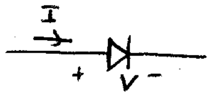
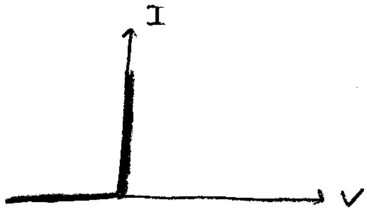
DIODES

31.07.2010

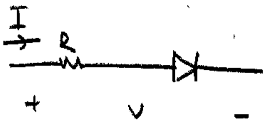
A circuit element that allows current flow in a single direction.





$$I = \begin{cases} 0, & V<0 \text{ (open circuit)} \\ \text{full current}, & V=0 \text{ (short circuit)} \end{cases}$$

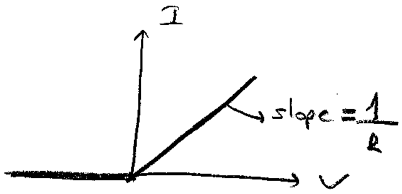
Ex-



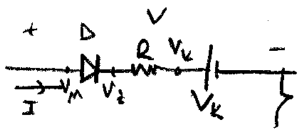
find I-V characteristic.

if $V<0$ $I=0$

if $V>0$ $I=\frac{V}{R}$



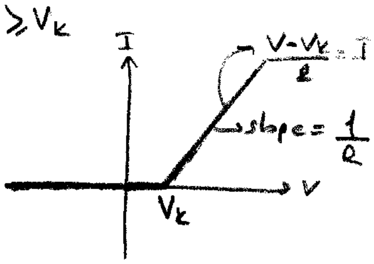
Ex-



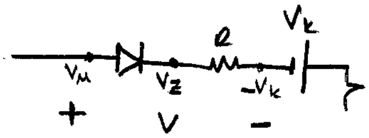
if I is passing $V=V_t=V_m \geq V_k$

if $V<V_k$, $I=0$

if $V\geq V_k$, $I=\frac{V-V_k}{R}$



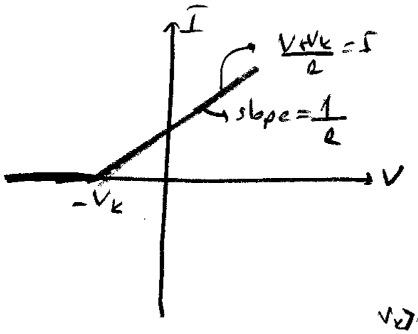
Ex. $V_k > 0$



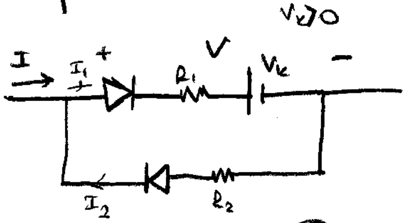
To observe current $V = V_M = V_Z \geq -V_k$

if $V < -V_k$, $I = 0$

if $V \geq -V_k$, $I = \frac{V - (-V_k)}{R} = \frac{V + V_k}{R}$



Ex.



$I = I_1 - I_2$ $\quad$ $V = V_k$, $V = 0$ → important points

if $V > V_k$

I_1 ✓ $\quad \Rightarrow I = I_1 = \frac{V - V_k}{R_1}$

I_2 ×

if $0 < V < V_k$

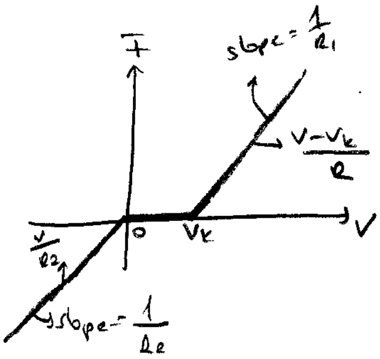
I_1 × $\quad \Rightarrow I = 0$

I_2 ×

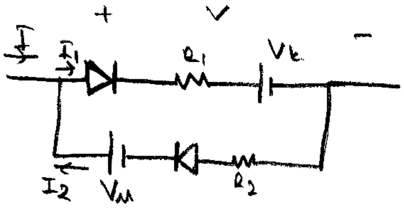
if $V < 0$

I_1 × $\quad \Rightarrow I = -I_2 = -\left[\frac{0 - V}{R_2}\right] = \frac{V}{R_2}$

I_2 ✓



Ex.



