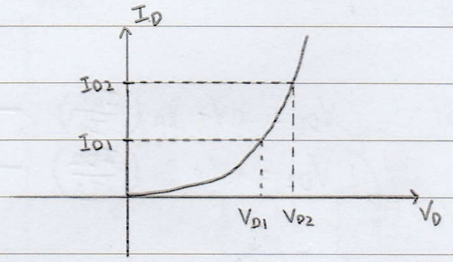
No.: Date:

Esmund Lim AE Tutorial 4

1a)



$$V_{D1} = nV_T \ln \frac{I_{D1}}{I_s} \quad \text{— (1)}$$

$$V_{D2} = nV_T \ln \frac{I_{D2}}{I_s} \quad \text{— (2)}$$

$V_{D1} = 0.6V$ $I_{D1} = 2.3mA$

$V_{D2} = 0.8V$ $I_{D2} = 245mA$

$$V_{D2} - V_{D1} = nV_T \ln \frac{I_{D2}}{I_s} - nV_T \ln\left(\frac{I_{D1}}{I_s}\right)$$
$$= nV_T \ln\left(\frac{I_{D2}}{\cancel{I_s}} \cdot \frac{I_s}{I_{D1}}\right)$$
$$= nV_T \ln\left(\frac{I_{D2}}{I_{D1}}\right)$$

Note: $\ln\left(\frac{3}{2}\right) - \ln\left(\frac{2}{3}\right) = \ln\left(\frac{3}{2} \cdot \frac{3}{2}\right) = \ln\left(\frac{9}{4}\right)$

$$nV_T = \frac{V_{D2} - V_{D1}}{\ln\left(\frac{I_{D2}}{I_{D1}}\right)}$$
$$= \frac{0.8V - 0.6V}{\ln\left(\frac{245mA}{2.3mA}\right)}$$
$$= 0.04284169762\ V$$
$$\approx 42.8\ mV$$

Sub nV_T into (1)

$$0.6 = 42.8mV\left[\ln\left(\frac{2.3mA}{I_s}\right)\right]$$
$$14.00504726 = \ln\left(\frac{2.3mA}{I_s}\right)$$
$$e^{14.00504726} = \frac{2.3mA}{I_s}$$
$$I_s = \frac{2.3mA}{e^{14.00504726}}$$
$$= 1.902887408 \times 10^{-9}\ A$$
$$\approx 1.90\ nA$$

$\therefore$ The empirical diode junction equation

$$V_D = nV_T \ln \frac{i_D}{I_s}$$
$$= (42.8mV) \ln\left(\frac{i_D}{1.90nA}\right) \quad \text{— (1)}$$

$$i_D = I_s e^{\frac{V_D}{nV_T}}$$
$$= (1.90nA) e^{\frac{V_D}{42.8mV}} \quad \text{— (2)}$$

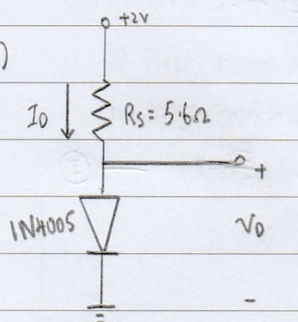
b) For $I_D = 20mA$

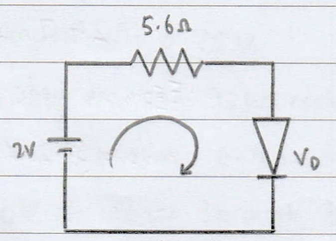
$$V_D = (42.8mV) \ln\left(\frac{20mA}{1.90nA}\right)$$
$$= 0.6920498469V$$
$$\approx 0.692V$$

For $I_D = 300mA$

$$V_D = (42.8mV) \ln\left(\frac{300mA}{1.90nA}\right)$$
$$= 0.8079543955V$$
$$\approx 0.808V$$

c)





$$I_D = \frac{V_S - V_D}{R}$$
$$= \frac{2 - V_D}{5.6} \quad \text{— (3)}$$

By iteration method (DC)

1st V_D value

obtained from (1) Sub into (3)

V_D	0.7V	0.797V	0.794V	0.794V
I_D	0.232A	0.215A	0.215A	0.215A

obtained from eqn (3) then sub into (1)

Qpt (0.215A, 0.794V)

