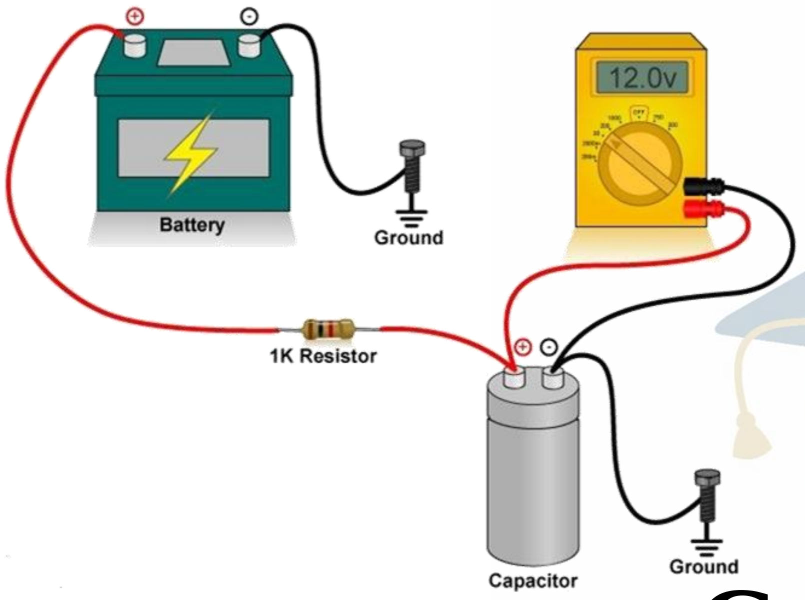

Grade 12 LS – Physics

Chapter 10 -A

Capacitor with a L.F.G of square signal

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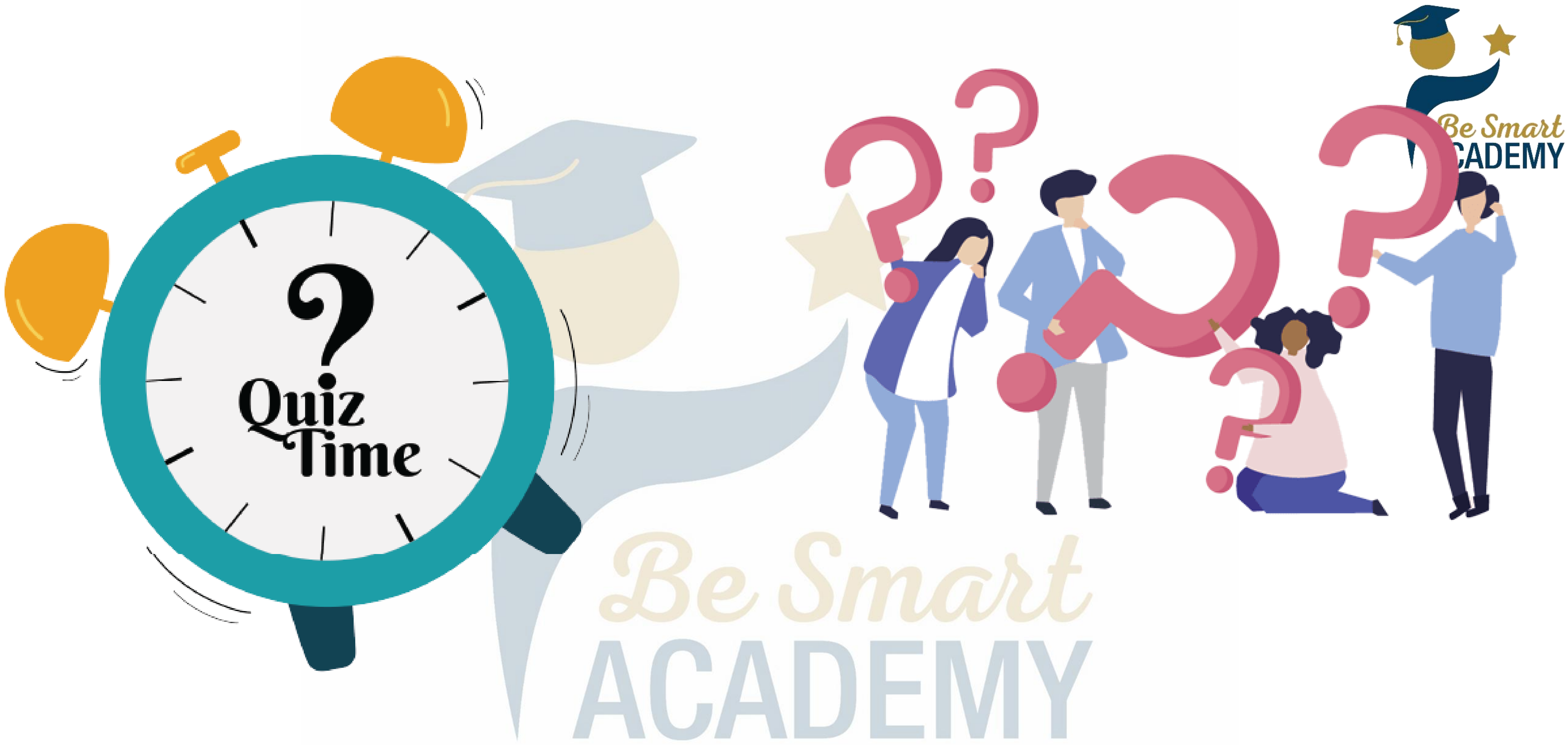
Quiz Time
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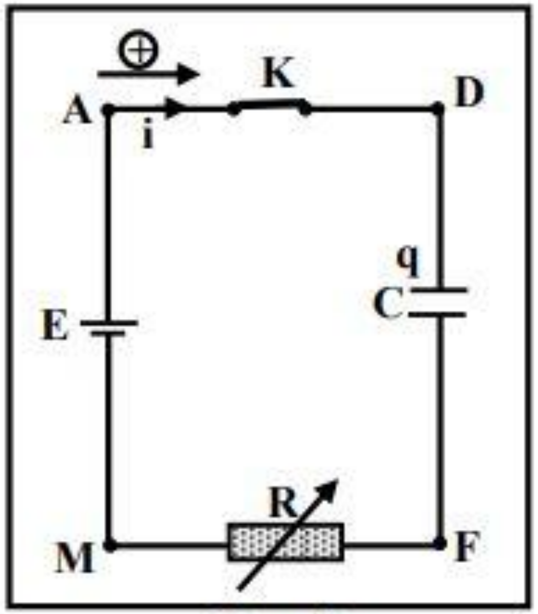
ACADEMY

