Assignment.

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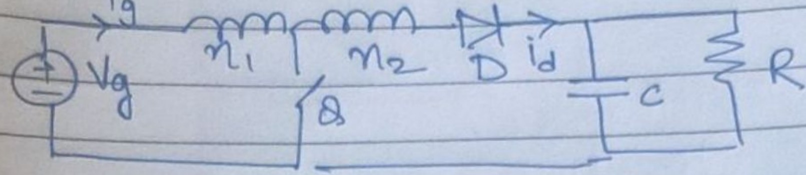
Q5.

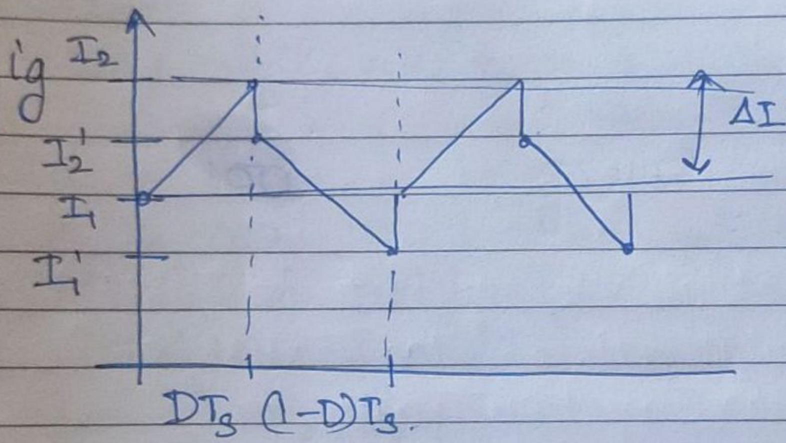


voltage second balance:

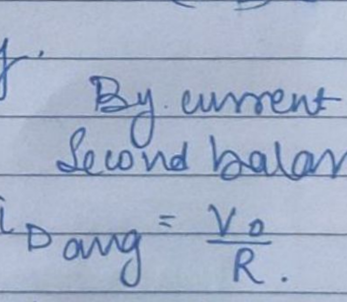
$$\frac{V_g(n_1+n_2)}{n_1} \cdot DT_s + (V_g - V_0)(1-D)T_s = 0.$$

$$V_g\left(D\left(1+\frac{n_2}{n_1}\right)+1-D\right) = V_0(1-D)$$

$$V_0 = V_g\left(\frac{1+Dn_2/n_1}{1-D}\right) = 132\text{ V}.$$



$$\Delta I = \frac{V_g}{L_1} DT_s = I_2 - I_1$$



$$\left.\begin{array}{l} I_2 n_1 = I_2'(n_1+n_2) \\ I_1'(n_1+n_2) = I_1 n_1 \end{array}\right\}$$ from continuity.

$$\frac{L_1}{L_2} = \left(\frac{n_1}{n_2+n_1}\right)^2.$$

$$L_1 = 15(1/3)^2 = 5/3\ \mu H.$$

By current second balance:

$$i_{D\,avg} = \frac{V_0}{R}.$$

$$\frac{1}{2}(I_1'+I_2')(1-D) = \frac{V_0}{R}.$$

$$I_1' + I_2' = \frac{2V_0}{R(1-D)}.$$

$$(I_1+I_2) = \frac{2V_0(n_1+n_2)}{R(1-D)n_1} \quad \Leftarrow \quad \frac{I_1 n_1 + I_2 n_1}{n_1+n_2} = \frac{2V_0}{R(1-D)}.$$

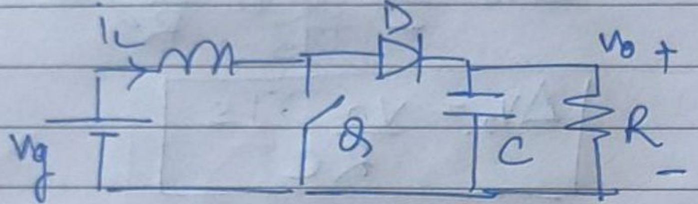
$$I_2 - I_1 = \frac{V_0}{L_1} DT_s = 172.8\ A$$

$$I_1 + I_2 = \left(1 + \frac{n_2}{n_1}\right) \frac{2V_0}{R(1-D)} = 330A.$$

$$\left.\begin{aligned} \underline{I_1 = 78.6A} \\ \underline{I_2 = 251.4A} \end{aligned}\right\} \qquad \left.\begin{aligned} I_1' = 26.2A \\ I_2' = 83.8 \end{aligned}\right\}.$$

$$\left.\begin{aligned} DT_s = 12\,\mu s \\ (1-D)T_s = 8\,\mu s. \end{aligned}\right\}.$$

