STATIC ELECTRICITY

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Induction & charging by Induction

- Induction charging is a method used to charge an object without actually touching the object to any other charged object.

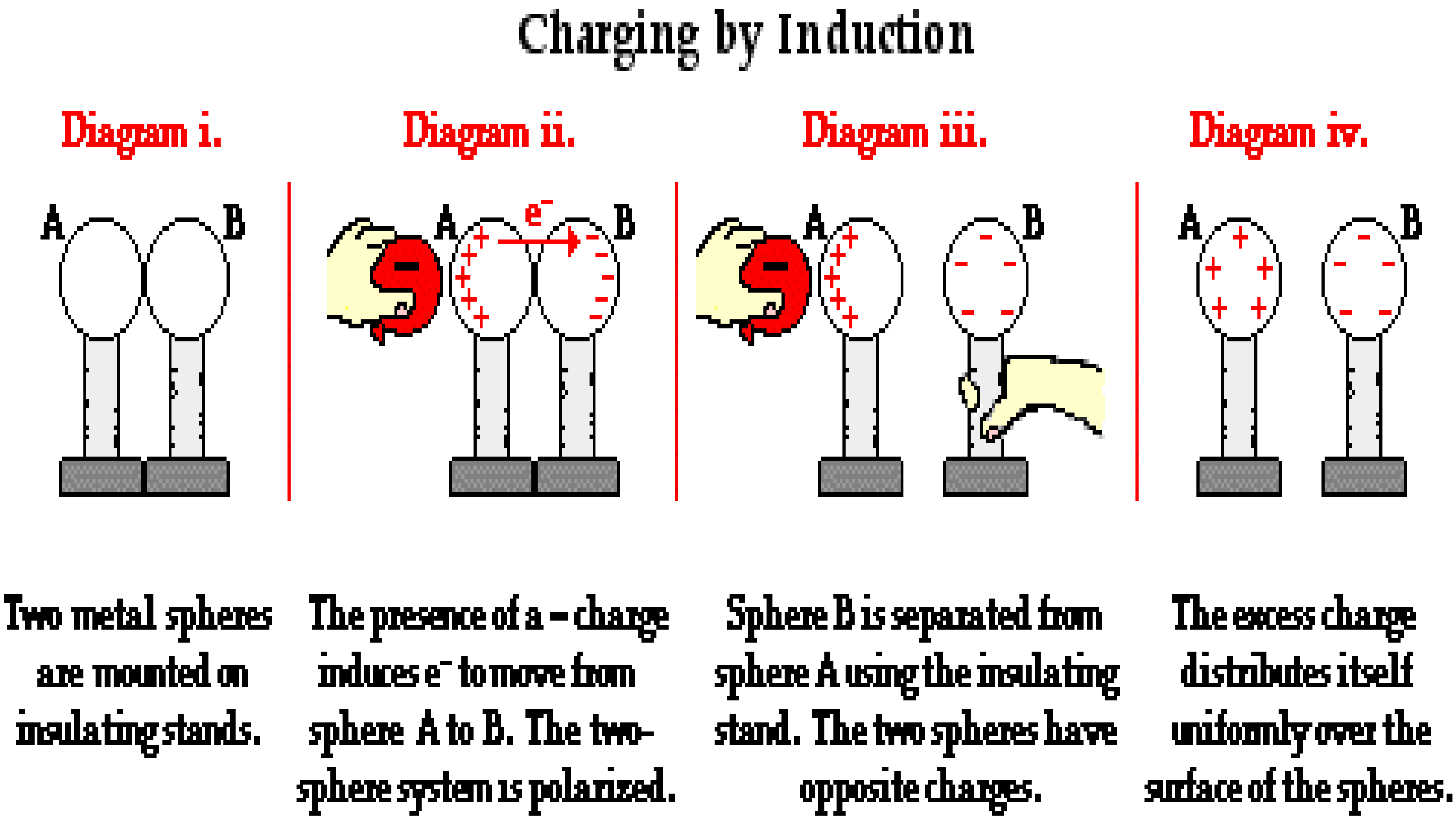
Charging a Two-Sphere System Using a Negatively Charged Object

- induction charging of two metal spheres.
- The metal spheres are supported by insulating stands so that any charge acquired by the spheres cannot travel to the *ground*.
- The spheres are placed side by side (see diagram i. below) so as to form a two-sphere system. Being made of metal (a conductor), electrons are free to move between the spheres - from sphere A to sphere B and vice versa.
- If a rubber balloon is charged negatively (perhaps by rubbing it with animal fur) and brought near the spheres, electrons within the two-sphere system will be induced to move away from the balloon. This is simply the principle that like charges repel.
- Being charged negatively, the electrons are repelled by the negatively charged balloon. And being present in a conductor, they are free to move about the surface of the conductor. Subsequently, there is a *mass migration* of electrons from sphere A to sphere B. This electron migration causes the two-sphere system to be polarized (see diagram ii. below).

Charging a Two-Sphere System Using a Negatively Charged Object

- Overall, the two-sphere system is electrically neutral. Yet the movement of electrons out of sphere A and into sphere B separates the negative charge from the positive charge.
- Looking at the spheres individually, it would be accurate to say that sphere A has an overall positive charge and sphere B has an overall negative charge.
- Once the two-sphere system is polarized, sphere B is physically separated from sphere A using the insulating stand. Having been pulled further from the balloon, the negative charge likely redistributes itself uniformly about sphere B (see diagram iii)
- Meanwhile, the excess positive charge on sphere A remains located near the negatively charged balloon, consistent with the principle that opposite charges attract.
- As the balloon is pulled away, there is a uniform distribution of charge about the surface of both spheres (see diagram iv.).
- This distribution occurs as the remaining electrons in sphere A move across the surface of the sphere until the excess positive charge is uniformly distributed.