Quiz **duration: 25 min**

The aim of this exercise is to study the effect of the resistance of a resistor on the charging of a capacitor.

For this aim we set-up the circuit of document 2 that includes:

An ideal generator of voltage $u_{AM} = E$; a capacitor initially uncharged, of capacitance $C = 4\mu F$; a resistor of adjustable resistance R and a switch K.



Doc. 2

At the instant $t_0 = 0$, we close K, and the charging process starts.

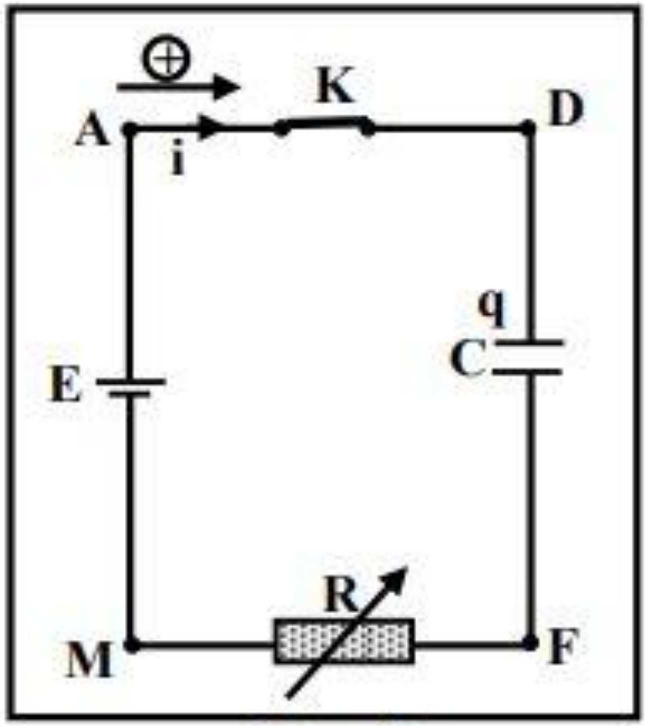
Quiz **duration: 25 min**

Theoretical study:

1. Derive the differential equation that describes the variation of the voltage $u_{DF} = u_c$ during the charging of the capacitor
2. The solution of this differential equation has the form of: $u_C = A + Be^{Dt}$. Determine the constants A, B and D in terms of E, R and C.
3. Verify that the capacitor becomes practically fully charged at $t = 5RC$.
4. Indicate the effect of the resistance of the resistor on the duration of the charging of capacitor.

1.Derive the differential equation that describes the variation of the voltage $u_{DF} = u_c$ during the charging of the capacitor.

Using law of addition of voltages:



Doc. 2

$$u_g = u_C + u_R \quad \Rightarrow \quad \mathrm{E} = u_C + \mathrm{Ri}$$

But $i = \frac{dq}{dt}$ and $q = C.u_C$

$$i = C.\frac{du_C}{dt}$$

$$E = u_C + RC\frac{du_C}{dt}$$

2.The solution of this differential equation is $u_C = A + Be^{Dt}$. Determine the constants A, B and D in terms of E, R and C.

$$u_C = A + Be^{Dt}$$

$$\frac{du_C}{dt} = B.D.e^{Dt}$$

Substitute u_C and $\frac{du_C}{dt}$ in differential equation:

$$\mathrm{E} = u_C + RC\frac{du_C}{dt}$$

$$\mathrm{E} = A + Be^{Dt} + \mathrm{RC.BD.}e^{Dt}$$

$$0 = -E + A + BDe^{Dt} + RC.BD.e^{Dt}$$

$$0 = -E + A + BD.e^{Dt}(1 + RC.D)$$

$$-E + A = 0$$

$$A = E$$

$$0 = -E + A + BD.e^{Dt}(1 + RC.D)$$

$$1 + RC.D = 0$$

$$1 = -RC.D \Rightarrow D = -\frac{1}{RC}$$

$$u_C = A + B.e^{D.t}$$

$$u_C = E + B.e^{-\frac{1}{RC}}$$

At t=0, $u_C = 0$

$$0 = E + B.e^{-\frac{0}{RC}}$$

$$0 = E + B.e^{0}$$

$$0 = E + B \Rightarrow B = -E$$

$$u_C = E - Ee^{-\frac{t}{RC}}$$

3. Verify that the capacitor becomes practically fully charged at $t = 5RC$.

$$u_C = E(1 - e^{-\frac{t}{RC}})$$

$$u_C = E(1 - e^{-\frac{5RC}{RC}})$$

$$u_C = E(1 - e^{-5})$$

$$u_C = E(1 - 00067)$$

$$u_C = 0.99E \cong E$$

For $t = 5RC$

the capacitor becomes practically fully charged

4. Indicate the effect of the resistance of the resistor on the duration of the charging of capacitor.

$\tau = RC$:

