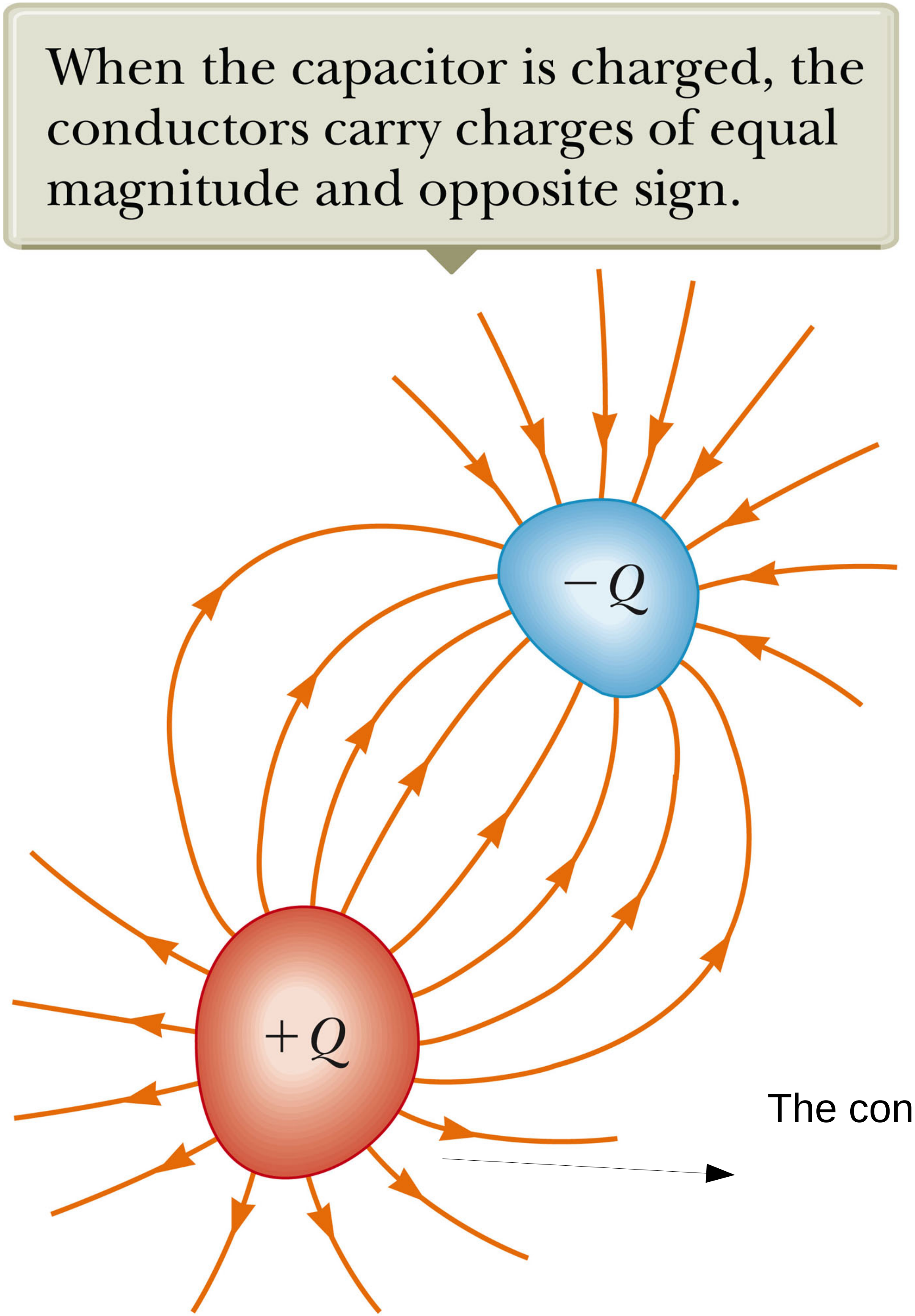
capacitors



A capacitor = 2 conductors with
Opposite charges. The conductors
Are called plates.

A insulator (air, plastic ..) is placed
Between the conductors.
(called a dielectric)

The electric field takes place between
The conductors.

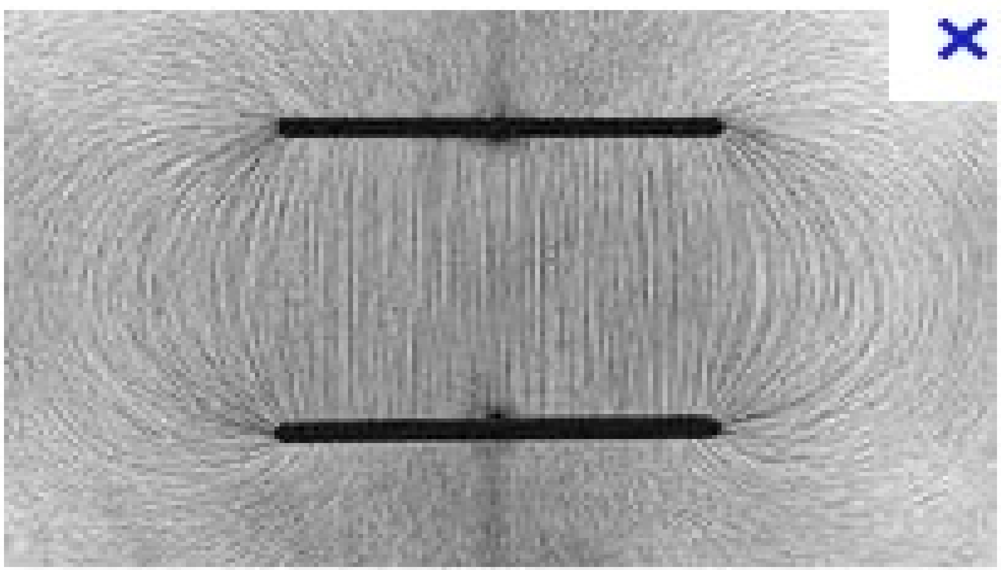
The electric field is lie a stretched spring.

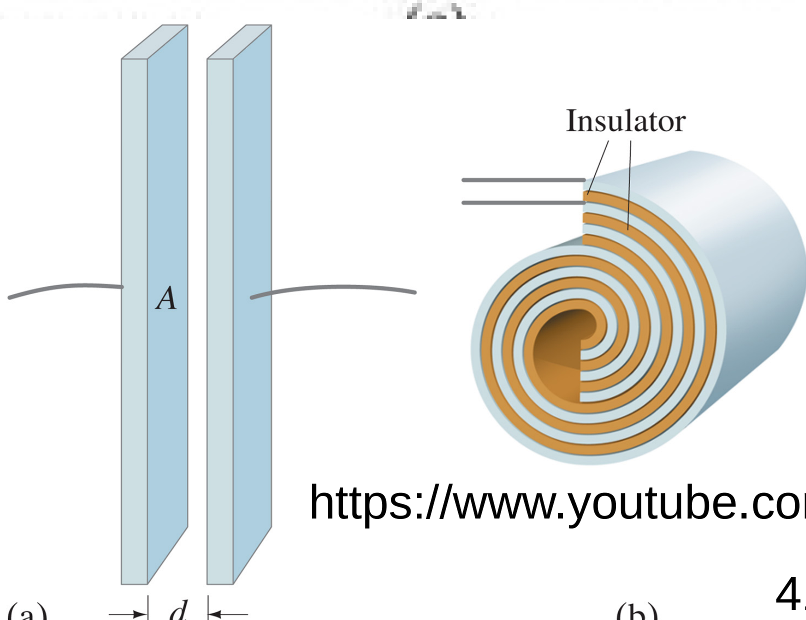
A capacitor is a device to package
Energy in an electrostatic field.
In a storehouse.

