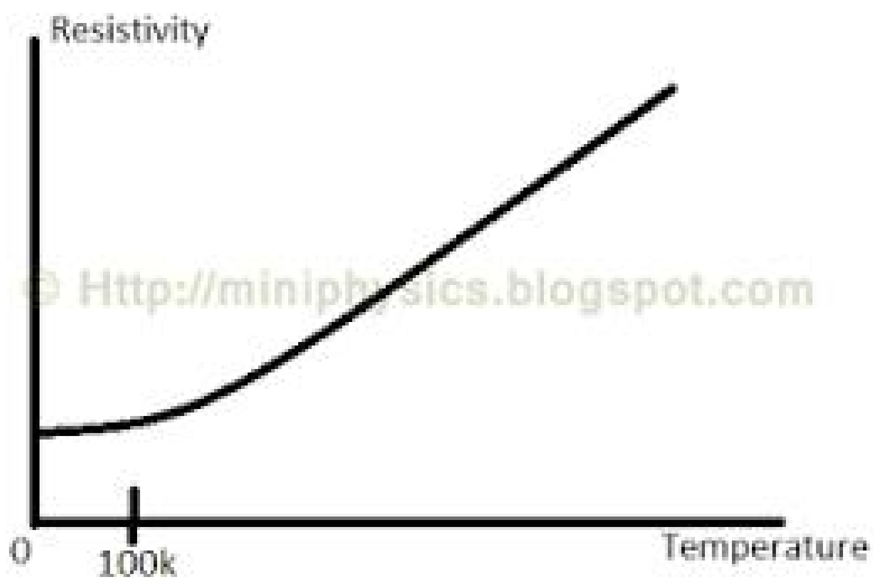
SUPERCONDUCTORS

A superconductor is any material that can conduct electricity with no resistance.

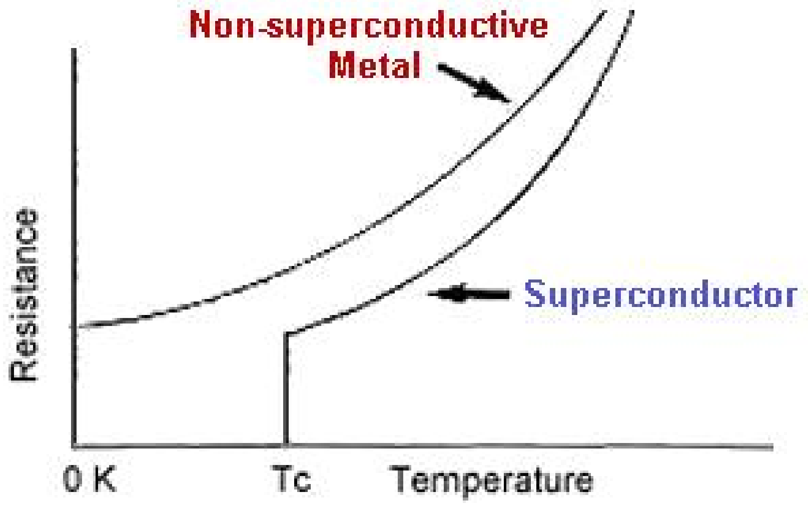
TEMPERATURE DEPENDENCE OF RESISTANCE OF METAL

- Because of loss of electrons atoms become positive ion cores.
- Lattice Vibrations
- Scattering of the conduction electrons by lattice vibrations
- $\rho=\rho_{\circ}+\rho(T)$



Superconductivity And its Properties

- At a particular temp T_c, the resistivity abruptly drops to zero.
- The temp At which a normal material turns into superconducting state is called **critical temperature.**
- Critical Temp is different for different superconductors.