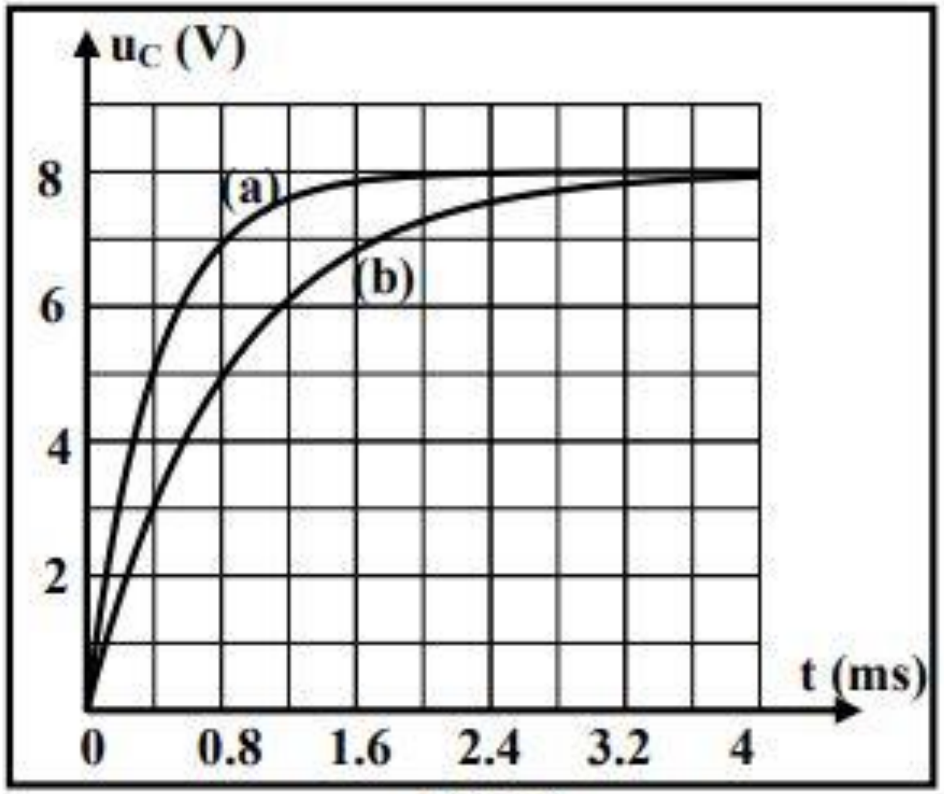
As the resistance increase, the charging time constant (τ) increases, therefore the charging process becomes slower.

Quiz duration: 25 min

Experimental study:

We adjust R to two different values R_1 and R_2; an appropriate device allows to trace, for each value of R, the voltage u_C as a function of time (Doc.3):

curve (a) corresponds to $R = R_1$ and curve (b) corresponds to $R = R_2$.



Doc. 3

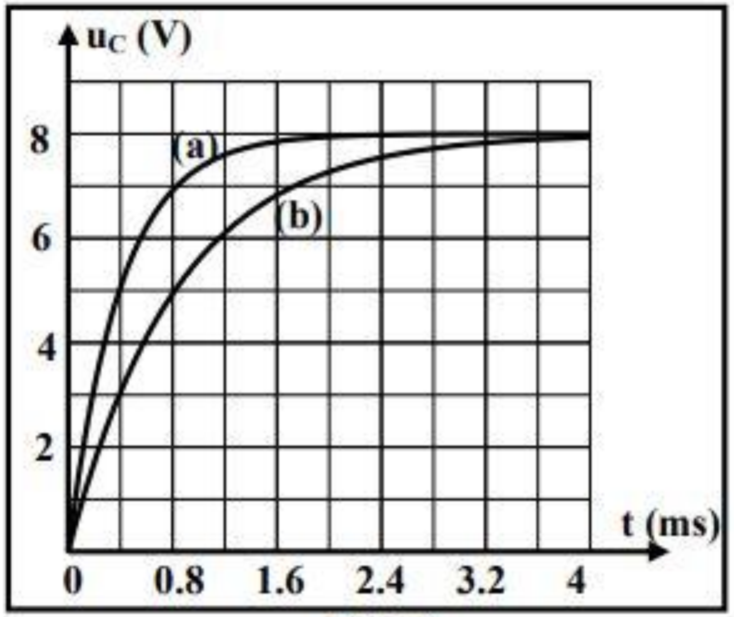
Quiz duration: 25 min

1. Using the curves of document 3:

a. Specify the value of E.

b. Specify, without calculation, whether that R_2 is equal, greater, or less than the value of R_1.

c. Determine the values of R_1 and R_2.