$\therefore V_D = 0.794V$

$I_D = 0.215A$

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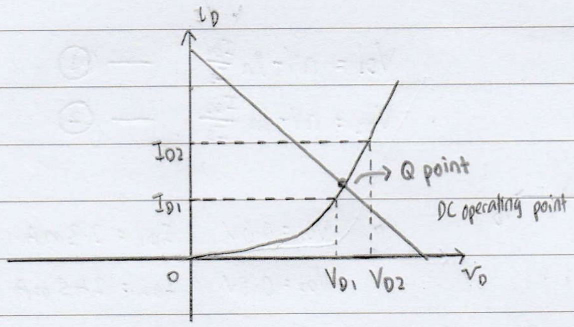
2)



$V_{D1} = nV_T \ln\left(\frac{I_{D1}}{I_S}\right)$ — ①

$V_{D2} = nV_T \ln\left(\frac{I_{D2}}{I_S}\right)$ — ②

$V_{D1} = 0.50V$ $\quad I_{D1} = 250\mu A$

$V_{D2} = 0.70V$ $\quad I_{D2} = 10mA$

$$V_{D2} - V_{D1} = nV_T \ln\left(\frac{I_{D2}}{I_S}\right) - nV_T \ln\left(\frac{I_{D1}}{I_S}\right)$$
$$= nV_T \ln\left(\frac{I_{D2}}{\cancel{I_S}} \cdot \frac{\cancel{I_S}}{I_{D1}}\right)$$
$$= nV_T \ln\left(\frac{I_{D2}}{I_{D1}}\right)$$
$$nV_T = \frac{V_{D2} - V_{D1}}{\ln\left(\frac{I_{D2}}{I_{D1}}\right)}$$
$$= \frac{0.7 - 0.5}{\ln\left(\frac{10mA}{250\mu A}\right)}$$
$$= 0.05421700614\,V$$
$$\approx 54.2mV$$

sub nV_T into ①

$$0.5 = 54.2mV\left(\ln \frac{250\mu A}{I_S}\right)$$
$$\frac{0.5}{54.2mV} = \ln \frac{250\mu A}{I_S}$$
$$I_S = \frac{250\mu A}{e^{\frac{0.5}{54.2mV}}}$$
$$= 24.70529422 \times 10^{-9}\,A$$
$$\approx 24.7nA$$

∴ Empirical diode junction equation

$$V_D = 54.2mV\left(\ln \frac{I_D}{24.7nA}\right) \quad — ③$$

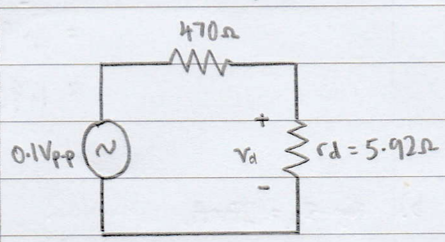
$gd = \frac{I_D}{nV_T}$ (gradient of slope at Q-pt)

$$= \frac{9.16mA}{54.2mV}$$
$$= 0.16900369$$

$$r_d = \frac{1}{gd}$$
$$= \frac{1}{0.16900369}$$
$$= 5.917030568\,\Omega$$
$$\approx 5.92\,\Omega \quad \text{(AC Diode resistance)}$$

AC Analysis

→ Remove DC component

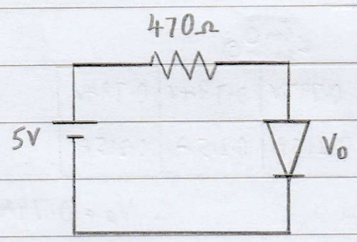


$$V_d = \frac{r_d}{r_d + R_S} V_S$$
$$= \frac{5.92}{5.92 + 470}(0.1)$$
$$= 1.243906539 \times 10^{-3}\,V_{p\text{-}p}$$
$$\approx 1.24\,mV_{p\text{-}p}$$

DC Analysis

→ Remove the AC component

and just deal with DC component



Load line equation

$$I_D = \frac{V_S - V_D}{R}$$
$$= \frac{5 - V_D}{470\Omega} \quad — ④$$

iteration method

V_D	0.7V	0.695V	0.695V
I_D	9.15mA	9.16mA	9.16mA

Q-pt (9.16mA, 0.695V)

