Superconductivity

Thomas Jefferson National Accelerator Facility

What is it?

Superconductivity allows electricity to flow through a conductor without resistance.

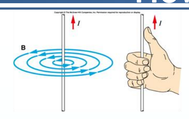
If you flow electricity into a metal wire loop, it will conduct electrical current until the power source is removed.

BUT if the loop is made superconducting by keeping it cooled with liquid Helium, you could start a flow of electricity, remove the power source and ONE YEAR LATER the electricity WOULD STILL BE FLOWING!

Now that's SUPERconductivity! It is a way of ELIMINATING energy loss!

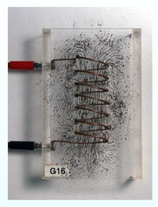
Here you see an ordinary cube-shaped magnet floating above a disc of superconducting material which is being cooled by liquid Nitrogen. This phenomena is called the Meissner Effect after one of the scientists who discovered it.
The superconducting disc behaves like a magnet and opposes the cube-shaped magnet forcing it to levitate.

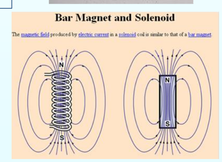
How do we produce useful magnetic fields?

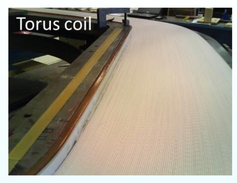


Magnetic field (B) ∝ Current (I) x Number of Turns (N)

A coil of wire looks just like a magnet with North and South poles



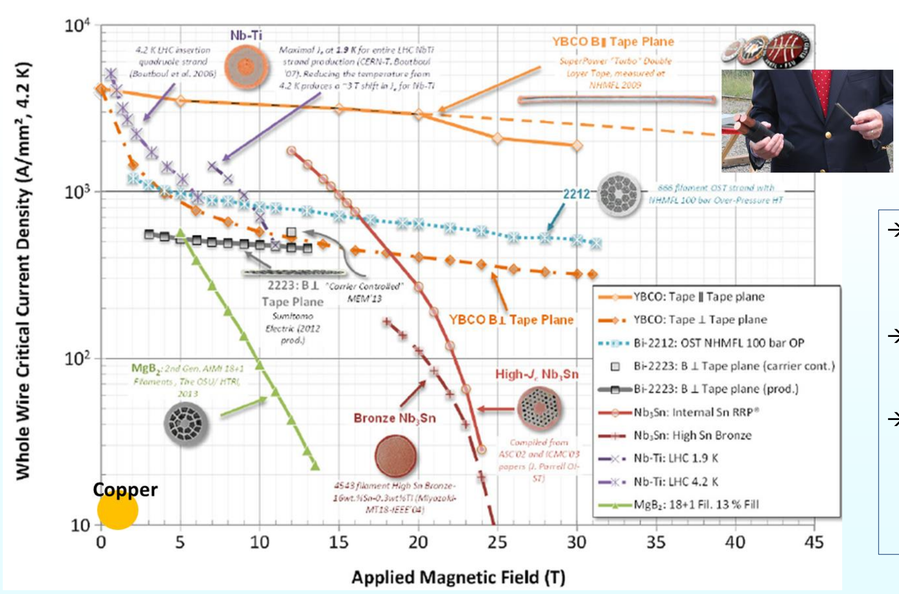




→ By making loops of wire with lots of turns and flowing electrical current through the wire

→ Just like the coils we are using in our two big superconducting magnets, the TORUS and the SOLENOID

Why do we use superconducting magnets?



→ So we can produce HIGHER magnetic fields, make our magnets SMALLER and INCREASE overall efficiency.

→ A small amount of superconductor can carry much more electricity than the same amount of Copper

→ The chart here shows some of the different types of superconductor and how much electrical current they can carry to produce different magnetic fields – can you spot where Copper is?

History of Superconductivity

1700 BC
Zimri-Lin (Iraq)
Built an 'ice-house' – pit filled with ice

1878

John Fleming (England)
Predicted at absolute zero, pure metals would have zero resistance

1895

William Hampson (England)
Liquefied air using Joule-Thompson Effect
→ *formed the British Oxygen Company*

1892

Carl von Linde (Germany)
Low temperature refrigeration using Joule-Thompson Effect
→ *formed the Linde Company*

1874

James Dewar (Scotland)
Research into electrical resistance at low temperatures

1900

Nikola Tesla (Serbia / America)
Increased intensity of electrical oscillations by lowering temperature

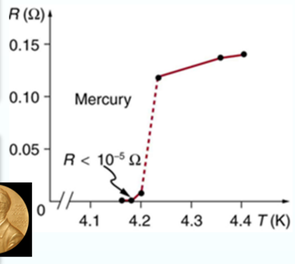
1905

Walther Hermann Nernst (Germany)
Developed 3rd Law of Thermodynamics
→ absolute zero is unattainable

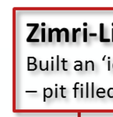
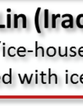
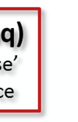
July 10th 1908

Heike Kamerlingh Onnes (Netherlands)
Uses the Hampson-Linde Cycle to achieve low temperatures
Liquefied Helium (4.2 K boiling point at atmospheric pressure)
Investigated platinum, gold and mercury

April 08th 1911 ; 16:00
Observed resistance of mercury drops to zero at 4.19 K
Conducts experiments on the 'usability' of superconductivity **BUT** even low magnetic fields destroyed the superconductivity!!
These are called Type I superconductors → not very useful!