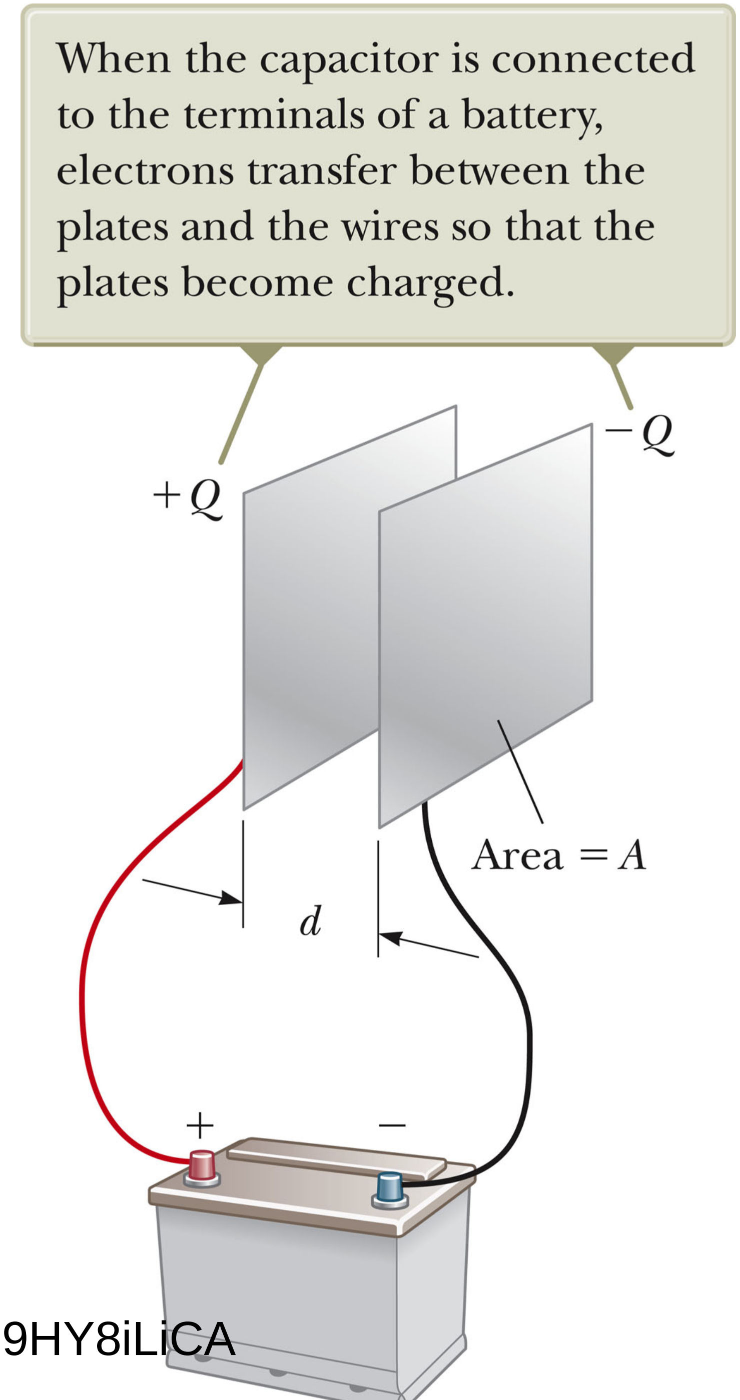
The conductor is an Equipotential

Fig. 26-1, p. 741

Example: parallel plate capacitor. Electric field
Is homogeneous between the plates.
Fringe problem.