Induction & charging by Induction



Conduction & charging by Conduction

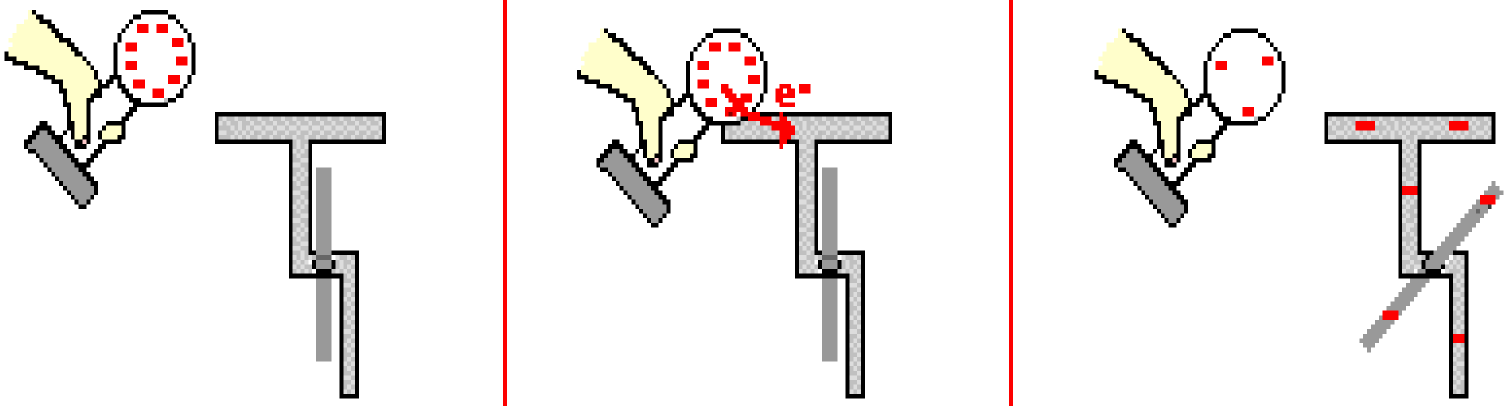
- Charging by conduction involves the contact of a charged object to a neutral object.
- Suppose that a positively charged aluminum plate is touched to a neutral metal sphere. The neutral metal sphere becomes charged as the result of being contacted by the charged aluminum plate. Or suppose that a negatively charged metal sphere is touched to the top plate of a neutral needle electroscope.
- The neutral electroscope becomes charged as the result of being contacted by the metal sphere.
- Each of these examples involves contact between a charged object and a neutral object.
- In contrast to induction, where the charged object is brought near but never contacted to the object being charged, conduction charging involves making the physical connection of the charged object to the neutral object. Because charging by conduction involves contact, it is often called **charging by contact**.

Charging by Conduction Using a Negatively Charged Object

- To explain the process of charging by contact,
- **CASE:** using a negatively charged metal sphere to charge a neutral needle electroscope. Understanding the process demands that you understand that like charges repel and have an intense desire to reduce their repulsions by spreading about as far as possible.
- A negatively charged metal sphere has an excess of electrons; those electrons find each other repulsive and distance themselves from each other as far as possible. The perimeter the sphere is the extreme to which they can go.
- it to predict what excess electrons on the metal sphere would be inclined to do if the sphere were touched to the neutral electroscope.
- Once the contact of the sphere to the electroscope is made, a countless number of excess electrons from the sphere move onto the electroscope and spread about the sphere-electroscope system.
- In general, the object that offers the most space in which to "hang out" will be the object that *houses* the greatest number of excess electrons.
- When the process of charging by conduction is complete, the electroscope acquires an excess negative charge due to the movement of electrons onto it from the metal sphere. The metal sphere is still charged negatively, only it has less excess negative charge than it had prior to the conduction charging process.

Charging a Neutral Object by Conduction

Diagram i. | Diagram ii. | Diagram iii.



A metal sphere with an excess of - charge is brought near to a neutral electroscope.

Upon contact, e- move from the sphere to the electroscope and spread about uniformly.

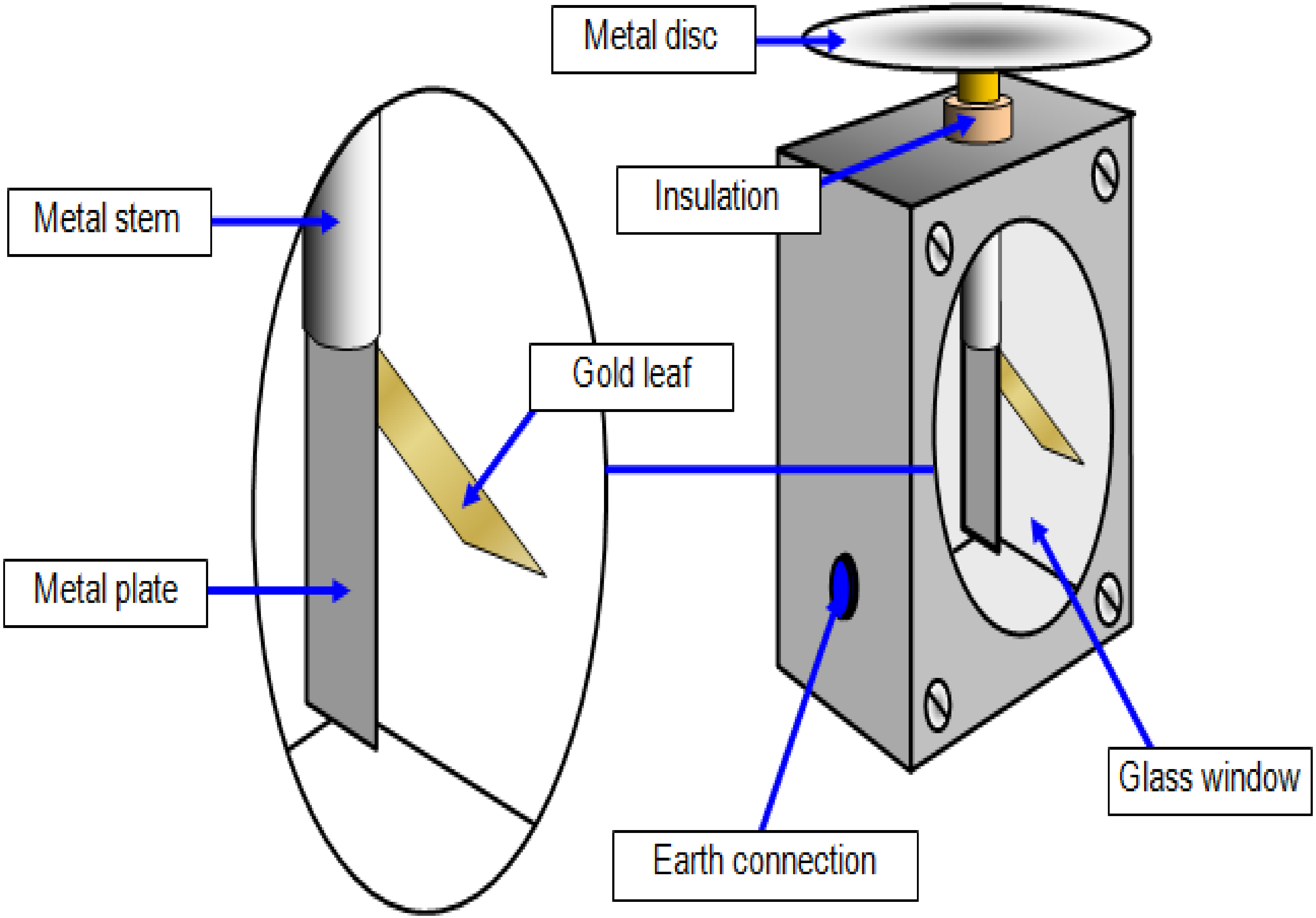
The metal sphere now has less excess - charge and the electroscope now has a - charge.

Electroscope

- An electroscope is a scientific instrument that is used to detect the presence and magnitude of electric charge on a body. OR
- An electroscope is a device that can be used to test for the presence of charge, or that can be charged. An electroscope is made from conducting material (generally metal). Charge is free to flow on a conductor, and if you put charge at a particular point it will distribute itself over the surface of the conductor
- There are three classical types of electroscopes: pith-ball electroscope (first), gold-leaf electroscope (second), and needle electroscope (third). We provide simulations for all of them.