Doc. 3

2. The capacitor is fully charged, the electric energy stored in the capacitor is W_C.

a. Is the value of W_C affected by the resistance of the resistor? Justify.

b. Deduce the value of W_C.

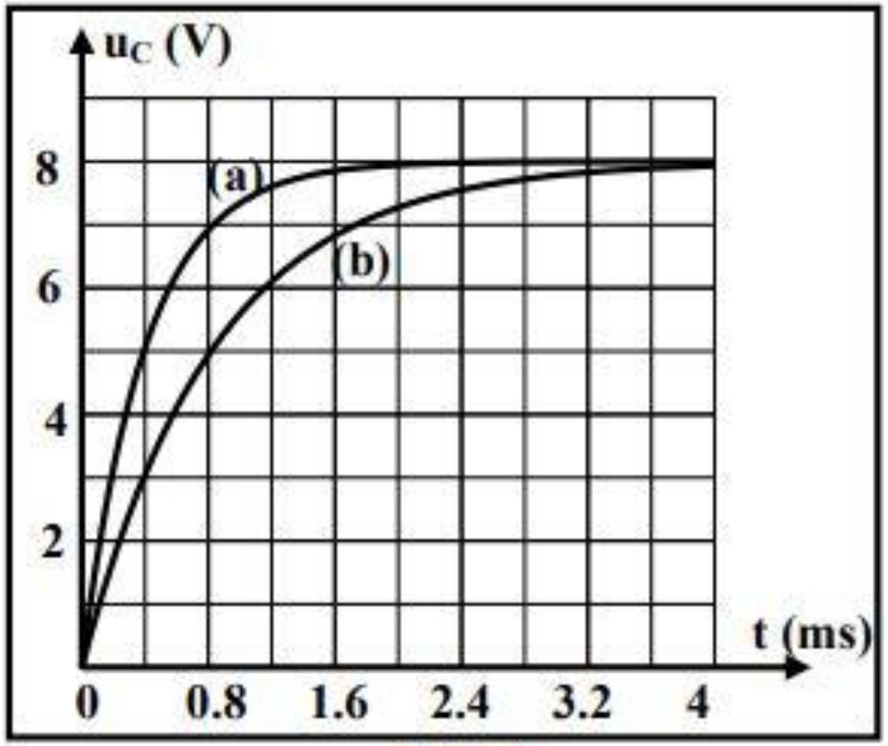
1.Using the curves of document 3:

a.Specify the value of E.

When the steady state is attained, the capacitor becomes fully charged.

Graphically, the steady state is attained at 8 V.

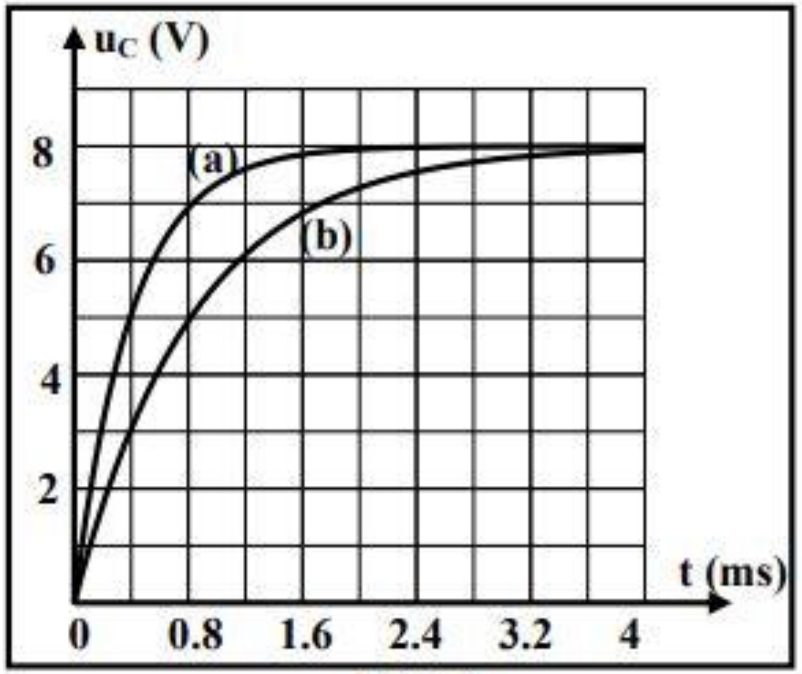
Therefore E = 8 V.



Doc. 3

b.Specify, without calculation, whether that R_2 is equal, greater, or less than the value of R_1.

- At any instant $u_{C(a)}$ attains max or the capacitor is completely charged at $t = 2s$.
- At any instant $u_{C(b)}$ attains max or the capacitor is completely charged at $t = 3.36s$.



Doc. 3

So, the charging process in curve (b) is slower, then $R_2 > R_1$.

c.Determine the values of R_1 and R_2.

