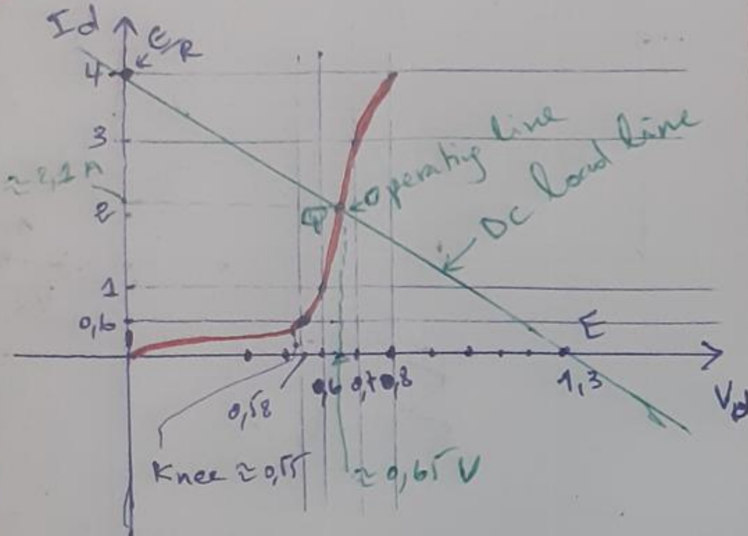
Solution of Series 3

Exercise 1

1) Trace the characteristic of this diode



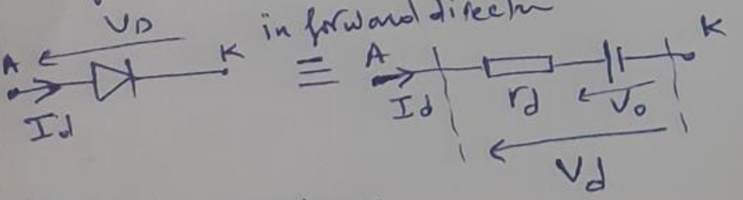
2) $\frac{1}{R_d} = \frac{\Delta I_d}{\Delta V_d} = \frac{3-0,6}{0,7-0,58} = 20$

$$\boxed{R_d = \frac{1}{20} = 0,05\,\Omega}$$

3) Determine the knee voltage V_0

$$\boxed{V_0 \simeq 0,55\,V}$$

4) Give the equivalent electrical diagram of this diode in the forward direction.



5) $V_{d\,max}$ and $I_{d\,max}$

$P_d = V_d \cdot I_d$

$P_{dmax} = V_{dmax} \cdot I_{dmax}$

$V_{dmax} = V_0 + R_d \cdot I_{dmax}$

$P_{dmax} = (V_0 + R_d\, I_{dmax}) \cdot I_{dmax}$

$\uparrow 3 \qquad \uparrow 0,55 \qquad \uparrow 0,05$

$0,05\, I_{dmax} + 0,55\, I_{dmax} - 3 = 0$

$\Delta = (0,55)^2 + 4 \cdot 0,05 \cdot 3 = 0,9$

$I_{dmax\,1} = \frac{-0,55 - \sqrt{\Delta}}{2 \cdot 0,05} = -15\,A$ ✗

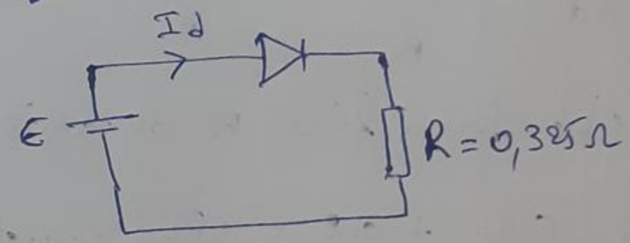
$I_{dmax\,2} = \frac{-0,55 + \sqrt{\Delta}}{2 \cdot 0,05} = 4\,A$ ✓

So $\boxed{I_{dmax} = 4\,A}$

$V_{dmax} = R_d\, I_{dmax} + V_0$

$$\boxed{V_{dmax} = 0,75\,V}$$

6)



→ Determine the value of E so that the DC load line passes through the point M(0V, 4A)

$E = R\, I_d + V_d$

$\Rightarrow \boxed{I_d = \frac{E}{R} - \frac{V_d}{R}}$

DC load line

for $(I_d = 4A)$ and $(V_d = 0) \Rightarrow$

$$\boxed{E = 4 \cdot 0,325 + 0 = 1,3\,V}$$

→ Operating point

The operating point of a diode is the point of intersection between the DC load line and the ~~diode's~~ diode's characteristics curve.

- The equation of DC load line is

$$I_d = \frac{E}{R} - \frac{V_D}{R}$$

if $V_d = 0 \Rightarrow I_d = \frac{E}{R} = 4\,A$

if $I_d = 0 \Rightarrow V_d = E = 1{,}3\,A$

$Q\,(2{,}1\,A\,,\ 0{,}65\,V)$

7] $\Delta E = e(t)$; $e(t) = 0{,}2\sin(\omega t)$

$$I_d = \frac{E + e(t)}{R} - \frac{V_d}{R} \ ; \ e(t) = 0{,}2\sin(\omega t)$$

⇒ the load line is dynamic

$$V_d = \begin{cases} 1{,}3 + 0{,}2 = 1{,}5\,V & \text{maximal value} \\ 1{,}3 - 0{,}2 = 1{,}1\,V & \text{min value} \end{cases}$$

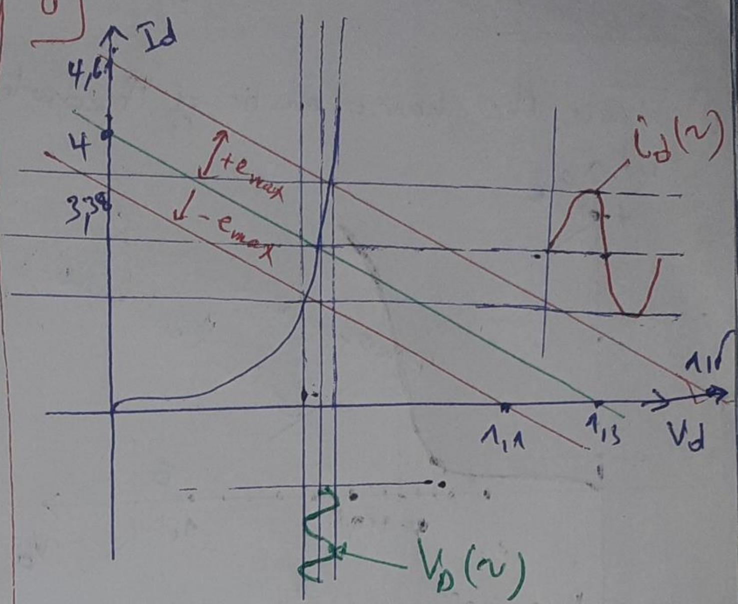
$$I_d = \begin{cases} \frac{E+e}{R} = \frac{1{,}3+0{,}2}{0{,}325} = 4{,}61\,A \\ \frac{E-e}{R} = \frac{1{,}3-0{,}2}{0{,}325} = 3{,}38\,A \end{cases}$$

$$\frac{1}{R_d} = \frac{\Delta I_d}{\Delta V_d}$$

$$\frac{i_d(\sim)}{V_d(\sim)} = \frac{1}{R_d}$$

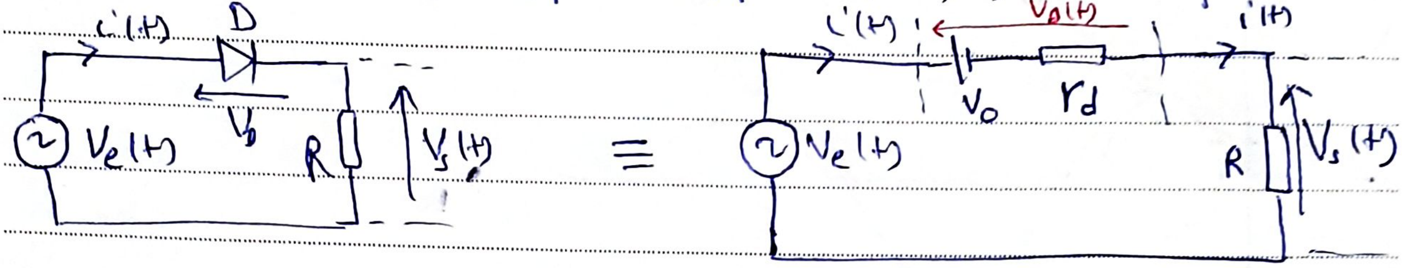
$$\Rightarrow i_d(\sim) = \frac{1}{R_d} V_d(\sim)$$

8]



Exercise 2 :

$V_0 = 0{,}5\ V$, $r_d = 5\,\Omega$, $V_e(t) = V_M \sin(\omega t)$; $\omega = 2\pi f$



1) Determine the ~~e~~xpressions for the current $i(t)$ and the voltage $V_D(t)$.

→ The diode D is reverse-biased if $V_e \leq V_0 \Rightarrow i(t) = 0$

→ The diode D is forward-biased if $V_e > V_0 \Rightarrow i(t) \neq 0$

* Applying the Kirchhoff's law (VKL)

$V_e(t) = V_0 + (r_d + R)\, i(t) \Rightarrow \boxed{i(t) = \dfrac{V_e(t) - V_0}{(R + r_d)}}$

* $V_D(t) = V_e(t) - V_s(t) = \underline{V_e(t) - R\, i(t)}$.

$$V_D(t) = \begin{cases} V_e(t) & \text{if } i(t) = 0 \quad \text{D is reverse-biased} \\ V_e(t) - R\, i(t) & \text{if } i(t) \neq 0 \quad \text{D is forward-biased} \end{cases}$$

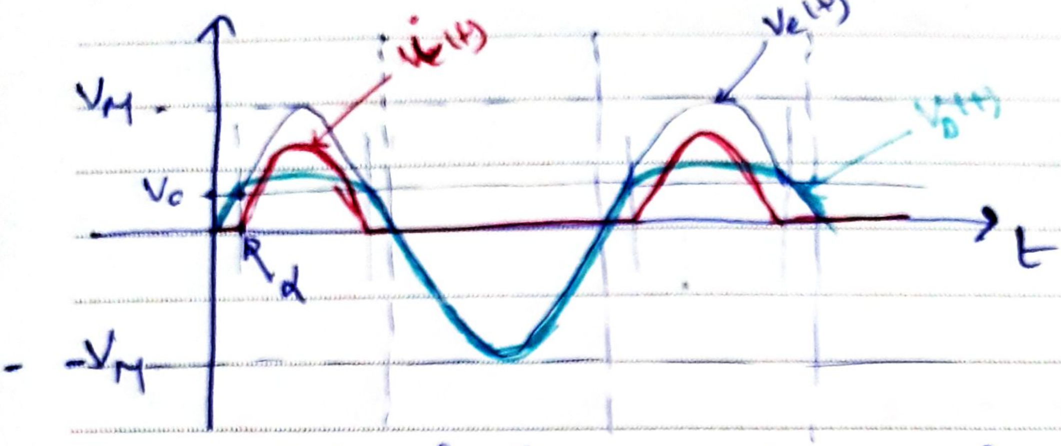
$V_D(t) = V_e(t) - R\, i(t) = e(t) - R \cdot \dfrac{V_e(t) - V_0}{(R + r_d)}$

$V_D(t) = \dfrac{\cancel{R V_e(t)} + r_d V_e(t) - \cancel{R V_e(t)} + R V_0}{(R + r_d)}$

$V_D(t) = \dfrac{r_d}{R + r_d} V_e(t) + \dfrac{R}{R + r_d} V_0$; if $r_d << R \Rightarrow V_D(t) \simeq V_0$

$$V_D(t) = \begin{cases} V_e(t) & \text{if } i(t) = 0 \quad \text{D is reverse-biased} \\ \dfrac{r_d}{r_d + R} V_e(t) + \dfrac{R}{r_d + R} V_0 \simeq V_0 & \text{if } i(t) \neq 0 \quad \text{D forward-biased} \end{cases}$$

2] Plot $i(t)$ and $V_D(t)$ on the same graph



3] Calculate the firing angle α : for $V_M = 2V_0$ then $V_M = 10V$

$V_e(\alpha) = V_0 = V_M \sin(\alpha) \iff \sin\alpha = \frac{V_0}{V_M}$

$$\boxed{\alpha = \arcsin\left(\frac{V_0}{V_M}\right)}$$

→ For $V_M = 2V_0 \Rightarrow \alpha = \arcsin\left(\frac{V_0}{2V_0}\right) = \arcsin\left(\frac{1}{2}\right)$

$$\boxed{\alpha = \frac{\pi}{6} = 0{,}52 \text{ rad}}$$

→ For $V_M = 10V \Rightarrow \alpha = \arcsin\left(\frac{V_0}{10}\right) = \arcsin\left(\frac{0{,}5}{10}\right)$

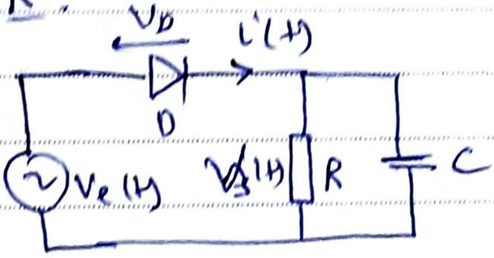
$$\boxed{\alpha = 0{,}05 \text{ rad}}$$

4] Compare the values (silicon – Germanium)

→ For $V_M = 2V_0 \Rightarrow \alpha = 0{,}52$ rad
→ For $V_M = 10V \Rightarrow \alpha = 0{,}03$ rad
} Germanium.

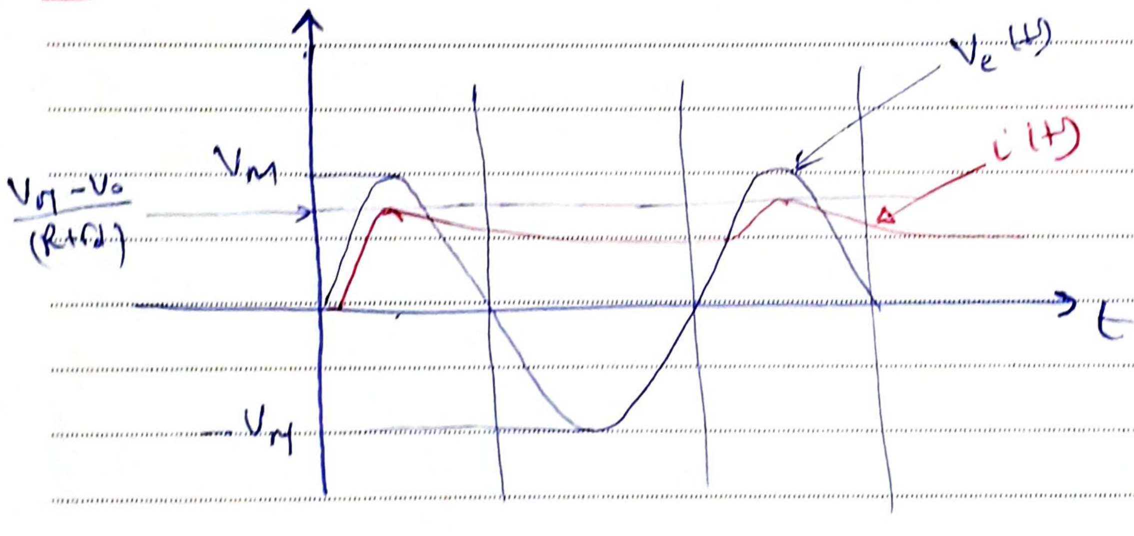
→ We notice that the change of the diode has almost no influence on the the firing angle.
→ For a good rectification, we have an interest in taking $V_M \gg V_0$.

5] Explain what happens when a capacitor C connected in parallel with the resistor R.



* When a capacitor C is connected in parallel to the Resistor R. the capacitor charges when the diode is forward-biased, up to the voltage $(V_M - V_0)$ (because $V_R(t) = V_e(t) - V_D(t)$), and when the diode is reverse-biased (if $V_e(t) < V_M - V_0$); the capacitor discharges through the Resistor R.

6] Plot the curve $i(t)$ in this case.

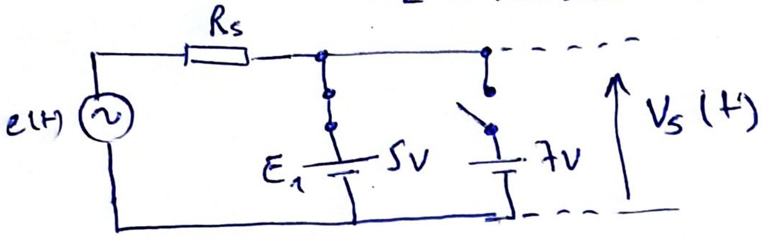


Exercise N°3

1- Determine ~~and~~ then plot the output $V_s(t)$ of the circuit

$E_1 = 5\,V$, $E_2 = 7\,V$, $V_e(t) = 12\sin(\omega t)$

* If $V_e(t) < 0$: D_1 is forward-biased
  D_2 is reverse-biased

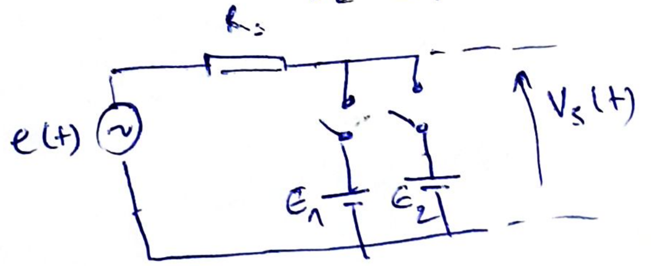


$\boxed{V_s(t) = E_1 = 5V}$

* If $V_e(t) > 0$
  * If $V_e(t) < 5V$: D_1 is forward-biased
    D_2 is reverse-biased

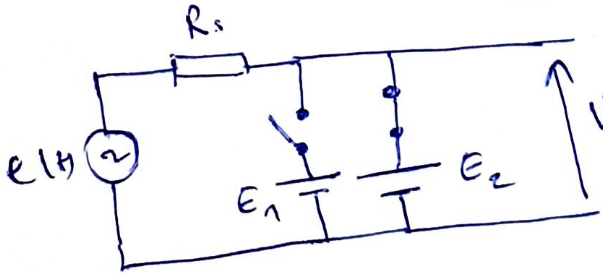
    $\boxed{V_s(t) = E_1 = 5V}$

  * If $5 \le V_e(t) < 7V$: D_1 is reverse-biased
    D_2 is reverse-biased

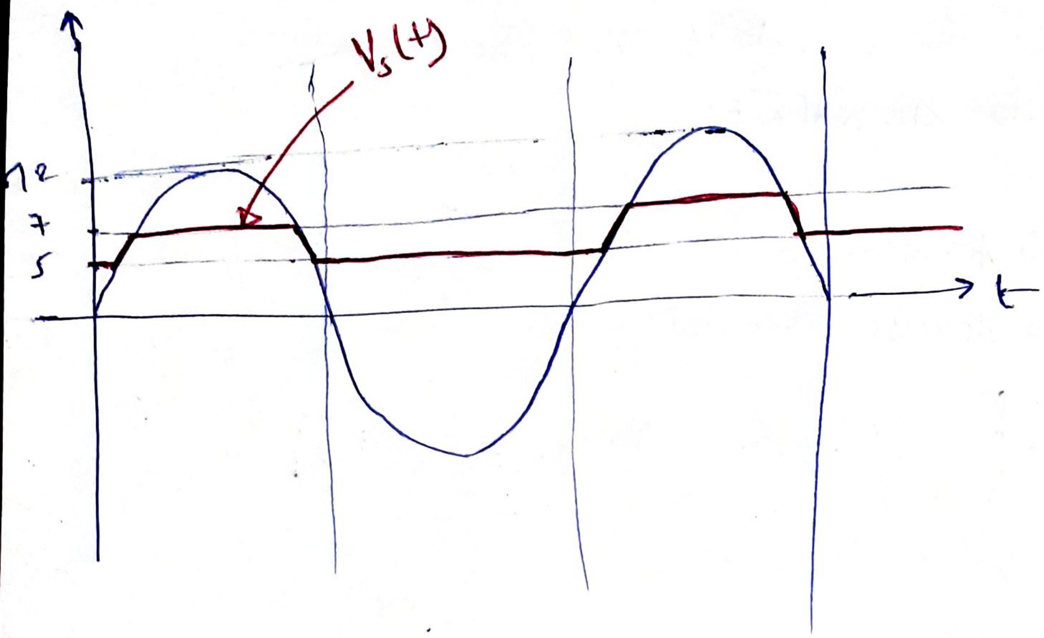


$\boxed{V_s(t) = V_e(t)}$

* If $V_e(t) > 7V$; D_1 is reverse-biased
  D_2 is forward-biased



$V_s(t) = \boxed{V_s(t) = E_2} = 7V$



Transfert characteristic $V_s = f(V_e)$