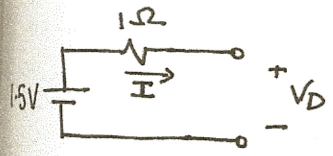
Chapter 3 - Problems

3.1



The diode can be reverse-biased and thus no current would flow, or forward - biased where current would flow.

(a) Reverse biased $I = 0A$ $V_D = 1.5V$

(b) Forward biased $I = 1.5A$ $V_D = 0V$

3.2

(a) Diode is conducting and thus has a 0V drop across it. Consequently

$V = \underline{\underline{-3V}}$ ✓

$I = \dfrac{3-(-3)}{10k\Omega} = \underline{\underline{0.6\,mA}}$ ✓

(b) Diode is cut off.

$V = \underline{\underline{3V}}$ ✓ $I = \underline{\underline{0A}}$ ✓

(c) Diode is conducting

$V = \underline{\underline{3V}}$ ✓

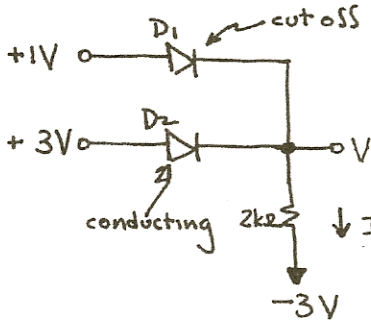
$I = \dfrac{3-(-3)}{10k\Omega} = \underline{\underline{0.6\,mA}}$ ✓

(d) Diode is cut off.

$V = \underline{\underline{-3V}}$ ✓ $I = \underline{\underline{0A}}$ ✓

3.3

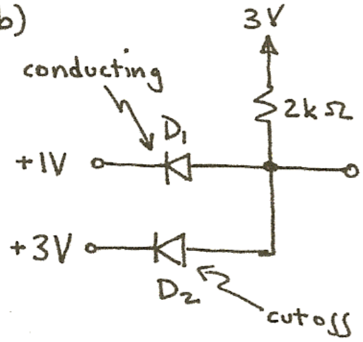
(a)



$V = \underline{\underline{3V}}$

$I = \dfrac{3-(-3)}{2k\Omega} = \underline{\underline{3mA}}$

(b)

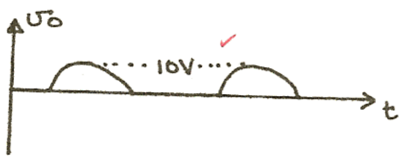


$I = \dfrac{3-(-1)}{2} = \underline{\underline{1mA}}$

$V = \underline{\underline{1V}}$

3.4

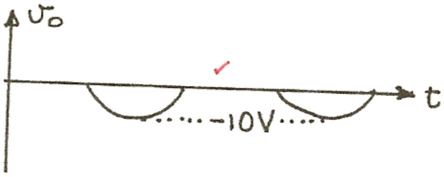
(a)



$V_{p+} = \underline{\underline{10V}}$ ✓ $V_{p-} = \underline{\underline{0V}}$ ✓

$f = 1kHz.$

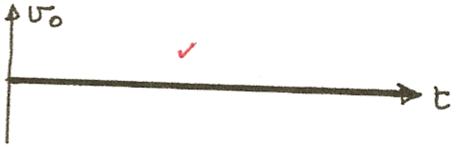
(b)



$V_{p+} = \underline{\underline{0V}}$ $V_{p-} = \underline{\underline{-10V}}$

$f = 1kHz$

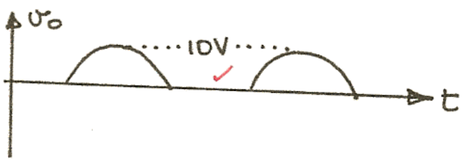
(c)



$v_O = \underline{\underline{0V}}$

Neither D_1 nor D_2 conducts so there is no output.