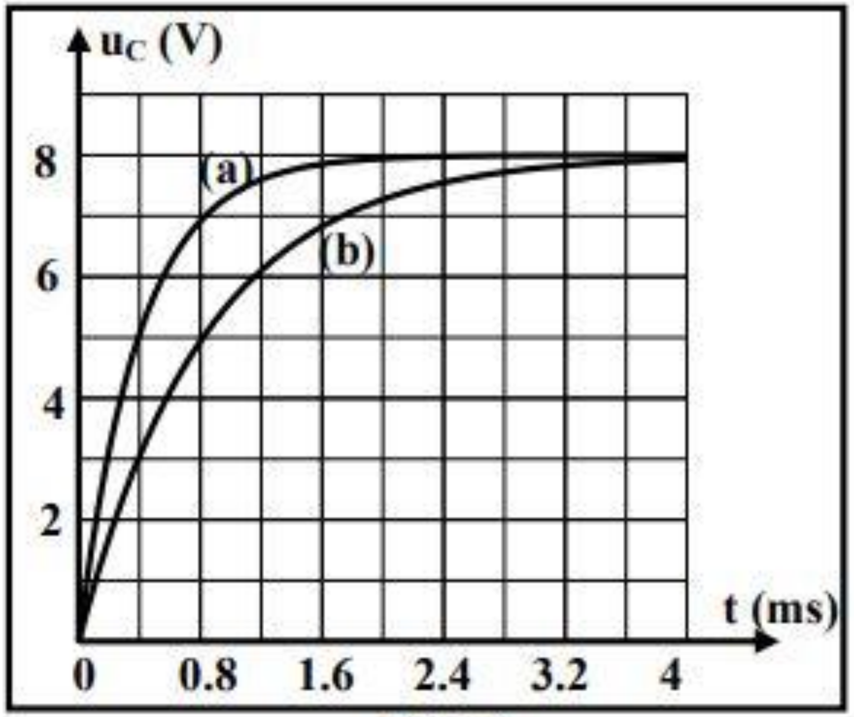
At t $= \tau_1 = R_1C$

$$u_{C(a)} = 0.63E = 0.63 \times 8 = 5V$$

Then $\tau_1 = 0.4ms$

$\tau_1 = R_1C$ ⇨ $R_1 = \frac{\tau_1}{C}$

$R_1 = \frac{0.4 \times 10^{-3}}{4 \times 10^{-6}}$ ⇨ $R_1 = 100\Omega$

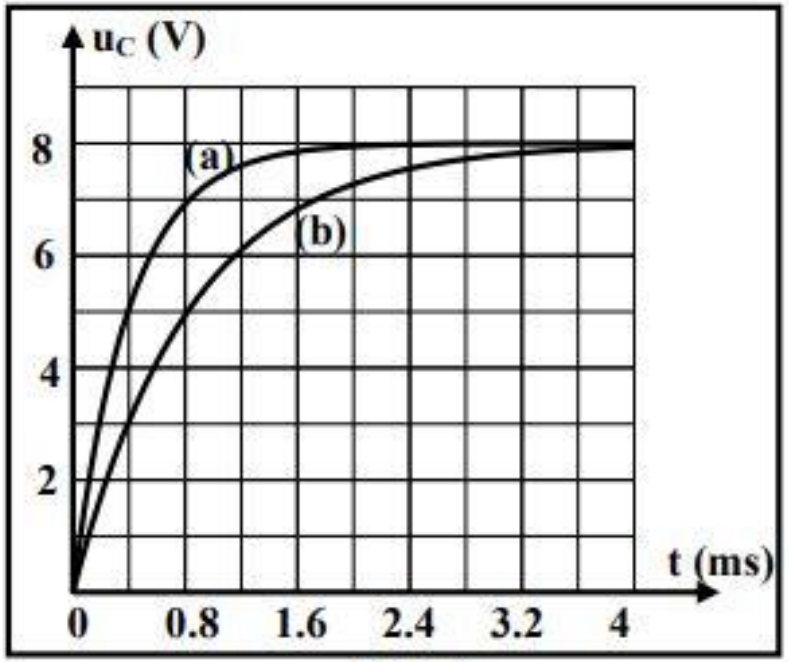


Doc. 3

$$\text{At } t = \tau_2 = R_2 C$$

$$u_{C(b)} = 0.63E = 0.63 \times 8 = 5V$$

$$\text{Then } \tau_2 = 0.8ms$$



Doc. 3

$$\tau_2 = R_2 C \quad \Rightarrow \quad R_2 = \frac{\tau_2}{C}$$

$$R_2 = \frac{0.8 \times 10^{-3}}{4 \times 10^{-6}} \quad \Rightarrow \quad R_1 = 200\Omega$$

2.The capacitor is fully charged, the electric energy stored in the capacitor is W_C.

a.Is the value of W_C affected by the resistance of the resistor? Justify.

$$W_C = \frac{1}{2} C.u_C^2$$

At the end of charging $u_C = E$

$$W_C = = \frac{1}{2} C.E^2$$

Then the energy stored depends only on C and E.