For mercury it is 4.2°K

Magnetic Field Effect (Critical Field H_c)

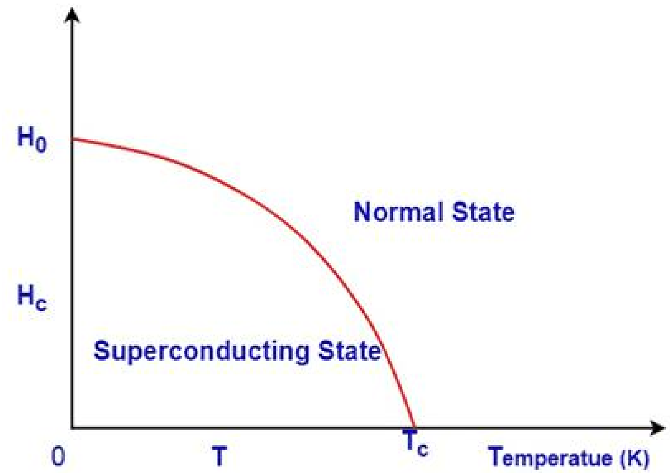
- The superconducting state of a superconductor is mainly dependent upon:

(i) Temperature

(ii) Strength of applied magnetic field

- Superconductivity vanishes if the temp of it is increased above T_c.
- Or very strong sufficient field H is applied to it.

- If sufficiently strong H is increased at any T below critical temp Tc , then superconductor is found to be converted into normal resistive conductor.



Variation in critical magnetic field with temperature

- The minimum value of the magnetic field required to destroy the superconducting phase completely is known as **critical magnetic field H_c**.
- **H_o is** critical field at T=0K

- Critical magnetic field Hc is the function of temperature given by;

$$H_c = H_\circ[\ 1 - T^2/T_c^2]$$

Where,

H_c = Critical field at ant temp T

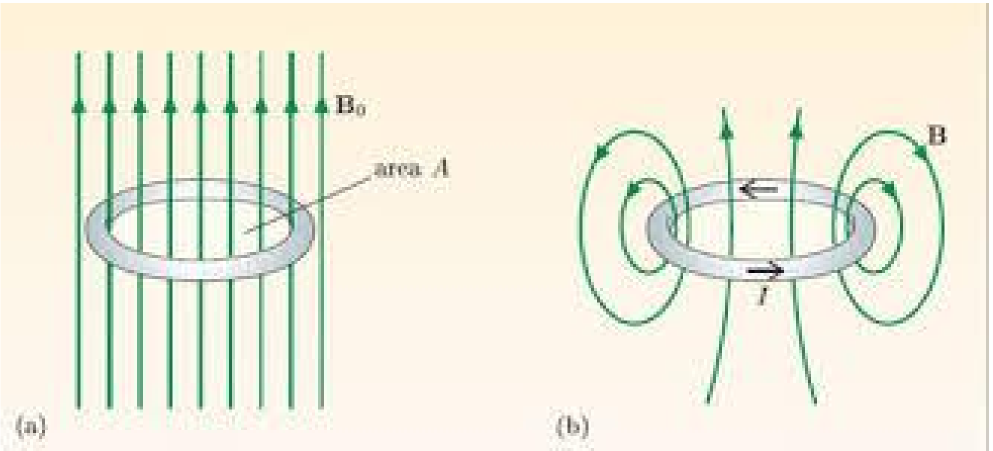
H_o = Critical field at 0°K

T_c = Critical temp of the superconductor

Material	**T**	**Bc,**
Aluminum	1.2 K	0.01 T
Indium	3.4 K	0.03 T
Lead	7.2 K	0.08 T
60Sn-40Pb	7.8 K	0.2 T
97Sn-3Ag	3.7 K	0.02 T
26Sn-34Bi-20Cd	3.7 K	0.06 T

