Biothermal physics

Ninth lecture

Bioelectricity

Part II

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Third Stage

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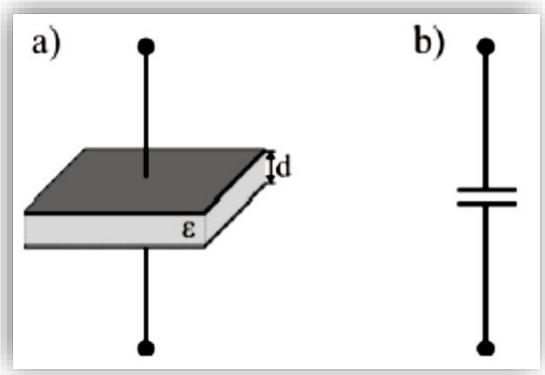
- ***Dielectrics*** (i.e. electrical insulators) are materials that are not able to conduct charge.
- ***A capacitance*** is a circuit element able to store, and to release, electric charge.
- It is created by the combination of ***conductors*** and ***dielectrics***. It consists of two conductive plates separated by a dielectric material.
- The amount of charge (Q) that to store is determined by its ***dimensions*** and by a ***fundamental parameter of the dielectric***:
- ***The permittivity*** (ε, units: C/V.m). Charge stored in the capacitance, at any time, is:

$$Q = C\,V$$

- where C is the capacitance value (units: farads, F), the value of the capacitance is:

$$C = \varepsilon \frac{A}{d} = \varepsilon_r \varepsilon_0 \frac{A}{d}$$



- Capacitance. a) simple implementation based on two conductive plates and a dielectric. b) Electrical symbol for a capacitance.
- where ε_0 is the permittivity of vacuum (= 8.9 $\times 10^{-12}$ C/V.m), ε_r is the relative permittivity of the material ($\varepsilon_r = \varepsilon / \varepsilon_0$), A is the area of the plates and d is the distance between the plates.

✓ ***Displacement currents***

$$\frac{dQ}{dt} = C\frac{dV}{dt}$$

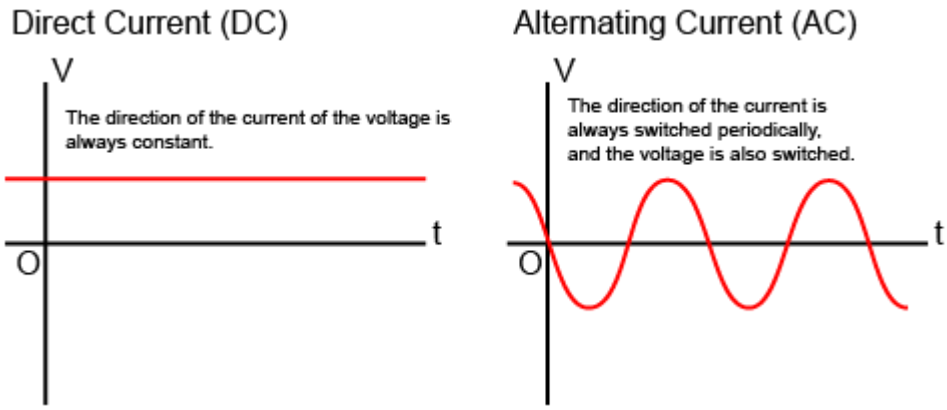
$$\Downarrow$$

$$I = C\frac{dV}{dt}$$

- ✓ the time derivative of the stored or released charge **(I=dQ/dt)** depends on the time derivative of the voltage, a capacitance acts as a conducting element for fast changing currents.
- ✓ Actual charges do not flow through the capacitance but current appears to do so (i.e. ***displacement currents***).
- ✓ ***Alternating currents (AC)***, which are currents whose direction reverses cyclically with a specific frequency.
- ✓ For an alternating signal (voltage or current), it can be said that a capacitance behaves similarly to a resistance with a value that depends on the frequency of the signal. The "resistance" of a capacitance (actually its ***impedance magnitude***

$$"R_{CAPACITANCE}" = |\mathbf{Z}_C| = \frac{1}{2\pi fC}$$

- ✓ where C is the capacitance value, f is the frequency of the alternating signal and π is the mathematical constant.
- ✓ Note that for ***high frequencies*** a capacitance will act as a ***short circuit*** whereas for ***low frequencies*** it will act as an ***open circuit***.
- ✓ capacitances are accompanied by resistances in ***series.***
- ✓ Both AC and DC describe types of current flow in a circuit.
- ✓ ***Direct Current (DC)***, the electric charge (current) only flows in one direction.
- ✓ ***Alternating Current (AC)***, electric charge changes direction periodically.



Types of electric circuit

- ✓ Series Circuit.
- ✓ Parallel Circuit.
- ✓ Series-Parallel Circuits.
- ✓ Open circuit
- ✓ Closed-circuit
- ✓ Short circuit
- ✓ D. C. Circuit
- ✓ A. C. Circuit

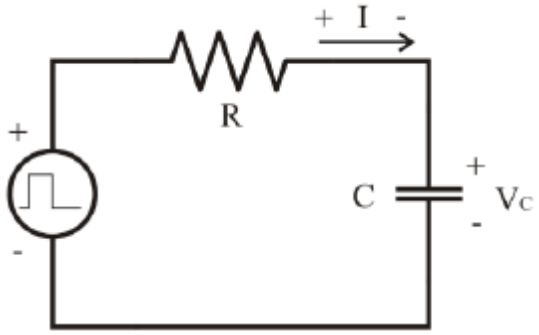


Figure shows what happens when a voltage pulse is applied to a circuit that consists of a resistance in series with a capacitance (*RC circuit*).