Therefore, its value of is not affected by the value the resistance.

b.Deduce the value of W_C.

$$W_C = \frac{1}{2} C.E^2$$

$$W_C = 0.5 \times 4 \times 10^{-6} \times (8)^2$$

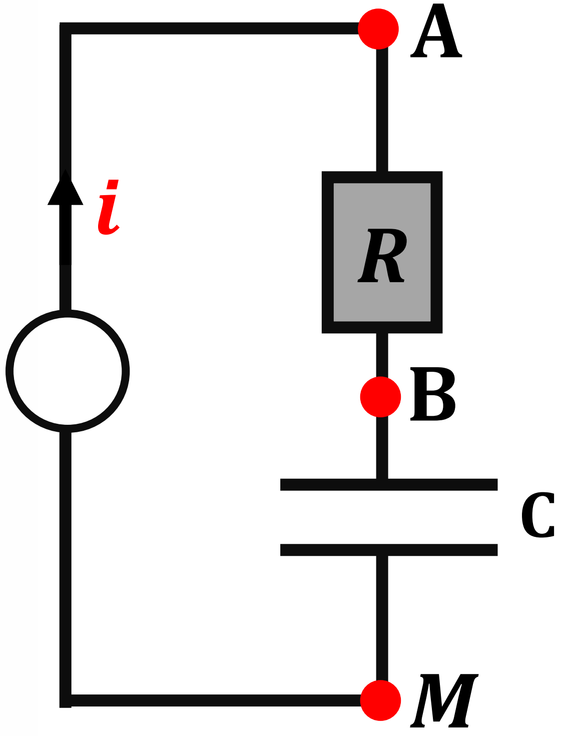
$$W_C = 1.28 \times 10^{-4} J$$


Quiz
Time

Quiz 2 **duration: 15 min**

A (LFG) delivers a voltage (0, +E) of variable frequency f.

It feeds a circuit containing, in series, a resistor of resistance $R = 10K\Omega$ and a capacitor of capacitance $C = 100nF$ as shown in the figure.



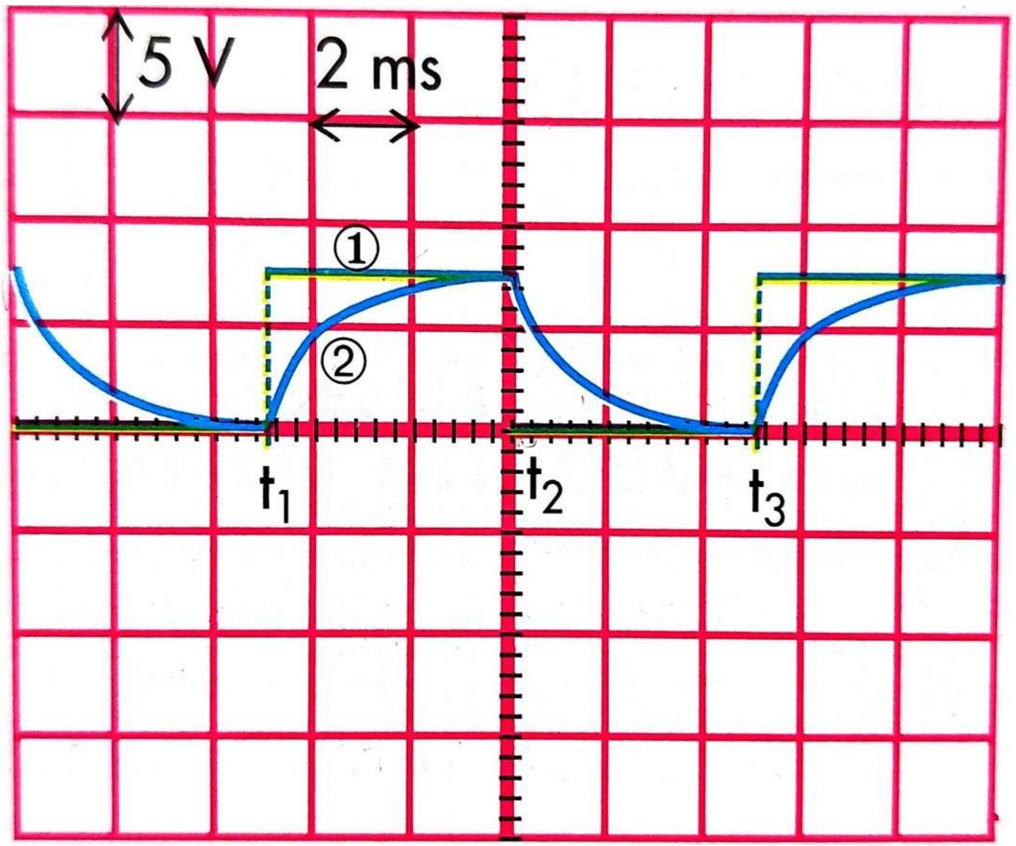
The oscilloscope, conveniently connected, allows us to display the voltage u_{AM} across the generator on channel (Y_1) and the voltage u_{BM} across the resistor the capacitor on channel (Y_1).

1) Showing the connections to the oscilloscope.

2) The waveform on the screen of the oscilloscope is represented by the adjacent figure. Identify the curve corresponding to voltage.

3) Determine the value of E.

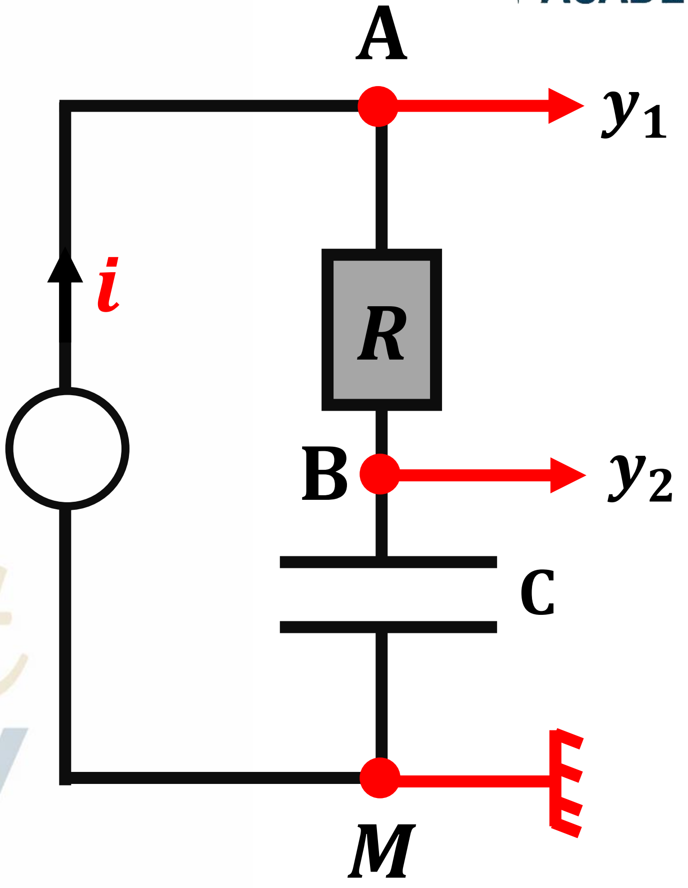
4) Calculate f.



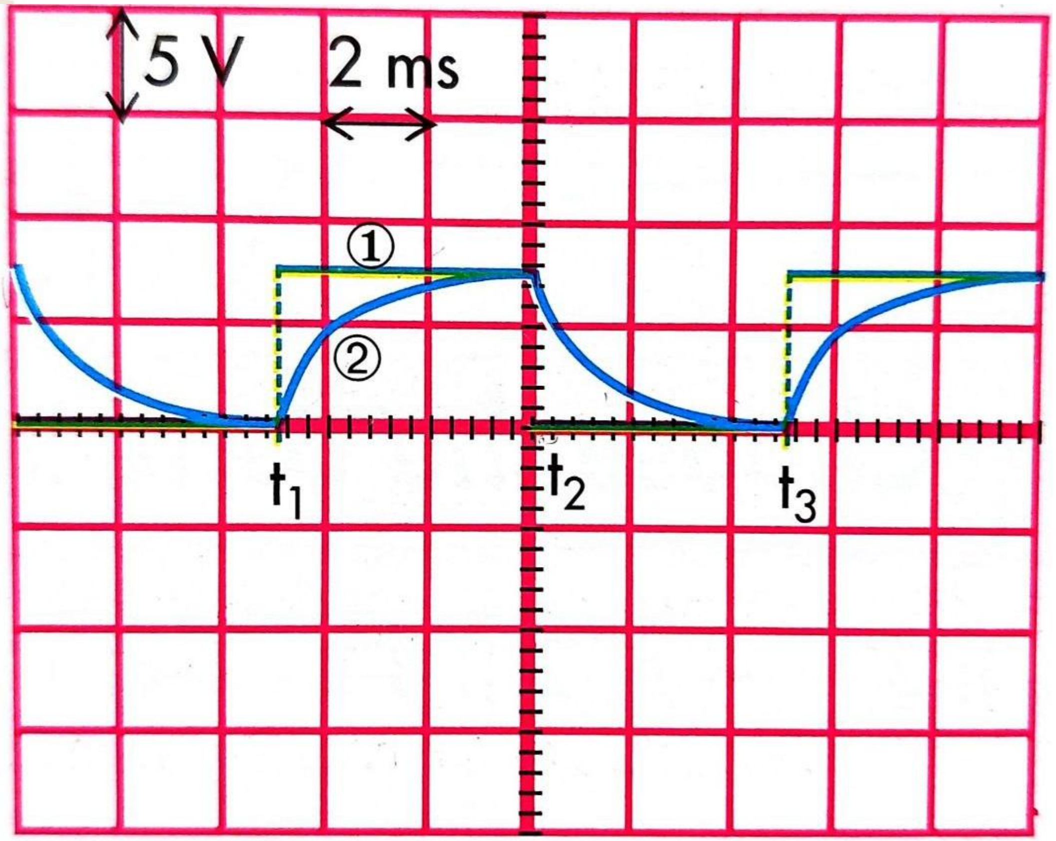
1) Showing the connections to the oscilloscope.

u_{AM} **displayed on channel (Y_1)**

u_{BM} **displayed on channel (Y_2).**



2) The waveform on the screen of the oscilloscope is represented by the adjacent figure. Identify the curve corresponding to voltage.



The channel (Y_1) displays the voltage across the generator.

This voltage being (0; +E) then:

Curve 1 is for LGF

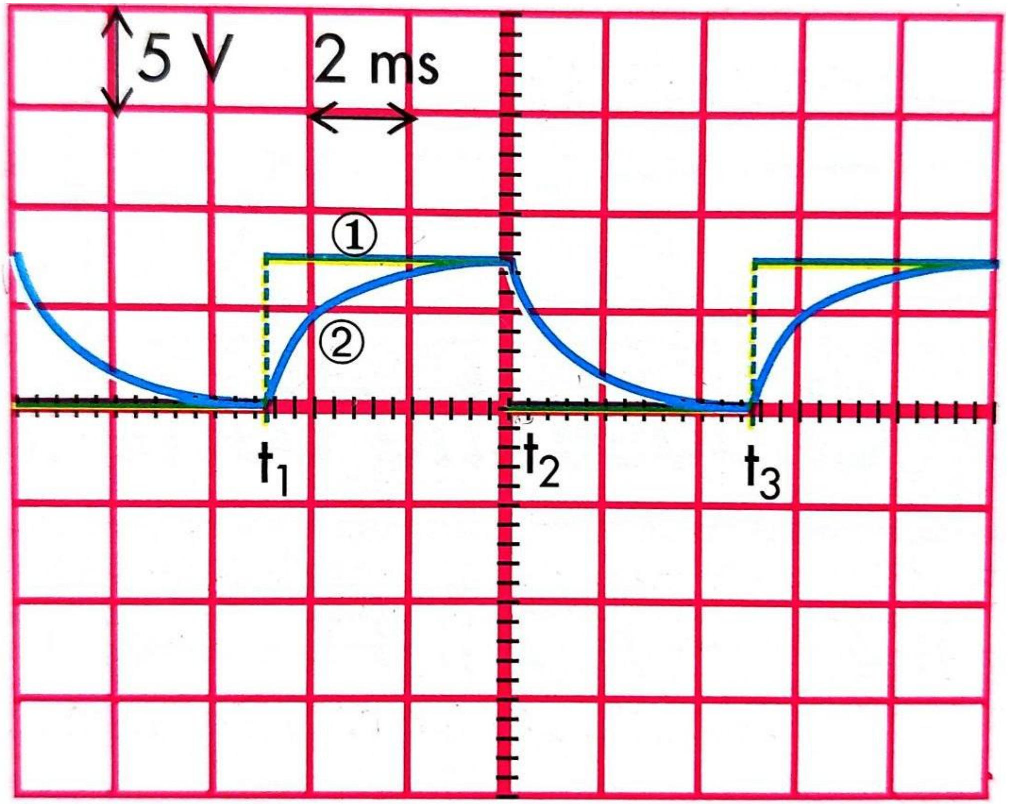
Curve 2 refers to capacitor

3) Determine the value of E.

$$u_{Cmax} = E = S_V \times y$$

$$u_{Cmax} = E = 5 \times 1.5$$

$$u_{Cmax} = E = 7.5V$$



4) Calculate f.

The period of the voltage delivered by the generator is

$$T = S_h \times x$$

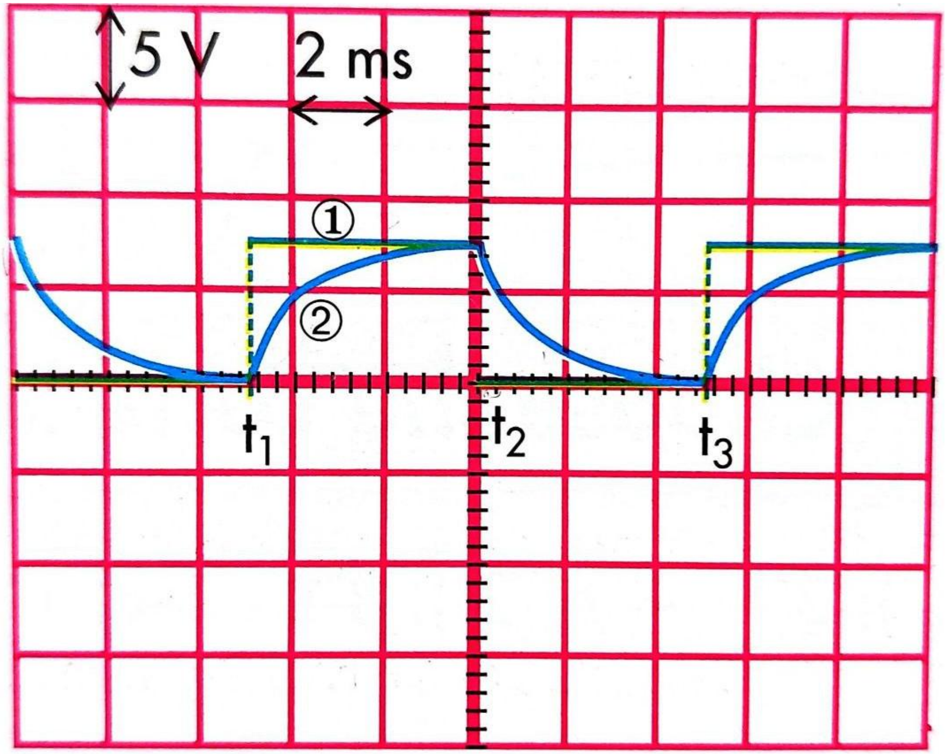
$$T = 2ms \times 5div = 10ms$$

$$f = \frac{1}{T} = \frac{1}{(10 \div 1000)} = 0.01Hz$$

5) We are studying the waveform in the interval [0, t_1].

a) Name the physical phenomenon that occurs in the circuit.

The voltage across the terminals of the capacitor decreases, then: Discharging of capacitor takes place.



b) What happens in the circuit during the interval [t_1; t_2]

The voltage across the terminals of the capacitor decreases, then: charging of capacitor takes place.

$$R = 10K\Omega; C = 100nF$$

6) Calculate the time constant the compare it with T.

$$\tau = RC$$

$$\tau = 10000 \times (100 \times 10^{-9})$$

$$\tau = 0.001s = 1ms$$

$$T = 10ms \qquad \tau = 1ms$$

$$T \gg \tau$$

The End