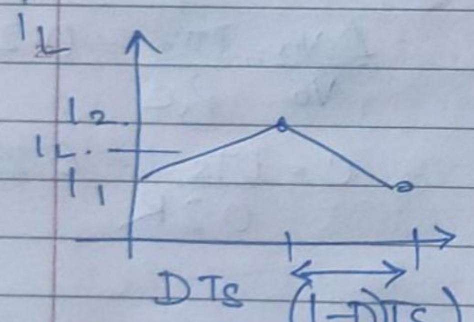
Q6.



using voltage second balance:

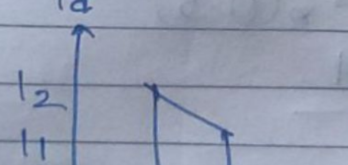
$$V_g \cdot DT_s + (V_g - V_0)(1-D)T_s = 0.$$

$$V_g(1) = V_g(1-D) \qquad V_0 = \frac{V_g}{1-D}.$$



$$\Delta I_L = \frac{V_g}{L} DT_s$$

$$I_L = \tfrac{1}{2}(I_1 + I_2)$$

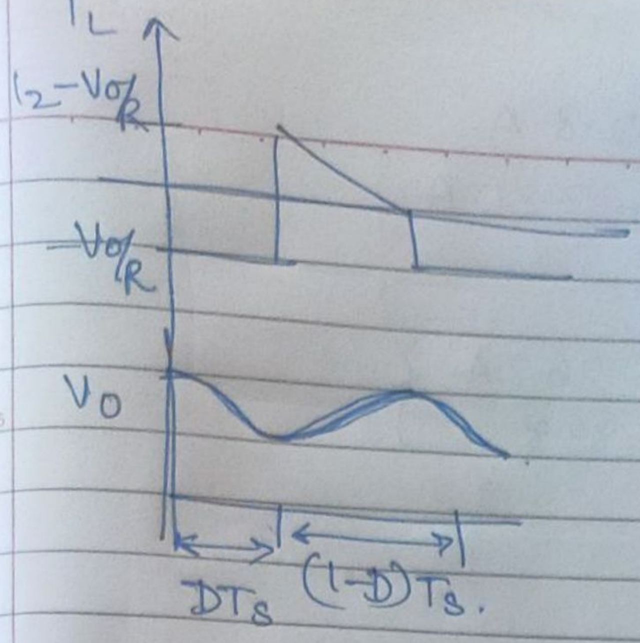


$$I_{d\,avg} = \frac{V_0}{R} = \frac{(I_1+I_2)}{2}(1-D)$$

$$\frac{\Delta I_L}{I_L} = \frac{V_g/L \cdot DT_s}{V_0} R(1-D) \qquad I_L = \frac{V_0}{R(1-D)}$$

$$= \frac{RDT_s}{L}(1-D)^2$$

$$i_C = i_D - V_0/R.$$



$$i_c = C\frac{dV_o}{dt}.$$

$$dV_o = \frac{1}{C} i_c \, dt.$$

$$\Delta V_o = \frac{1}{C}\int_{DT_s}^{T_s} i_c \, dt$$

$$\Delta V_o = \frac{1}{C}\int_{DT_s}^{T_s}\left(i_D - \frac{V_o}{R}\right) dt.$$

$$\frac{\Delta V_o}{V_o} = \frac{DT_s}{RC}$$

$$\boxed{\Delta V_o = \frac{V_o \, DT_s}{RC}}$$

Case ①.

$$\frac{\Delta I_L}{I_L} = 0.5. \qquad \frac{V_o}{V_g} = \frac{1}{1-D}. \qquad \therefore\ D = 0.5.$$

$$\frac{R\,DT_s}{L}(1-D)^2 = 0.5$$

$$\frac{\Delta V_o}{V_o} = \frac{DT_s}{RC} = 0.2$$

$$L = \frac{R\,T_s\,D\,(1-D)^2}{0.5} \qquad C = \frac{DT_s}{0.2R} = 6.25\,\mu F$$

$$= 8\times10^{-5}\times(0.5)^3$$

$$\underline{L = 10\,\mu H.}$$

$$K_{int} = D(1-D)^2 = 0.125$$

$$K = \frac{2L}{RT_s} = 0.5 \qquad K > K_{int}$$

it is in CCM.

case (2)

$K = \frac{2L}{RT_s} = 1/6 = 0.17$

assuming ccm.

$L = 10\mu H \quad C = 6.25\mu F$.

$\frac{\Delta I_L}{I_L} = 0.5$.

$\frac{RT_s}{L} D(1-D)^2 = 0.5$.

