STRING OF LED'S

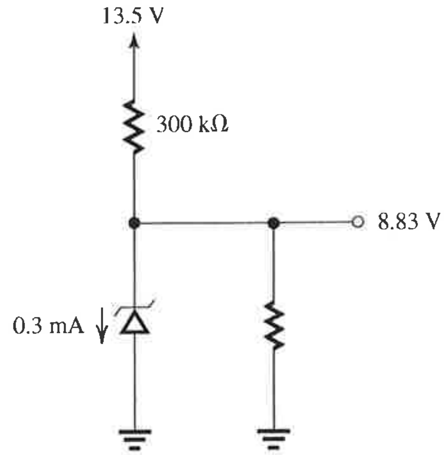
D1 + C1 FORM A RECTIFIER / FILTER TO GET A DC LEVEL.

THE IDEA SEEMS TO BE TO LIGHT UP MORE LEDS AS THE INPUT VOLTAGE INCREASES.

HOWEVER, THE VOLTAGE AT ANODE OF D2 IS ALMOST CONSTANT (2 DIODE DROPS) SO D3-D4-D24 WILL PROBABLY NEVER TURN ON (OR ONLY BARELY)

D28 WILL CERTAINLY NEVER LIGHT.

WEEK 3



Lowest output voltage = 8.83 V

Line Regulation $= \dfrac{r_Z}{R + r_Z} = \dfrac{30}{300 + 30}$

$= 90 \dfrac{\text{mV}}{\text{V}}$

Load Regulation $= -(r_Z \| R) = -29.1 \dfrac{\text{mV}}{\text{mA}}$

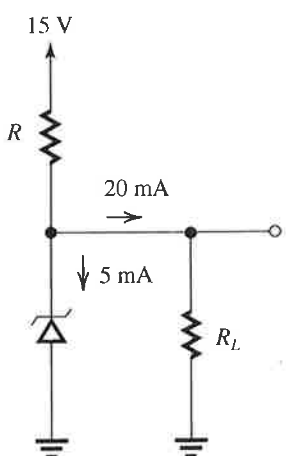
4.64

(a) $V_{ZT} = V_{ZO} + r_z I_{ZT}$

$10 = V_{ZO} + 7(0.025)$

$\Rightarrow V_{ZO} = 9.825$ 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:



$R \le \dfrac{15 - (V_{ZO} + r_Z I_Z)}{20 + 5}$

$\le \dfrac{15 - (9.825 + 7(0.005))}{25}$

$\le 205.6\ \Omega.$

$\therefore$ use $R = 205\ \Omega$

(c) Line regulation $= \dfrac{7}{205 + 7} = 33 \dfrac{\text{mV}}{\text{V}}$

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

V_O changes by $\pm 5 \times 33 = \pm 165$ mV

corresponding to $\dfrac{\pm 165}{10} \times 100 = \pm 1.65\%$

(d) Load Regulation $= -(r_Z \| R)$

$= -(7 \| 205) = -6.77\ \Omega$

or -6.77 V/A

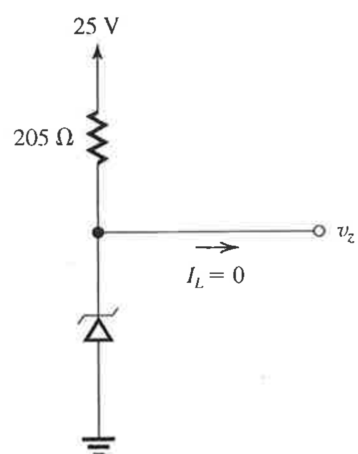
$\Delta V_O = -6.77 \times 20 \text{ mA} = -135.4$ mV

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

(e) The maximum zener current occurs at no load $\equiv I_L = 0$ and the supply at