The gold leaf electroscope

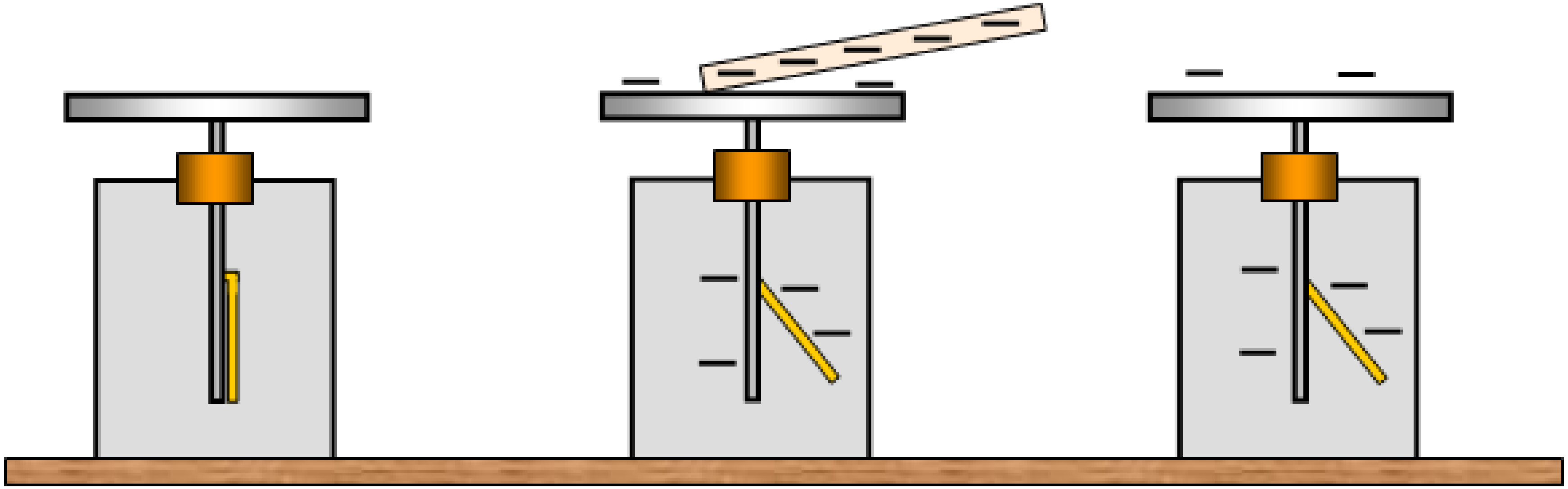
- This is an instrument for detecting and measuring static electricity or voltage.
- A metal disc is connected to a narrow metal plate and a thin piece of gold leaf is fixed to the plate. The whole of this part of the electroscope is insulated from the body of the instrument. A glass front prevents air draughts but allows you to watch the behaviour of the leaf.


Metal disc
Insulation
Metal stem
Gold leaf
Metal plate
Glass window
Earth connection

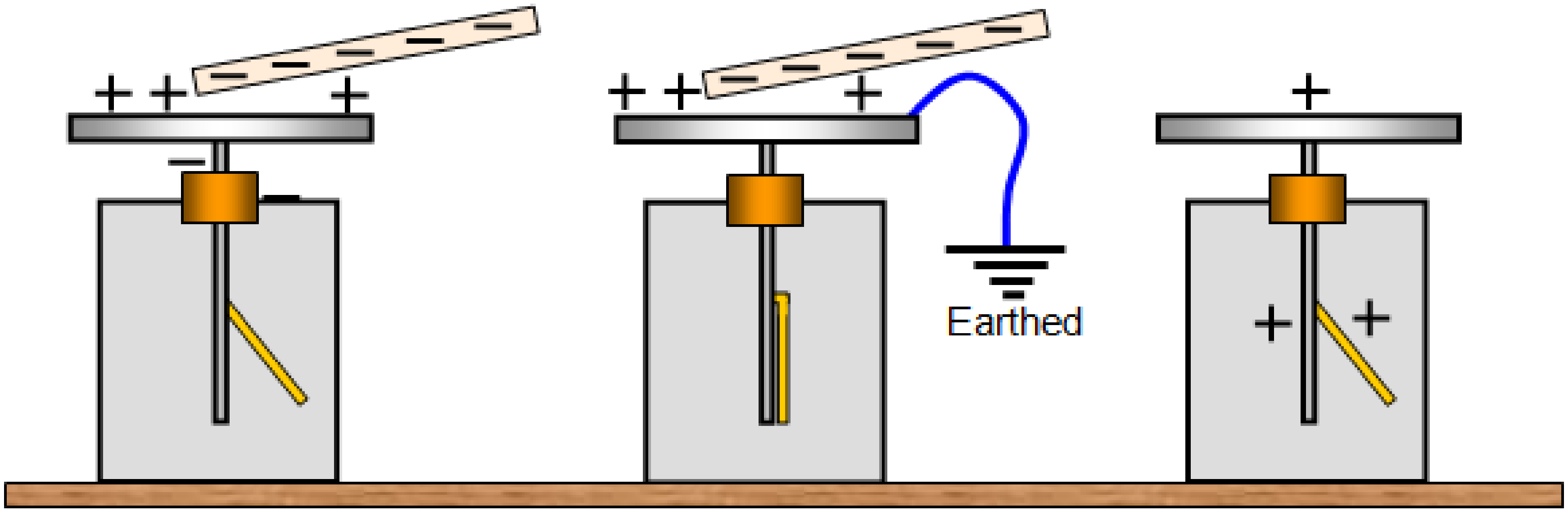
When a charge is put on the disc at the top it spreads down to the plate and leaf. This means that both the leaf and plate will have the same charge. Similar charges repel each other and so the leaf rises away from the plate - the bigger the charge the more the leaf rises.

- The leaf can be made to fall again by touching the disc - you have earthed the electroscope. An earth terminal prevents the case from becoming live.

- The electroscope can be charged in two ways:
- (a)by contact - a charged rod is touched on the surface of the disc and some of the charge is transferred to the electroscope. This is not a very effective method of charging the electroscope.
- (b) by induction - a charged rod is brought up to the disc and then the electroscope is earthed, the rod is then removed.
- The two methods give the gold leaf opposite charges.