https://www.youtube.com/watch?v=Pd9HY8iLiCA

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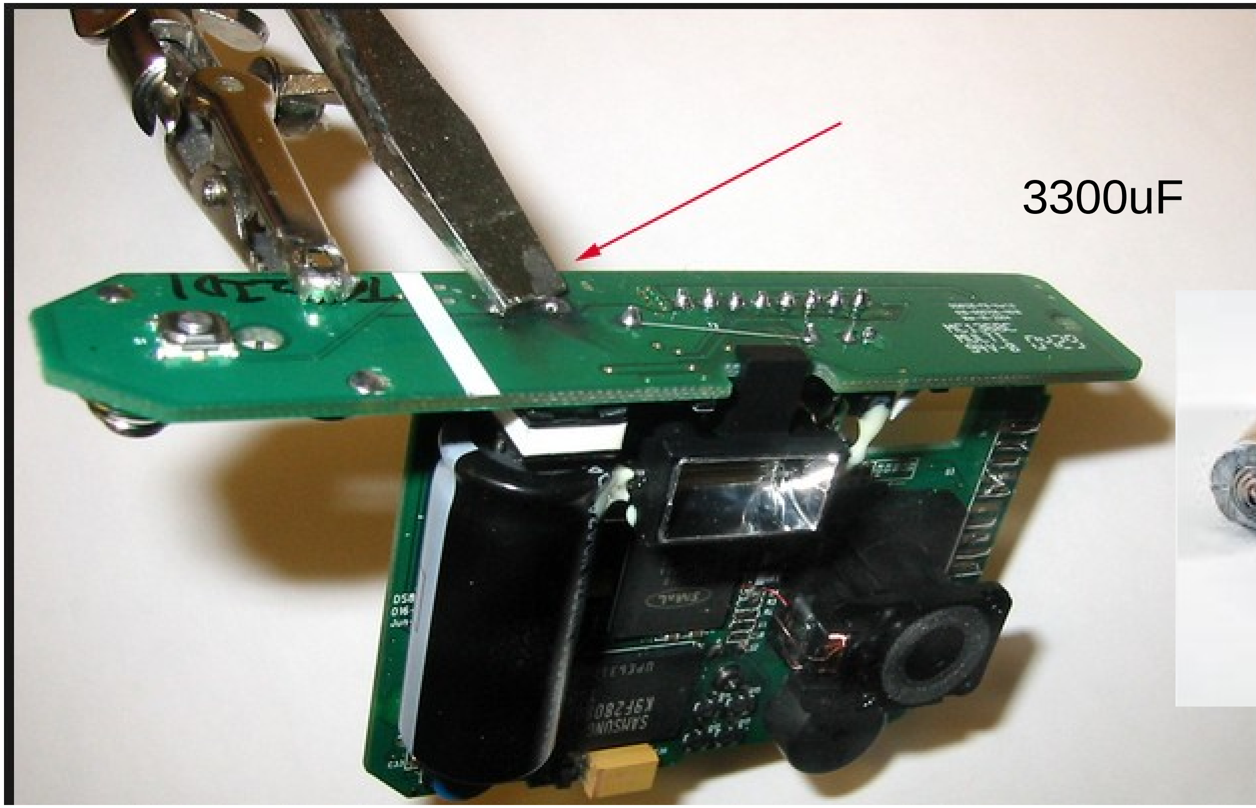
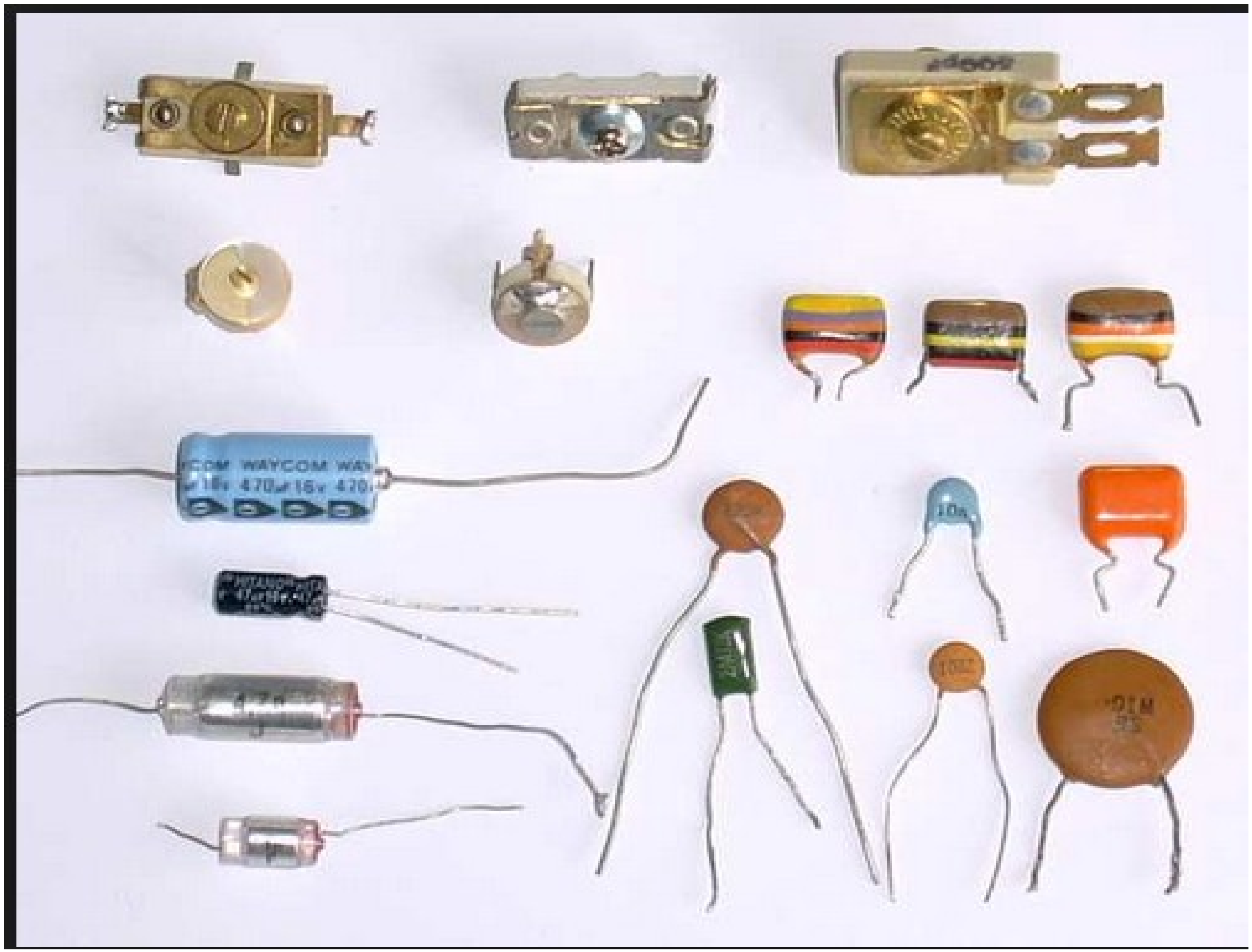
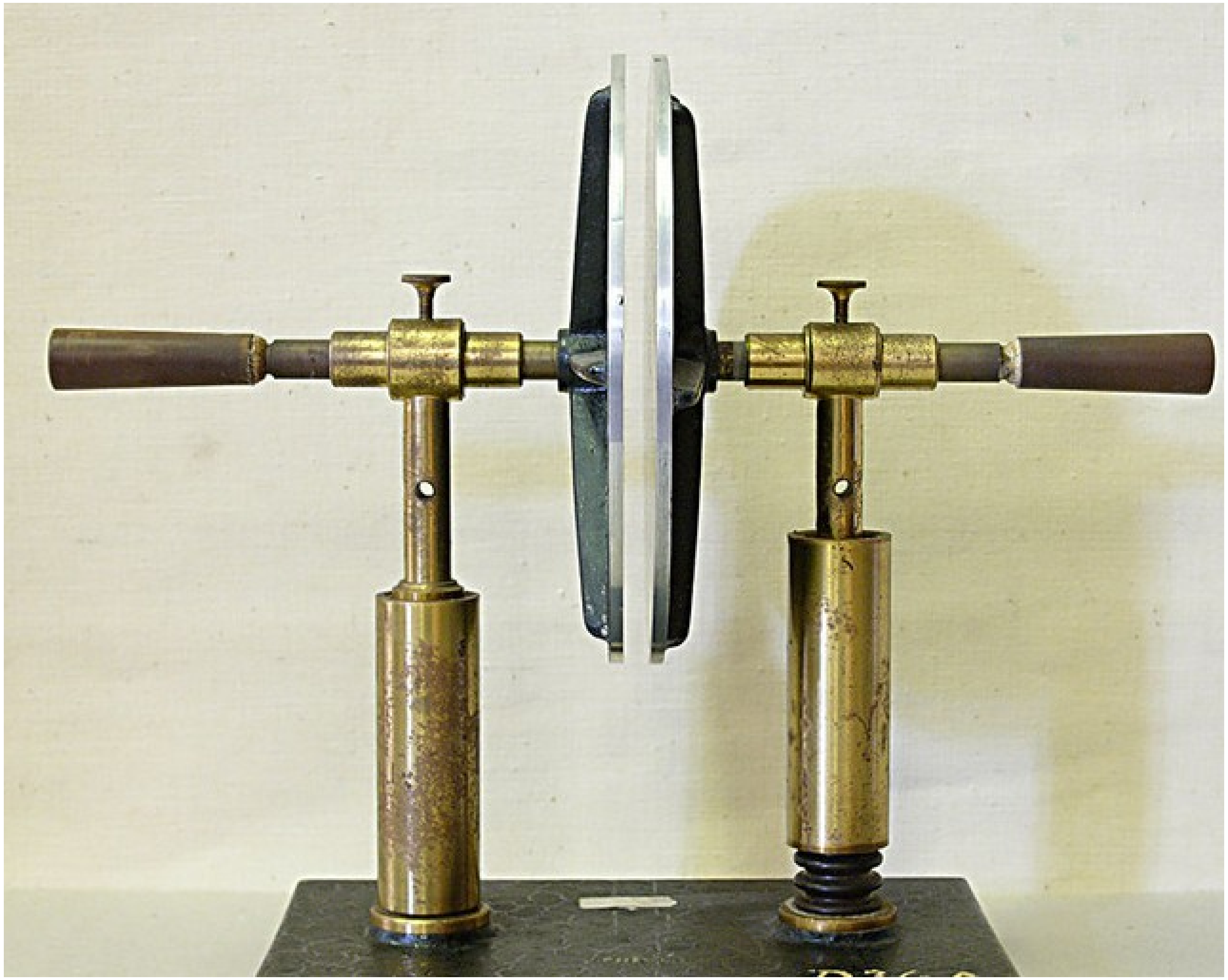


http://www.ladyada.net/make/sudc4kap/make.html



Larger the capacitors, more charge it can hold. The amount of charge it can
Hold depends on the geometry. A Van Graaf is spherical and can not hold
Has much as those cylinders with rolled conductors inside.
The geometry and therefore the amount of charges $\rightarrow$ the capacitance.