$D(1-D)^2 = 1/24$.

$\therefore D = 0.0459, 0.767$

$\frac{\Delta V_o}{V_o} = \frac{DT_s}{RC} = 6.09\times10^{-3}$, ~~or~~ 0.1022.

case (3)

$\frac{\Delta I_L}{I_L} = 2$. $\quad R = \frac{2 \cdot L}{T_s D(1-D)^2} = 16\,\Omega$.

$K = \frac{2L}{RT_s} = \frac{1}{8} = K_{int}$.

$\therefore$ converter in critical mode.

$K = K_{int}$.

Q7: 2 phase buck boost converter $\quad D = 0.6, \left|\frac{D}{1-D}\right| = 1.5$

$K = \frac{L}{RT_s} = 0.2$

$K_{int} = (1-D)^2 = 0.16$.

$\therefore$ converter in ccm. $\quad K > K_{int}$

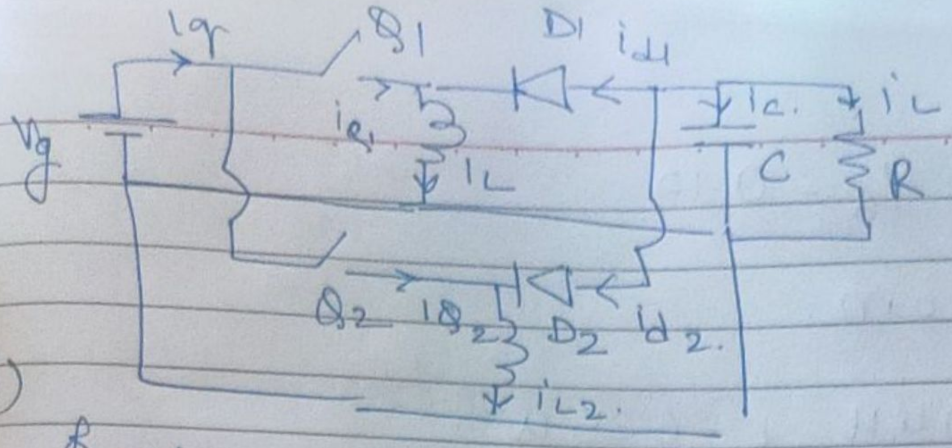
$v_o = \frac{-D}{1-D} v_g$. $\quad L_1 = L_2 = 10\mu H$

$C = 22\mu F$

$R = 5\,\Omega$

$T_s = 10\mu s$

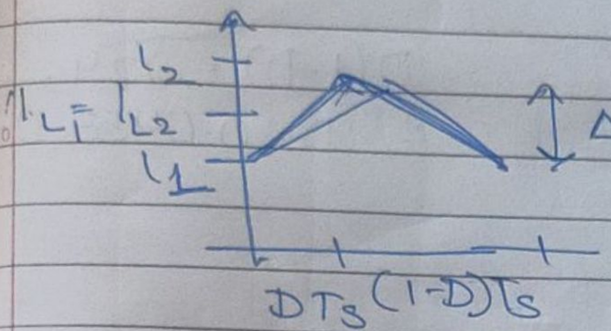
$i_o = i_{Q_1} + i_{Q_2}$.



(i)

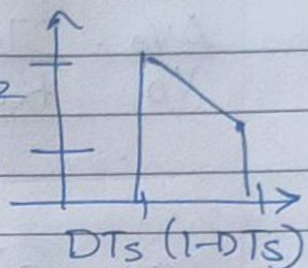
$\phi = 0^\circ$ $\therefore$ IIle circuits are similar

$\therefore i_{L_1} = i_{L_2}$ $\quad i_{d_1} = i_{d_2}$



$\Delta I_L = \left(\frac{V_g}{L}\right) D T_s$

$i_{d_1} = i_{d_2}$



$$i_{d_1} + i_{d_2} + i_c + i_L = 0.$$

$$2i_d + i_c + i_L = 0.$$

average $\longrightarrow$ $i_{c\,avg} = 0$ $\quad i_{L\,avg} = V_o/R$.

$$i_{d\,avg} = -\frac{V_o}{2R}.$$

$$\frac{(I_1 + I_2)}{2}(1-D) = \frac{-V_o}{2R} = \frac{D V_g}{2(1-D)R}$$

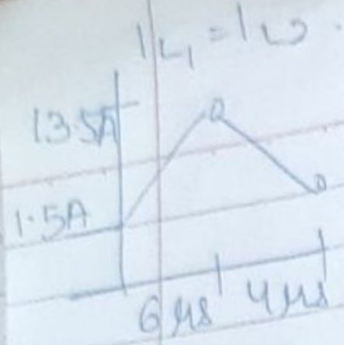
$$\frac{I_1 + I_2}{2} = \frac{D V_g}{2R(1-D)^2}.$$