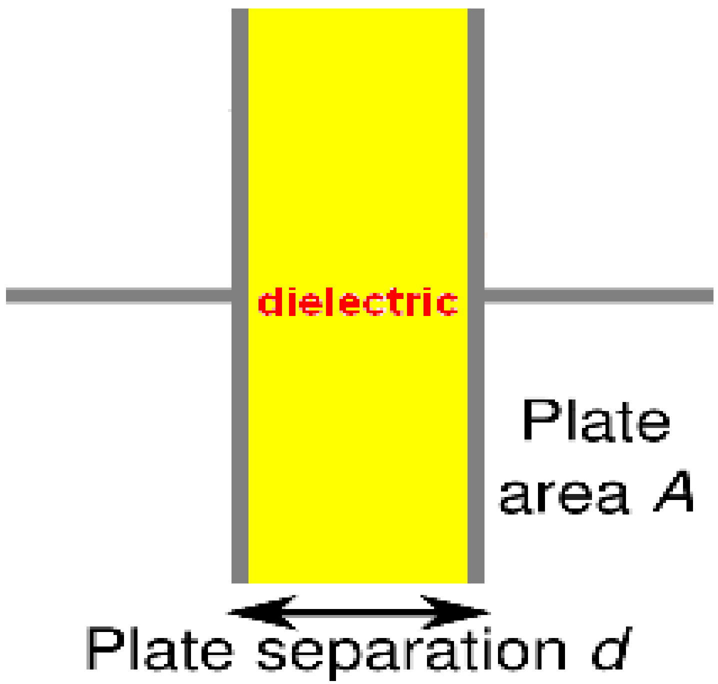
Charging by contact



Charging by induction

Capacitors

- A basic capacitor has two parallel plates separated by an insulating material
- A capacitor stores an electrical charge between the two plates.

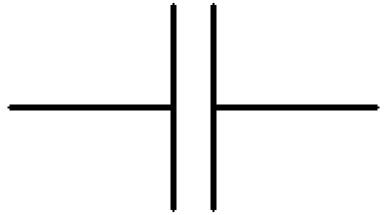


The Capacitance of a Capacitor

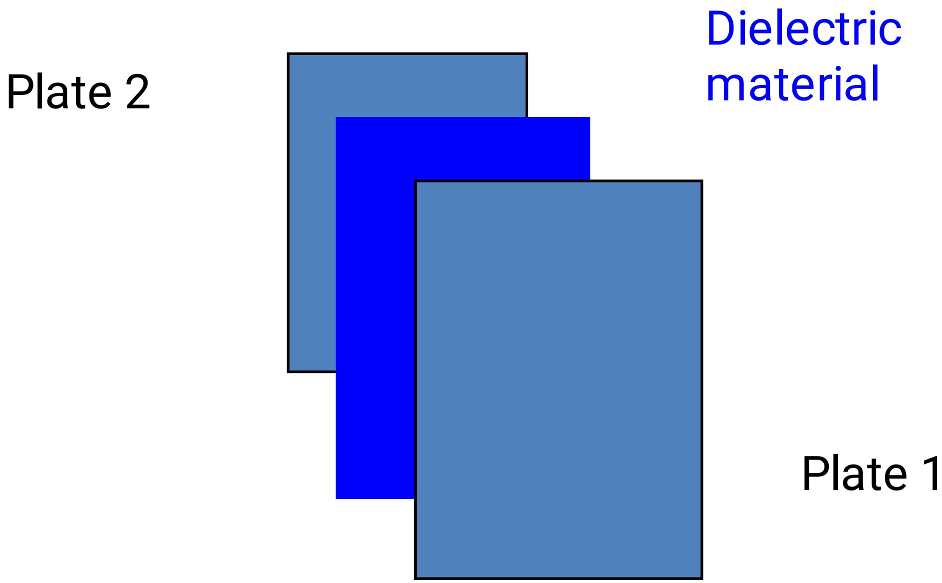
- Capacitance is the electrical property of a capacitor and is the measure of a capacitors ability to store an electrical charge onto its two plates with the unit of capacitance being the **Farad** (abbreviated to F) named after the British physicist Michael Faraday.
- Capacitance is defined as being that a capacitor has the capacitance of **One Farad** when a charge of **One Coulomb** is stored on the plates by a voltage of **One volt**.
- **Standard Units of Capacitance**

  Microfarad (μF)

Capacitors



- Basic capacitor construction



The dielectric material is an insulator therefore no current flows through the capacitor

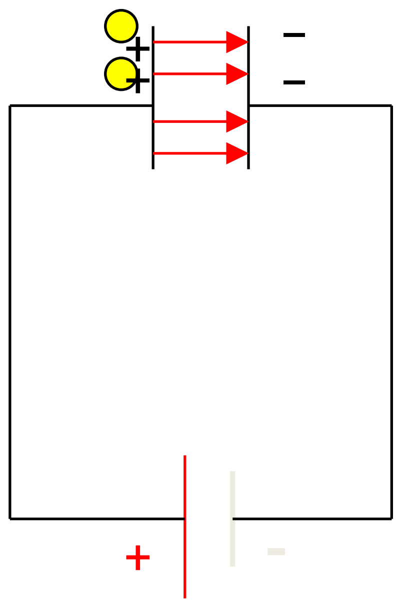
Effect of Dimensions

- Capacitance increases with
  - increasing surface area of the plates,
  - decreasing spacing between plates, and
  - increasing the relative dielectric constant of the insulator between the two plates.

Capacitors

Storing a charge between the plates

- Electrons on the left plate are attracted toward the positive terminal of the voltage source
- This leaves an excess of positively charged holes
- The electrons are pushed toward the right plate
- Excess electrons leave a negative charge

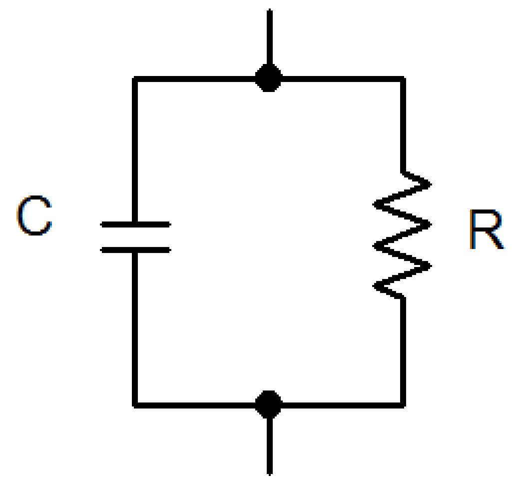


Electrical Properties of a Capacitor

- Acts like an open circuit at steady state when connected to a d.c. voltage or current source.
- Voltage on a capacitor must be continuous
  - There are no abrupt changes to the voltage, but there may be discontinuities in the current.
- An ideal capacitor does not dissipate energy, it takes power when storing energy and returns it when discharging.