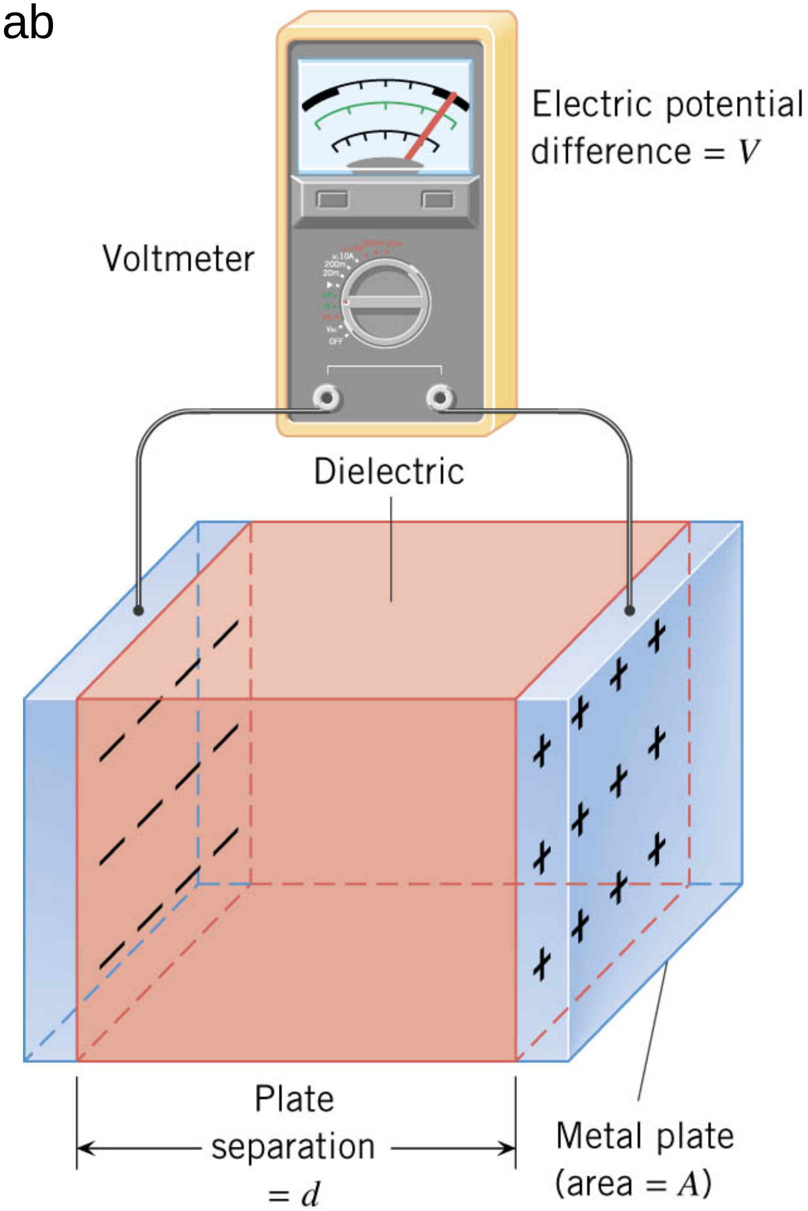


Demo here.

https://phet.colorado.edu/en/simulation/capacitor-lab

A parallel plate capacitor consists of two metal plates, one carrying charge +q and the other carrying charge –q.

It is common to fill the region between the plates with an electrically insulating substance called a ***dielectric***.



-
- The amount of charge Q and -Q
- A capacitor can hold depends
- On the geometry (area of plates
- And distance between plates)
-
- And the voltage drop across the plates.
- (depends on power supply used to charge)
-
- We have : **Q = C V**
-
- V is the voltage across the capacitor (volts)
- C is the capacitance. It is a constant. It depends on geometry. Unit is farads (F)
- Q is the amount of charge in coulombs.
-

THE RELATION BETWEEN CHARGE AND POTENTIAL DIFFERENCE FOR A CAPACITOR

The magnitude of the charge in each place of the capacitor is directly proportional to the magnitude of the potential difference between the plates.

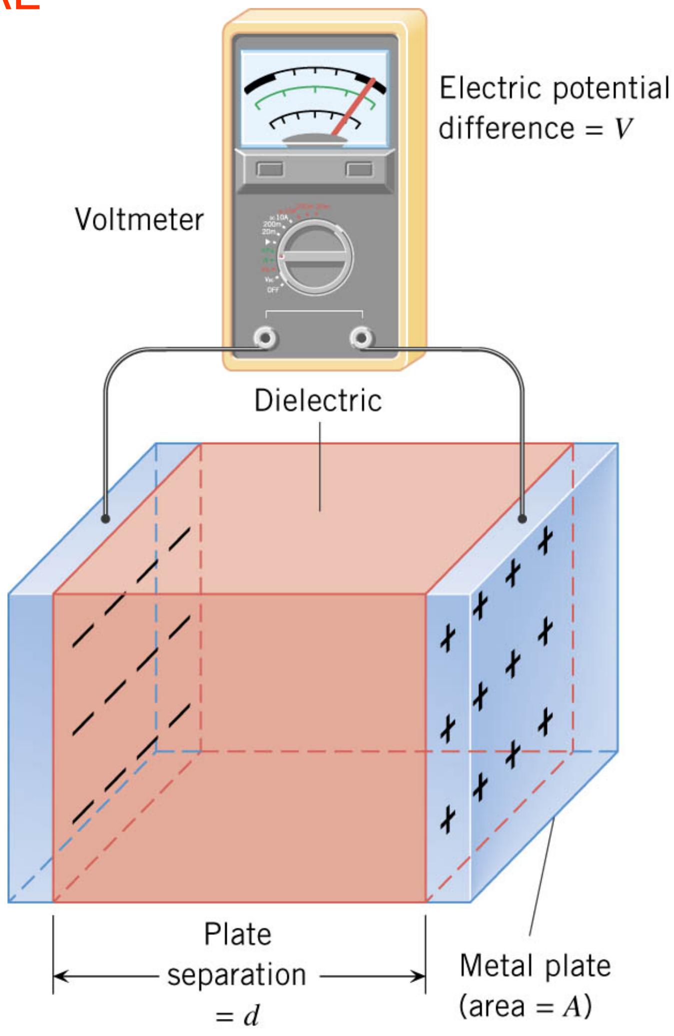
$$q = CV$$ Or **V = q / C**

The capacitance *C* is the proportionality constant.

SI Unit of Capacitance: coulomb/volt = farad (F)

Think of capacity. The capacitance is the charge
Per unit volt. So if you charge a 4pF with a 9V
Battery then the maximum charge is ? ___________

The charge is proportional to the voltage.

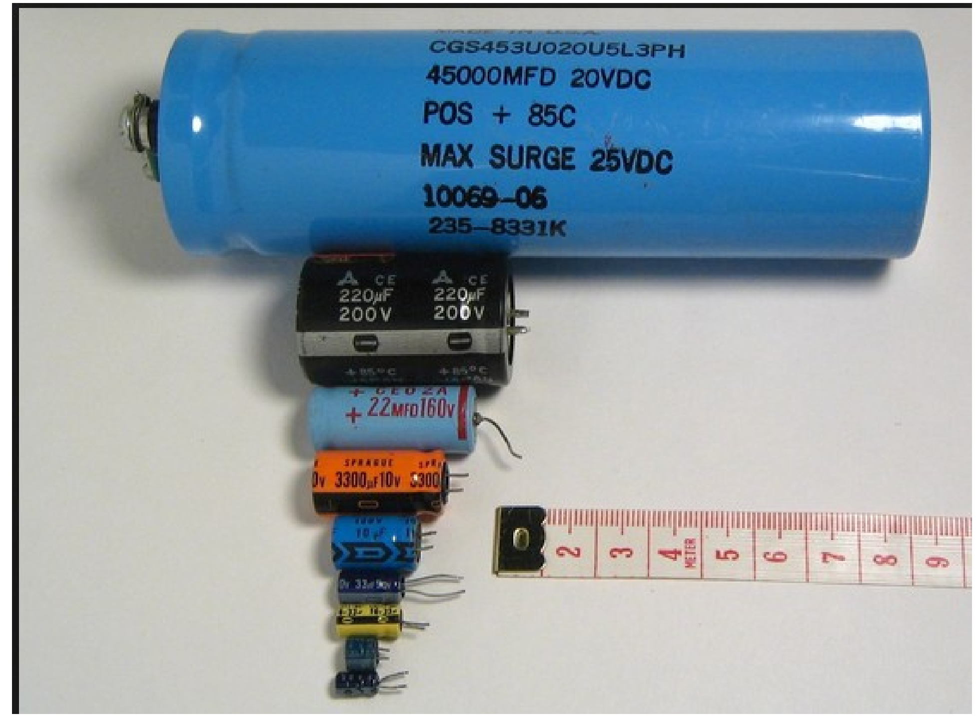


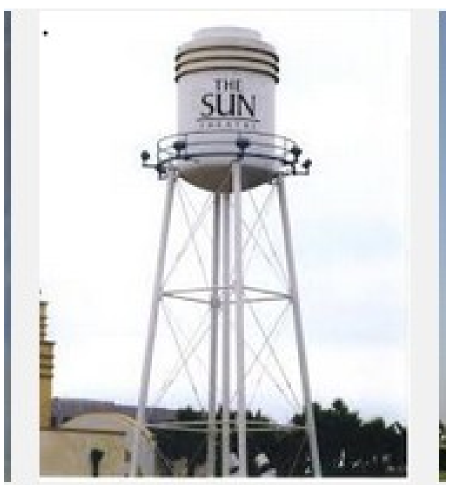
capacitance

The capacitance is a constant.