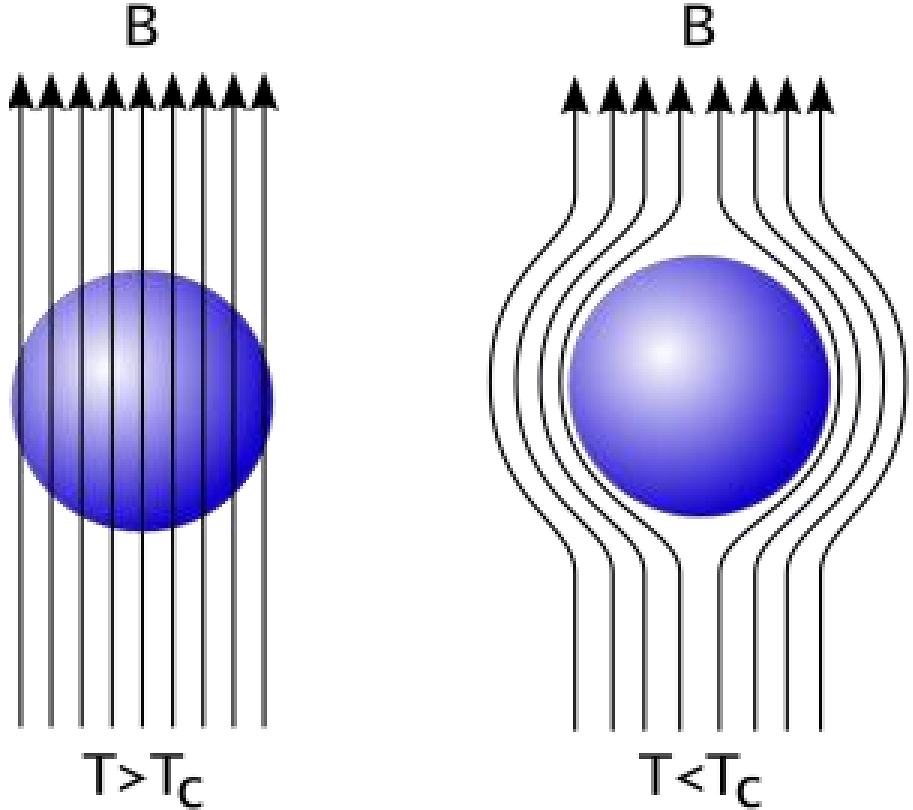
Persistent current

- A superconductor can carry current for a long time (several years) without any applied field(voltage). The current is called as "persistent current".
- Coils of superconductor with persistent current produce magnetic field.
- **Superconducting magnets**



MEISSNER EFFECT

- A superconducting material kept in a **magnetic field expels** the magnetic flux out of its body when **cooled below the critical temperature** and exhibits perfect diamagnetism. This effect is called **'Meissner effect'**.



- As specimen expels magnetic flux, it exhibit perfect diamagnetism, **susceptibility** is found out to be -1.

- For normal state, magnetic induction inside the specimen is given by,

$$B=\mu_o (H + M)$$

Where, μo = Absolute permeability
H = External field applied
M = Magnetization produced within specimen

At $T< Tc$, $B = 0$ i.e. superconducting state

$$\mu_o (H + M) = 0$$

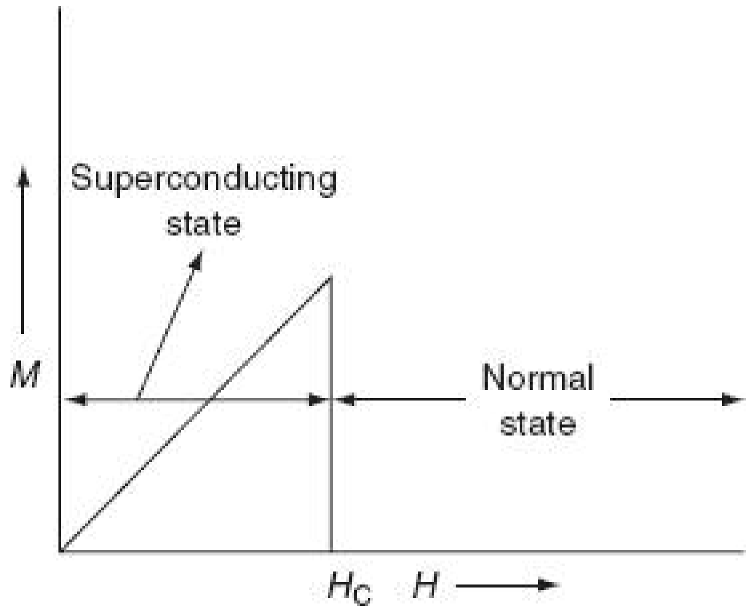
- **Susceptibility ,** χ **= M/H = -1**

It's the diamagnetism which brings strong repulsion to an external magnets.