$\therefore V_D = V_D + V_d$ peakvalue of sinusoidal wave

$= (0.695 + 0.62m\sin\omega t)V$

$\therefore i_D = I_D + i_d$

$= (9.16m + \frac{0.62}{5.92}\sin\omega t)\,A$

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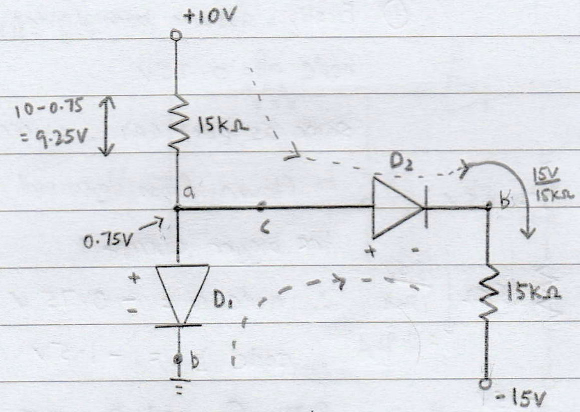
ON $i_D > 0$
off $V_D < 0$

3a)



① Firstly, assume both diodes are conducting, node a will have a voltage drop of 0.75V, node b = 0V

② By the first assumption, a voltage drop of 15V across 15kΩ resistor and a current of 1mA will flow down.

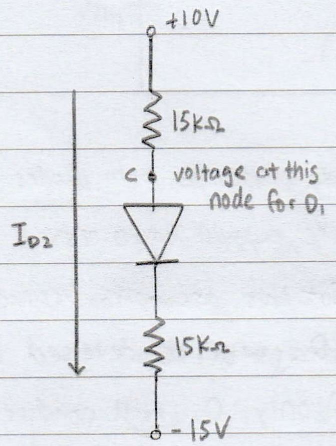
③ For both diode to be conducting, current flowing from top 15kΩ have to be greater than 1mA

$$I_{15k\Omega} = \frac{9.25V}{15k\Omega}$$
$$= 0.617\,mA < 1mA$$

∴ current will have to flow from ground as a supplementary current to satisfy the bigger current

↳ D_1 will be reversed biased (not conducting o/c)

↳ only D_2 conducts



Q-pt for D_2

(I_{D2}, V_{D2})

$= \left(\frac{10-(-15)-0.75}{15k\Omega+15k\Omega}, 0.75V\right)$

$= (0.808mA, 0.75V)$

Q-pt for D_1

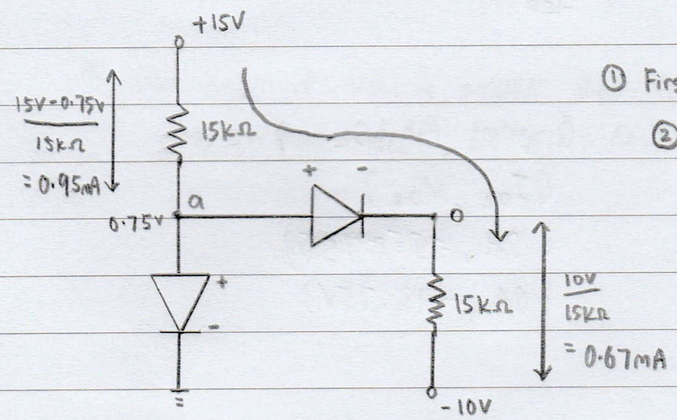
(I_{D1}, V_{D1})

$= (0A, 10V - 0.808mA(15k\Omega))$

$= (0A, -2.125V)$

$= (0A, -2.13V)$

b)



① First, assume node a = 0.75V

② current flowing from top 15kΩ resistor is greater than bottom, 0.95mA > 0.67mA

∴ able to flow through both diode

↳ D_1 and D_2 conducting

Q-pt for D_2

(I_{D2}, V_{D2})

$= (0.67mA, 0.75V)$

Q-pt for D_1

(I_{D1}, V_{D1})