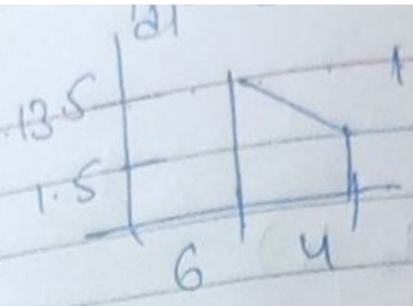
$$I_L = I_{L_1\,avg} = i_{L2\,avg} = \frac{I_1 + I_2}{2} = \underline{7.5\,A = I_L}$$

$$\underline{I_2 = 13.5\,A}$$

$$I_1 = I_L - \frac{\Delta I_L}{2}$$

$$= \frac{D V_g}{2R(1-D)^2} - \frac{V_g D T_s}{2L} = \underline{1.5\,A} = I_1$$

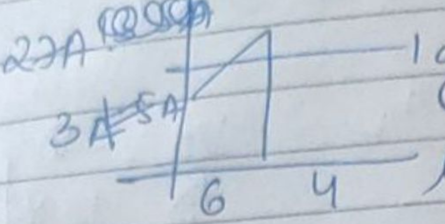


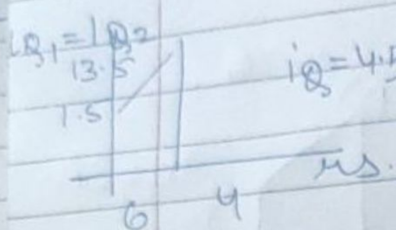


$i_g = i_{Q_1} + i_{Q_2}$

$= 2 i_Q$

$i_L = 7.5A$



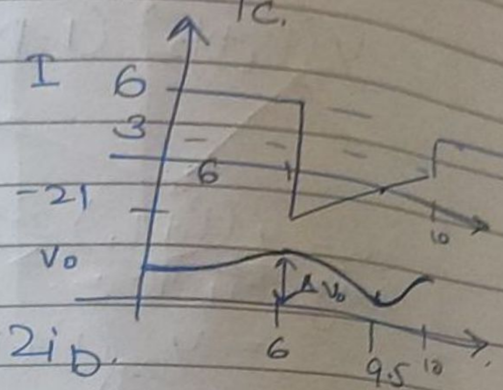


for voltage ripple:

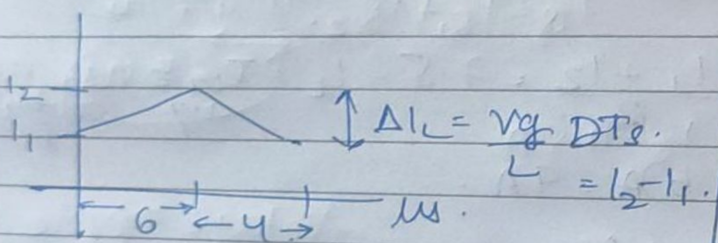
$i_c = -2 i_D - i_L$

$= -2 i_d - \frac{V_0}{R}$

$= -2 i_D + \frac{D V_g}{(1-D) R} = 6 - 2 i_D$



(ii) $\phi = 90 \div T/4 = 2.5\,\mu s$



$\Delta I_L = \frac{V_g}{L} D T_s$

$= I_2 - I_1$

$\therefore I_2 - I_1 = 12$

$i_C = C \frac{dv}{dt}$

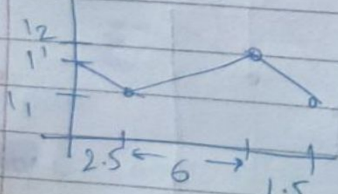
$dv = \frac{1}{C} i_C \, dt$

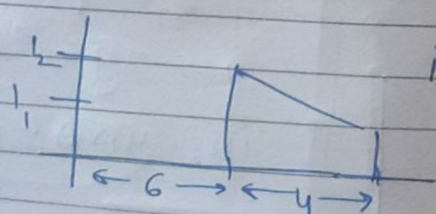
$\Delta V_0 = \frac{1}{C} \int_{9.5\,\mu s}^{6\,\mu s} i_C \, dt$

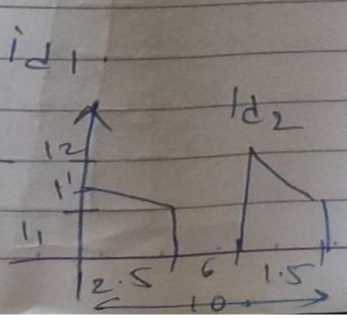
$= \frac{1}{C} \left(\frac{1}{2} \times 21 \times 3.5 \right)$

