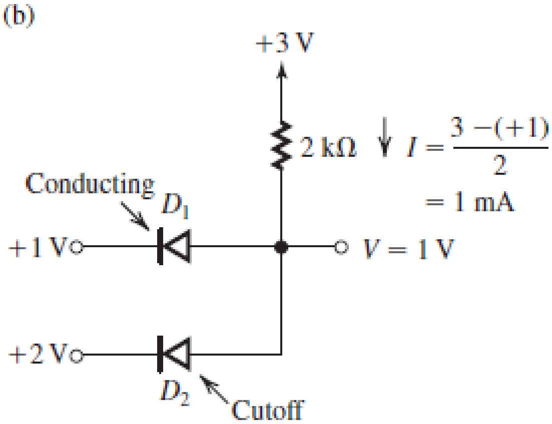
$V = -3$ V

**4.3**

(a)




(b)



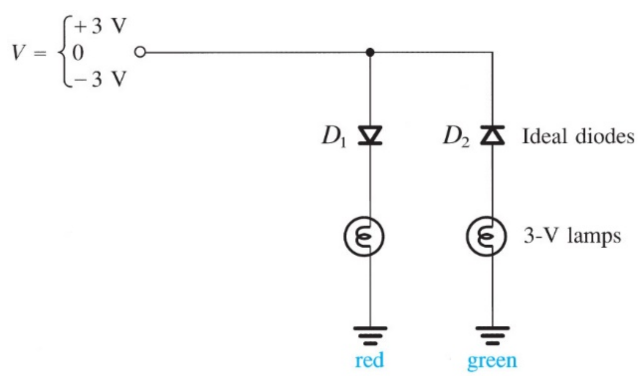




**Figure P4.16**

**4.16**

| $V$ | RED | GREEN | |
|---|---|---|---|
| 3 V | ON | OFF | - $D_1$ conducts |
| 0 | OFF | OFF | - No current flows |
| –3 V | OFF | ON | - $D_2$ conducts |

**4.19** $I_1 = I_S\, e^{0.7/V_T} = 10^{-3}$

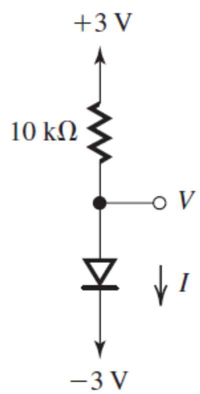
$i_2 = I_S e^{0.5/V_T}$

$$\frac{i_2}{i_1} = \frac{i_2}{10^{-3}} = e^{\frac{0.5-0.7}{0.025}}$$

$i_2 = 0.335\ \mu\text{A}$

**4.41**

(a)

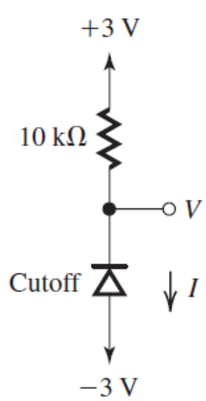



$V = -3 + 0.7 = -2.3$ V

$$I = \frac{3 + 2.3}{10}$$

$= 0.53$ mA

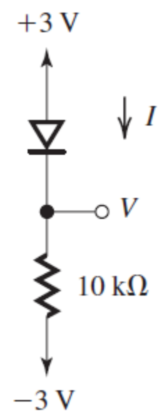
(b)




$I = 0$ A

$V = 3 - I\,(10) = 3$ V

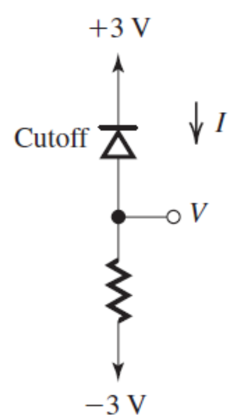
(c)




$V = 3 - 0.7 = 2.3$ V

$$I = \frac{2.3 + 3}{10} = 0.53 \text{ mA}$$

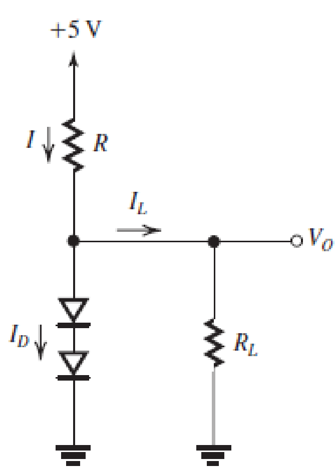
(d)




$I = 0$ A

$V = -3$ V

**4.56**




Diode has 0.7 V drop at 1 mA current

$V_O = 1.5$ V when $R_L = 1.5$ kΩ

$I_D = I_S e^{V/V_T}$

$1 \times 10^{-3} = I_S e^{0.7/0.025}$

$\Rightarrow I_S = 6.91 \times 10^{-16}$ A

Voltage drop across each diode = $\dfrac{1.5}{2} = 0.75$ V.

$\therefore I_D = I_S e^{V/V_T} = 6.91 \times 10^{-16} \times e^{0.75/0.025}$

$= 7.38$ mA

$I_L = 1.5/1.5 = 1$ mA

$I = I_D + I_L = 7.39$ mA $+ 1$ mA

$= 8.39$ mA

$\therefore R = \dfrac{5 - 1.5}{8.39 \text{ mA}} = 417\ \Omega$

Use a small-signal model to find voltage $\Delta V_O$ when the value of the load resistor, $R_L$, changes:

$r_d = \dfrac{V_T}{I_D} = \dfrac{0.025}{7.39} = 3.4\ \Omega$

When load is disconnected, all the current $I$ flows through the diode. Thus

$\Delta I_D = 1$ mA

$\Delta V_O = \Delta I_D \times 2r_d$

$= 1 \times 2 \times 3.4$

$= 6.8$ mV

With $R_L = 1$ kΩ,

$I_L \simeq \dfrac{1.5 \text{ V}}{1} = 1.5$ mA

$\Delta I_L = 0.5$ mA

$\Delta I_D = -0.5$ mA

$\Delta V_O = -0.5 \times 2 \times 3.4$

$= -3.4$ mV

With $R_L = 750\ \Omega$,

$I_L \simeq \dfrac{1.5}{0.75} = 2$ mA

$\Delta I_L = 1$ mA

$\Delta I_D = -1$ mA

$\Delta V_O = -1 \times 2 \times 3.4$

$= -6.8$ mV

With $R_L = 500\ \Omega$,

$I_L \simeq \dfrac{1.5}{0.5} = 3$ mA

$\Delta I_L = 2.0$ mA

$\Delta I_D = -2.0$ mA

$\Delta V_O = -2 \times 2 \times 3.4$

$= -13.6$ mV

**4.60** (a) Three 6.8-V zeners provide $3 \times 6.8 =$ 20.4 V with $3 \times 10 = 30$-Ω resistance. Neglecting $R$, we have

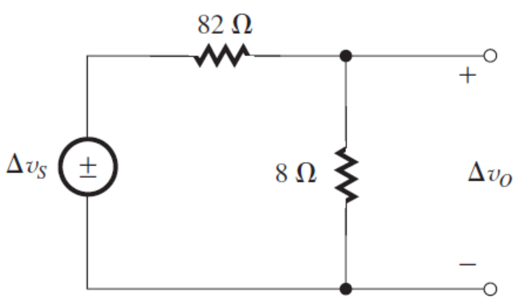
Load regulation $= -30$ mV/mA.

(b) For 5.1-V zeners we use 4 diodes to provide 20.4 V with $4 \times 30 = 120$-Ω resistance.

Load regulation $= -120$ mV/mA

For part (b) of our problem the zener resistance of the diodes was 25 Ohm. Therefor the total zener resisitance would have been 100 Ohm and the load regulation -120 mV/mA.

**4.61**




Small-signal model

From the small-signal model we obtain

$$\frac{\Delta v_O}{\Delta v_S} = \frac{8}{8+82} = \frac{8}{90}$$

Now $\Delta v_S = 1.0$ V.

$$\therefore \Delta v_O = \frac{8}{90}\Delta v_S = \frac{8}{90} \times 1.0$$

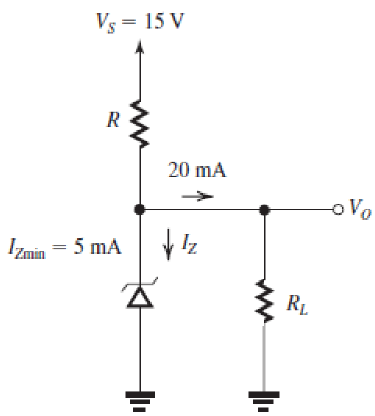
$= 88.9$ mV

**4.66** (a) $V_{ZT} = V_{Z0} + r_z I_{ZT}$

$10 = V_{Z0} + 7\,(0.025)$

$\Rightarrow V_{Z0} = 9.825\text{ V}$

(b) The minimum zener current of 5 mA occurs when $I_L = 20$ mA and $V_S$ is at its minimum of $20(1 - 0.25) = 15$ V. See the circuit below:




$$R \le \frac{15 - V_{Z0}}{20 + 5}$$

where we have used the minimum value of $V_S$, the maximum value of load current, and the minimum required value of zener diode current, and we assumed that at this current $V_Z \simeq V_{Z0}$. Thus,

$$R \le \frac{15 - 9.825 + 7}{25}$$

$\le 207\ \Omega$.

$\therefore$ use $R = 207\ \Omega$

(c) Line regulation $= \dfrac{7}{207 + 7} = 33\ \dfrac{\text{mV}}{\text{V}}$

$\pm 25\%$ change in $v_S \equiv\ \pm 5$ V

$V_O$ changes by $\pm 5 \times 33 = \pm 0.165$ mV

corresponding to $\dfrac{\pm 0.165}{10} \times 100 = \pm 1.65\%$

(d) Load regulation $= -\,(r_Z \parallel R)$

$= -(7 \parallel 207) = -6.77\ \Omega$

or $-6.77$ V/A

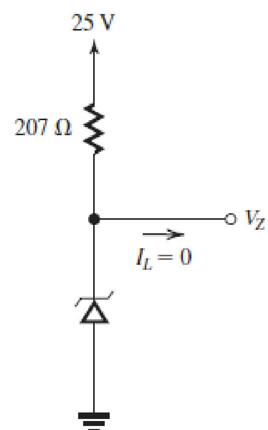
$\Delta V_O = -6.77 \times 20\text{ mA} = -135.4\text{ mV}$

corresponding to $-\dfrac{0.1354}{10} \times 100 = -1.35\%$

(e) The maximum zener current occurs at no load $I_L = 0$ and the supply at its largest value of

$20 + \dfrac{1}{4}\,(20) = 25$ V.

$V_Z = V_{Z0} + r_Z I_Z$




$= 9.825 + 7 \times \dfrac{25 - V_Z}{207}$

$207 V_Z = 207\,(9.825) + 7\,(25) - 7 V_Z$

$\Rightarrow V_Z = 10.32$ V

$I_{Z\max} = \dfrac{25 - 10.32}{0.207} = 70.9$ mA

$P_Z = 10.32 \times 70.9$

$= 732$ mW