Chapter 24  Capacitance

- **Capacitor** is a device that stores electrostatic potential energy.
- A capacitor consists of 2 spatially separated conductors which can be charged to \( +Q \) and \( -Q \).
- The **capacitance** is defined as the ratio of the charge on one conductor of the capacitor to the potential difference between the conductors.

Comments on Circuit Diagrams:

1. Wires have no electrical resistance.
2. Components are ideal
3. PHYS241 only deals with:
   - (a) Resistors, \( R \)
   - (b) Capacitors, \( C \)
   - (c) Inductors, \( L \)
   - (d) Batteries, Generators, switches & wires

Equivalent Capacitors
Capacitors in Parallel

Capacitors connected in parallel can be replaced with an equivalent capacitor that has the same total charge, \( Q \) and the same applied potential \( V \).

\[\begin{array}{c}
\text{a} \\
V \\
\text{b}
\end{array}\]

\[\begin{array}{c}
\begin{array}{c}
Q_1 \\
C_j \\
C_2 \\
C_j
\end{array}
\end{array}\]

\[\begin{array}{c}
Q_2 \\
Q_3
\end{array}\]

Capacitors in Series

Capacitors are in series when a potential difference that is applied across their combination is the sum of the resulting potential differences across each capacitor.

\[\begin{array}{c}
\text{a} \\
+Q \\
+Q \\
+Q
\end{array}\]

\[\begin{array}{c}
\text{b} \\
-Q \\
-Q \\
-Q
\end{array}\]

Capacitors in Series

Capacitors that are connected in series can be replaced with an equivalent capacitor that has the same charge \( Q \) and the same total potential difference \( V \) as the actual series capacitors.

\[\begin{array}{c}
\text{a} \\
+Q \\
+Q \\
+Q
\end{array}\]

\[\begin{array}{c}
\text{b} \\
-Q \\
-Q \\
-Q
\end{array}\]

Dielectrics

- **Empirical observation:** Inserting a non-conducting material between the plates of a capacitor changes the VALUE of the capacitance.
- **Definition:** The dielectric constant of a material is the ratio of the capacitance when filled with the dielectric to that without it.
Dielectric Strength

*The maximum value of the electric field that a dielectric material can tolerate before breaking down.

* It limits the voltage that can be applied to a capacitor. The maximum voltage is called the breakdown potential.

Dielectric Properties

<table>
<thead>
<tr>
<th>material</th>
<th>k</th>
<th>dielectric strength (kV/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>air (1 atm)</td>
<td>1.00054</td>
<td>3</td>
</tr>
<tr>
<td>paraffin</td>
<td>2.1–2.5</td>
<td>10</td>
</tr>
<tr>
<td>glass (Pyrex)</td>
<td>5.6</td>
<td>14</td>
</tr>
<tr>
<td>mica</td>
<td>5.4</td>
<td>10–100</td>
</tr>
<tr>
<td>polystyrene</td>
<td>2.55</td>
<td>24</td>
</tr>
<tr>
<td>H₂O (20°C)</td>
<td>80</td>
<td>?</td>
</tr>
<tr>
<td>titania ceramic</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>strontium titanate</td>
<td>310</td>
<td>8</td>
</tr>
</tbody>
</table>

Demo: Dielectrics & Capacitance

Effect of Dielectrics on the Electric Field
Dielectric Combinations

Summary

• Capacitors in parallel and in series

• Electric response of dielectric materials
  – atomistic view polarized atoms
  – dielectric constant