It depends on the geometry of the capacitor
and on the dielectric.
It is a measure of how much charge
the capacitor can store.

Like the volume of a water tower tells
how much water it can hold.

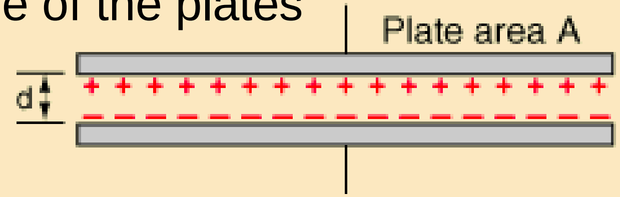




Unit is farad (F). example:
10 microfarad capacitor.

Parallel Plate Capacitor

Capacitance Depends on the distance between the plates and the size of the plates



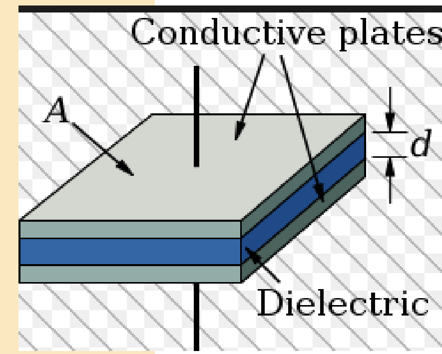
$$C = \frac{\varepsilon A}{d} = \frac{k\varepsilon_0 A}{d}$$ Show

The capacitance of flat, parallel metallic plates of area **A** and separation **d** is given by the expression above where:

$$\varepsilon_0 = 8.854 \ x \ 10^{-12} \ F/m$$ = permittivity of space and

k = relative permittivity of the dielectric material between the plates.

k=1 for free space, k>1 for all media, approximately =1 for air.



The Farad, F, is the SI unit for capacitance, and from the definition of capacitance is seen to be equal to a Coulomb/Volt.

The dielectric increases the capacitance by a factor k the dielectric constant.

(a) What is the capacitance of a parallel plate capacitor with metal plates, each of area 1.00 m^2, separated by 1.00 mm? (b) What charge is stored in this capacitor if a voltage of $3.00 \times 10^3 \text{ V}$ is applied to it? 1mm = 10^{-3} m

Go back to simulation and check if the equation works:
1) compute the capacitance given area and distance. C = e0 x Area / distance
1mm = 10^{-3} m so 1mm^2 = 1mmx1mm = 10^{-6}m^2
2) compute the charge for a voltage = 1.5V

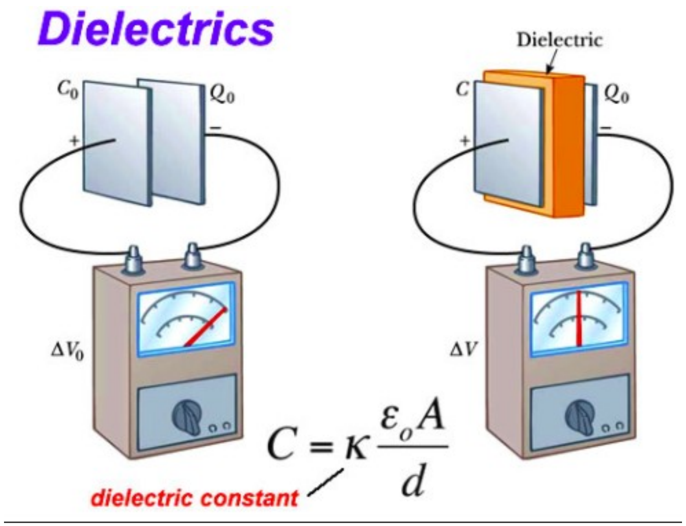
Material	Dielectric constant κ
Vacuum	1.00000
Air	1.00059
Bakelite	4.9
Fused quartz	3.78
Neoprene rubber	6.7
Nylon	3.4
Paper	3.7
Polystyrene	2.56
Pyrex glass	5.6
Silicon oil	2.5
Strontium titanate	233
Teflon	2.1
Water	80

See simulation. The dielectric Increases the capacitance.

C = k e0 x area/distance

$$\varepsilon_0 = 8.854 \ x \ 10^{-12}$$

k is the dielectric constant.



Each key of the Keyboard of computers are made is like a tiny capacitor/
The separation of the plates is normally 5.00×10^{-3} m and decreases to 0.150×10^{-3}m. The plate area is 9.50×10^{-5} m^2
The dielectric between the plate has a dielectric constant of 3.50. Determine the capacitance when the key is pressed
And not pressed.

What charge is stored in a $180\ \mu F$ capacitor when 120 V is applied to it?

(a) What is the capacitance of a parallel plate capacitor with metal plates, each of area $1.00\ m^2$, separated by 1.00 mm? (b) What charge is stored in this capacitor if a voltage of $3.00 \times 10^3\ V$ is applied to it?

Find the charge stored when 5.50 V is applied to an 8.00 pF capacitor.

Calculate the voltage applied to a $2.00\ \mu F$ capacitor when it holds $3.10\ \mu C$ of charge.

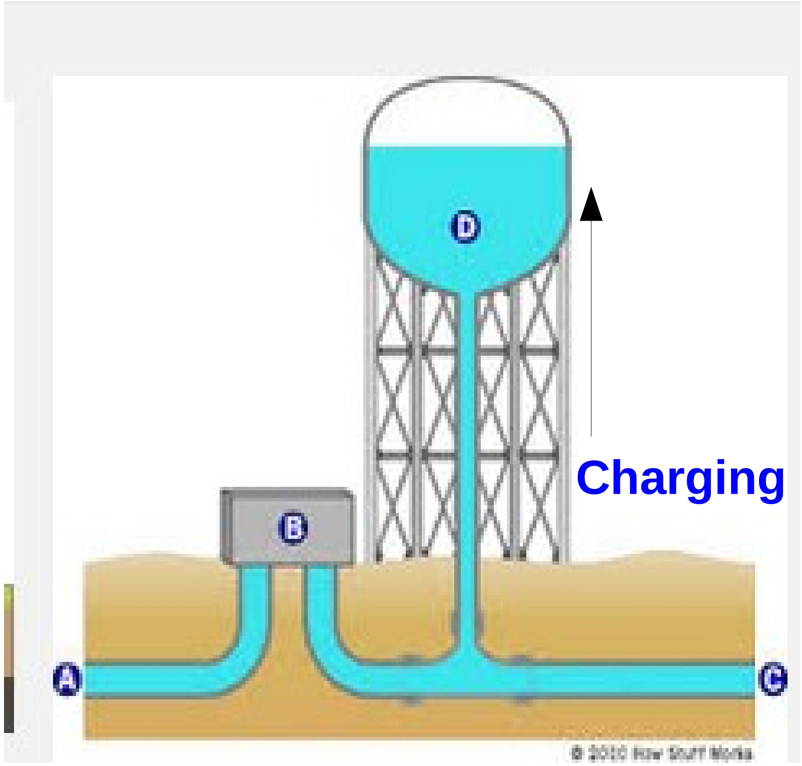
What capacitance is needed to store $3.00\ \mu C$ of charge at a voltage of 120 V?

What is the capacitance of a large Van de Graaff generator's terminal, given that it stores 8.00 mC of charge at a voltage of 12.0 MV?

Find the capacitance of a parallel plate capacitor having plates of area $5.00\ m^2$ that are separated by 0.100 mm of Teflon.

(a)What is the capacitance of a parallel plate capacitor having plates of area $1.50\ m^2$ that are separated by 0.0200 mm of neoprene rubber? (b) What charge does it hold when 9.00 V is applied to it?

