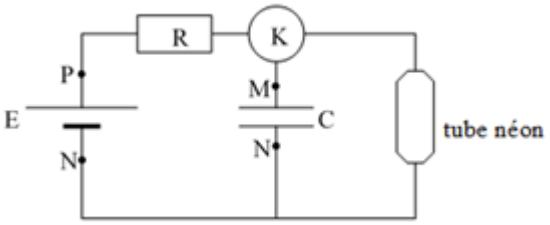
Principle of neon tube using a capacitor

A neon discharging tube is an electric dipole that lights up if the voltage across its terminals is greater than a specific voltage $\mathbf{U_a}$ and puts off when the voltage across its terminals becomes less than a certain voltage $\mathbf{U_e}$ **($U_e<U_a$)** called cut off voltage.

This lamp behaves as an open switch when it is off and as a resistor of resistance **R'** when it is on.

To study the functioning of this dipole we consider the following circuit **(Doc.1) K** is an automatic switch that connects and disconnect the generator at specific time intervals.

1– The tube is turned off . (R = 100 kΩ ; C = 10 µF).



Doc.1

1.1-What is the phenomenon observed across the terminals of the capacitor ?

1.2- Establish the differential equation describing the variations of the voltage $u_C = u_{MN}$ across the terminals of the capacitor.

1.3-The solution of the differential equation is $u_C = A(1 - e^{-\frac{t}{\tau}})$.

1.3.1-Determine the expressions of the constants A and τ.

1.3.2- Name the constant **τ**, give its significance and calculate its value.

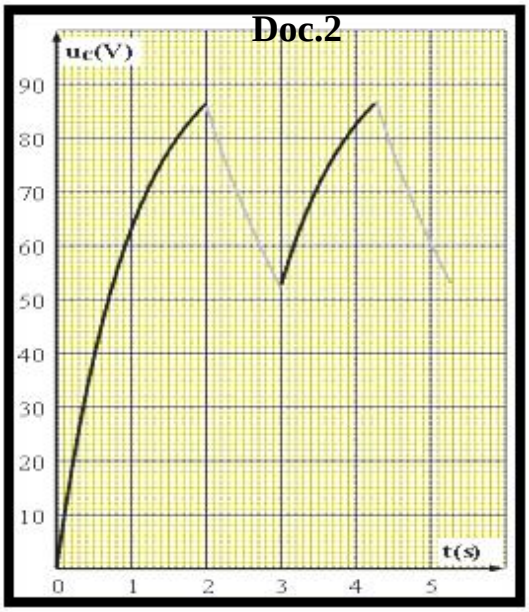
1.4-

1. 4.1- Verify that if the tube is not connected to the circuit, the maximum voltage $\mathbf{u_C}$ can attain is **E**

1.4.2- Indicate the time interval during which the maximum voltage is attained practically

1.4.3-The **document (2)** represents u_C as a function of time during charging and discharging the capacitor. Determine the value of **E** graphically.

Doc.2



2- The tube is turned on

2.1-Determine, graphically the value $\mathbf{U_a}$ at which the tube is on.

2.2-Determine , graphically the voltage $\mathbf{U_e}$

2.3- Deduce the duration of lightening of the tube.

2.4- Calculate the average power received by the tube during this lighting phase.

2.5- Let $u_C = U_a\, e^{-\frac{t}{\tau'}}$ the voltage across the terminals of the capacitor during its discharging starting from the instant **t=0** taken as origin of time .

2.5.1-Calculate the value of **τ'.**

2.5.2-Deduce the value of **R'.**

Part		Principle of neon tube using a capacitor	Score 6.5
1	1.1.	Charging of capacitor	0.25
	1.2	law of addition of voltages $\Rightarrow$ E= u_R+ u_C leads to $\frac{du_C}{dt}+\left(\frac{1}{RC}\right)u_C=\frac{E}{RC}$	0.75
	1.3.1	$\frac{du_C}{dt}=\frac{A}{\tau}e^{-\frac{t}{\tau}}\Rightarrow\frac{A}{\tau}e^{-\frac{t}{\tau}}+\frac{1}{RC}A\left(1-e^{-\frac{t}{\tau}}\right)-\frac{E}{RC}=0$ $Ae^{-\frac{t}{\tau}}\left(\frac{1}{\tau}-\frac{1}{RC}\right)+\frac{1}{RC}(A-E)=0\Rightarrow\begin{cases}\tau=RC\\A=E\end{cases}$	0.75 0.5
	1.3.2	τ : is the time constant of RC circuit . duration of a neutral capacitor during charging for u_C to attain 0.63E τ = 1s	
	1.4.1	if the tube is not connected to the circuit , the steady state attained (i=0 and u_R=0 $\Rightarrow u_{C(max)}$ = E.	0.25
	1.4.2	The state is practically attained after 5τ (t > 5τ)	0.25
	1.4.3.	from (Doc.2) 0.63 E=63 V $\Rightarrow$ E =100V	0.5
2	2.1	(Doc.2) functioning of the tube at t = 2s $\Rightarrow U_a$ = 85V	0.25
	2.2	(Doc.2) cut of voltage at t=3s during its discharge U_e=54V,	0.5
	2.3	The tube lights for Δt = 1s during which the capacitor is discharged in the tube of resistance R’	0.5
	2.4	$E_e=\frac{1}{2}Cu^2$ $p_{av}=\frac{\Delta E_e}{\Delta t}=\frac{C}{2\Delta t}\left[(U_e)^2-(U_a)^2\right]$ P_a =-2.15×10^{-2}J	1
	2.5.1	$U_e=U_a e^{-\frac{1}{R'C}}\Rightarrow\frac{U_e}{U_a}=e^{-\frac{1}{\tau'}}\Rightarrow\frac{1}{\tau'}=\ln\left(\frac{U_a}{U_e}\right)$ $\tau'=\frac{1}{\ln\left(\frac{U_a}{U_e}\right)}=2.2s$	1
	2.5.2	R’= τ’/C =2.2×10^5 Ω	0.5