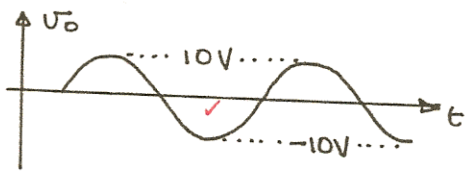
(d)



$V_{p+} = \underline{\underline{10V}}$ $V_{p-} = \underline{\underline{0V}}$ $f = 1kHz$

Both D_1 and D_2 conduct when $v_I > 0$ just like (a)

(e)

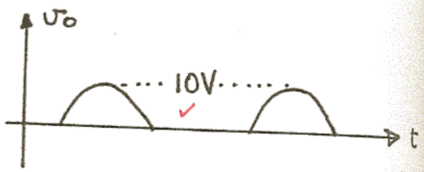


$V_{p+} = \underline{\underline{10V}}$ $V_{p-} = \underline{\underline{-10V}}$ $f = 1kHz$

D_1 conducts when $v_I > 0$ and D_2 conducts when $v_I < 0$. Thus the output follows the input.

CHAPTER 3 PROBLEMS

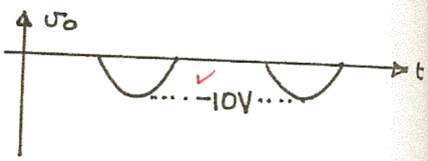
(f)



$V_{p+} = \underline{\underline{10V}}$ $V_{p-} = \underline{\underline{0V}}$ $f = 1kHz$

- D_1 is cutoff when $v_I < 0$

(g)



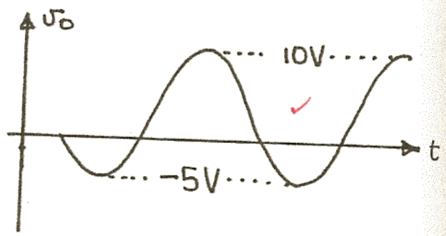
$V_{p+} = \underline{\underline{0V}}$ $V_{p-} = \underline{\underline{-10V}}$ $f = 1kHz$

D_1 shorts to ground when $v_I > 0$ and is cut off when $v_I < 0$ whereby the output follows v_I.

(h)

$v_O = \underline{\underline{0V}}$ ~ The output is always shorted to ground as D_1 conducts when $v_I > 0$ and D_2 conducts when $v_I < 0$.

(i)



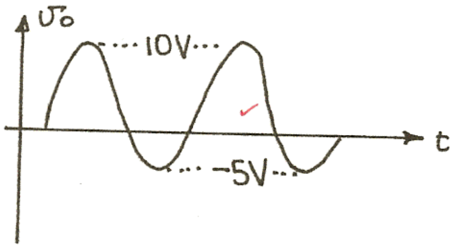
$V_{p+} = \underline{\underline{10V}}$ $V_{p-} = \underline{\underline{-5V}}$ $f = 1kHz$

-When $v_I > 0$, D_1 is cutoff and v_O follows v_I.

When $v_I < 0$, D_1 is conducting and the circuit becomes a voltage divider where the negative peak is

$$\frac{1k\Omega}{1k\Omega + 1k\Omega} \cdot -10V = -5V$$

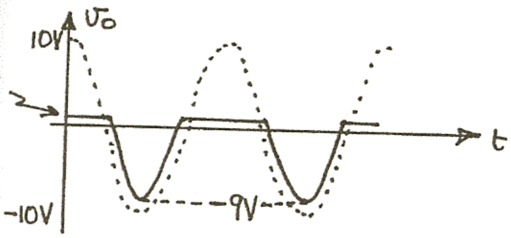
(j)



$V_{p+} = \underline{\underline{10V}}$ $V_{p-} = \underline{\underline{-5V}}$ $f = 1kHz$

When $v_I > 0$, the output follows the input as D_1 is conducting. When $v_I < 0$, D_1 is cut off and the circuit becomes a voltage divider.