Charging



With voltage drop = charge on plate /capacitance

V = Q / C

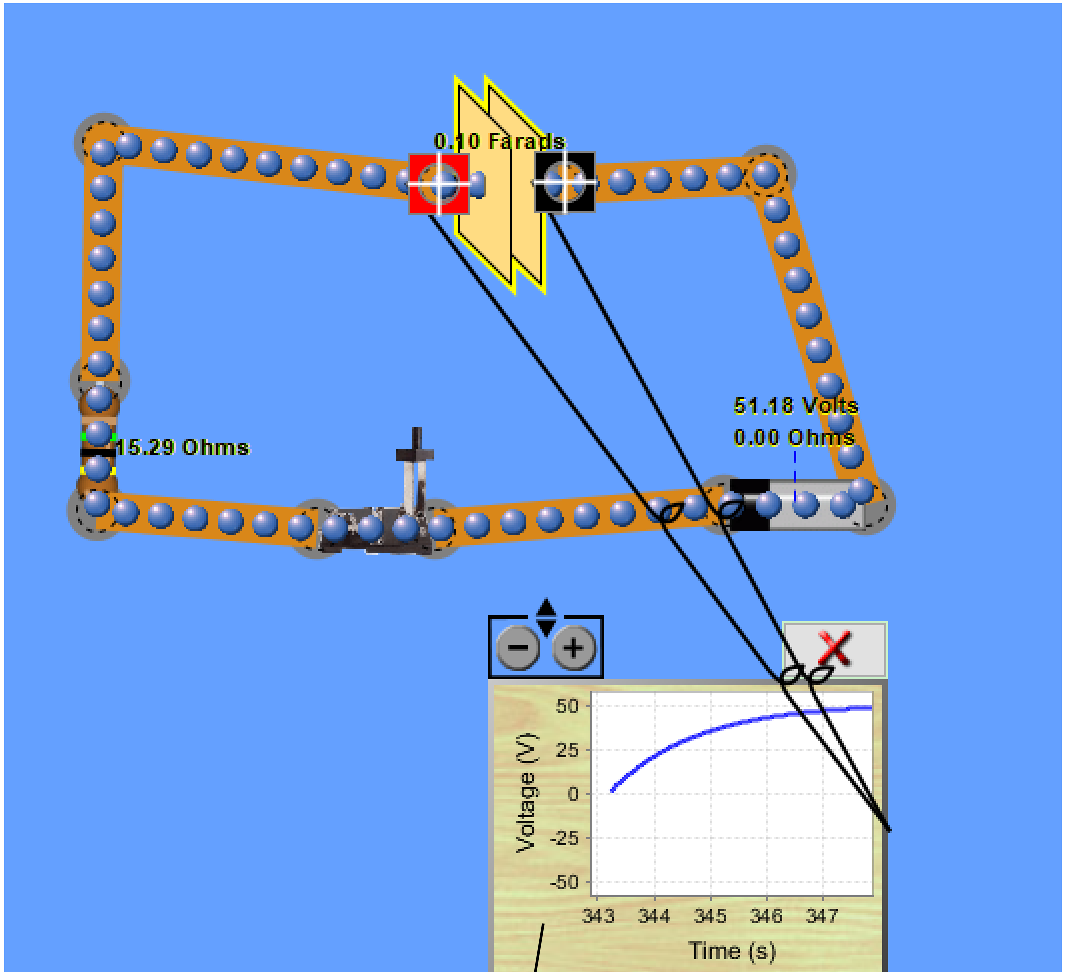
C is the capacitance. (constant). Depends on the Geometry of the capacitor. How much charges it Can takes. Unit is farad.
Q is the charge of the capacitor. Coulombs,

Charging → → At the beginning it is easy to pump the water up Then it gets harder because of the weight of The water. Same idea when you charge a capacitor

T = RC is called the time constant of the capacitor. It it the time it takes to charge it at 63%.

https://phet.colorado.edu/en/simulation/circuit-construction-kit-ac

Use C = 0.05F R=50 ohms Battery = 50V



This graph shows the voltage across the capacitor as a function of time. V(t). The voltage increases from 0 to 50V. First the voltage increases quickly then Slowly. The slope is steep then flats out.

Note for me: capacitor_app.jar from phys116

https://phet.colorado.edu/en/simulation/circuit-construction-kit-ac

This is charging a capacitor
Through a resistance

The voltage of the battery is 50V
The resistance is 15.29 ohms
The capacitance is 0.1 Farads

The time constant is R C = 1.53s
It is the time to get to 63% of the
Maximum voltage 50V.

Observe the voltage across the
Capacitor. It is increasing until
It reaches 50V.

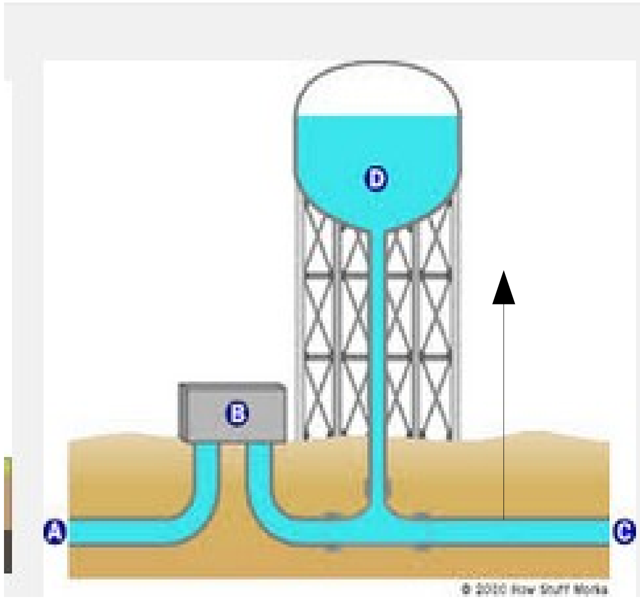
What is 63% of the max value ?
Check if after t = RC the voltage is
Indeed about 63% of 50V

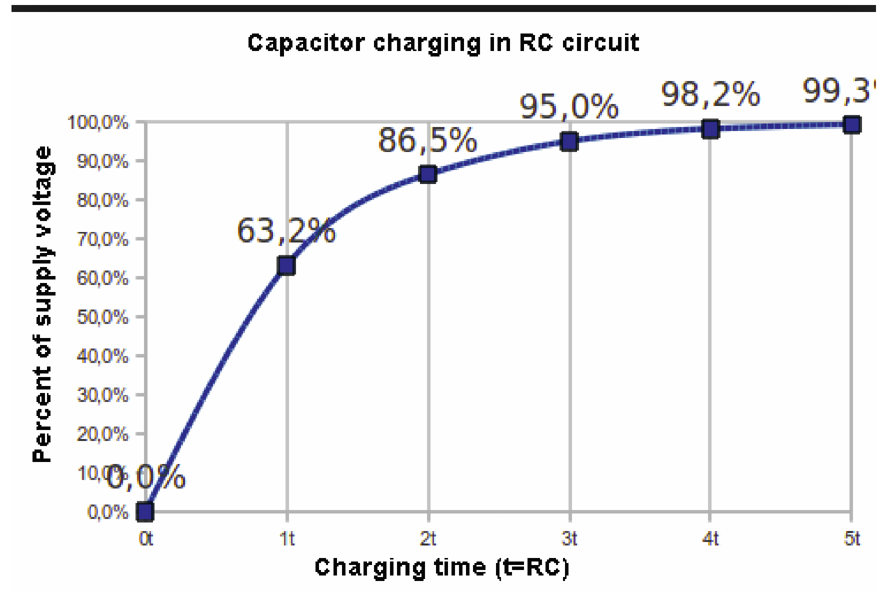
The equation of the charge is:
$V(t)=50(1-e^{-t/RC})$
Plug that with wolfram alpha.

plot 50*(1-e^(-t/1.53)) t from 0 to 5

Check that when t=1.53s
The voltage is about 63% of 50

Use the equation to find the voltage when
t=2s, 3s, 4s





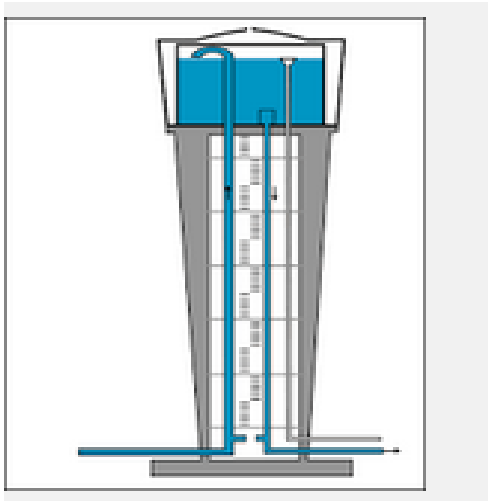
http://micro.magnet.fsu.edu/electromag/java/capacitor/index.html

Equation of charge $V(t) = Vmax\,(1 - e^{-(t/RC)})$ Vmax is the voltage of power supply used To charge the capacitor.