$\underline{\Delta V_0 = 1.67\ V}$

i_{L_2} will be shifted 2.5 μs from i_{L_1}.







$$\frac{I'-I_2}{1.5} = \frac{I_2-I_1}{-4} = -3.$$

$$\therefore I_2' = I_2 - 4.5$$

$$I_2' = I_2 - \frac{1.5}{4}(I_2 - I_1).$$

$$= 0.625 I_2 + 0.375 I_1.$$

$$(I_{d1} + I_{d2})_{avg} = -I_L = -\frac{V_0}{R} = \frac{-DV_g}{R(1-D)} = 6.$$

$$\tfrac{1}{2}(I_1+I_2)(1-D) + i_{d2\,avg} = 6.$$ $D = 0.6$

$$i_{d2\,avg} = \tfrac{1}{2}(I'+I_1)\,2.5 + \tfrac{1}{2}(I_2+I')\,1.5$$

$$= \tfrac{1}{2}\left((I'+I_1)0.25 + (I'+I_2)0.15\right)$$

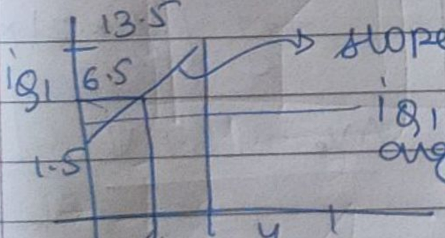
$$= \frac{0.4}{2}(I_1+I_2) = i_{d1\,avg}.$$

$$\therefore \tfrac{1}{2}(I_1+I_2)(0.4) = 6/2 = 3.$$

$$\therefore \frac{I_1+I_2}{2} = 7.5 = I_L = I_{L1\,avg} = I_{L2\,avg}$$

$I_1 = 1.5A$

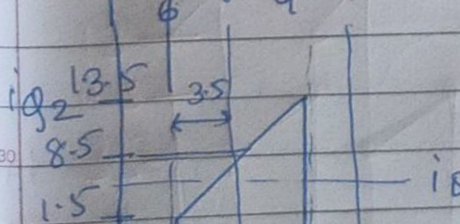
$I_2 = 13.5A$ $\quad I' = (I_2 - 4.5)A = 9A.$



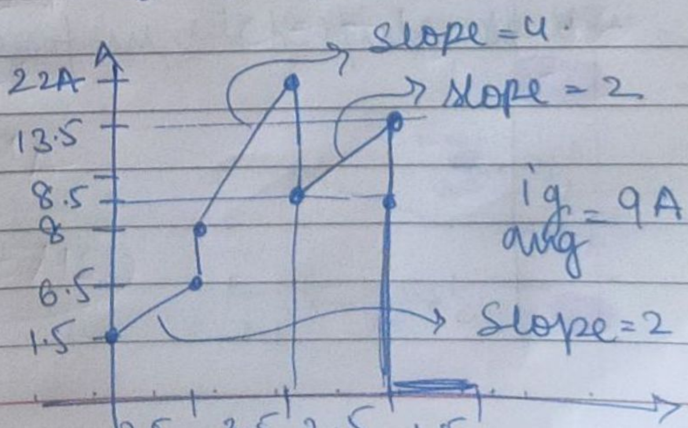
slope = 2A/μs.