(k)



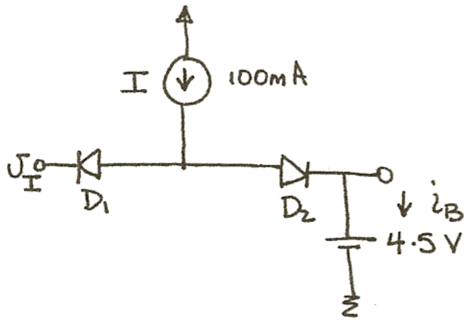
$V_{p+} = \underline{\underline{1V}}$ $V_{p-} = \underline{\underline{-9V}}$ $f = 1kHz$

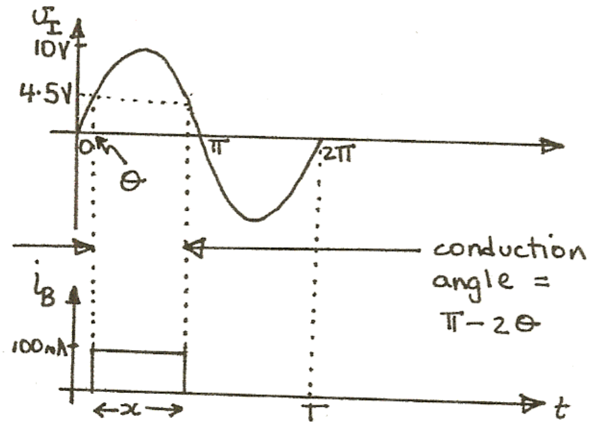
When $v_I > 0$, D_1 is cutoff and D_2 is conducting. The output becomes 1V.
When $v_I < 0$, D_1 is conducting and D_2 is cutoff. The output becomes :-

$$v_O = v_I + 1V$$

CHAPTER 3 PROBLEMS

3.5





- When $v_I < 4.5V$ D_1 conducts and D_2 is cutoff so $i_B = 0A$. For $v_I > 4.5V$ D_2 conducts and D_1 is cut off thus disconnecting the input v_I. All of the current then flows through the battery.

$$10 \sin\theta = 4.5\ V$$
$$\theta = \sin^{-1}(4.5/10)$$

conduction angle $= \pi - 2\theta$

Fraction of cycle that $i_B = \underline{\underline{100mA}}$ is given by :-

$$x = \frac{\pi - 2\theta}{2\pi} = 0.35$$

3.19

$$i_1 = I_S\, e^{0.7/V_T} = 10^{-3}$$

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

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

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

3.20

$$i = I_S\, e^{v/nV_T} = I_S\, e^{0.7/0.025} = 5(10^{-3})$$

$$I_S = 5(10^{-3})\, e^{-0.7/0.025} = \underline{\underline{3.46\times10^{-15} A}}$$

v	i
0.71 V	7.46 mA
0.8 V	273.21 mA
0.69 V	3.35 mA
0.6 V	91.65 μA

Let $i_1 = I_S\, e^{v_1/0.025}$

$$i_2 = 10\, i_1 = I_S\, e^{v_2/0.025}$$

$$\frac{i_2}{i_1} = 10 = e^{\frac{v_2 - v_1}{0.025}}$$

$$\therefore\ \Delta v = v_2 - v_1 = \underline{\underline{57.56\, mV}}$$

3.21

To calculate I_S use

$$I_S = I\, e^{-V/nV_T} = I\, e^{-V/n\times0.025}$$

To calculate the voltage of the measured current

$$i_2 = 0.01\, i_1 \qquad \text{so,}$$

$$\frac{i_2}{i_1} = 0.01 = e^{\frac{V_2 - V_1}{nV_T}}$$

$$V_2 = V_1 + nV_T \ln 0.01$$

$$= V + n(0.025)\ln($$

V [V]	I	I_S $n=1$ [A]	I_S $n=2$ [A]	V n= [V
0.7	1 A	6.91×10^{-13}	8.32×10^{-7}	0.5
0.650	1 mA	5.11×10^{-15}	2.26×10^{-9}	0.5
0.650	10 μA	5.11×10^{-17}	2.26×10^{-11}	0.5
0.7	10 mA	6.91×10^{-15}	8.32×10^{-9}	0.5

3.22

Let $I_1 = I_S\, e^{V_1/nV_T}$ and

$$I_2 = I_S\, e^{V_2/nV_T} = I$$

Calculate n by :-

$$\frac{I_2}{I_1} = e^{\frac{V_2 - V_1}{nV_T}}$$

$$n = \frac{1}{V_T}\left[\frac{V_2 - V_1}{\ln I_2/I_1}\right] = \frac{1}{0.025}$$

Calculate I_S by :-

$$I_S = I_1\, e^{-V_1/nV_T}$$

Calculate the diode voltage by :- $V_3 = nV_T \ln \frac{10 I_1}{I_S}$

25 $= 5(10^{-3})$

3.46×10^{-15} A

.025

mV

x0.025

To calculate the voltage at 1% of the measured current use

$i_2 = 0.01\, i_1$ so,

$$\frac{i_2}{i_1} = 0.01 = e^{\frac{V_2 - V_1}{n V_T}}$$

$$V_2 = V_1 + n V_T \ln 0.01$$
$$= V + n(0.025)\ln(0.01)$$

V [V]	I	I_s n=1 [A]	I_s n=2 [A]	V n=1 [V]	V n=2 [V]
0.7	1A	6.91×10^{-13}	8.32×10^{-7}	0.585	0.470
0.650	1mA	5.11×10^{-15}	2.26×10^{-9}	0.535	0.420
0.650	10μA	5.11×10^{-17}	2.26×10^{-11}	0.535	0.420
0.7	10mA	6.91×10^{-15}	8.32×10^{-9}	0.584	0.470

3.22

Let $I_1 = I_S\, e^{V_1/nV_T}$ and

$$I_2 = I_S\, e^{V_2/nV_T} = I_1/10$$

Calculate n by :-

$$\frac{I_2}{I_1} = e^{\frac{V_2 - V_1}{nV_T}}$$

$$n = \frac{1}{V_T}\left[\frac{V_2 - V_1}{\ln I_2/I_1}\right] = \frac{1}{0.025}\left[\frac{V_2 - V_1}{\ln 0.1}\right]$$

Calculate I_S by :-

$$I_S = I_1\, e^{-V_1/nV_T}$$

Calculate the diode voltage at $10I_1$ by :- $V_3 = nV_T \ln \frac{10 I_1}{I_S}$

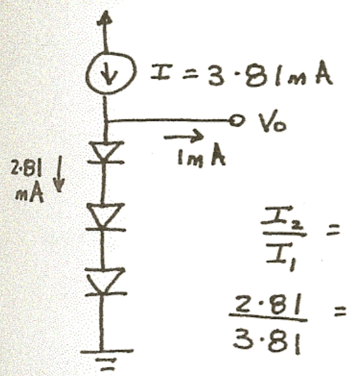
I	V_1 [V]	V_2 [V]	n	I_s [A]	V_3 [V]
10mA	0.7	0.6	1.737	10^{-9}	0.8
1mA	0.7	0.6	1.737	10^{-10}	0.8
10A	0.8	0.7	1.737	10^{-7}	0.9
1mA	0.7	0.58	2.085	1.47×10^{-9}	0.82
10μA	0.7	0.64	1.042	2.15×10^{-17}	0.7

3.23

$\therefore$ The voltage across each diode is $V_o/3$

$$I = I_S\, e^{\frac{V_o/3}{nV_T}} = 10^{-14}\, e^{\frac{2/3}{0.025}}$$

$= \underline{3.81\text{mA}}$

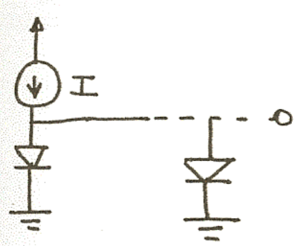


$$\frac{I_2}{I_1} = e^{\frac{(V_2 - V_1)/3}{0.025}}$$

$$\frac{2.81}{3.81} = e^{\frac{(V_2 - 2)/3}{0.025}}$$

$\Delta V = V_2 - 2 = \underline{-22.8\text{mV}}$

3.24



With one diode the current

thre

With

curr

so

the

The

Δ

3.

