Capacitors

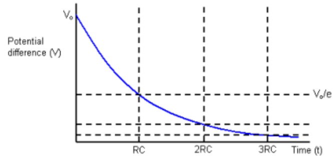
Definitions

Charging and discharging

Capacitors can charge up (gain charge) and discharge (lose charge). This **charging and discharging** is non-linear.

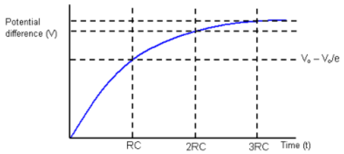
Discharging a capacitor

τ is the **time constant** for the circuit when V drops to 37% of V_o. The bigger the value of RC the slower the rate at which the capacitor discharges.

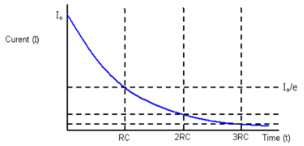


Charging a capacitor

τ is the **time constant** for the the circuit when V reaches 63% of V_o.



For both charging and discharging, the current looks like this:



In all cases one time constant is 63% change

Equations

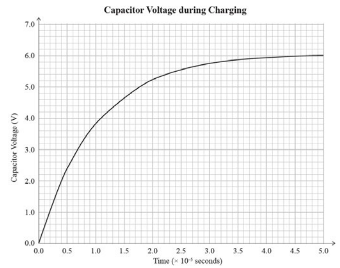
$E=\frac{1}{2}QV$	Energy	E	J
	Charge	Q	C
	Voltage	V	V
$\tau = RC$	Time constant	τ	s
	Resistance	R	Ω
	Capacitance	C	F
$Q=CV$	Charge	Q	C
	Capacitance	C	F
	Voltage	V	V

Questions

QUESTION ONE (2018;1)

Casey sets up a battery, a switch, and a 3.00 Ω light bulb in series.

The battery voltage is measured to be 6.02 V and the internal resistance of the battery is approximately 0.09 Ω. Casey now adds a capacitor in series with the battery and closes the switch. Casey measures the voltage across the capacitor as it charges.



(c) Using information from the graph, determine the capacitance of the capacitor.

(d) Casey discharges the capacitor, removes the light bulb, and begins to charge the capacitor again. Casey predicts that, by removing the light bulb, less energy will be converted to light and heat, and so the capacitor will charge more quickly, and have more stored energy once fully charged. Use physical reasoning to discuss each aspect of Casey's prediction. You should discuss, with explanations:
- whether the capacitor will charge more quickly than before
- whether less energy will be converted to light and heat during the charging process without the light bulb
- whether more energy will be stored in the fully charged capacitor.

Terms

Tips

- A capacitor is regarded to be fully charged/discharged after 5 x τ.

Answers

(c) Voltage after 1 τ= 0.63 x V_{max} = 0.63 x 6.02 V = 3.79 V
From graph: (time, 3.79 V) τ = 1.0 x 10^{-5}s
τ = *R* x *C so* 1.0 x 10^{-5} s = 3.09 Ω x *C so C* = 3.24 x 10^{-6} F

(d) The capacitor will charge more quickly because the circuit has less resistance and τ = *RC*, so current is higher, delivering charge to the plates more quickly. (No energy would have been converted to light, but) more energy would be converted to heat passing through the (internal) resistance of the battery and coil since current is now higher. So the same amount of energy will be converted in the charging process (it just happens faster). The fully charged capacitor will store the same amount of energy as before. Energy stored is $E = ½ CV^2$ or *E* = ½*QV* and none of these values have changed.