Properties of a Real Capacitor

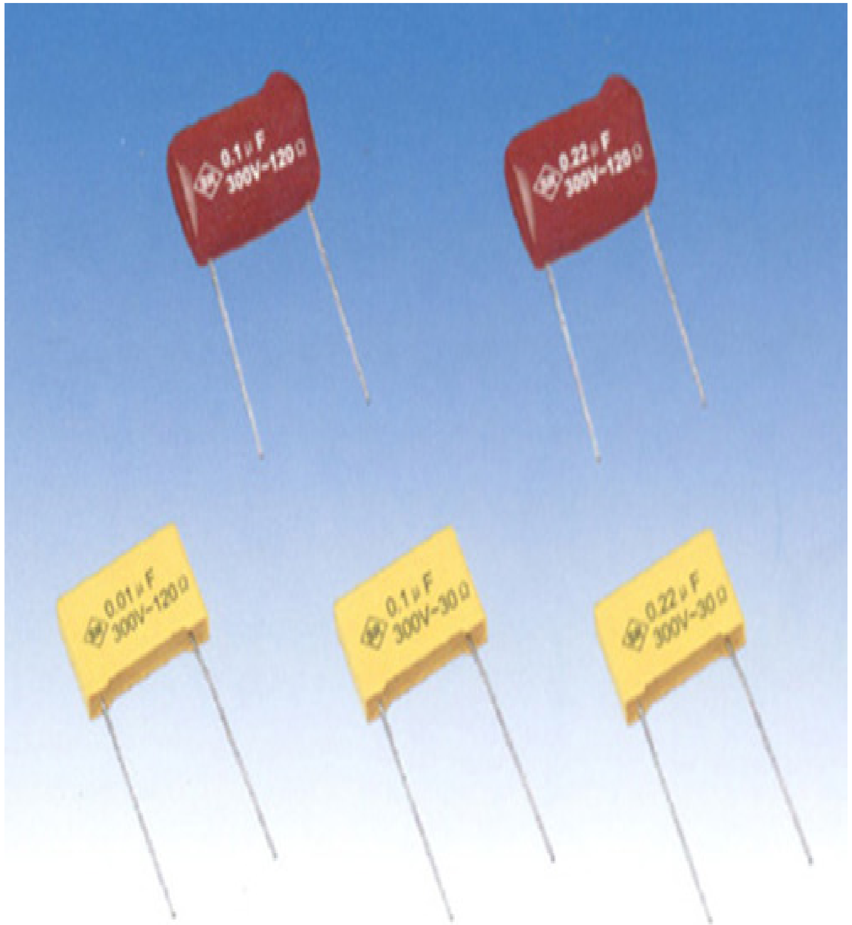
- A real capacitor does dissipate energy due leakage of charge through its insulator.
  - This is modeled by putting a resistor in parallel with an ideal capacitor



Capacitors

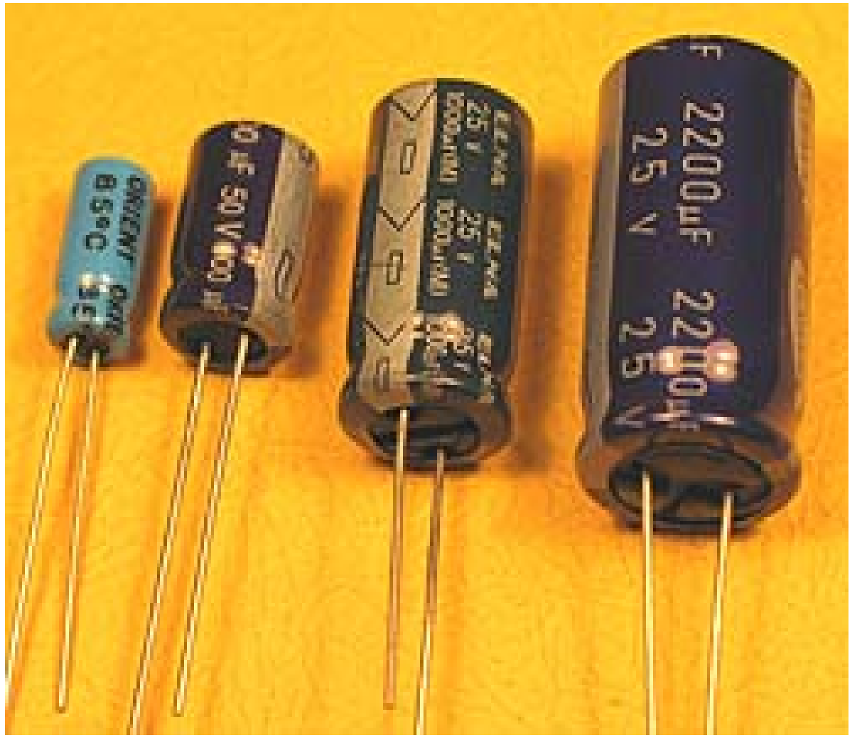
Types of capacitors

- The dielectric material determines the type of capacitor
- Common types of capacitors are:
  - Mica
  - Ceramic
  - Plastic film