The

IC

The

Ⓑ

$\therefore\ i_D = i_{D2} = i_{D1}\, e^{\frac{v_{D2}-v_{D1}}{nV_T}}$

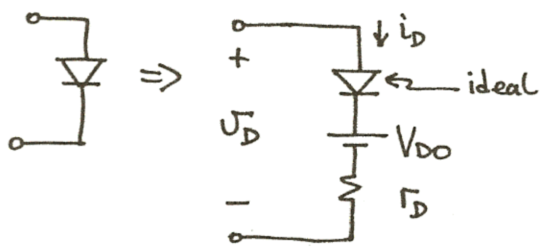
$= 1 \times e^{\frac{0.75-0.7}{1\times0.025}}$

$= 7.389\ mA$

$\therefore\ R = \frac{10-3}{I_D} = \frac{10-3}{7.389} = \underline{\underline{0.947 k\Omega}}$

3.37

Piecewise linear model:



Given $n = 2$, $V_D = 0.7V$ $i_D = 1mA$

The current throug the diode model is given by:

$i_D = \frac{v_D - V_{D0}}{r_D}$ ✓ ~ need to find the parameters V_{D0} and r_D

Using the exponential model to find the diode voltage at 10mA

$\frac{i_{D2}}{i_{D1}} = e^{\frac{v_{D2}-v_{D1}}{nV_T}}$ ✓

$v_{D2} = nV_T \ln\left(\frac{i_{D2}}{i_{D1}}\right) + V_{D1} = 0.05 \ln\left(\frac{10}{1}\right) + 0.7$

$= 0.815V$

FINDING V_{D0} & r_D using the given facts:

$i_D = \frac{0.7 - V_{D0}}{r_D} = 1mA$ ✓ ①

$i_D = \frac{0.815 - V_{D0}}{r_D}$ ✓ $= 10mA$ ②

②/① $\Rightarrow \frac{0.815 - V_{D0}}{0.7 - V_{D0}} = 10$ ✓

$V_{D0} = \underline{0.687V}$ ✓

$r_D = \frac{0.7 - V_{D0}}{1} = \underline{\underline{12.8\,\Omega}}$ ✓

Using the piecewise linear model

$i_D = \frac{v_D - 0.687}{12.8} \Rightarrow v_D = 0.687 + 12.8\, i_D$ ✓

Using the exponential model

$\frac{i_{D2}}{i_{D1}} = e^{\frac{v_D - 0.7}{0.05}} \Rightarrow v_D = 0.7 + 0.05 \ln\left(\frac{i_{D2}}{1}\right)$ ✓

i_D (mA)	PIECEWISE LINEAR v_D (V)	EXPONENTIAL v_D (V)	Error (mV)
0.5	0.693 ✓	~~0.655~~ 0.665	28.0 ✓
5	0.751 ✓	0.780 ✓	−29.5 ✓
14	0.866 ✓	0.832 ✓	34.0 ✓

3.38

Looking at the copy of FIG 3.12 below we see at

$i_D = 1mA \to v_D = 0.7V$

$i_D = 10mA \to v_D = 0.8V$

$\therefore$ slope $= \frac{1}{r_D} = \frac{10-1}{0.8-0.7} = 90\ \frac{mA}{V}$

$\therefore\ r_D = \frac{1}{90\times10^{-3}} = \underline{\underline{11.1\,\Omega}}$

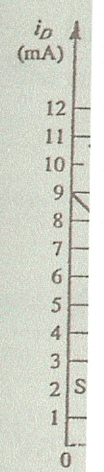
To

i_D

10

i_D (mA)