TYPES OF SUPERCONDUCTORS

- **Type – I superconductors**

- In the presence of a magnetic field $H<H_c$, the material in superconducting state is a perfect diamagnet.
- The transition from superconducting state to normal state in the presence of a magnetic field occurs sharply at the critical value H_c.
- Eg. Al,In,Pb



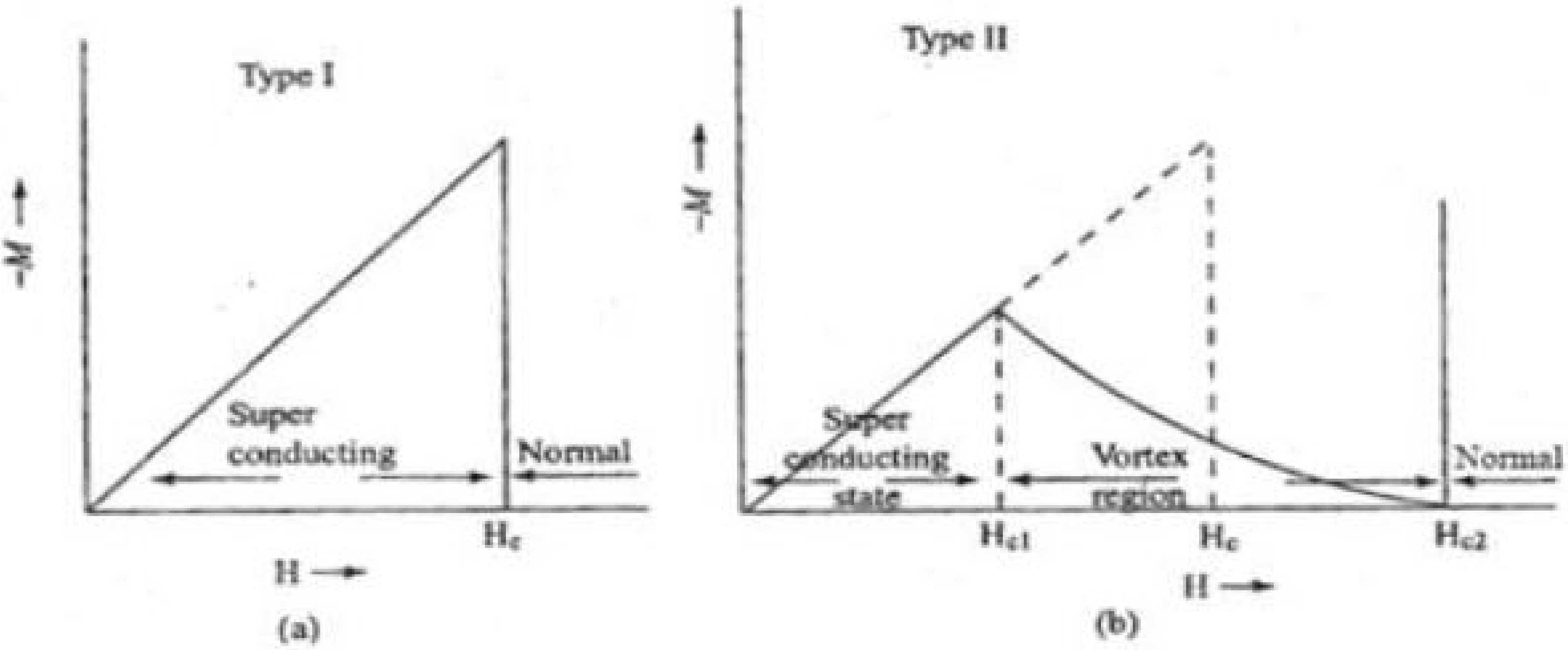
TYPE-II SUPERCONDUCTORS

- Characterized by two critical magnetic fields, H_{c1} and H_{c2}.
- **$H < H_{c1}$**

  Expels the magnetic field from its body completely and behaves as a perfect diamagnet.
- **$H > H_{c1}$**

  Flux penetrates and fills partially in the body of the material. With further increase in H, the flux filling also increases and diamagnetic property decreases.
- **$H = H_{c2}$**

  Material turns into a normal conductor



- The specimen is in **mixed state between Hc1 and Hc2 .** And above Hc2 returns to the normal state.
- The Meissner effect is incomplete in the region between Hc1 and Hc2. This region is called as **vortex or mixed region.**
- In this region, the specimen possess zero resistance and partial penetrating flux.