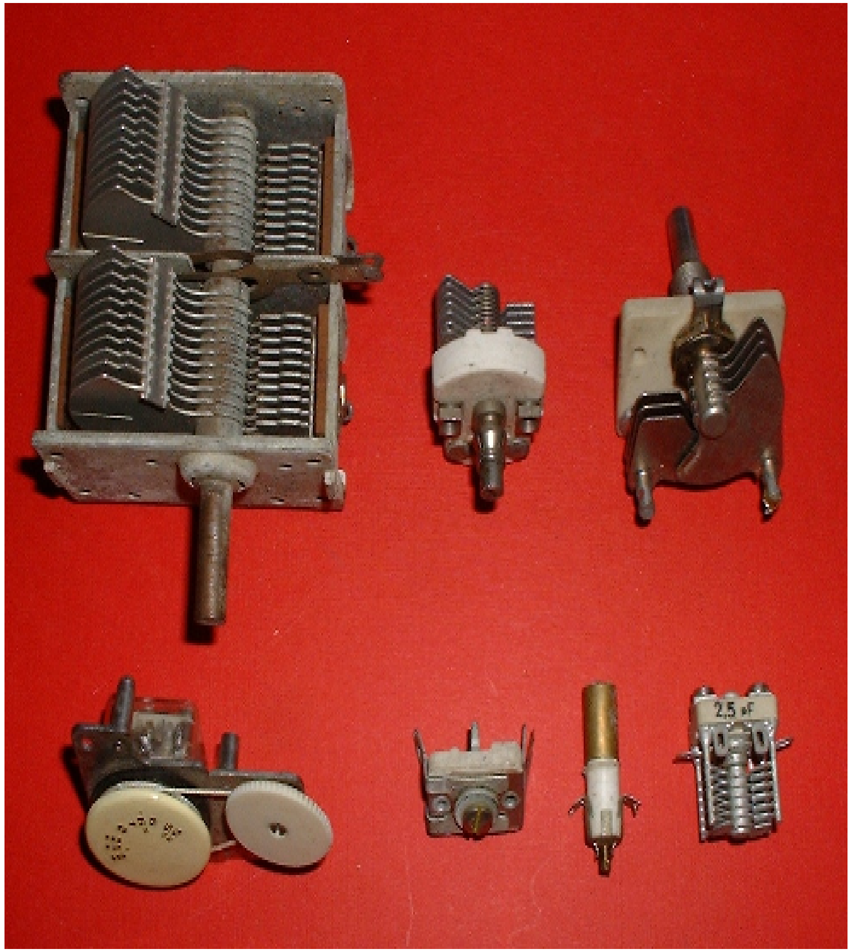
Capacitors

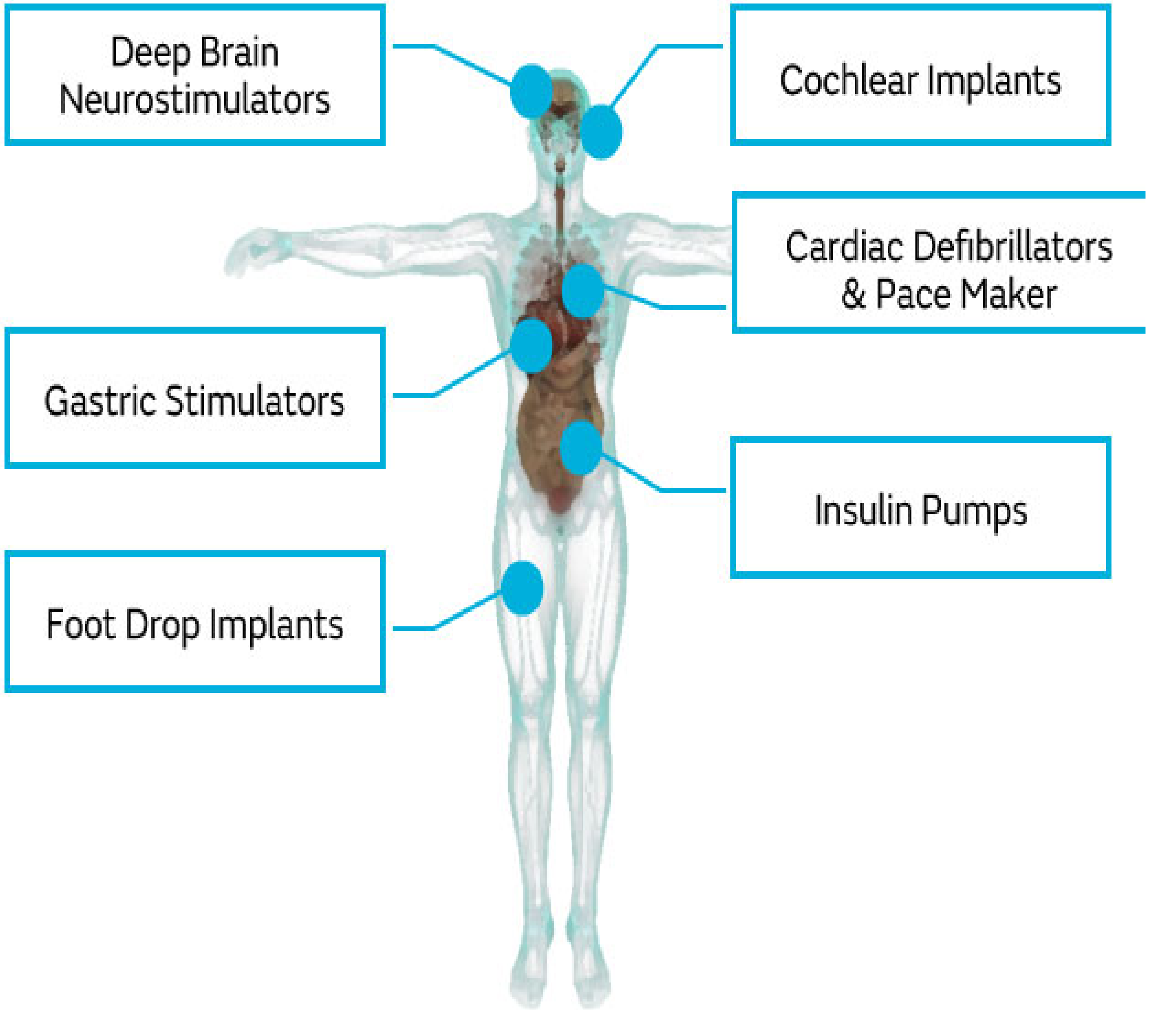
- Some capacitors are polarised, they can only be connected one way around
- Electrolytic capacitors are polarised
- Electrolytic capacitor definition
- An electrolytic capacitor is a type of capacitor that uses an electrolyte (ionic conducting liquid) as one of its conducting plates to achieve a larger capacitance or high charge storage.



Capacitors

- Variable capacitors are used in communication equipment, radios, televisions and VCRs
- They can be adjusted by consumers by tuning controls.
- Switching Power Supplies
- UPS
- Air Conditioning
- Fans
- Fluid Pumps and General Purpose Motors