1913
Lead is superconducting at 7 K

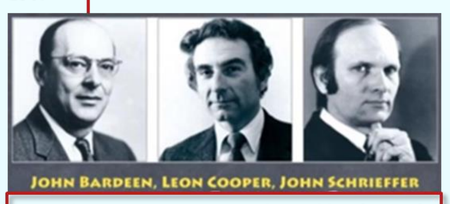
1933



Walther Meissner & Robert Ochsenfeld (Germany)
Discovered that superconductors expelled magnetic fields (Meissner-Ochsenfeld Effect)

1935

Fritz London & Heinz London (Germany)
Furthered research on the Meissner-Ochsenfeld Effect

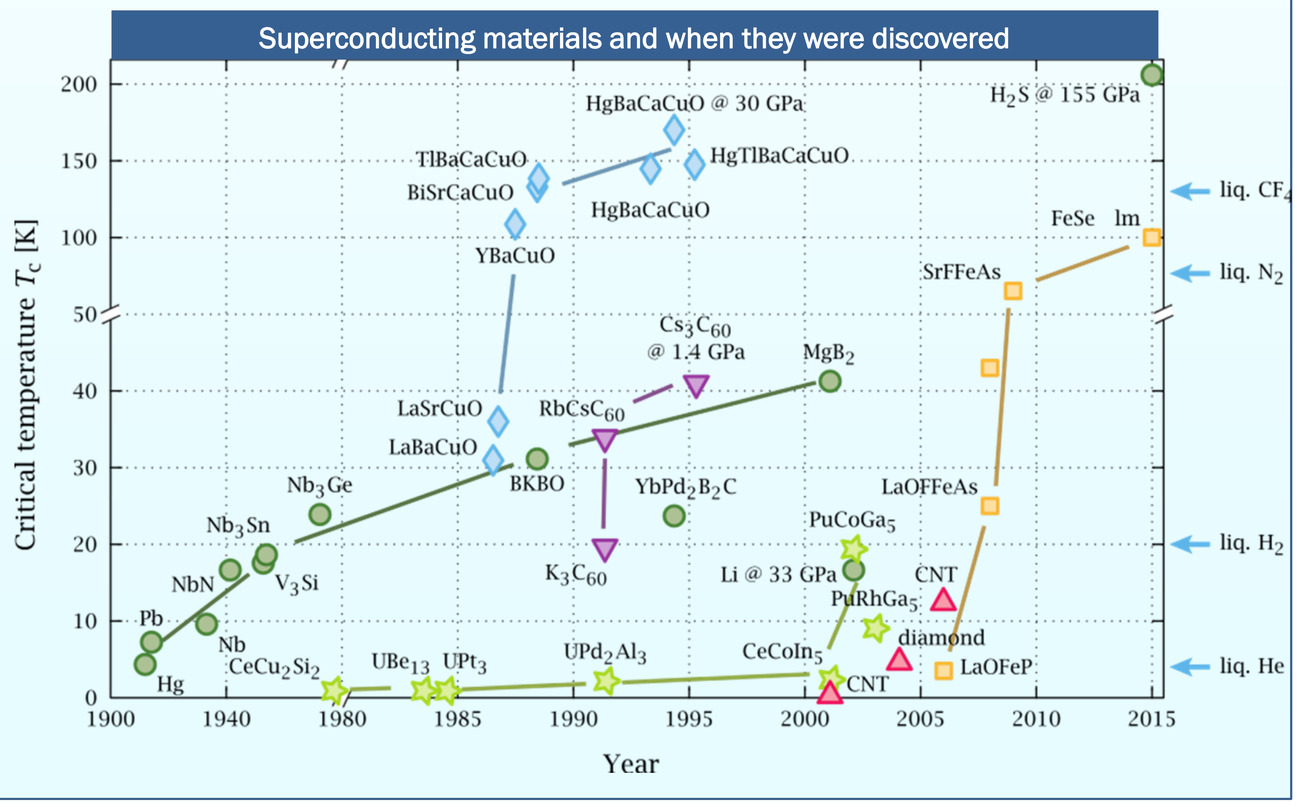
1935

Rjabinin & Shubnikov (Russia)
Experimentally discovered Type II superconductors.
→ Much more useful, can carry current in a magnetic field

1967


Bardeen, Cooper, Schrieffer(USA)
Developed the BCS theory to explain superconductivity

Superconducting materials and when they were discovered



Contributing Institutions

- Jefferson Lab, Newport News, VA, USA