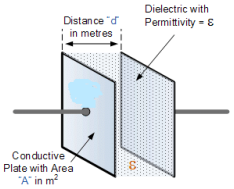
Capacitance

Definitions

Capacitors

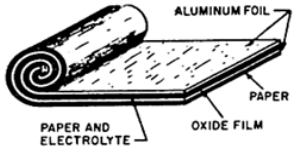


A **capacitor** in a DC circuit stores charge – charge gathers on one plate and is repelled from the other plate – charges never move between the plates inside a capacitor. The charges that build up on the capacitors plate form an electric field that can be used to store energy.

Most capacitors have a very small value because the value of absolute permittivity ε_o is a very small number. Capacitance is often measured in:

Microfarads, µF	$= 10^{-6}$ F
Nanofarads, nF	$= 10^{-9}$ F
Picofarads, pF	$= 10^{-12}$ F

To make a capacitor physically smaller, most capacitors are rolled up.



Equations

$V = Ed$	Voltage	V	V
	Electric Field Strength	E	V m^{-1}
	Distance	d	m
$\Delta E = Vq$	Change in Energy	ΔE	J
	Voltage	V	V
	Charge	q	C
$E = \frac{1}{2}QV$	Energy	E	J
	Charge	Q	C
	Voltage	V	V
$Q = CV$	Charge	Q	C
	Capacitance	C	F
	Voltage	V	V
$C = \frac{\varepsilon_o \varepsilon_r A}{d}$	Capacitance	C	F
	Absolute permittivity	ε_o	F m^{-1}
	Relative permittivity	ε_r	-
	Distance between plates	d	m
$C_T = C_1 + C_2 + \ldots$	Capacitance	C	F
$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$	Capacitance	C	F

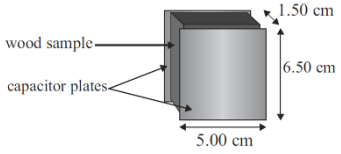
Questions

QUESTION THREE (2018;3)

To make a capacitor, Casey places a thin layer of rubber between two 1.20 m^2 aluminum plates, and then squeezes the sheets together. The rubber has a dielectric constant of 8.90 and is compressed to a thickness of 1.00 × 10^{-4} m.

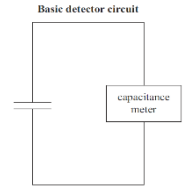
(a) Show that the capacitance of Casey's capacitor is 9.45 × 10^{-7} F.

MOISTURE METER (2010;2)



area of the plates = 3.25 × 10^{-3} m^2

The moisture content of wood can be tested by measuring capacitance. A simple moisture meter is based on two parallel metal plates. The test sample fits between the plates. The relative permittivity of wood decreases when wood is dried. By measuring the capacitance of this capacitor, the moisture content of the wood can be determined.



(b) Explain how the capacitance will change as the wood dries.

(c) The plates are connected to a capacitance meter. This measures 4.99 × 10^{-11} F. Calculate the relative permittivity, ε_r, of the wood.

Terms

Capacitance, C, is the ability of a capacitor to store energy as an electric field.

Absolute permittivity is a measure of the resistance of a vacuum to the development of an electric field. $\varepsilon_o = 8.854 \times 10^{-12}$ F m^{-1}

Relative permittivity, also known as a dielectric's permittivity, ε_r is defined as the ratio of the dielectric's absolute permittivity to the electric constant.

The permittivity of a material has a characteristic that quantifies the resistance it provides to the development of an electric field. $\varepsilon = \varepsilon_o \times \varepsilon_r$

Tips

- Capacitors are insulators so the total capacitance for capacitor combinations is calculated using the **opposite method** to resistors (which are conductors)
- A capacitor in a D.C. circuit is only 50% efficient so they don't tend to be used as batteries (Energy supplied, E = QV; E stored, E = ½QV)
- The dielectric constant (AKA relative permittivity) changes the capacitance. ε_e is about 1 for air, 2 for petrol and 81 for pure water.

Answers

(a) $$C = \frac{8.85 \times 10^{-12}\ \text{F} \times 0.687\ \text{m}^2}{0.0519\ \text{m}} = 1.17 \times 10^{-10}\ \text{F}$$

(b) Capacitance decreases because the relative permittivity has decreased and $C = \frac{\varepsilon_r \varepsilon_0 A}{d}$

(c) $$C = \frac{\varepsilon_r \varepsilon_0 A}{d}$$

$$\varepsilon_r = \frac{Cd}{\varepsilon_0 A}$$

$$\varepsilon_r = \frac{4.99 \times 10^{-11} \times 0.0150}{8.85 \times 10^{-12} \times 0.0500 \times 0.650}$$

$$\varepsilon_r = 26.0$$