3.3



3.64

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

$10 = 9.6 + r_z \times 50\times10^{-3}$

$r_z = \underline{\underline{8\,\Omega}}$

Power rating:

$V_Z = V_{Z0} + r_z \times 2I_{ZT}$

$= 9.6 + 8\times100\times10^{-3}$

$= 10.4\,V$

$P = 10.4\times100\times10^{-3} = \underline{\underline{1.04\,W}}$

(b) $V_Z = V_{Z0} + r_z I_{ZT}$

$9.1 = V_{Z0} + 30\times10\times10^{-3}$

$V_{Z0} = \underline{\underline{8.8\,V}}$

$V_Z = 8.8 + 30\times20\times10^{-3} = 9.4\,V$

$P = 9.4\times20\times10^{-3} = \underline{\underline{188\,mW}}$

(c) $6.8 = 6.6 + 2\times I_{ZT}$

$I_{ZT} = \underline{\underline{100\,mA}}$

$V_Z = 6.6 + 2\times200\times10^{-3} = 7\,V$

$P = 7\times200\times10^{-3} = \underline{\underline{1.4\,W}}$

(d) $18 = 17.2 + r_z\times5\times10^{-3}$

$r_z = \underline{\underline{160\,\Omega}}$

$V_Z = 17.2 + 160\times10\times10^{-3} = 18.8\,V$

$P = 18.8\times10\times10^{-3} = \underline{\underline{188\,mW}}$

(e) $7.5 = V_{Z0} + 1.5\times200\times10^{-3}$

$V_{Z0} = \underline{\underline{7.2\,V}}$

$V_Z = 7.2 + 1.5\times400\times10^{-3} = 7.8\,V$

$P = 7.8\times400\times10^{-3} = \underline{\underline{3.12\,W}}$

3.65

(a) Three 6.8V zeners provide $3\times6.8 = 20.4\,V$ with $3\times10 = 30\,\Omega$ resistance. Neglecting R, we have

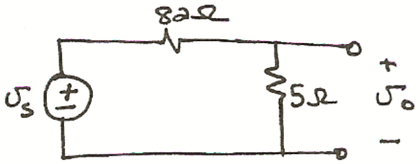
Load Regulation $= \underline{\underline{-30\,mV/mA}}$.

(b) For 5.1 V zeners we use 4 diodes to provide 20.4 V with $4\times30 = 120\,\Omega$ resistance.

Load regulation $= \underline{\underline{-120\,mV/mA}}$

3.66

Small signal model for line regulation:



$$\frac{\Delta v_o}{\Delta v_S} = \frac{5}{5+82}$$

$V_o = 5I + V_Z$

$V_o + \Delta V_o = 5(I+\Delta I) + V_Z$

$\Delta V_o = 5\Delta I$

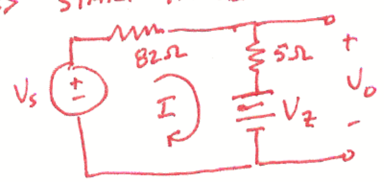
$= \left(\frac{5}{87}\right)\Delta V_S$

$\Delta v_o = \frac{5}{87}\times\Delta v_S$ ✓

$= \frac{5}{87}\times1.3$

$= \underline{\underline{74.7\,mV}}$ ✓

⇒ START HERE



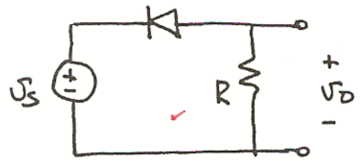
$V_S = 82I + 5I + V_Z$

$V_S + \Delta V_S = 82(I+\Delta I) + 5(I+\Delta I) + V_Z$

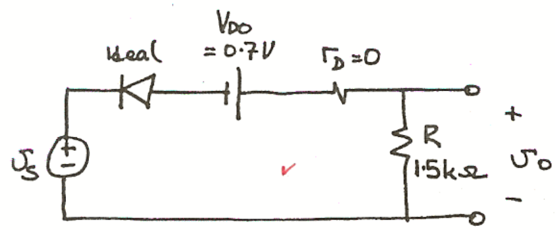
$\Delta V_S = 82\Delta I + 5\Delta I$

$$\Delta I = \frac{\Delta V_S}{87}$$

3.72

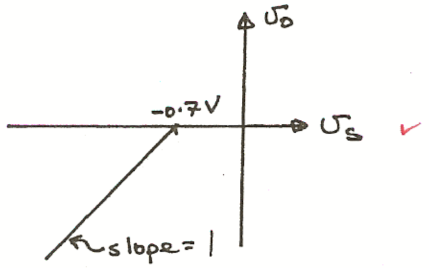


Using the constant voltage drop model:

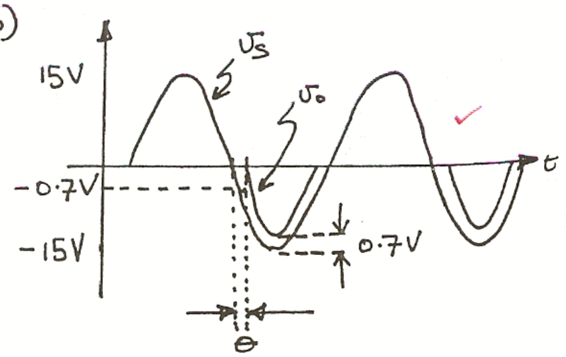


(a) $v_O = v_S + 0.7\ V$, for $v_S \leq -0.7V$

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



(b)



(c) The diode conducts at an angle $\theta = \sin^{-1}\dfrac{0.7}{15} = 2.67°$ & stops

at $\pi - \theta = 177.33° = 3.095$ rad

$\theta = 0.0466$ rad

CONT.

Thus the conduction angle is $\pi - 2\theta$
$= 174.66°$ or 3.05 rad.

$$v_{O,avg} = \frac{-1}{2\pi}\int_{\theta}^{\pi-\theta} 15\sin\phi - 0.7\, d\phi$$

$$= \frac{-1}{2\pi}\Big[-15\cos\phi - 0.7\phi\Big]_{\theta}^{\pi-\theta}$$

$\boxed{\cos(\pi-\theta) = -\cos(\theta)}$

$$= \frac{-1}{2\pi}\Big[15\times 2\cos\theta - 0.7(\pi - 2\theta)\Big]$$

$$= \underline{\underline{-4.43V}}$$

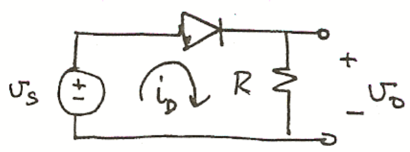
(d) Peak current in diode is:

$$\frac{15-0.7}{1.5\times 10^3} = \underline{\underline{9.5\,mA}}$$

(e) PIV occurs when v_S is at its the peak and $v_O = 0$.

$$PIV = \underline{\underline{15V}}$$

3.73



$$i_D = I_S e^{v_D/nV_T}$$

$$\frac{i_D}{i_D(1mA)} = e^{\frac{v_D - v_D(\text{at } 1mA)}{nV_T}}$$

$$v_D = v_D(\text{at } 1mA) + nV_T \ln\left(i_D/10^{-3}\right)$$

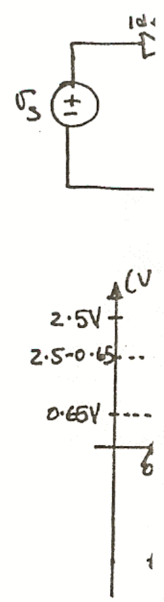
$$= \quad '' \quad + nV_T \ln\left(\frac{v_O/R}{10^{-3}}\right)$$

$$= \quad '' \quad + nV_T \ln\left(v_O/R\right) \quad R \text{ in } k\Omega$$

$v_O = v_S$

$= v_S -$

3.74



Find t_1

$\frac{2.5}{T/4}$

$t_2 = T/2$

$v_O\big|_{avg} =$