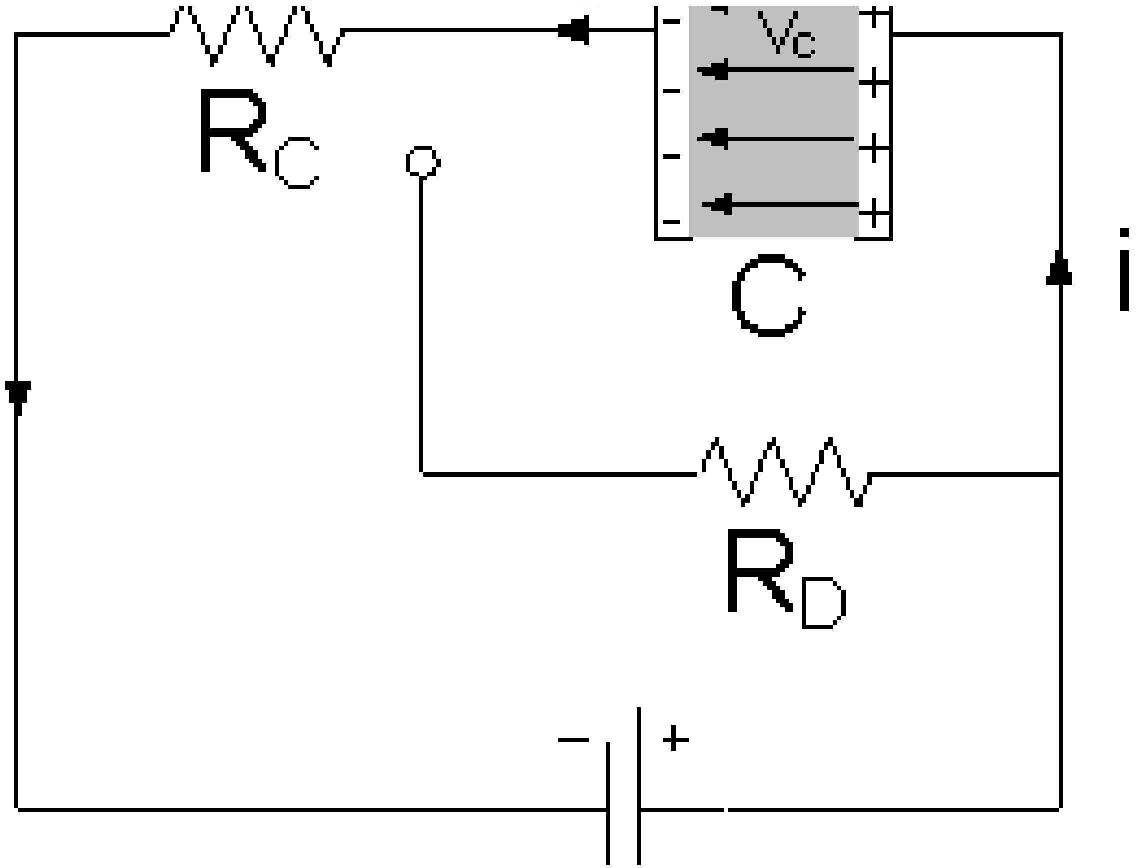




Medical Applications

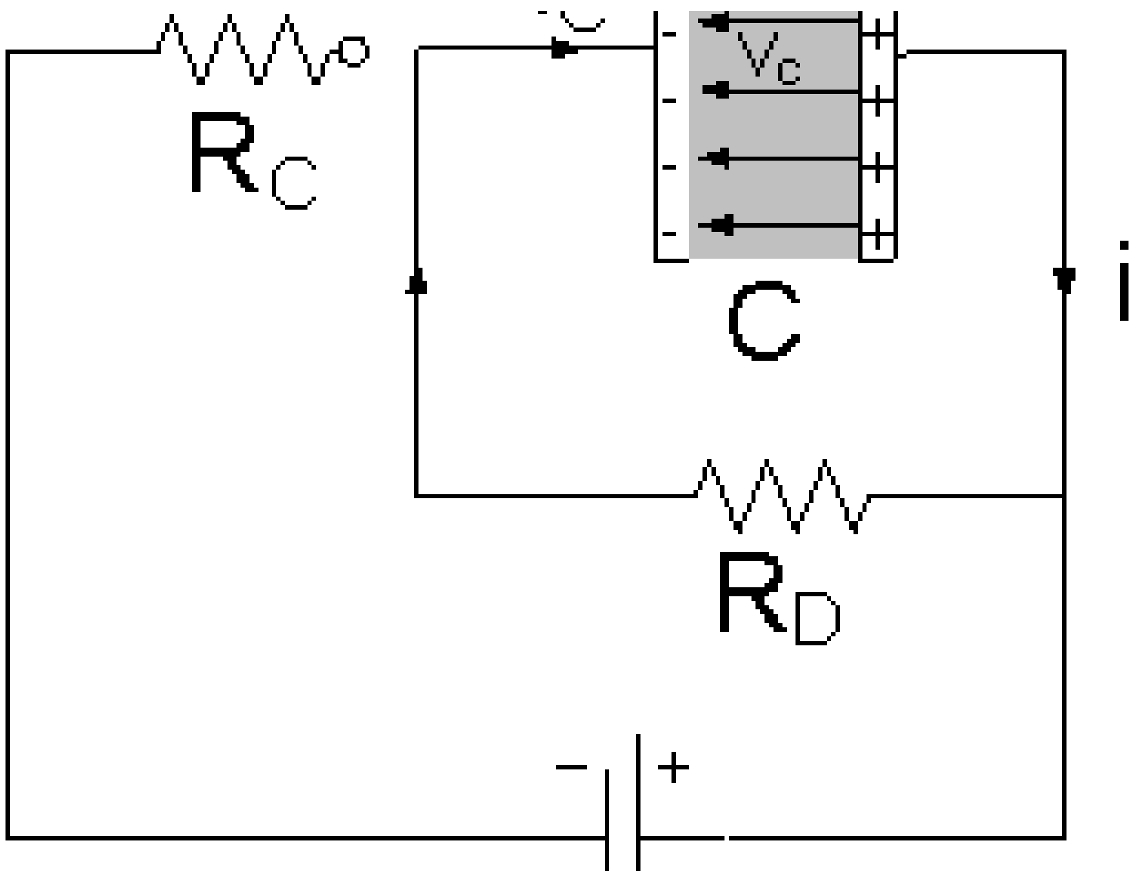
Charging and Discharging a Capacitor

- When a Capacitor is connected to a circuit with Direct Current (DC) source, two processes, which are called "charging" and "discharging" the Capacitor, will happen in specific conditions.
- In Figure the Capacitor is connected to the DC Power Supply and Current flows through the circuit. Both Plates get the equal and opposite charges and an increasing Potential Difference, v_c, is created while the Capacitor is charging. Once the Voltage at the terminals of the Capacitor, v_c, is equal to the Power Supply Voltage, $v_c = V$, the Capacitor is fully charged and the Current stops flowing through the circuit, the Charging Phase is over.



The Capacitor is Charging

- A Capacitor is equivalent to an Open-Circuit to Direct Current, $R = \infty$, because once the Charging Phase has finished, no more Current flows through it. The Voltage v_c on a Capacitor cannot change abruptly.
- When the Capacitor disconnected from the Power Supply, the Capacitor is discharging through the Resistor R_D and the Voltage between the Plates drops down gradually to zero, $v_c = 0$,