R is the resistance through which the cap is charging
C is the capacitance of the capacitor.
V(t) is the voltage across the capacitor.

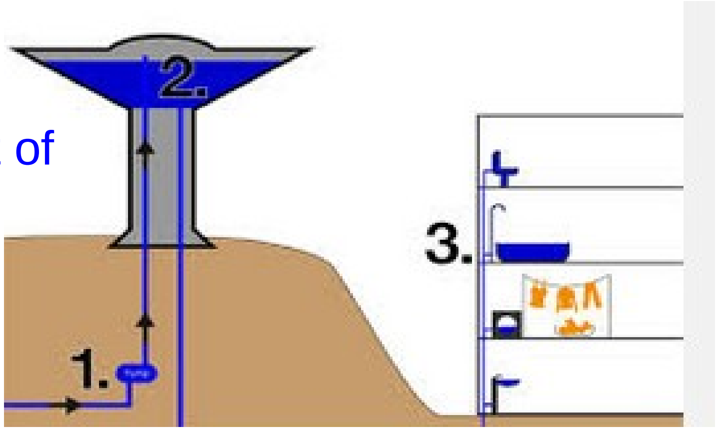
Suppose you are charging a capacitor with a power supply of 20V
The capacitance is 0.1F and the resistance is 100 ohms

What is RC ? What is the voltage across capacitor when t = RC
What is the equation V(t) ? What is the voltage when t = 5s, 10s, 20s, 30s ?
Use TI



Discharging in a load

Like emptying the tower.
First it’s fast. The weight of
The water is pushing
Then it slows down.



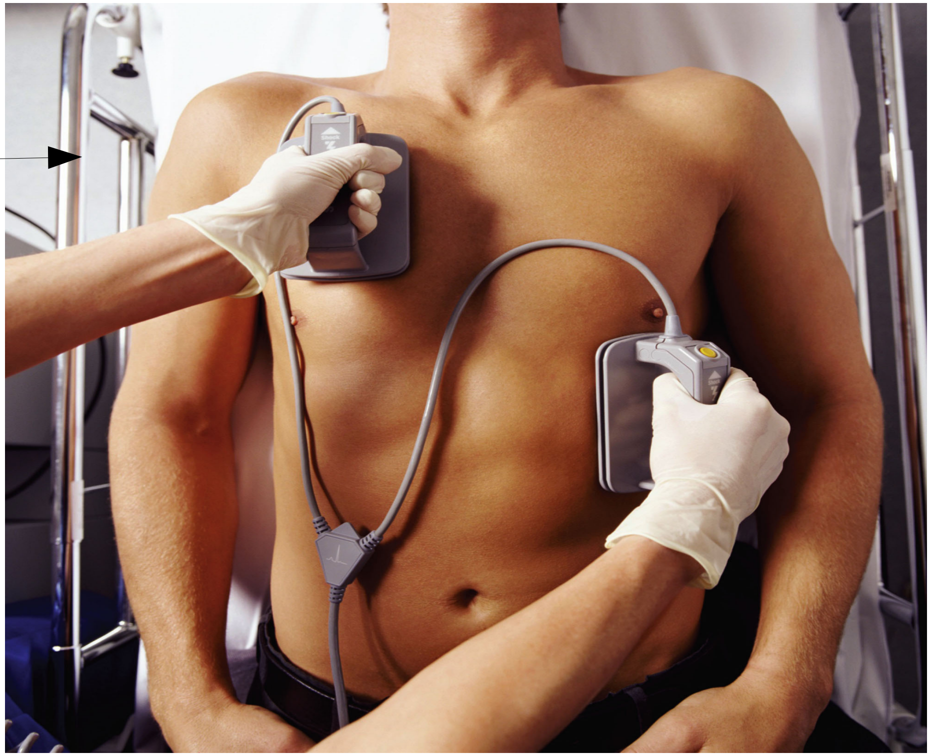
http://micro.magnet.fsu.edu/electromag/java/capacitor/index.html

The load is the heart.

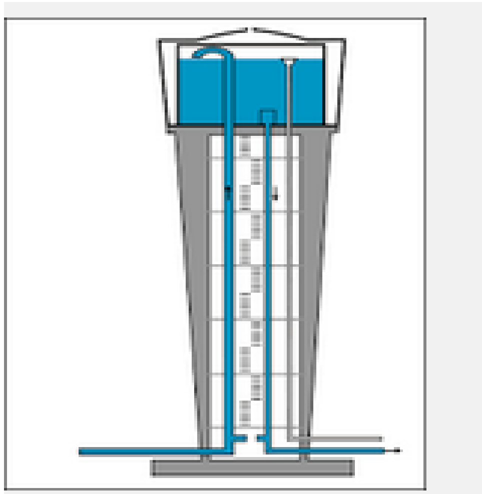
The capacitor discharges in the load.

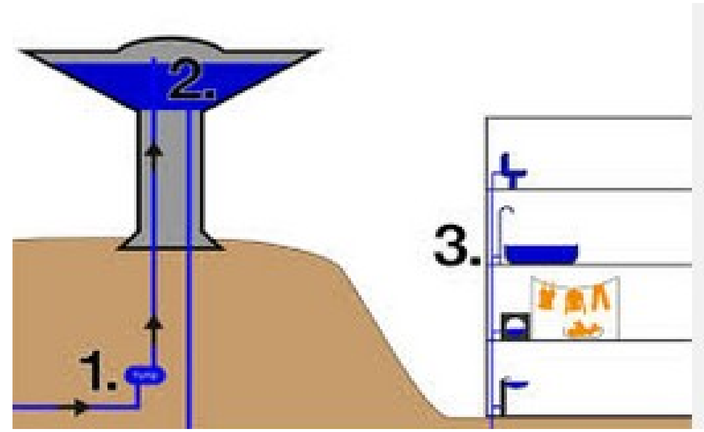
The time it takes to discharge
Depends on C and R.
If the resistor is small (heart) =
Huge surge in current. The energy is
Dumped in a small amount of time.

RC is the time for 63% of the capacitor
To be discharged.
It remains 37% of the initial voltage.