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

$V_Z = V_{ZO} + r_Z I_Z$



$= 9.825 + 7 \times \dfrac{25 - V_Z}{205}$

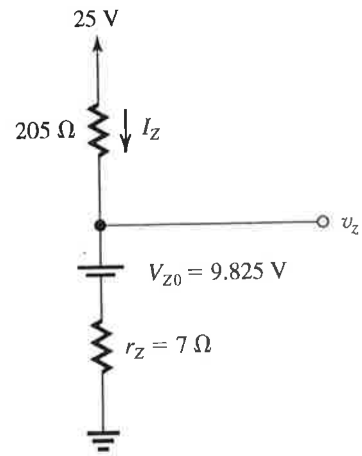
$205\ V_Z = 205(9.825) + 7(25) - 7V_Z$

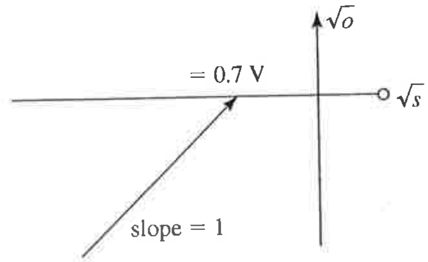
$\Rightarrow V_Z = 10.326$ V

$P_Z = 10.326 \times \left(\dfrac{25 - 10.326}{205}\right)$

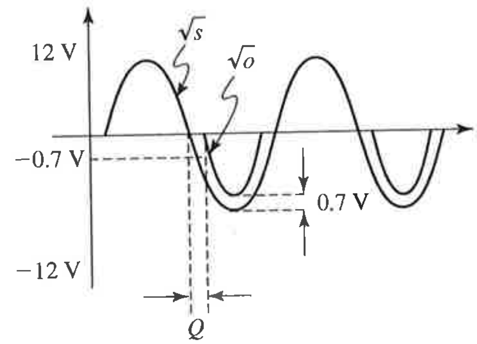
$= 739.4$ mW

Alternate circuit to calculate V_Z





(b)



$$I_Z = \frac{25 - V_{ZO}}{250 + 7}$$

$$= \frac{25 - 9.825}{205 + 7}$$

$$= 71.6 \text{ mA}$$

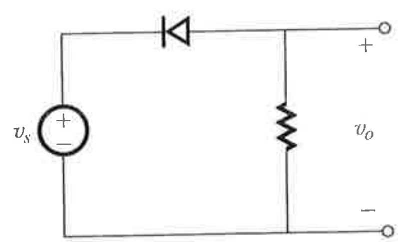
$$V_Z = V_{ZO} + I_Z 7$$

$$= 9.825 + 0.0716 \times 7$$

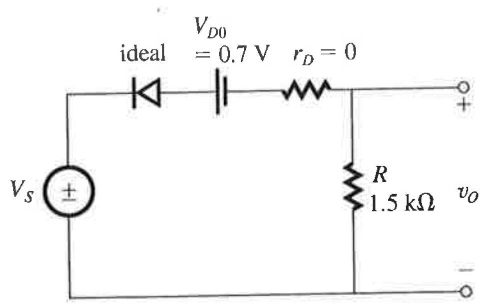
$$= 10.326 \text{ V}$$

as above!

4.65



using the constant voltage drop model:



(a) $v_O = v_S + 0.7$ V, For $v_S \leq -0.7$ V

$v_O = 0$, for $v_S \geq -0.7$ V

(c) The diode conducts at an angle

$$\theta = \sin^{-1}\left(\frac{0.7}{12}\right) = 3.34° \text{ \& stops}$$

at $\pi - \theta = 176.65°$

Thus the conduction angle is $\pi - 2\theta$

$= 173.31°$ or 3.025 rad.

$$v_{O,\text{avg}} = \frac{-1}{2\pi} \int_{\theta}^{\pi-\theta} (12\sin\phi - 0.7)\, d\phi$$

$$= \frac{-1}{2\pi}[-12\cos\phi - 0.7\phi]_{\theta}^{\pi-\theta}$$

$$= \frac{-1}{2\pi}[12 \times 2\cos\theta - 0.7(\pi - 2\theta)]$$

$$= -4.572 \text{ V}$$

(d) Peak current in diode is:

$$\frac{12 - 0.7}{1.5 \times 10^3} = 2.53 \text{ mA}$$

(e) PIV occurs when v_S is at its the peak and

$v_O = 0$.

PIV = 12 V

(b) For $v_{O,\text{avg}} = 100$ V

$$V_s = \frac{\pi}{2} \times 101.4 = 159.3 \text{ V}$$

$$\text{Turns Ratio} = \frac{120\sqrt{2}}{159.3} = 1.065 \text{ to } 1$$

4.72

Refer to Fig. 4.23

For $2V_{Do} << V_s$

$$V_{o,\text{avg}} = \frac{2}{\pi}V_s - 2V_{Do} = \frac{2}{\pi}V_s - 1.4$$

(a) For $V_{o,\text{avg}} = 10$ V

$$10 \text{ V} = \frac{2}{\pi} \cdot V_s - 1.4$$

$$\therefore V_s = 11.4\left(\frac{\pi}{2}\right) = 17.9 \text{ V}$$

$$\text{Turns ratio} = \frac{120\sqrt{2}}{17.9} = 9.5 \text{ to } 1$$

(b) For $V_{o,\text{avg}} = 100$ V

$$100 \text{ V} = \frac{2}{\pi} \cdot V_S - 1.4$$

$$\Rightarrow V_S = 101.4\left(\frac{\pi}{2}\right) = 159 \text{ V}$$

$$\text{Turns ratio} = \frac{120\sqrt{2}}{159} = 1.07 \text{ to } 1$$

4.73

$120\sqrt{2} \pm 10\% : 24\sqrt{2} \pm 10\%$

$\Rightarrow$ turns Ratio = 5:1

$$v_S = \frac{24\sqrt{2}}{2} \pm 10\%$$

$$\text{PIV} = 2V_S|_{\max} - V_{DO}$$

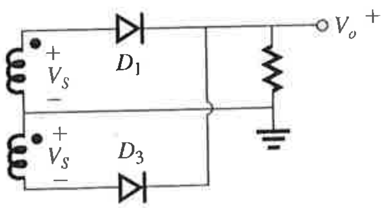
$$= 2 \times \frac{24\sqrt{2}}{2} \times 1.1 - 0.7$$

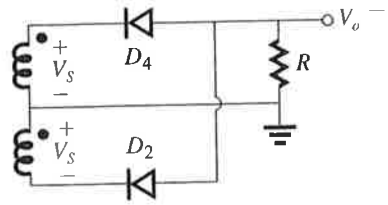
$$= 36.6 \text{ V}$$

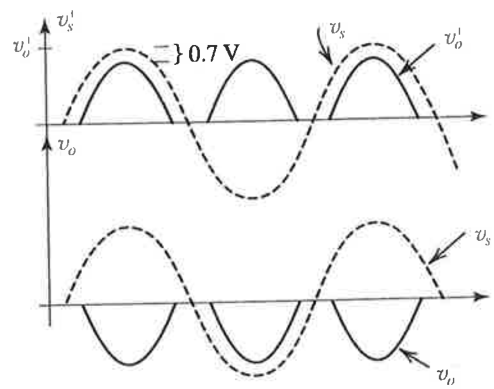
using a factor of 1.5 for safety we select a diode having a PIV rating of 55 V

4.74

The circuit is a full wave rectifier with centre tapped secondary winding. The circuit can be analyzed by looking at v_O^+ and v_O^- seperately.







$$v_{O,\text{avg}} = \frac{1}{2\pi}\int (V_S \sin\phi - 0.7)d\phi = 15$$

$$= \frac{2V_S}{\pi} - 0.7 = 15$$

assumed $V_S >> 0.7$ V

$$V_S = \frac{15 + 0.7}{2}\pi = 24.66 \text{ V}$$

Thus voltage across secondary winding

$$= 2V_S = 49.32 \text{ V}$$

Looking at D_4

$$\text{PIV} = V_S - V_O^-$$

$$= V_S + (V_S - 0.7)$$

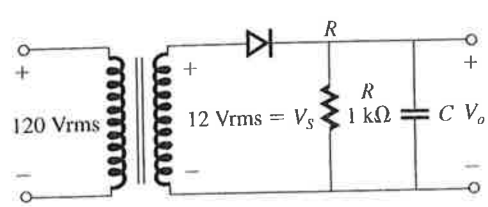
$$= 2V_S - 0.7$$

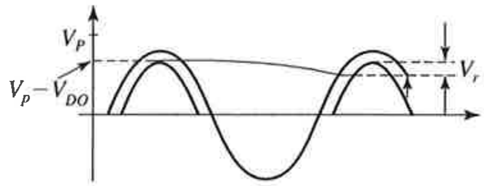
$$= 48.6 \text{ V}$$

If choosing a diode, allow a safety margin of

$1.5\text{PIV} = 73$ V

4.75





(i) $v_r \cong (V_P - V_{DO})\frac{T}{CR}$ Eq. (4.28)

$$0.1(V_P - V_{DO}) = (V_P - V_{DO})\frac{T}{CR}$$

$$C = \frac{1}{0.1 \times 60 \times 10^3} = 166.7\ \mu\text{F}$$

(ii) for

$$v_r = 0.01(V_P - V_{DO}) = \frac{(V_P - V_{DO})T}{CR}$$

(a)

(i) $v_{O,\text{avg}} = V_P - V_{DO} - \frac{1}{2}V_r$

$$= 12\sqrt{2} - 0.7 - \frac{1}{2}(12\sqrt{2} - 0.7)0.1$$

$$= (12\sqrt{2} - 0.7)\left(1 - \frac{0.1}{2}\right)$$

$$= 15.5\ \text{V}$$

ii) $v_{O,\text{avg}} = (12\sqrt{2} - 0.7)\left(1 - \frac{0.01}{2}\right)$

$$= 16.19\ \text{V}$$

(b)

i) using eq (4.30) we have the conduction angle =

$\omega\Delta t \cong \sqrt{2V_r/(V_p - V_{DO})}$

$$= \sqrt{\frac{2 \times 0.1(V_P - 0.7)}{(V_P - 0.7)}}$$

$$= \sqrt{0.2}$$

$$= 0.447\ \text{rad}$$

∴ Fraction of cycle for

$$\text{conduction} = \frac{0.447}{2\pi} \times 100$$

$$= 7.1\%$$

(ii) $\omega\Delta t \simeq \sqrt{2 \times 0.01\frac{(V_P - 0.7)}{V_P - 0.7}} = 0.141\ \text{rad}$

Fraction of cycle = $\frac{0.141}{2\pi} \times 100 = 2.25\%$

(c)(i) use eq (4.31)

$$i_{D,\text{avg}} = I_L\left(1 + \pi\sqrt{\frac{2(V_P - V_{DO})}{V_r}}\right)$$

$$= \frac{V_{O,\text{avg}}}{R}\left(1 + \pi\sqrt{\frac{2(V_P - V_{DO})}{0.1(V_P - V_{DO})}}\right)$$

$$= \frac{15.5}{10^3}\left(1 + \pi\sqrt{\frac{2}{0.1}}\right)$$

$$= 233\ \text{mA}$$

(ii) $i_{D,\text{avg}} = \frac{16.19}{10^3}(1 + \pi\sqrt{200})$

$$= 735\ \text{mA}$$

NB next user $I_L \cong V_P/R = \frac{V_P - V_{DO}}{R}$

but here are used $i_{D,\text{avg}} = \frac{V_P - V_{DO} - \frac{1}{2}V_r}{R}$

which is more accurate.

(d) (i) $i_{D,\text{peak}} = I_L\left(1 + 2\pi\sqrt{\frac{2(V_P - V_{DO})}{V_r}}\right)$

$$= \frac{15.42}{10^3}\left(1 + 2\pi\sqrt{\frac{2}{0.1}}\right)$$

$$= 449\ \text{mA}$$

(ii) $i_{D,\text{peak}} = \frac{16.19}{10^3}\left(1 + 2\pi\sqrt{\frac{2}{0.01}}\right)$

$$= 1455\ \text{mA}$$

4.76

(i) $v_r = 0.1(V_P - V_{DO}) = \frac{(V_P - V_{DO})}{2fCR}$

The factor of 2 accounts for dischrge occuring only half of the period $T/2 = \frac{1}{2f}$

$$C = \frac{1}{(2fR)0.1} = \frac{1}{2(60)10^3 \times 0.1} = 83.3\ \mu\text{F}$$

(ii) $C = \frac{1}{2(60)10^3 0.01} = 833\ \mu\text{F}$

(a) i) $V_O = V_P - V_{DO} - \frac{1}{2}v_r$

$$= (V_P - V_{DO})\left(1 - \frac{0.1}{2}\right)$$

$$= (16.27)\left(1 - \frac{0.1}{2}\right)$$

$$= 15.5\ \text{V}$$

(ii) $V_O = (16.27)\left(1 - \frac{0.01}{2}\right) = 16.19\ \text{V}$

(b)

(i) Fraction of cycle $= \dfrac{2\omega\Delta t}{2\pi} \times 100$

$= \sqrt{\dfrac{2V_r/(V_P - V_{DO})}{\pi}} \times 100$

$= \dfrac{1}{\pi}\sqrt{2(0.1)} \times 100 = 14.2\%$

(ii) Fraction fo Cycle $= \dfrac{2\sqrt{2(0.01)}}{2\pi} \times 100$

$= 4.5\%$

(c) use eq (4.34)

(i) $i_{D,\text{avg}} = I_L\left(1 + \pi\sqrt{\dfrac{V_P - V_{DO}}{2V_r}}\right)$

$= \dfrac{15.5}{1}\left(1 + \pi\sqrt{\dfrac{1}{2(0.1)}}\right) = 124.4 \text{ mA}$

(ii) $i_{D,\text{avg}} = \dfrac{16.19}{1}\left(1 + \pi\dfrac{1}{\sqrt{2(0.01)}}\right) = 376 \text{ mA}$

(d) use eq(4.35)

(i) $\hat{i}_D = I_L\left(1 + 2\pi\dfrac{1}{\sqrt{2(0.1)}}\right) = 233 \text{ mA}$

(ii) $\hat{i}_D = I_L\left(1 + 2\pi\dfrac{1}{\sqrt{0.02}}\right) = 735 \text{ mA}$

4.77

1) $v_r = 0.1(V_P - V_{DO} \times 2) = \dfrac{V_P 2V_{DO}}{2fCR}$

discharge occurs only over $\dfrac{1}{2}T = \dfrac{1}{2f}$

$C = \dfrac{(V_P - 2V_{DO})}{(V_P - 2V_{DO})}\dfrac{1}{2(0.1)fR} = 83.3 \ \mu\text{F}$

(ii) $C = \dfrac{1}{2(0.01)fR} = 833 \ \mu\text{F}$

(b) (i) Fraction of cycle $= \dfrac{2\omega\Delta t}{2\pi} \times 100$

$= \sqrt{\dfrac{2(0.1)}{\pi}} \times 100 = 14.2\%$

(ii) Fraction of cycle

$= \sqrt{\dfrac{2(0.01)}{\pi}} \times 100 = 4.5\%$

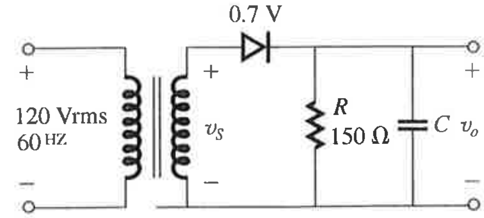
(c) i) $i_{D,\text{avg}} = \dfrac{14.79}{1}\left(1 + \pi\sqrt{\dfrac{1}{0.2}}\right) = 119 \text{ mA}$

(ii) $i_{D,\text{avg}} = \dfrac{15.49}{1}(1 + \pi/\sqrt{0.02}) = 356 \text{ mA}$

(d) (i) $\hat{i}_D = \dfrac{14.79}{1}\left(1 + 2\pi\sqrt{\dfrac{1}{0.2}}\right) = 223 \text{ mA}$

(ii) $\hat{i}_D = \dfrac{15.49}{1}\left(1 + 2\pi\sqrt{\dfrac{1}{0.02}}\right) = 704 \text{ mA}$

4.78



$v_{O,\text{peak}} = V_P - V_{DO} = 16$

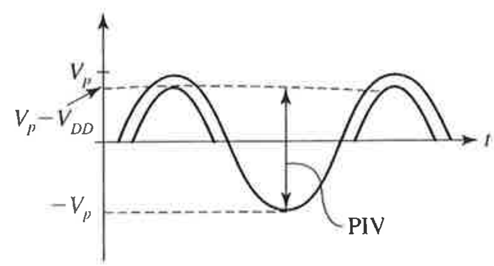
$V_P = 16.7 \text{ V}$

$V_{\text{rms}} = \dfrac{16.7}{\sqrt{2}} = 11.8$

(b) $V_r = (V_P - V_{DO})\dfrac{T}{CR}$ Eq (4.28)

$2 = \dfrac{16}{60 \times C \times 150}$

$C = 889 \ \mu\text{F}$



$\text{PIV} = V_P - V_{DO} - V_r/2 + V_P$

$= V_{O,\text{avg}} + V_P$

$= 15 + 16.7$

$= 31.7 \text{ V}$

For a 50% safety margin $\text{PIV} = 1.5 \times 31.7$

$= 47.6 \text{ V}$

(d) $i_{D,\text{avg}} = I_L\left(1 + \pi\sqrt{\dfrac{2(V_P - V_{DO})}{V_r}}\right)$

using $I_L = \dfrac{v_{O,\text{avg}}}{R} = \dfrac{15}{R}$ we have

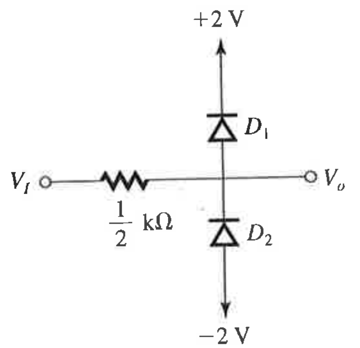
$i_{D,\text{avg}} = \dfrac{15}{150}\left(1 + \pi\sqrt{\dfrac{2(16)}{2}}\right)$

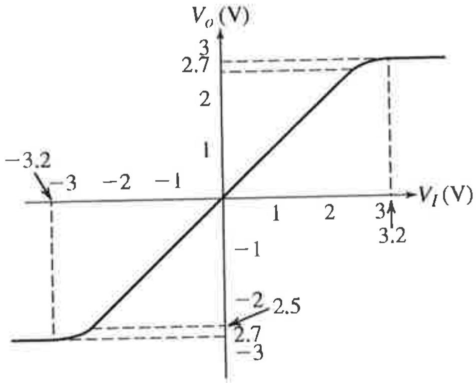
$= 1.36 \text{ A}$

(e) $i_{D,\text{peak}} = I_L\left(1 + 2\pi\sqrt{\dfrac{2(V_P - V_{DO})}{V_r}}\right)$

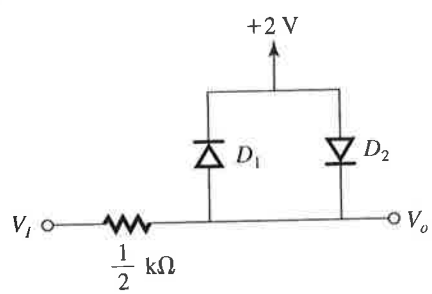
$= \dfrac{15}{150}\left(1 + 2\pi\sqrt{\dfrac{2(16)}{2}}\right)$