$i_{Q1\,avg} = 4.5A.$

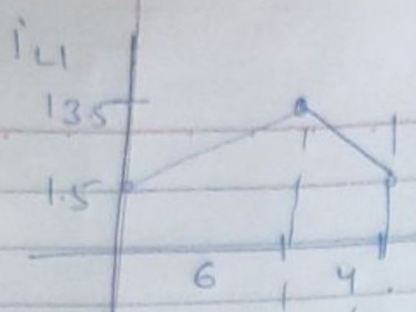
$i_Q = i_{Q1} + i_{Q2}.$



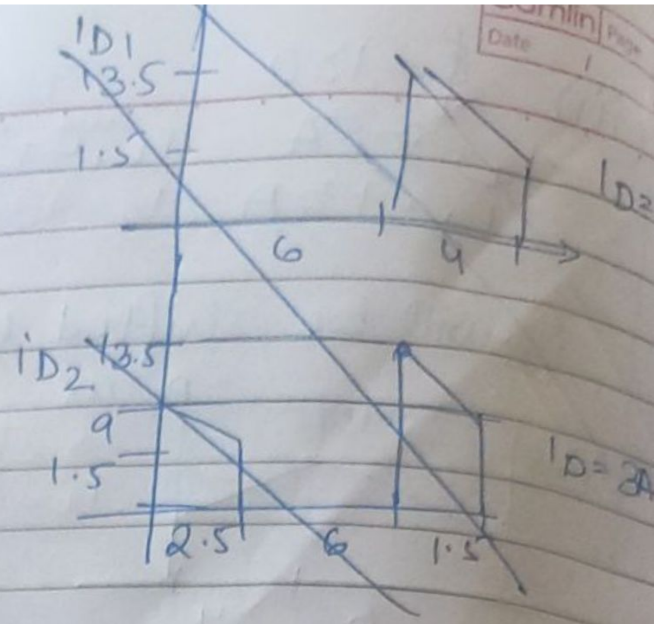
$i_{Q2} = 4.5A.$



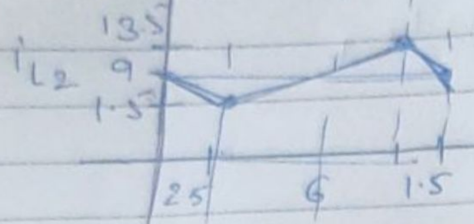
$i_{g\,avg} = 9A.$



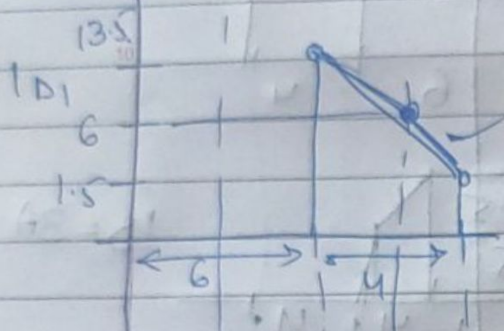
$i_L = 7.5 A$



$i_D = 3A$

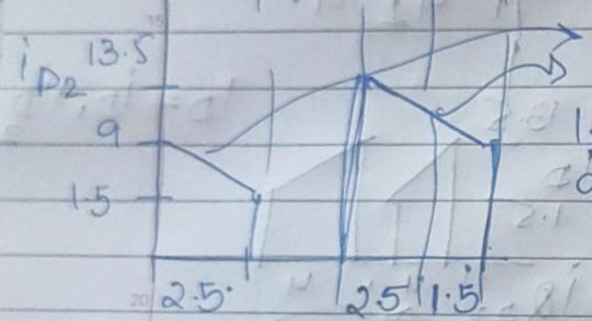


$i_L = 7.5 A$



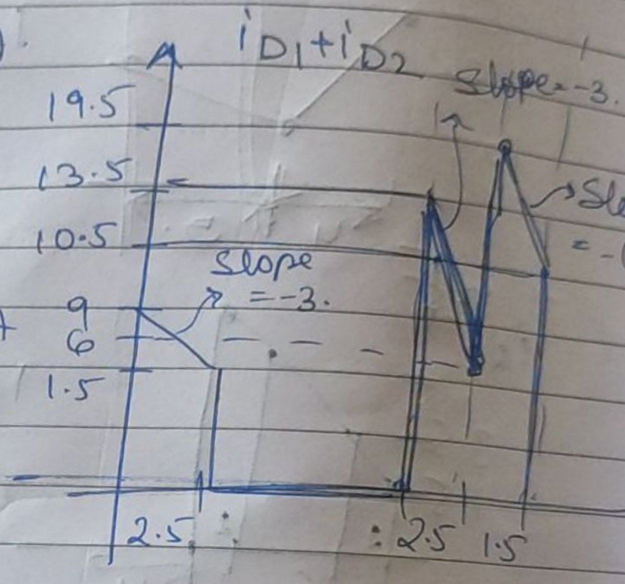
slope $= -3A$

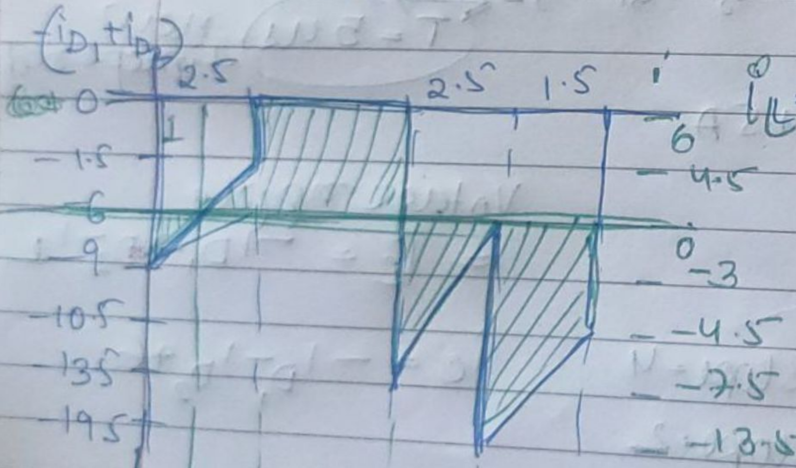
$i_{D_1 avg} = 3A$