$= (0.95mA - 0.67mA, 0.75V)$

$= (0.28mA, 0.75V)$

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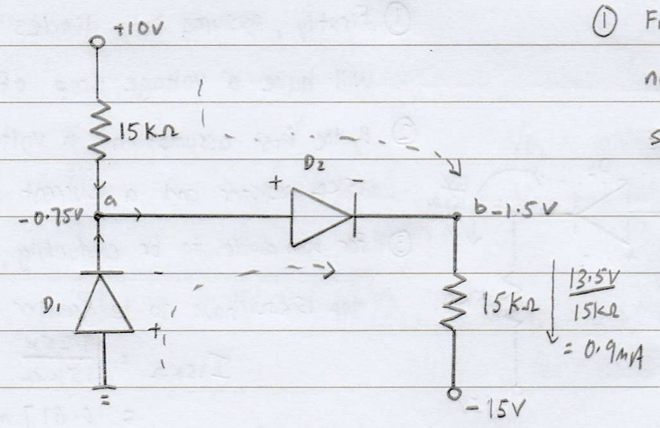
c)



① Firstly, assume both diodes are conducting

node a = 0.75V

same as part (a), current will have to flown from ground to satisfy the bigger current

∴ node a = − 0.75 V

node b = − 1.5V

Both D_1 and D_2 are conducting

Q-pt for D_1

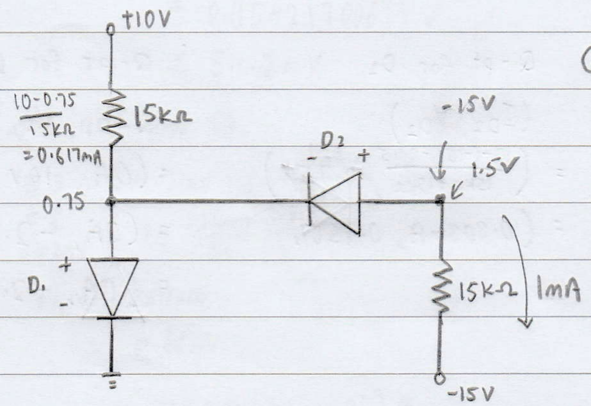
$= \left(0.9mA - \frac{10.75}{15k\Omega}, 0.75V\right)$

$= (0.183mA, 0.75V)$

Q-pt for D_2

$= (0.9mA, 0.75V)$

d)



① Firsty, assume both diodes are conducting

node a will be 0.75V

But this assumption cannot work as D_2 will be reversed biased

only D_1 will conduct

Q-point for D_1

(I_{D1}, V_{D1})

$(0.617mA, 0.75V)$

Q-point for D_2

(I_{D2}, V_{D2})

$(0A, -15-0.75V)$

$(0A, -15.75V)$

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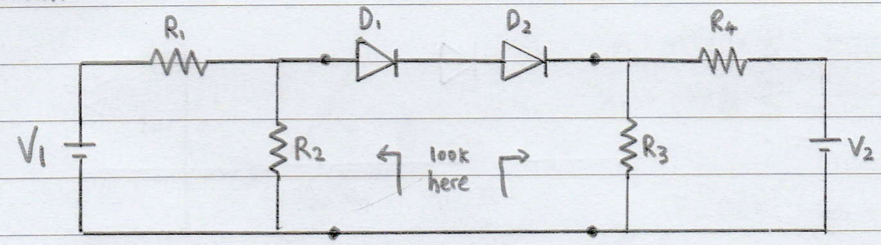
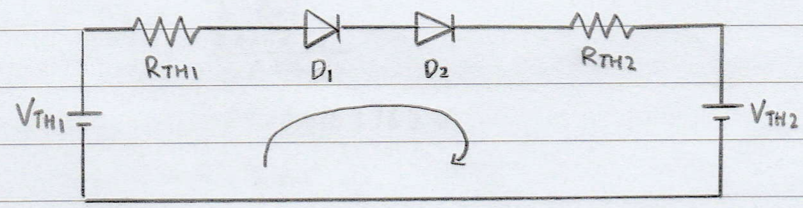
Extra question



By Thevenin Theorem

$V_{TH1} = \frac{R_2}{R_1+R_2} V_1 \qquad R_{TH1} = R_1 // R_2$

$V_{TH2} = \frac{R_3}{R_3+R_4} V_2 \qquad R_{TH2} = R_3 // R_4$



Empirical Diode Junction Equation

$V_D = nV_T \ln \left(\frac{I_D}{I_S} \right)$ —— ①

Load line equation

$I_D = \dfrac{V_{TH1} - V_{TH2} - 2V_D}{R_{TH1} + R_{TH2}}$ —— ②

use this 2 equation and do iteration method to solve Q-point

Q-pt same for both

* what happen if V_{TH1} is smaller than V_{TH2}

→ question ended, current = 0