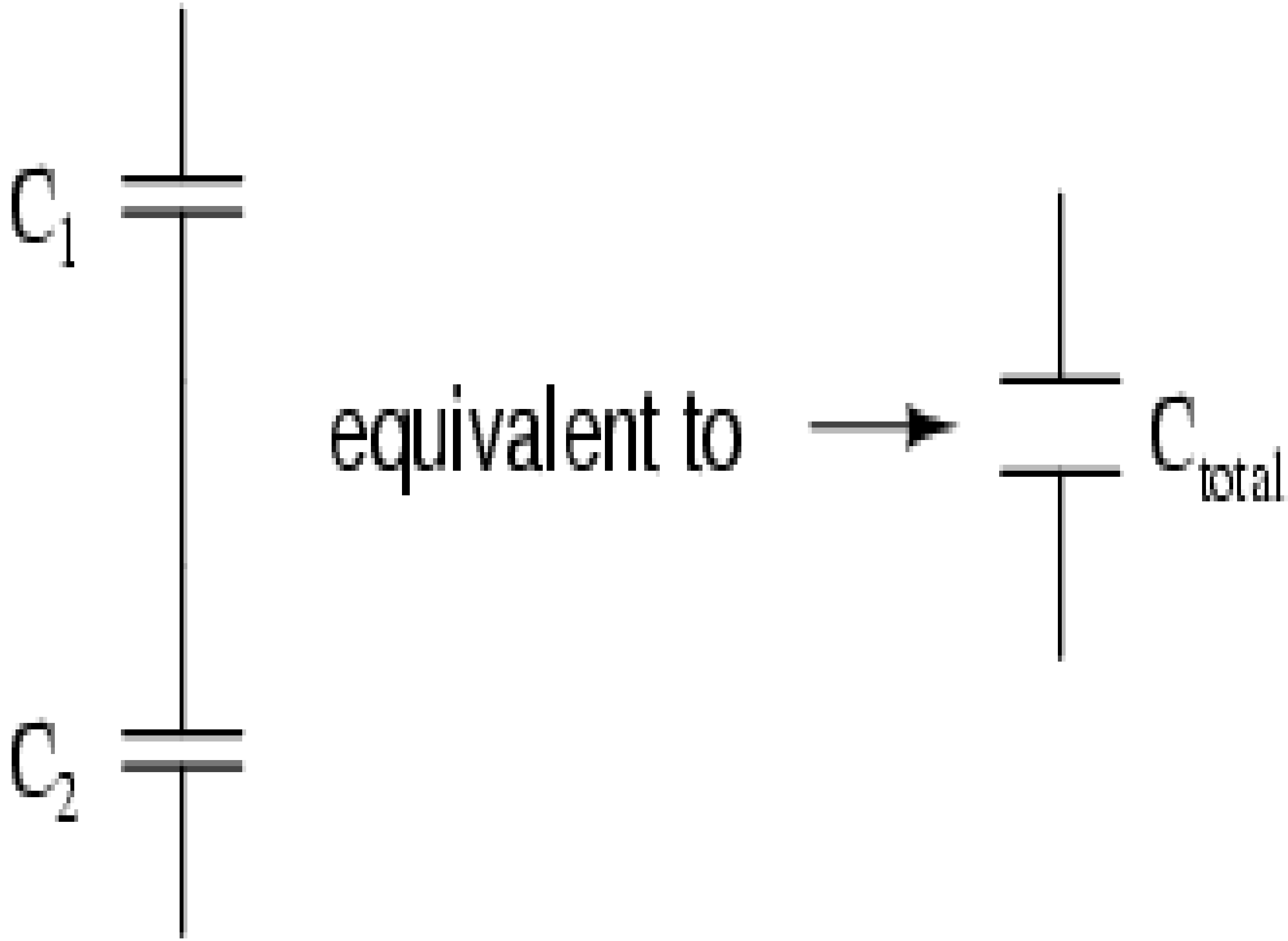


Capacitor is Discharging

- the Resistances of R_C and R_D affect the charging rate and the discharging rate of the Capacitor respectively.
- The product of Resistance R and Capacitance C is called the Time Constant τ, which characterizes the rate of charging and discharging of a Capacitor,
- The smaller the Resistance or the Capacitance, the smaller the Time Constant, the faster the charging and the discharging rate of the Capacitor, and vice versa.

capacitors in series

- When capacitors are connected in series, the total capacitance is less than any one of the series capacitors’ individual capacitances. If two or more capacitors are connected in series, the overall effect is that of a single (equivalent) capacitor having the sum total of the plate spacings of the individual capacitors.
- an increase in plate spacing, with all other factors unchanged, results in decreased capacitance.



C1
C2
equivalent to
Ctotal

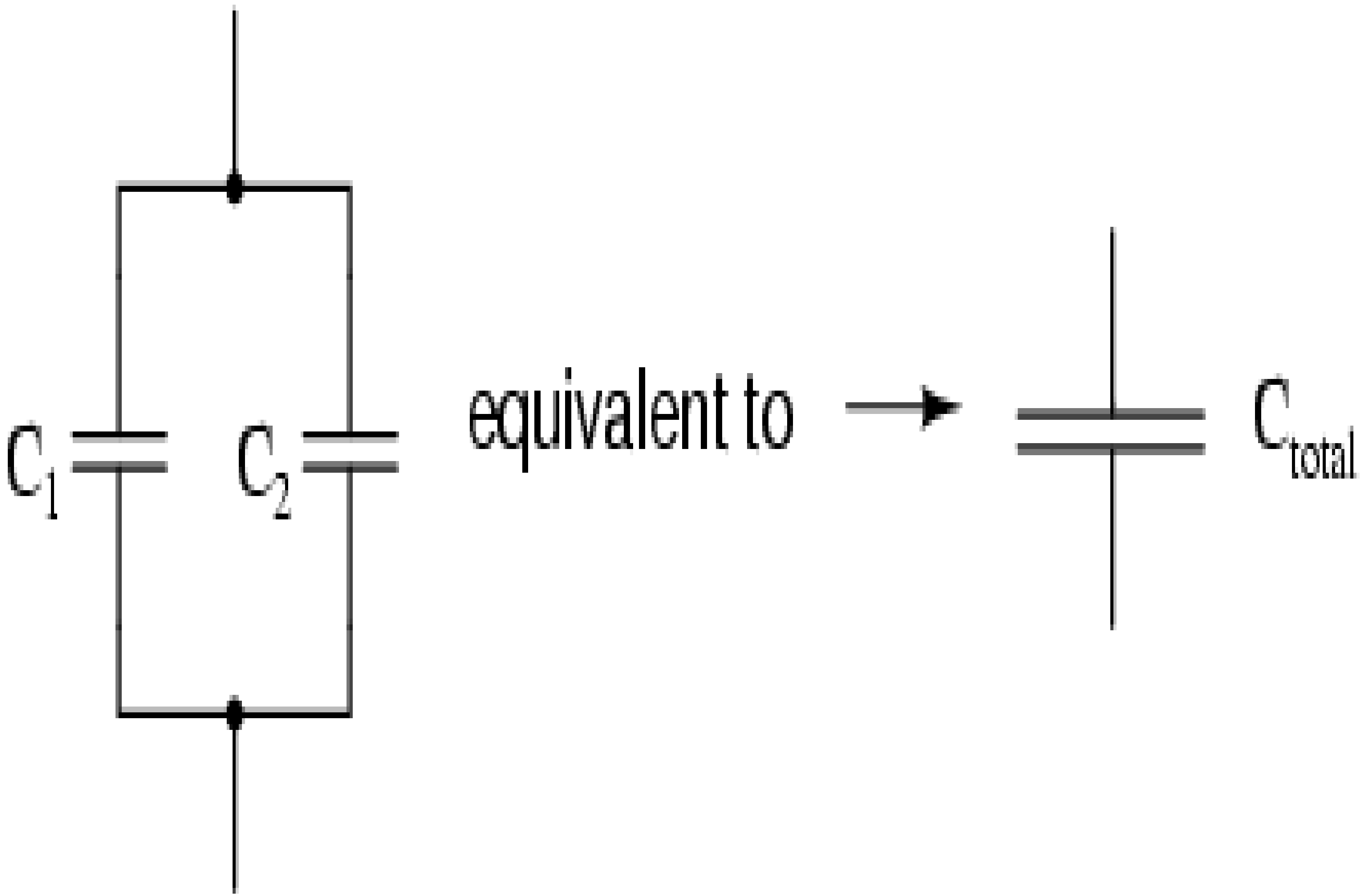
- Thus, the total capacitance is less than any one of the individual capacitors' capacitances. The formula for calculating the series total capacitance is the same form as for calculating parallel resistances:

Series Capacitances

$$C_{total} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots \frac{1}{C_n}}$$

capacitors in parallel

- When capacitors are connected in parallel, the total capacitance is the sum of the individual capacitors' capacitances. If two or more capacitors are connected in parallel, the overall effect is that of a single equivalent capacitor having the sum total of the plate areas of the individual capacitors.
- an increase in plate area, with all other factors unchanged, results in increased capacitance.


C_1
C_2
equivalent to
C_{total}

- Thus, the total capacitance is more than any one of the individual capacitors' capacitances. The formula for calculating the parallel total capacitance is the same form as for calculating series resistances:

Parallel Capacitances

$$C_{total} = C_1 + C_2 + \ldots C_n$$

REVIEW of CS and CP:

- Capacitances diminish in series.
- Capacitances add in parallel.