slope $= -3A$

$i_{D_2 avg} = 3A$



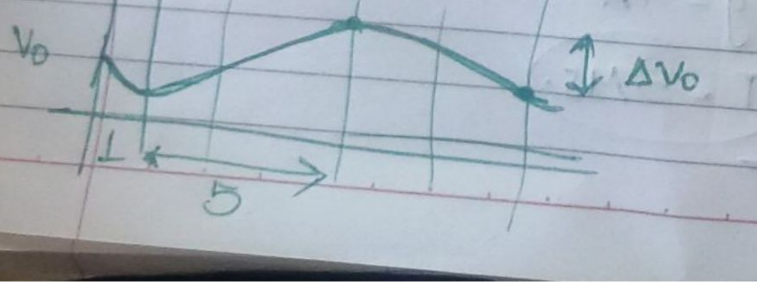


$i_C = -i_{D_1} - i_{D_2} + 6$

$$i_C = C\frac{dv_0}{dt}$$

$$\Delta v_0 = \frac{1}{C}\int_1^6 i_C\,dt$$

$$= 1.107\ V$$



(iii) $\phi = 180°$ $\quad T_s/2 = 5\mu s$

$I_L = 7.5A = I_{L_1 avg} - I_{L_2 avg}$

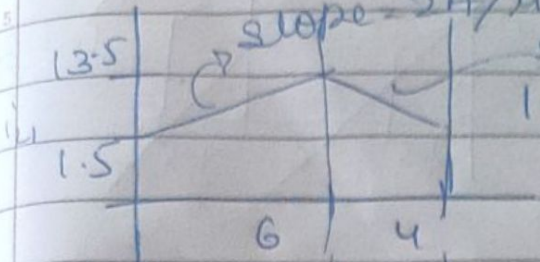
$I_1 = 1.5A \quad I_2 = 13.5A$

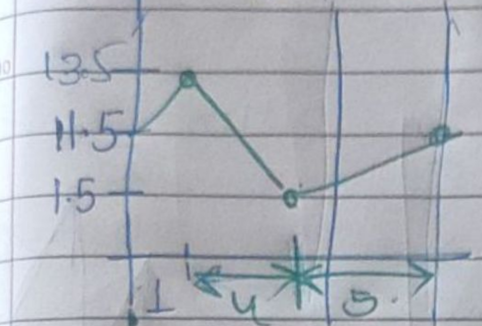
i_{L_2} will be shifted by $5\mu s$ from i_{L_1}