COMPARISON B/W TYPE1,2 SUPERCONDUCTORS

Type I superconductor	Type II Superconductor
1. These superconductor are called as soft superconductor.	These superconductor are called as hard superconductor.
2. They exhibit complete Missner effect.	They do not exhibit complete Missner effect.
3. They have only one critical magnetic field, H_c	They have two critical magnetic field, lower critical magnetic field HC_1 and upper magnetic field HC_2
4. The material loses magnetization abruptly.	The material loses magnetization gradually.
5. Example :Pb,Sn,Hg	Example: Nb-Sn, Nb – Zr, Nb_3Ge, Nb3si

SUPER CAPACITORS

- Supercapacitor is an electronic device that store large amount of electric charge. These capacitors are also known as ultracapacitors or electric double layer capacitors.
- A energy storage device that stores energy electrostatically by polarizing an electrolytic solution.
- Stores energy via electrostatic charges on opposite surfaces of the electric double layer.

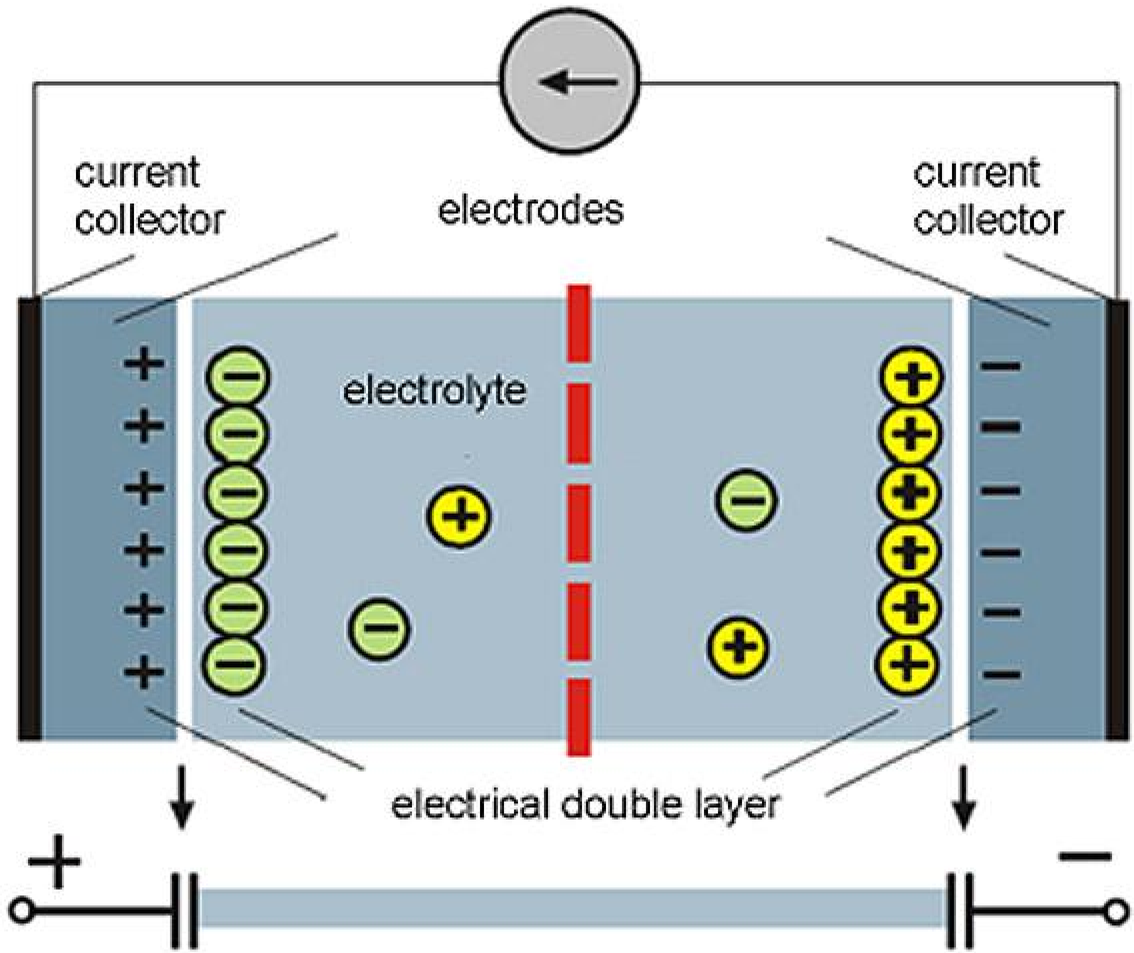
Principle

- They store and release energy by reversible absorption and desorption of ions at the interfaces between electrode materials and electrolytes.

- Compared to common rechargeable batteries they have-

1. Considerably high specific power
2. Longer cycle life times

Working


current
collector
electrodes
current
collector
electrolyte
electrical double layer
+
−

Types of capacitors

i) Electrostatic capacitors:

- Low capacitance
- Capacity: few Pico-farads to low μF

ii) Electrolytic capacitor:

- Higher capacitance than electrostatic capacitor
- Capacity: μF

iii) Super capacitor:

- Higher capacity than electrolytic capacitor
- Capacity : F
- Used for energy storage undergoing frequent charge and discharge cycles at high current and short duration.

Advantages and Disadvantages

ADVANTAGES	DISADVANTAGES

ADVANTAGES

- Long Life
- Rapid charging
- Low cost
- High power storage
- Faster release

DISADVANTAGES

- Low energy density
- Individual cell shows low voltage
- Not all energy can be used during discharge
- High self discharge
- Voltage balancing required

APPLICATIONS

- LED flashlights, laptop batteries, digital cameras etc
- Used in portable media players, laptops or similar hand held machine
- For energy harvesting systems
- Emergency power back up in low power equipments
- Industrial lasers, medical equipment

COMPARISON WITH CAPACITOR AND BATTERIES, ENERGY DENSITY, POWER DENSITY

- It takes longer time to charge our regular alkaline or Li-ion batteries. Imagine if we go for advanced industrial requirements like electrical vehicles, the charging time is big hurdle.

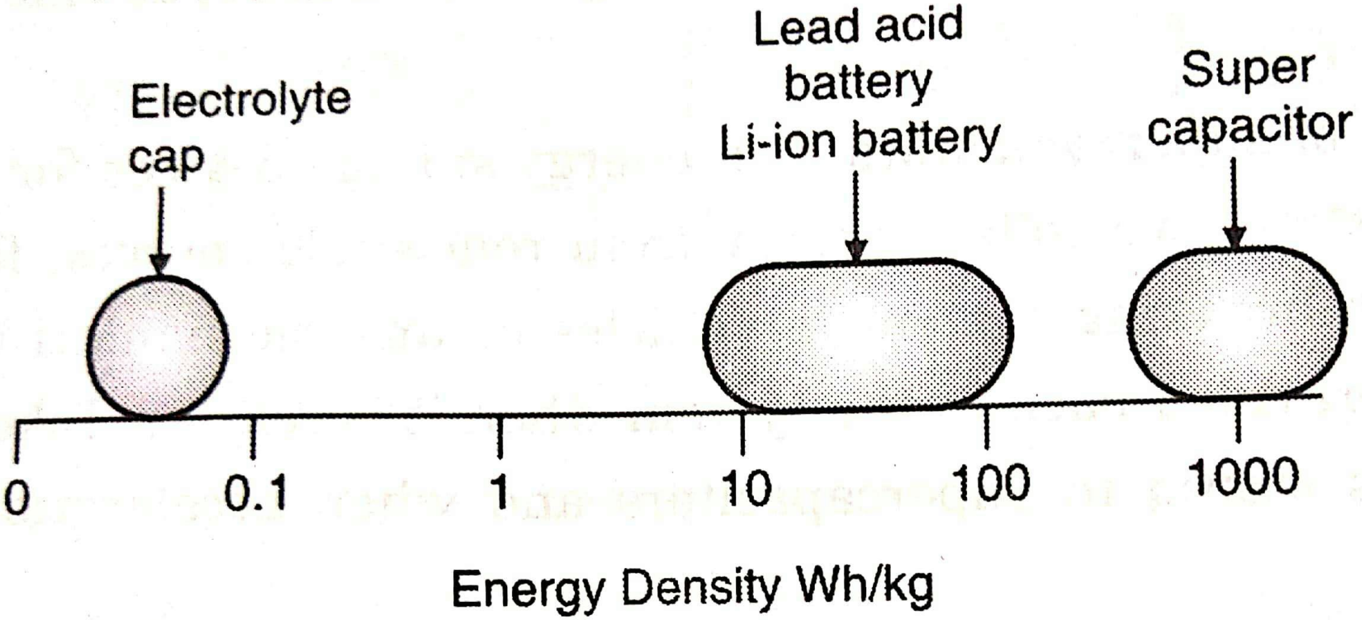
- Conventional capacitor is energy storage device and energy stored in given by

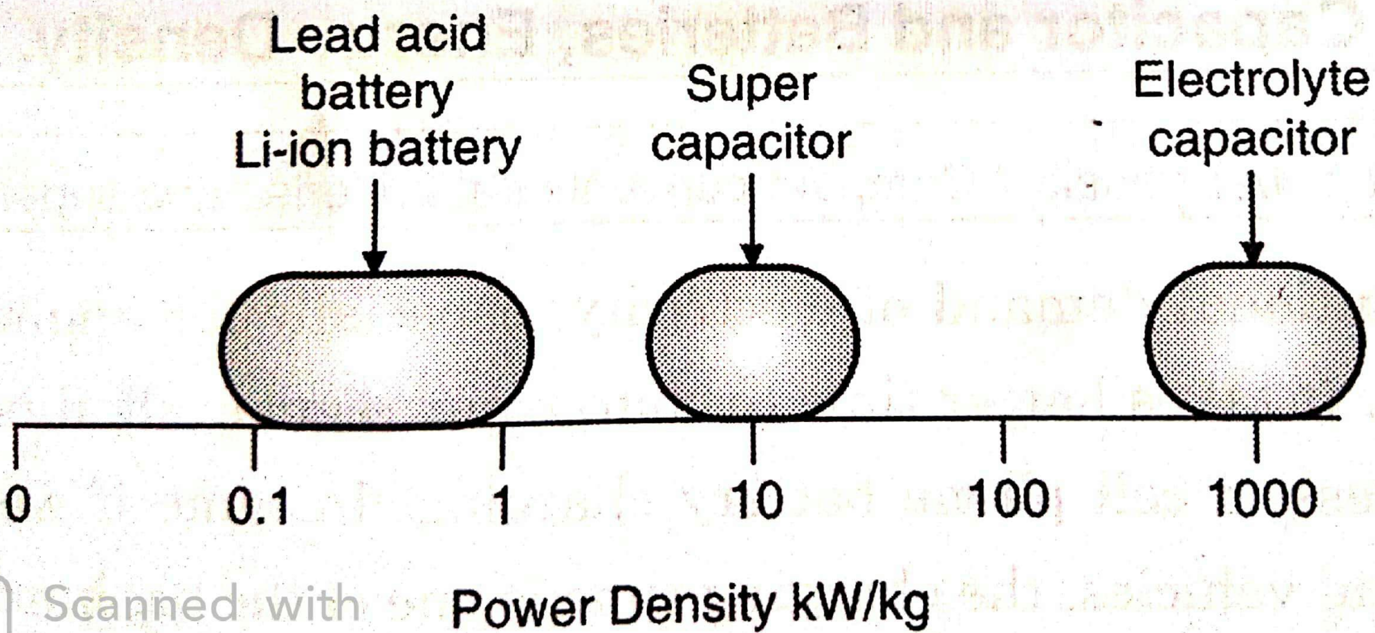
$$E=1/2\ CV^2$$

- If the capacitor energy is represented in terms of energy stored in capacitor it is represented in terms of per unit volume of that capacitor, it is called as **energy density**.

- **Specific power** is a term which describes the speed at which energy can be delivered to or absorbed from the load. If it is measured per mass, it is said to be representing specific power.

- Similarly, if measured volumetrically i.e. per unit volume of capacitor, it is known as **power density.**


Electrolyte cap
Lead acid battery
Li-ion battery
Super capacitor
0
0.1
1
10
100
1000
Energy Density Wh/kg


Lead acid battery
Li-ion battery
Super capacitor
Electrolyte capacitor
0
0.1
1
10
100
1000
Power Density kW/kg