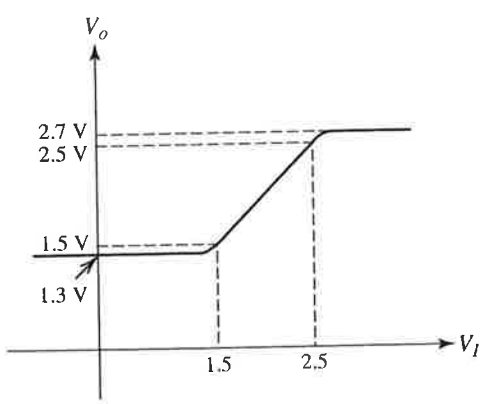
$= 2.61 \text{ A}$

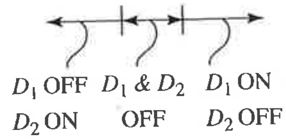




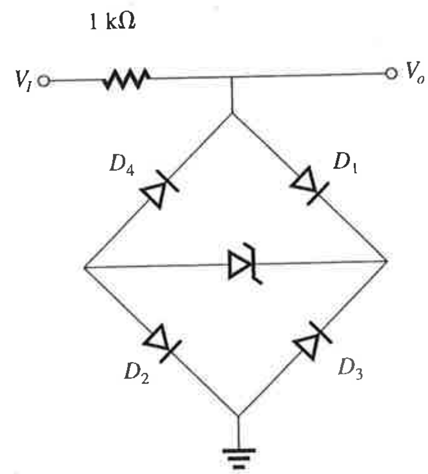
4.87





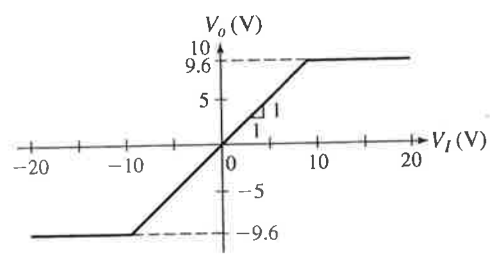


4.88

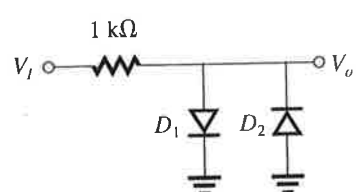


Each diode has 0.7 V drop when conducting
The Zener has 8.2 V drop when conducting. So the limiter thresholds are

$\pm(2 \times 0.7 + 8.2) = \pm 9.6\ V$



4.89



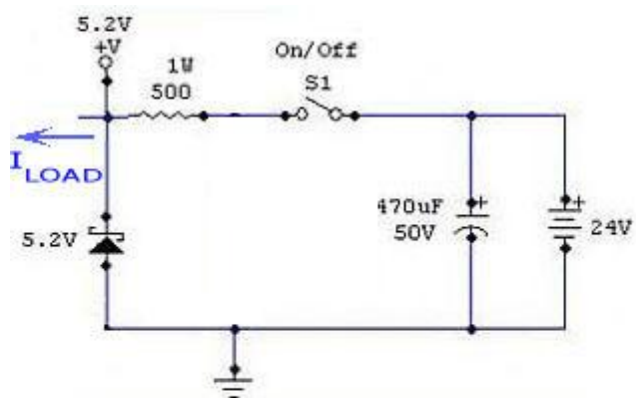
Diodes have 0.7 V drop at 1 mA current

$\therefore$ For diode D_1

$$\frac{i_D}{1\text{ mA}} = e^{(v_O - 0.7)/V_T}$$

$$i_O = 1 \times 10^{-3}\, e^{(v_O - 0.7)/V_T}$$

Solution: Problem B) What does the portion of the circuit shown below do? Assume a 1W zener (19mA max), so that we want at least 1.9mA flowing through the zener at all times. You also know that the resistor can dissipate a maximum of 1W before overheating.



This circuit creates a lower voltage (5.2V) regulated power supply from the much higher voltage (24V) battery – also battery voltages change with load, so the 24V is only nominal.

1. How much current goes through the Zener when $I_{LOAD}=0$?

$$I_{500\Omega} = \frac{24-5.2}{500} = 37.6\text{mA}$$
$$I_{Zener} + I_{Load} = I_{500\Omega}$$
$$I_{Zener,\ no\ load} = I_{500\Omega} = 37.6\text{mA}$$

Note – this would destroy the zener, so some current must be flowing in load.

2. What is the maximum value for I_{LOAD} before the power supplies fails?

$$I_{Zener,min} + I_{Load,max} = I_{500\Omega} = 37.6\text{mA}$$
$$I_{Load,max} = I_{500\Omega} - I_{Zener,min} = 37.6\text{mA} - 1.9\text{mA} = 35.7\text{mA}$$

3. For this maximum current compare the power dissipated in the load ("useful power") to the power dissipated in the 500Ω resistor ("wasted power") and calculate the efficiency, η=useful power/total power.

$$P_{Load,max} = I_{Load,max} \cdot 5.2\text{V} = 35.7\text{mA} \cdot 5.2\text{V} = 186\text{mW}$$
$$P_{500\Omega} = I_{500\Omega} \cdot \ 24-5.2 \ = 37.6\text{mA} \cdot 18.8\text{V} = 707\text{mW}$$
$$P_{Zener} = I_{Zener,min} \cdot 5.2\text{V} = 1.9\text{mA} \cdot 5.2\text{V} = 10\text{mW}$$
$$\eta = \frac{P_{Load,max}}{P_{Load,max} + P_{500\Omega} + P_{Zener}} = \frac{186}{186+707+10}$$
$$= \frac{186}{903} = 0.206 \approx 21\%$$

Note that this is the maximum efficiency. If the load current drops, so does the efficiency.

Also – it is OK if you didn't include P_{Zener}, I didn't include it in the original problem statement (but it doesn't change the answer much).