INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

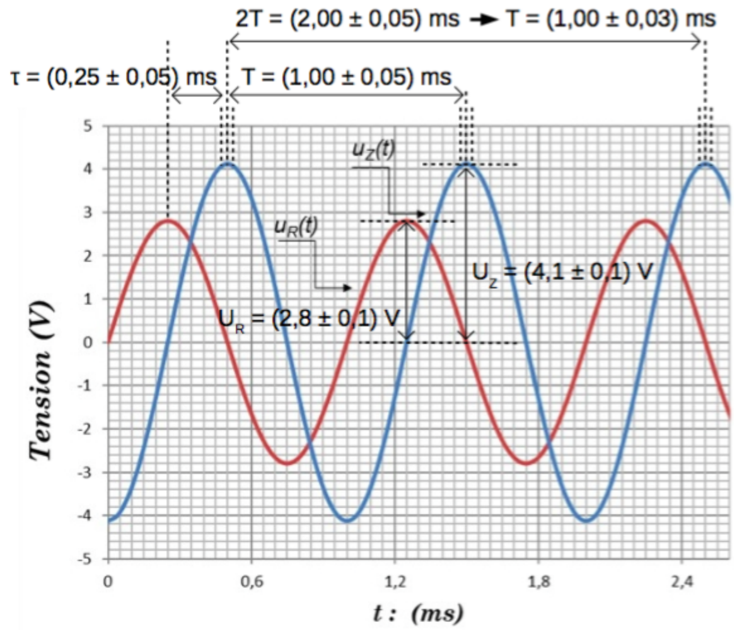
FIMI
SCAN 1st
Year 2018-2019

Exam 3 - Physics

December, 21st 2018, duration : 1h30

Exercise 1 : Straigthforward application of lectures and practicals (5.5 points)

1.a	Taking half a graduation for left and right uncertainties (0.025 ms) we read :$T = 1.00 \pm 0.05\,\mathrm{ms}$ *Bonus* :$2T = 2.00 \pm 0.05$ ms so $T = 1.00 \pm 0.03$ ms Time shift : $\tau = 0.25 \pm 0.05$ ms	0.5 +0.25 0.5
1.b	$u_R = 2.8 \pm 0.1$ V and $u_Z = 4.1 \pm 0.1$ V (no score if confusion between peak and peak-to-peak amplitude) *Bonus* : if peak-to-peak amplitude is computed to reduce uncertainties	0.5 +0.25
2.	$u_R(t)$ and therefore $i(t)$ is ahead of $u_Z(t)$	0.5
3.	$\varphi = 2\pi\frac{\tau}{T}$ (or $\varphi = 360\frac{\tau}{T}$ in degree)	0.5
4.	$\varphi \simeq \frac{\pi}{2} \simeq 1.57$ rad (or $90°\ldots$) Using the min/max method, we have $\varphi = 1.57 \pm 0.40$ rad or $\varphi = 90 \pm 23°$	0.5 0.5
5.	Using the modulus of $\underline{u_Z}$, $\underline{u_R}$, $\underline{Z}$ and $\underline{\mathrm{i(t)}}$: $U_z = ZI$ and $I = \frac{U_R}{R}$ so that : $Z = R\frac{U_Z}{U_R}$	0.5
6.	$Z = 10^4 \times \frac{4.1}{2.8} = 14\,643\,\Omega$	0.5
7.	Given $i(t)$ is ahead of $u_Z(t)$ with a phase shift of $\pi/2$, the unknow dipole is a capacitor	1.0



Exercise 2 : Nonlinear characteristic and operating point (5 points)

1. Using successive source transformation or Thevenin's theorem we have :
$E = \frac{R_2}{R_1+R_2}E_1 - E_2$ and $R = \frac{R_1 R_2}{R_1+R_2}$ 1.5

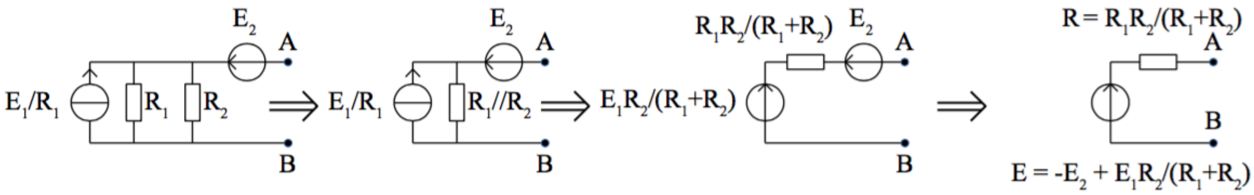


FIGURE 1 – Using successive source transformation

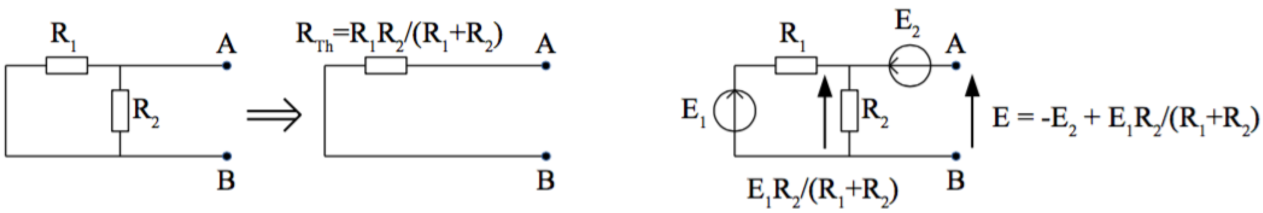


FIGURE 2 – Using Thevenin's theorem

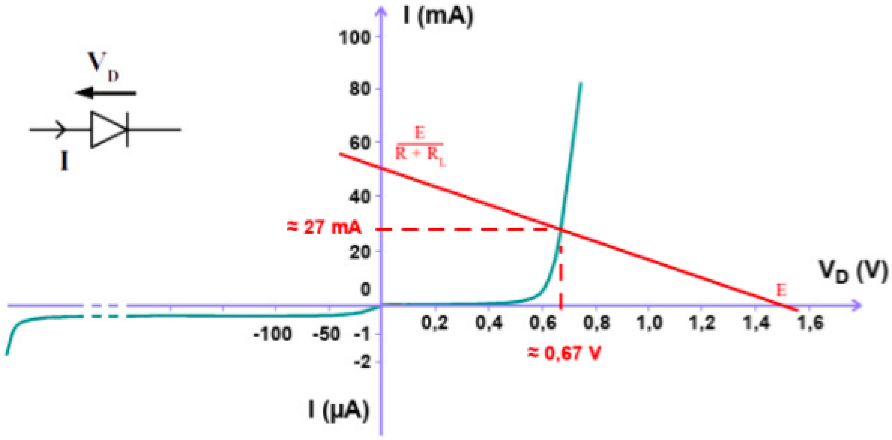
2.a The orientation of I being provided, Kirchhoff circuit's law writes : $E-(R+R_L)I = V_D$ 0.5
It is supposed that $E > 0$. We can use logic and absurdity to demonstrate that $V_D > 0$.
Assuming that $V_D < 0$ then $I \leq 0$ given the IV characteristics of the diode. Given the previous expression of V_D we have $V_D > 0$ which is absurd. The only possibility is $V_D > 0$ and $I > 0$ 0.5

2.b Given $E-(R+R_L)I = V_D$ we have another expression of I as function of V_D :

$$I = \frac{E - V_D}{R + R_L}$$

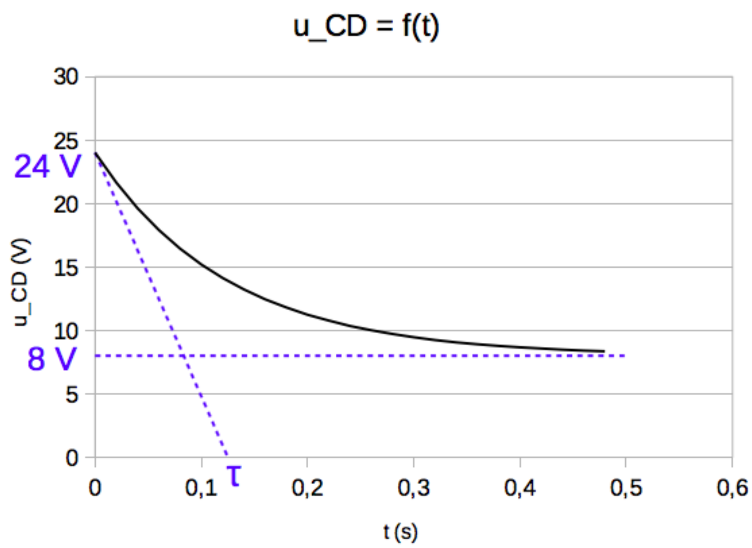
1.0

This provide the equation of a straight line crossing the horizontal axis at $V_D = E =$1.5 V and the vertical axis at $I = \frac{E}{R+R_L}$ =0.05 A 0.5
We can then determine graphically the operating point of the circuit : $V =$0.67 $\pm$ 0.02 V and $I =$27 $\pm$ 2 mA 1.0
Bonus : uncertainites +0.5



Exercise 3 : Circuit in transient regime (9.5 points)

	Notice : signs of the following expression have to be adapted according to the choice of positive orientation.	
1.	In steady state regime : $u_{DB} = L\frac{di_{DB}}{dt} = 0\,\text{V}$, so that $u_{CB} = 0\,\text{V}$	0.5
	$u_{AC} = u_{AD} = E = 24\,\text{V}$	0.5
	$i_{AC} = u_{AC}/R_1 = 2\,\text{A}$ and $i_{AD} = u_{AD}/R_3 = 3\,\text{A}$	0.5
	$i_{CB} = u_{CB}/R_2 = 0\,\text{A}$	0.5
	$i_{CD} = i_{AC} - i_{CB} = 2\,\text{A}$ and $i_{DB} = i_{CD} + i_{AD} = 5\,\text{A}$	0.5
	Total current supplied by E : $i_{BA} = i_{AC} + i_{AD} = 5\,\text{A}$	0.5
2.	Illustration of a possible solution :	
	Once K is open we have $u_{DB} = L\frac{di_{DB}}{dt}$	0.5
	In branch ADB : $L\frac{di_{DB}}{dt} + R_3 i_{DB} = E$	1.0
	Computing the time derivative of the previous equation gives : $L\frac{d^2 i_{DB}}{dt^2} + R_3\frac{di_{DB}}{dt} = 0$ (1)	1.0
	$u_{CB} = \frac{R_2}{R_1+R_2}E$(voltage divider or Kirchhoff circuit's law)	0.5
	And : $u_{CD} = u_{CB} - u_{DB} = \frac{R_2}{R_1+R_2}E - L\frac{di_{DB}}{dt}$ (2)	0.5
	We deduce : $\frac{di_{DB}}{dt} = \frac{R_2}{(R_1+R_2)L}E - \frac{1}{L}u_{CD}$ (3) and $\frac{d^2 i_{DB}}{dt^2} = -\frac{1}{L}\frac{du_{CD}}{dt}$ (4)	
	Combining (1), (3) and (4) we get : $\frac{du_{CD}}{dt} + \frac{R_3}{L}u_{CD} = \frac{R_2 R_3}{(R_1+R_2)L}E$	0.5
3.	From the previous differential equation :	
	$\lim_{t\to+\infty} u_{CD}(t) = \frac{R_2}{R_1+R_2}E = 8\,\text{V}$ (or $\lim_{t\to+\infty} u_{DB}(t) = 0\,\text{V}$ so that $u_{CD} = u_{CB}$)	0.5
4.	Using $\tau = L/R_3$, solution : $u_{CD} = A\exp(-t/\tau) + \frac{R_2}{R_1+R_2}E$	1.0
	Warning ! : At $t = 0^+$ $u_{CD}(0^+) \neq 0\,\text{V}$ but $u_{CD}(0^+) = 24\,\text{V}$	
	Indeed, u_{AC} abruptly changes from $E = 24\,\text{V}$ to $u_{AC}(0^+) = \frac{R_1}{R_1+R_2}E = 16\,\text{V}$	
	The current flowing through the coil is always continuous. At $t = 0^-$ this current is equal to $\frac{E}{R_1} + \frac{E}{R_3}$. At $t = 0+$ this current flows through resistor R_3 so that $u_{AD}(0^+) = \frac{R_1+R_3}{R_1}E = 40\,\text{V}$. Given $u_{CD} = u_{AD} - u_{AC}$ we have : $u_{CD}(0^+) = \left(\frac{R_1+R_3}{R_1} - \frac{R_1}{R_1+R_2}\right)E = \left(\frac{R_1R_3+R_1R_2+R_2R_3}{R_1(R_1+R_2)}\right)E = 24\,\text{V}$	+0.5
	Given this result we find $A = \frac{R_3}{R_1}E = 16\,\text{V}$	0.5
	The plot shall exhibit an exponential decay from 24 V at $t = 0$ to 8 V.	0.5



u_CD = f(t)
u_CD (V)
30
25
24 V
20
15
10
8 V
5
0
0
0,1
τ
0,2
0,3
0,4
0,5
0,6
t (s)