Discharging in a load





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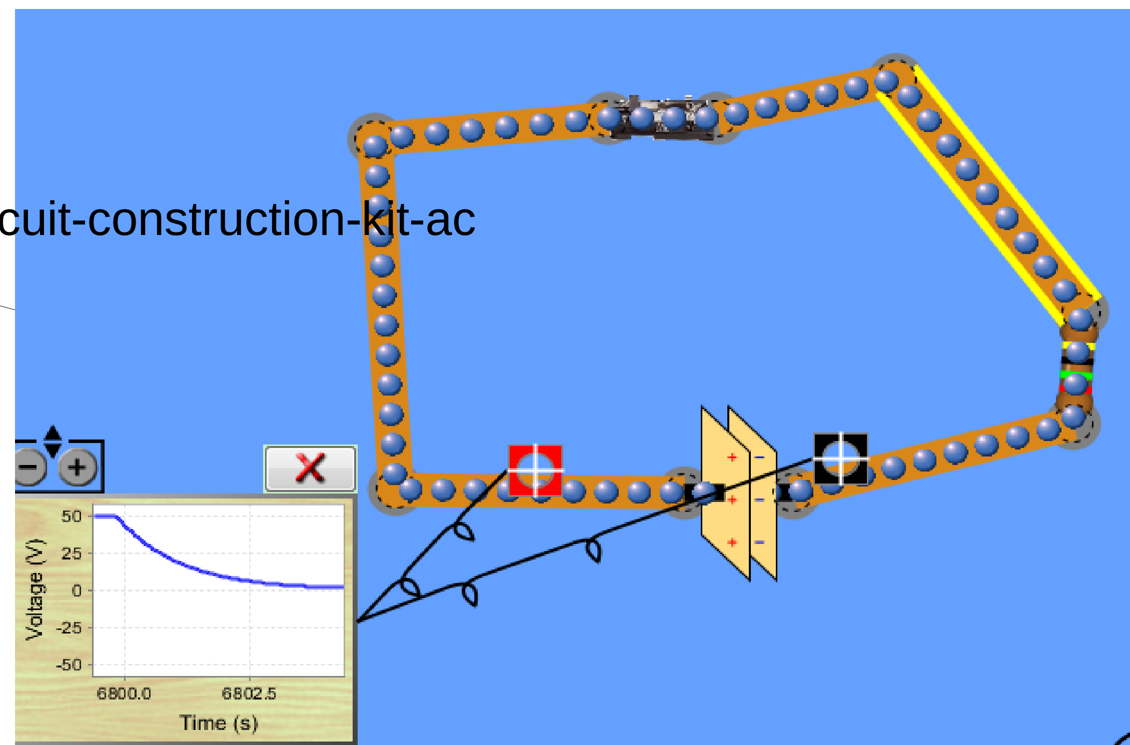


Use C = 0.1F   R=15.3 ohms
Battery = 50V

Use wolfram alpha:

plot 50*e^(-x/1.53) x from 0 to 5

This is the equation that describes the Graph of the Discharge of the capacitor: Voltage versus time.
It is an exponential decay.

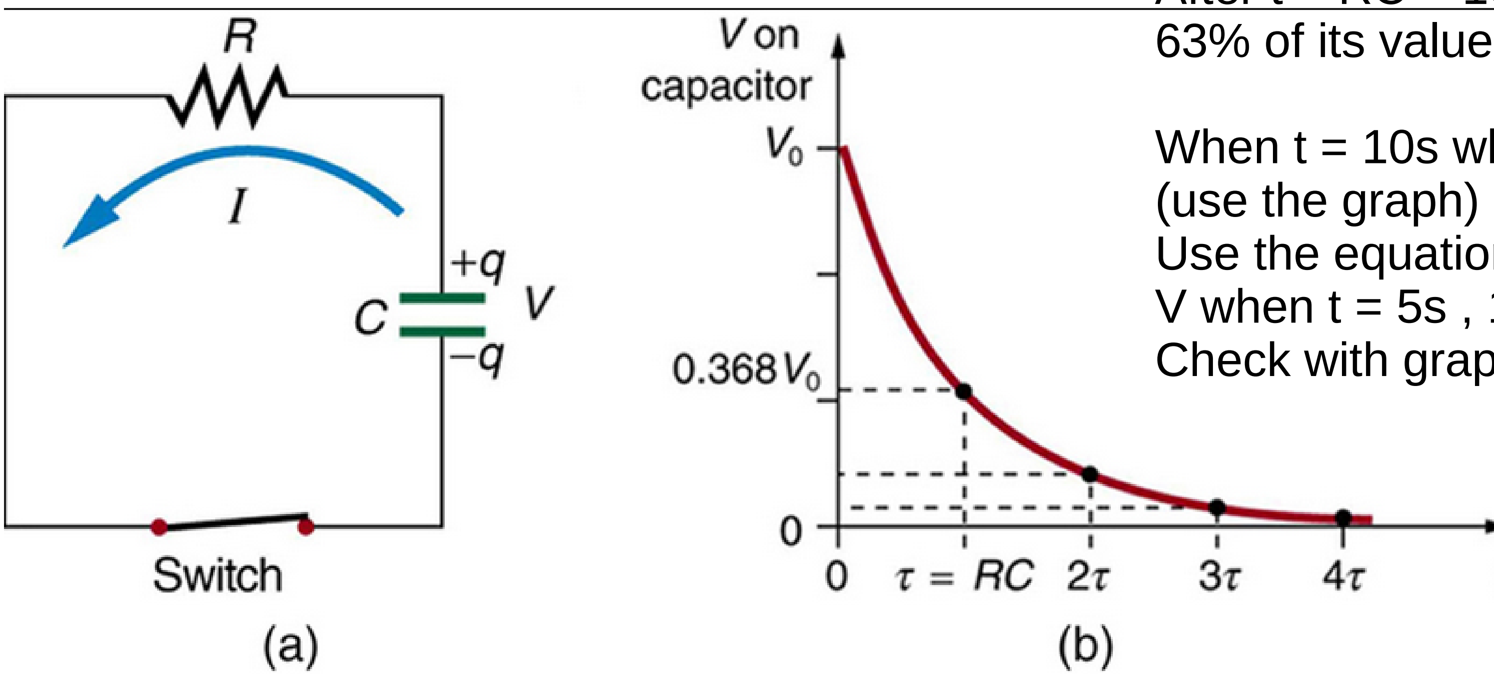
RC is called the time constant (seconds).
C is the capacitance (farads)
R the resistance of the load (ohms)

$$V = V_0 \, e^{-\frac{t}{RC}}$$

ln V = ln(Vo) – t / RC

Suppose V = 50V, R 100ohms C = 0.1F
What is the equation ?
Plot using wolfram alpha.

plot 50*e^(-t/10) for t from 0 to 50



After t = RC = 10s the capacitor loses 63% of its value. So 37% is left.

When t = 10s what is the voltage.
(use the graph) is it 37% of 20V ?
Use the equation to compute
V when t = 5s , 10s, 20s ?
Check with graph

A 10V voltage is used to charge a capacitor through a 500 ohms resistor.

The capacitance of the capacitor is 0.01 F (micro farad)

A) What is the time constant in seconds ?

B) The capacitor is now discharging in the resistance.

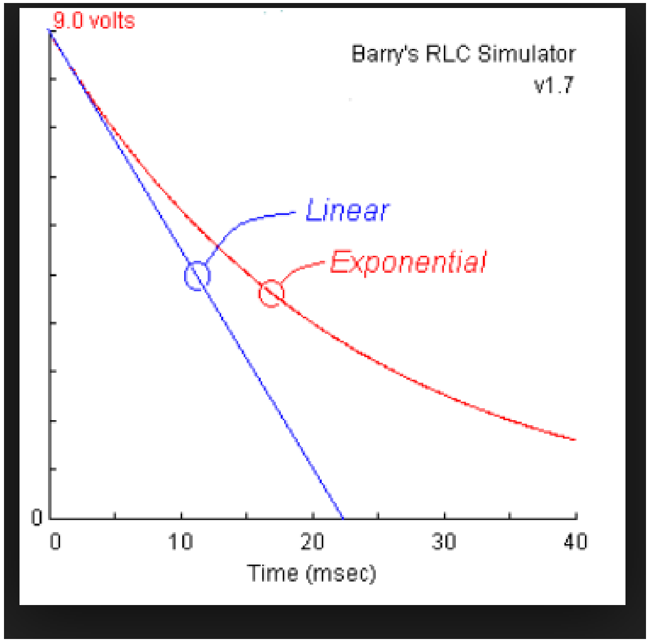
C) What is the equation of the voltage across the capacitor ?

D) Plot the equation for x between 0 and 10

E) Use the equation to find the voltage at 2 s , 4 s , 6s, 8s   check with graph,

F) The time constant is the time it takes for voltage to decrease by 37%. 37% of 10 is _____-
Use your graph to find the time it takes for the voltage to decrease by 37%

Compare to the time constant R * C



$$V = V_0 \, e^{-\frac{t}{RC}}$$

.ln V = ln(Vo) – t / RC

1/RC is the slope of the line.

Using oscilloscope: