RC circuits Physlet Activity

If you are not already there, go to the URL
http://cs.clark.edu/~mac/physlets/RCandRLcircuits/RCtimeC1.htm
The screen below should appear.

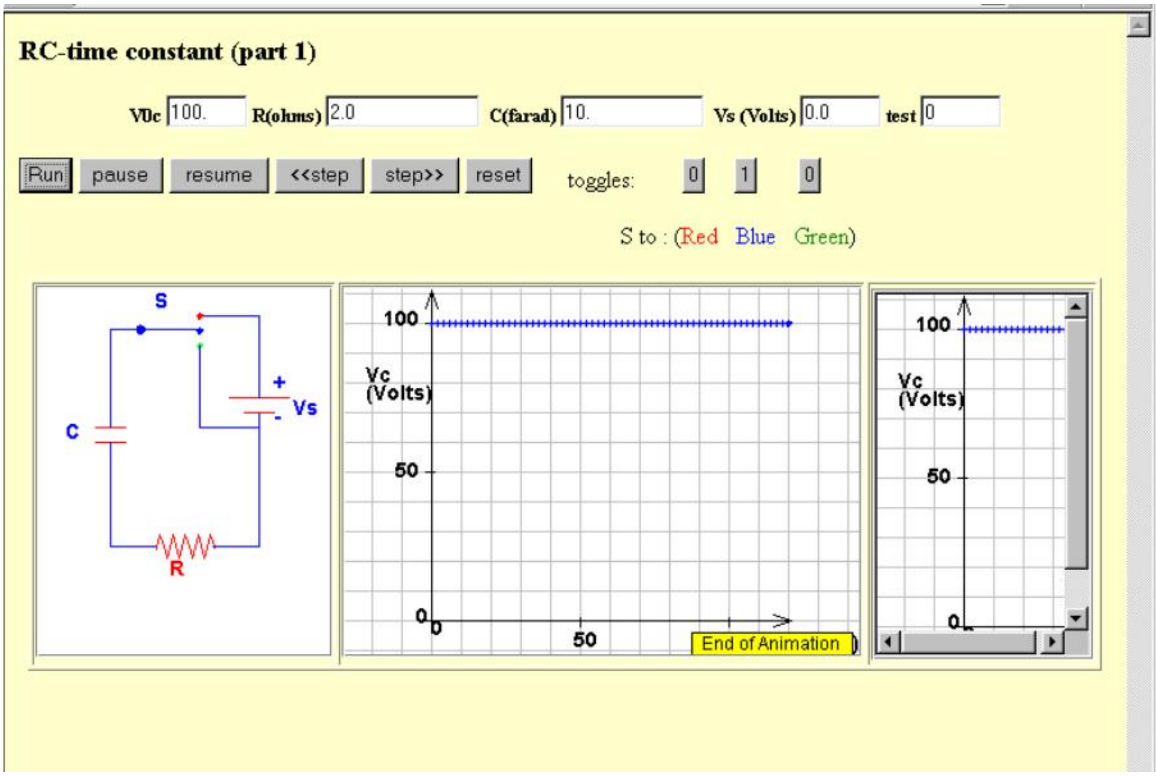


Figure 1. Working environment of capacitor physlet.

Background: The toggle buttons let you change the switch position to either: discharge the capacitor without the battery (green) ; charge the capacitor with the battery (red); or do nothing (blue). The graph is a graph of the voltage across the capacitor as a function of time. The graph in the Figure 1 above shows what happens to the capacitor's voltage (after clicking on Run) if the switch is left on the middle toggle) i.e. nothing changes. The initial voltage across the cap V0c, the resistance R, the value of capacitance C, and the battery (source) voltage Vs can all be changed by you. After you are done with all of the activities below go to http://cs.clark.edu/~mac/quizes/q2form.htm and complete the quiz to test your understanding.

Activity 1. ***The discharge of a capacitor and the time constant.***

Using: V0c=100 volts R=2.0 ohms C=10.0 Farads Vs=0.0 toggle the switch to green (bottom terminal) and Run the simulation.

- What is the initial charge, Qo, on the capacitor? (remember Q=CV)
- Does the capacitor's voltage **increase or decrease** during this simulation?
- For this switch position the capacitor voltage is the total voltage pushing current through the resistor. With this in mind, what is the initial current (at time t=0.0) flowing through R? (remember V=IR)
- How much charge leaves the capacitor in the first 0.10 sec? ($\Delta Q = I \Delta t$)
- What is the current flowing through R when the capacitor's voltage is 50 Volts?
- After a very long time what will be the current flowing through R?

The time constant is defined to be the time it takes the capacitor to discharge to 1/e (0.368) of its initial value when it discharges through a resistor (no battery). In this case, since the capacitor's initial voltage is 100 Volts, the time constant is the time it takes the capacitor to discharge to 36.8 Volts. Euler's number, e=2.718, is sometimes referred to as the natural number since it is so important in describing many natural processes.

- What is the time constant for this simulation as measured from your graph or data table?
- What is the product of R & C?
- How does this product compare to the time constant estimated from your graph?

Activity 2. ***Discharging with larger R.***

Using: V0c=100 volts R=4.0 ohms C=10.0 Farads Vs=0.0 toggle the switch to green (bottom terminal) and Run the simulation.

- What is the initial charge, Qo, on the capacitor?
- What is the initial current (at time t=0.0) flowing through R?
- How much charge leaves the capacitor in the first 0.10 sec? (($\Delta Q = I \Delta t$)
- Does the initial current represent a faster, slower, or same discharge rate relative to the simulation in activity 1 above?
- What is the time constant for this simulation?
- How does this compare to the time constant for activity 1?

Activity 3 .

Using: V0c=100 volts R=8.0 ohms C=5.0 Farads Vs=0.0 toggle the switch to green (bottom terminal) and Run the simulation.

- What is the initial charge, Qo, on the capacitor?
- What is the initial current (at time t=0.0) flowing through R?
- How much charge leaves the capacitor in the first 0.10 sec? (($\Delta Q=I\ \Delta t$)
- Does the initial current represent a faster, slower, or same discharge rate relative to the simulation in activity 2 above?
- What is the time constant for this simulation?
- How does this compare to the time constant for activity 2?

QI. Which equation below best describes the capacitor's voltage as a function of time when it discharges through a resistor R as in Activities 1 through 3? Most calculators have an ex button. For example if RC=20.0s then at t=20.0s e(-t/RC) = 0.368.

a. $V_c=100-100e^{(-t/RC)}$

b. $V_c=100e^{(-t/RC)}$

c. $V_c=100e^{(-t/RC)} - 100$

d. $V_c=100e^{(t/RC)}$

QII. For the parameters of Activity 1 (i.e. R=2 Ω and V0c=100 V), which equation below best describes the total current flowing through R in Amps as the capacitor discahrges?

a. $I=50-50e^{(-t/RC)}$

b. $I =50e^{(-t/RC)}$

c. $I=50e^{(-t/RC)} - 50$

d. $I =50e^{(t/RC)}$

Q III. For the parameters of Activity 1, which equation below best describes the capacitor's charge as a function of time?

a. $Q=1000-1000e^{(-t/RC)}$

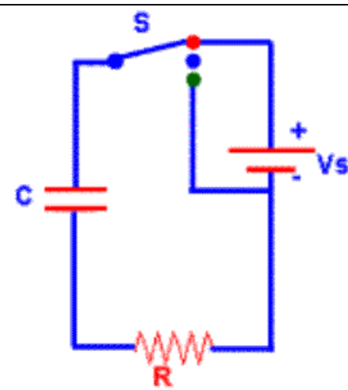
b. $Q=1000e^{(-t/RC)}$

c. $Q=1000e^{(-t/RC)} - 1000$

d. $Q=1000e^{(t/RC)}$

Activity 4. ***Charging a Capacitor***

Using: V0c=0.0 R=2.0 C=10.0 Farads Vs=100.0 Volts toggle the switch to the up position (red terminal) and then Run the simulation. In this case the total voltage driving current through the resistor is Vs-Vc. The total voltage starts at 100.0 V when the capacitor has no charge and then drops to zero as the capacitor charges up.



- Does the capacitor's voltage increase or decrease during this simulation?
- What will be the final voltage on the capacitor (after a very long time)?
- The total voltage pushing current through the resistor is Vs-Vc. At a time t=0.0 what is the current
- flowing through R?
- When Vc=80 Volts what is the current flowing through R?
- Does the current flowing through R increase or decrease during this simulation?
-

Q IV. Which equation below best describes the capacitors voltage (in volts) as a function of time?

a. $Vc=100-100e^{(-t/RC)}$

b. $Vc=100e^{(-t/RC)}$

c. $Vc=100e^{(-t/RC)} - 100$

d. $Vc=100e^{(t/RC)}$

Q V. Which equation below best describes the total voltage (in volts)

a. $V_T=100-100e^{(-t/RC)}$

b. $V_T =100e^{(-t/RC)}$

c. $V_T =100e^{(-t/RC)} - 100$

d. $V_T =100e^{(t/RC)}$

QVI. Which equation below best describes the total current flowing through R in Amps.

a. $I=50-50e^{(-t/RC)}$

b. $I =50e^{(-t/RC)}$

c. $I=50e^{(-t/RC)} - 50$

d. $I =50e^{(t/RC)}$

The equation for the voltage of the capacitor as a function of time is $Vc=100-100e^{(-t/RC)}$. To find the time required for the capacitor to reach a certain voltage Vc you can use the natural log (ln) and a little algebra. The natural log is the function that undoes the exponent . That is $\ln(e^{x})=x$.

- Find the time it takes the capacitor to reach a voltage Vc of 80 volts (show all steps).

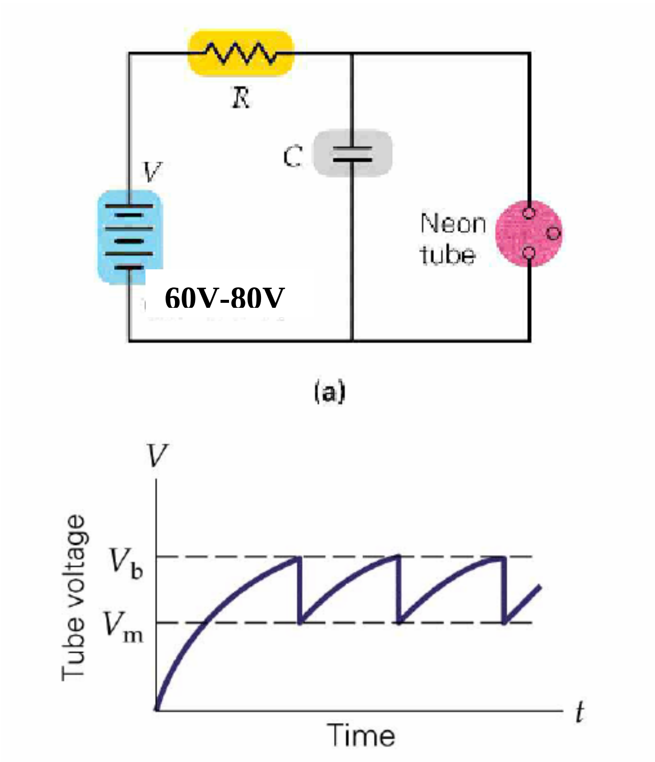
Hint: Starting with Vc=100-100e(-t/RC) after a few steps you should have 0.20 = e(-t/RC) and from here you can take the natural log (ln) of both sides of this equation to get 1.61= t/RC Remember that RC=20.0 sec. From this it's a few small steps to t=32.2 sec.

- Find the time it takes the capacitor to reach a voltage Vc of 90 volts (show all steps).
- Find the time it takes the capacitor to reach a voltage Vc of 63.2 volts (show all steps).

Write an equation for the time it takes the capacitor to reach a voltage Vc for any R,C and VS.

Activity 5. *Blinking Neon light* .

The circuit below shows a simple set-up to get a blinking light.



Assume that the capacitor charges up from the battery through the resistor from zero volts. When Vc reaches 80 volts (the breakdown voltage Vb of the neon bulb) the neon light discharges very rapidly (essentially zero resistance) and then stops discharging when it gets to a voltage of 60 volts (the voltage needed to maintain discharge through the neon bulb Vm). The time between flashes (flash period) is essentially the time required to charge from 60 to 80 volts. To calculate the flash period, subtract the 60V charge time from the 80 V charge time.

- Find the flash period assuming that the battery voltage is 100 V, R=2.0 ,C=10.0 F, Vb=80 V, and

Vm=60 V. Hint:You've already calculated the 80 V flash time.

After you are done with all of the above activities, go to

http://cs.clark.edu/~mac/quizes/q2form.htm and complete the quiz to test your

understanding. Print the finished quiz page out and turn it in with the rest of this activity.