slope $= 2A/\mu s$

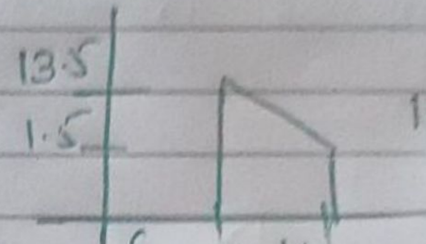
slope $= -3A/\mu s$

$I_L = 7.5A$

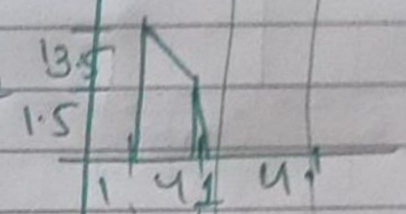




$I_L = 7.5A$

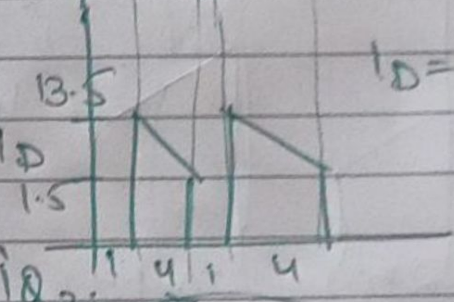


$I_D = 3A$

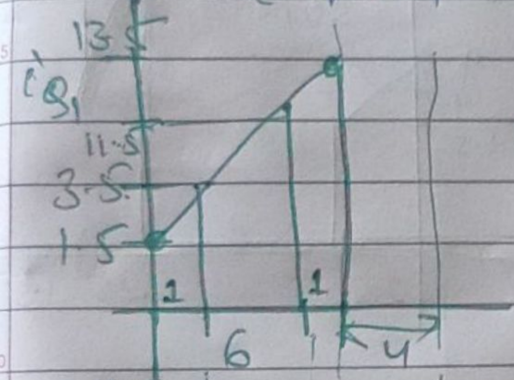


$I_D = 3A$

$I_D = i_{D_1} + i_{D_2}$

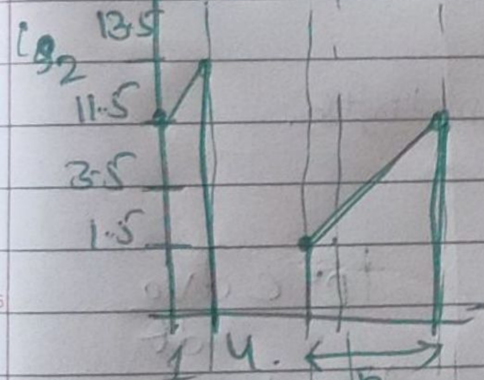


$\boxed{T = 5\mu s}$ new timeperiod



$I_Q = 4.5A$

$I_Q = I_{Q_1} + i_{Q_2}$



$I_Q = 4.5A$

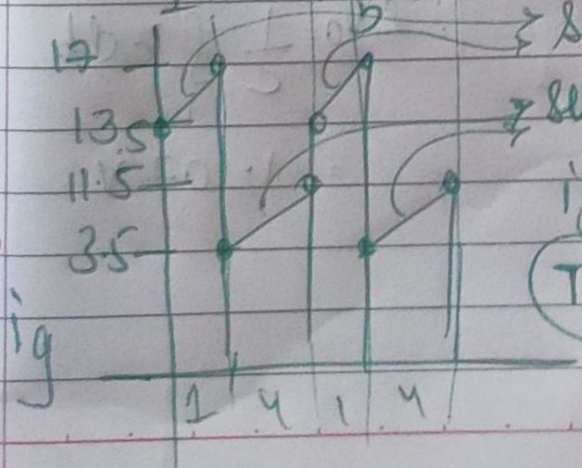
Votage ripple

$= i_C = -I_{D_1} - i_{D_2} - i_2$

$i_C = -I_{D_1} - I_{D_2} + 6$

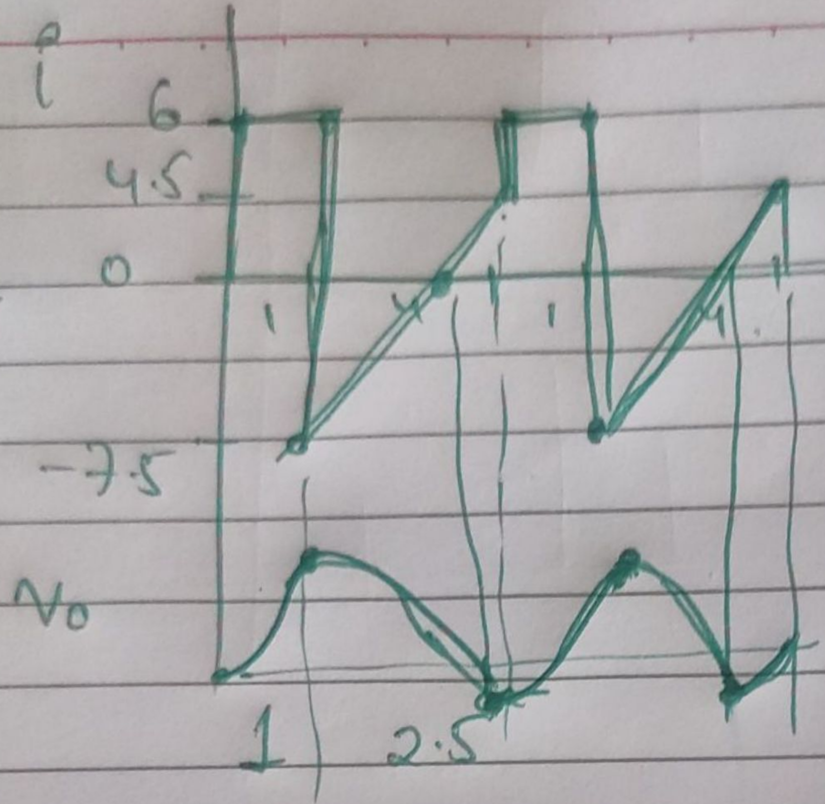
slope $= 4$

slope $= 2$



$i_g = 9A$

$\boxed{T = 5\mu s}$



$$i_c = C\frac{dv_0}{dt}$$

$$\Delta v_0 = \frac{1}{C}\int_{3.5}^{1} i_c\, dt$$

$$= \frac{1}{22}\left(\frac{1}{2}\times 7.5\times 2.5\right)$$

$$\underline{\Delta v_0 = 0.426\ V}$$