$I = I_1 - I_2$

$V = V_k$
$V = V_M$
important points

assume $V_M < V_k$

if $V > V_k$

I_1 ✓ $\quad I = I_1 = \frac{V - V_k}{R_1}$

I_2 ×

if $V_M < V < V_k$

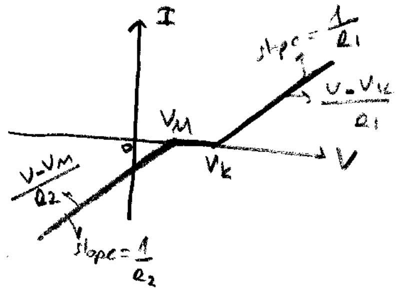
I_1 × $\quad I = 0$

I_2 ×

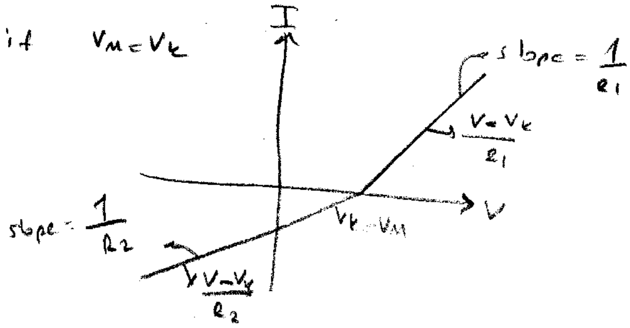
if $V < V_M$

I_1 ×

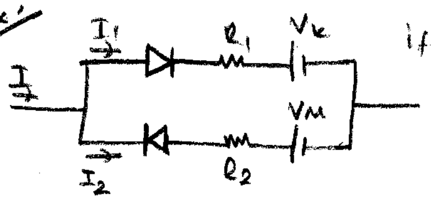
I_2 ✓ $\quad I = -I_2 = -\left[\frac{V_M - V}{R_2}\right] = \frac{V - V_M}{R_2}$



if $V_M = V_k$



Ex:



if $V_k < V_M$

important points $V_M = V_k$

if $V > V_M$

I_2 ✗

I_1 ✓ $\Rightarrow I = I_1 = \dfrac{V - V_k}{R_1}$

if $V_k < V < V_M$

I_1 ✓

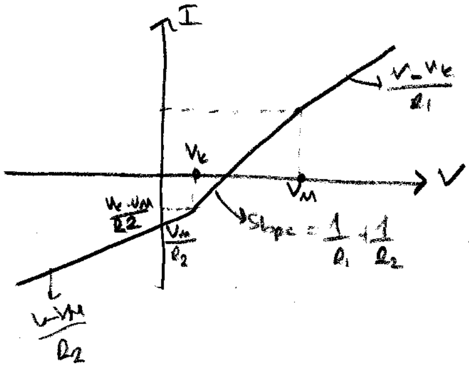
I_2 ✓ $\Rightarrow I_1 = \dfrac{V - V_k}{R_1}$, $I_2 = \dfrac{V_M - V}{R_2}$

$$I = I_1 - I_2 = \frac{V - V_k}{R_1} - \frac{V_M - V}{R_2}$$

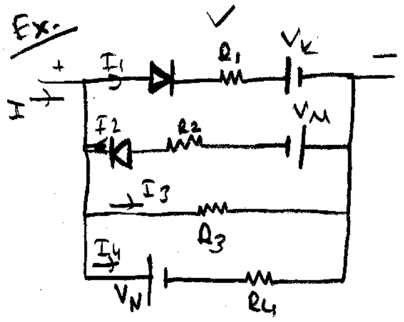
if $V < V_k$

I_1 ✗

$I_2 = \dfrac{V_M - V}{R_2}$ $\quad I = -I_2 = \dfrac{V - V_M}{R_2}$



Ex.



$I = I_1 - I_2 + I_3 + I_4$

always existing currents

$I_3 = \dfrac{V}{R_3}$

$I_4 = \dfrac{V - V_N}{R_4}$

if $V > V_k$ I_1 exists

$I_1 = \dfrac{V - V_k}{R_1}$ I_2 not exists

if $-V_M < V < V_k$

I_2, I_1
× ×

if $V < -V_M$

I_1 ×

$I_2 = \dfrac{-V_M - V}{R_2}$

if $V > V_k$

$I = I_1 + I_3 + I_4$ I_2 ×

$= \dfrac{V - V_k}{R_1} + \dfrac{V}{R_3} + \dfrac{V - V_M}{R_4}$

$= V\left[\dfrac{1}{R_1} + \dfrac{1}{R_3} + \dfrac{1}{R_4}\right] - \left(\dfrac{V_k}{R_1} + \dfrac{V_N}{R_4}\right)$

if $-V_M < V < V_k$

$I_1 I_2$
× ×

$I = I_3 + I_4 = \dfrac{V}{R_3} + \dfrac{V - V_N}{R_4}$

$= V\left[\dfrac{1}{R_3} + \dfrac{1}{R_4}\right] - \dfrac{V_N}{R_4}$

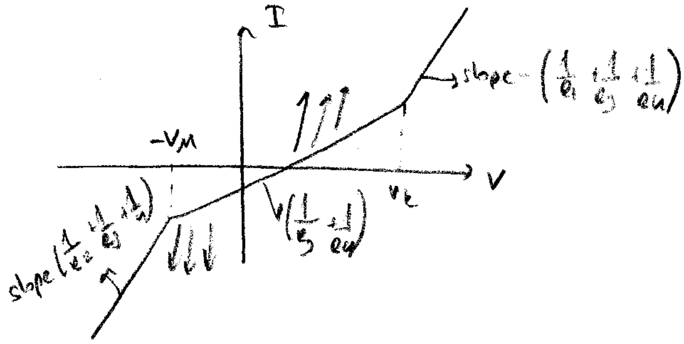
if $V < -V_M$

I_1 ×

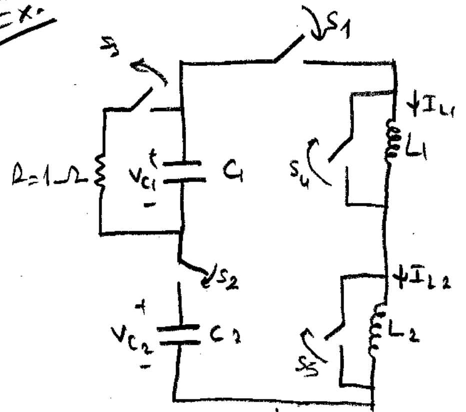
$I = -I_2 + I_3 + I_4$

$= \dfrac{V + V_M}{R_2} + \dfrac{V}{R_3} + \dfrac{V - V_N}{R_4}$

$= V\left[\dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}\right] + \left[\dfrac{V_M}{R_2} - \dfrac{V_N}{R_4}\right]$



Ex.



$C_1 = C_2 = 1F$
$R = 1\Omega$
$L_1 = 1H$
$L_2 = 2H$
$V_{C1}(0) = 2V$
$V_{C2}(0) = 1V$
$I_{L1}(0) = 2A$
$I_{L2}(0) = 5A$

S_1, S_2 closed when $t = \ln 2$

S_3, S_4, S_5 opened when $t = \ln 2$

Find $V_{C1}(t)$ $t \geq 0$
also find $V_{C1}(t) + V_{C2}(t)$ when $t \geq \ln 2$

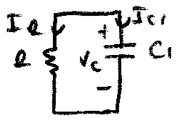
Soltn.

$0 < t < \ln 2$

$C_1 \longrightarrow$ operating
$C_2 \longrightarrow$ remains in its initial condition
$L_1 \longrightarrow$ " " " "
$L_2 \longrightarrow$ " " " "

$V_{C2}(\ln 2^-) = V_{C2}(0)$
$I_{L1}(\ln 2^-) = I_{L1}(0)$
$I_{L2}(\ln 2^-) = I_{L2}(0)$

$0 < t < \ln 2$



$$I_{C1} = -I_R$$
$$C_1 \frac{dV_{C1}}{dt} + I_R = 0$$
$$C_1 \frac{dV_{C1}}{dt} + \frac{V_{C1}}{R} = 0$$
$$\frac{dV_{C1}}{dt} + \frac{1}{C_1 R} V_{C1} = 0 \qquad V_C(0) = 2$$
$$V_{C1}(t) = k\, e^{\frac{-t}{C_1 R}}$$
$$V_{C1}(t) = k\, e^{-t}$$
$$V_{C1}(0) = 2 = k$$
$$V_{C1}(t) = 2e^{-t}$$
$$V_{C1}(\ln 2) = 2\, e^{-\ln 2} = 1V$$

$\Longrightarrow$

$\underline{t = \ln 2}$

$C_1, C_2 \rightarrow$ series

$L_1, L_2 \rightarrow$ series

$V_C(\ln 2^+) = V_{C1}(\ln 2^-) + V_{C2}(\ln 2^-) = 1 + 1 = 2V$

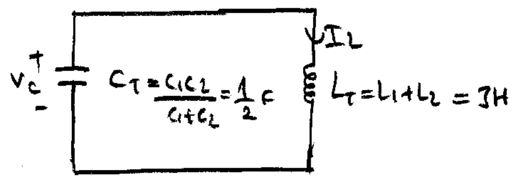
$\phi \ln(2)^- = \phi \ln(2)^+$

$L_1 I_{L1}(\ln(2)^-) + L_2 I_{L2}(\ln(2)^-) = (L_1 + L_2) I_L(\ln(2)^+)$

$1 \times 2 + 2 \times 5 = 3 \times I_L(\ln(2)^+)$

$I_L(\ln(2)^+) = 4A$

$\underline{t > \ln 2}$



$\equiv$

$C_T = \frac{C_1 C_2}{C_1 + C_2} = \frac{1}{2} F$

$L_T = L_1 + L_2 = 3H$

$V_C = V_L$

$V_C = L_T \frac{dI_L}{dt}$

$\boxed{\frac{dI_L}{dt} = \frac{1}{3} V_C}$

$C \frac{dV_C}{dt} = I_C = -I_L$

$\frac{1}{2} \frac{dV_C}{dt} = -I_L$

$\boxed{\frac{dV_C}{dt} = -2I_L}$

$\frac{d^2 I_L}{dt^2} = \frac{1}{3} \frac{dV_C}{dt}$

$\boxed{\frac{d^2 V_C}{dt} + \frac{2}{3} V_C = 0}$

$\boxed{\frac{d^2 I_L}{dt^2} + \frac{2}{3} I_L = 0}$

$s^2 + \frac{2}{3} = 0$ char-eq

$s = \pm j \sqrt{\frac{2}{3}}$ nat-freq

$V_C(t) = A_1 \cos\left(\sqrt{\frac{2}{3}}(t - \ln 2)\right) + A_2 \sin\left(\sqrt{\frac{2}{3}}(t - \ln 2)\right)$

$V_C(\ln 2^+) = 2V$

$\frac{dV_C}{dt}(\ln 2^+) = -2 I_L(\ln 2^+)$

$= -2 \times 4 = -8$

$\Rightarrow$

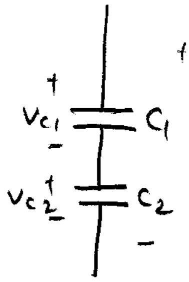
$$V_C(\ln 2^+) = 2 = A_1$$

$$\frac{dV_C}{dt} = -\sqrt{\frac{2}{3}}\,A_1 \sin\left(\sqrt{\frac{2}{3}}\,(t-\ln 2)\right) + \sqrt{\frac{2}{3}}\,A_2 \cos\left(\sqrt{\frac{2}{3}}\,(t-\ln 2)\right)$$

$$\frac{dV_C}{dt}(\ln(2)^+) = 0 + \sqrt{\frac{2}{3}}\,A_2 = -8$$

$$A_2 = -\frac{8\sqrt{3}}{\sqrt{2}} = -4\sqrt{6}$$

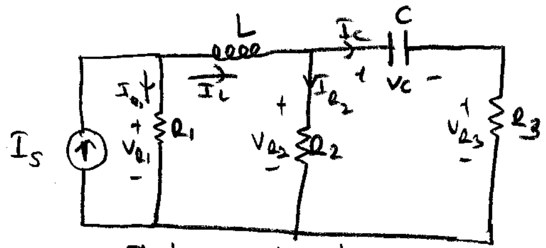
$$V_C(t) = 2\cos\left(\sqrt{\frac{2}{3}}\,(t-\ln 2)\right) - 4\sqrt{6}\,\sin\left(\sqrt{\frac{2}{3}}\,(t-\ln 2)\right)$$



$$V_{C_1}(t) = \frac{C_2}{C_1+C_2}\,V_C(t)$$

$$V_{C_2}(t) = \frac{C_1}{C_1+C_2}\,V_C(t)$$

Ex-



Find second order diff eqn. for V_C and I_L.

Soltn.

$$I_S = I_{R_1} + I_{L_1} \qquad V_{R_1} = V_C + V_L + V_{R_3}$$

$$I_S = \frac{V_{R_1}}{R_1} + I_L \qquad I_S = \frac{V_C + V_L + V_{R_3}}{R_1} + I_L$$

$$I_S = \frac{V_C}{R_1} + \frac{L}{R_1}\frac{dI_L}{dt} + \frac{V_{R_3}}{R_1} + I_L$$

$$\boxed{I_S = \frac{V_C}{R_1} + \frac{L}{R_1}\frac{dI_L}{dt} + \frac{R_3}{R_1}C\frac{dV_C}{dt} + I_L}$$

$$I_L = I_{R_2} + I_C$$

$$I_L = \frac{V_{R_2}}{R_2} + C\frac{dV_C}{dt}$$

$$I_L = \frac{V_C + V_{R_3}}{R_2} + C\frac{dV_C}{dt}$$

$$I_L = \frac{V_C}{R_2} + \frac{R_3}{R_2}I_C + C\frac{dV_C}{dt}$$

$$I_L = \frac{V_C}{R_2} + \frac{R_3}{R_2}C\frac{dV_C}{dt} + C\frac{dV_C}{dt}$$

$$\boxed{I_L = \frac{1}{R_2}V_C + \left[\frac{R_3}{R_2}C + C\right]\frac{dV_C}{dt}}$$

$\Longrightarrow$

$$I_L - \frac{V_C}{R_2} = \frac{(R_2+R_3)C}{R_2}\frac{dV_C}{dt}$$

$$\boxed{\frac{dV_C}{dt} = \frac{R_2}{(R_2+R_3)C} I_L - \frac{1}{(R_2+R_3)C} V_C}$$

$$I_S = \frac{1}{R_1}V_C + \frac{L}{R_1}\frac{dI_L}{dt} + \frac{R_3 C}{R_1}\left[\frac{R_2}{(R_2+R_3)C}I_L - \frac{1}{(R_2+R_3)C}V_C\right] + I_L$$

$$I_S = \left[\frac{1}{R_1} - \frac{R_3}{R_1(R_2+R_3)}\right]V_C + \left[\frac{R_2R_3}{R_1(R_2+R_3)}+1\right]I_L + \frac{L}{R_1}\frac{dI_L}{dt}$$

$$\boxed{\frac{dI_L}{dt} = \frac{R_1}{L}I_S - \frac{1}{L}\left[1-\frac{R_3}{(R_2+R_3)}\right] - \frac{1}{L}\left[\frac{R_2R_3}{R_2+R_3}+R_1\right]I_L}$$

$\frac{1}{C}\frac{R_2}{R_2+R_3} = A$ $\quad \frac{1}{(R_2+R_3)C} = B$ $\quad \boxed{\frac{dV_C}{dt} = AI_L - BV_C}$ *

$\frac{R_1}{L} = k$ $\quad \frac{1}{L}\left[1-\frac{R_3}{R_2+R_3}\right] = M$ $\quad \frac{1}{L}\left[\frac{R_2R_3}{R_2+R_3}\right] = N$ $\quad \boxed{\frac{dI_L}{dt} = k - MV_C - NI_L}$

**

$\frac{d}{dt}$ ** put * inside ;

$$V_C = \frac{k}{M}I_S - \frac{N}{M}I_L - \frac{1}{M}\frac{dI_L}{dt}$$

$$\frac{d^2I_L}{dt^2} = k\frac{dI_S}{dt} - M\frac{dV_C}{dt} - N\frac{dI_L}{dt}$$

$$\frac{d^2I_L}{dt^2} + N\frac{dI_L}{dt} = k\frac{dI_S}{dt} - M(AI_L - BV_C)$$

$$\frac{d^2I_L}{dt^2} + N\frac{dI_L}{dt} + MAI_L = k\frac{dI_S}{dt} + MBV_C$$

$$\frac{d^2I_L}{dt^2} + N\frac{dI_L}{dt} + MAI_L = k\frac{dI_S}{dt} + MB\left[\frac{k}{M}I_S - \frac{N}{M}I_L - \frac{1}{M}\frac{dI_L}{dt}\right]$$

$$\frac{d^2I_L}{dt^2}(N+B)\frac{dI_L}{dt} + (MA\times NB)I_L = k\frac{dI_S}{dt} + BkI_S$$

$\Longrightarrow$

$\frac{d}{dt}$ * put ** inside

$$\frac{d^2V_c}{dt^2} = A\frac{dI_L}{dt} - B\frac{dV_c}{dt}$$

$$\frac{d^2V_c}{dt^2} + B\frac{dV_c}{dt} = A\left[kI_S - MV_c - NI_L\right] \qquad I_L = \frac{1}{A}\frac{dV_c}{dt} + \frac{B}{A}V_c$$

$$\frac{d^2V_c}{dt^2} + B\frac{dV_c}{dt} + AMV_c = AkI_S - ANI_L$$

$$\frac{d^2V_c}{dt^2} + B\frac{dV_c}{dt} + AMV_c = AkI_S - \left[N\frac{dV_c}{dt} + NBV_c\right]$$

$$\boxed{\frac{d^2V_c}{dt^2} + (B+N)\frac{dV_c}{dt} + (AM + BN)V_c = AkI_S}$$