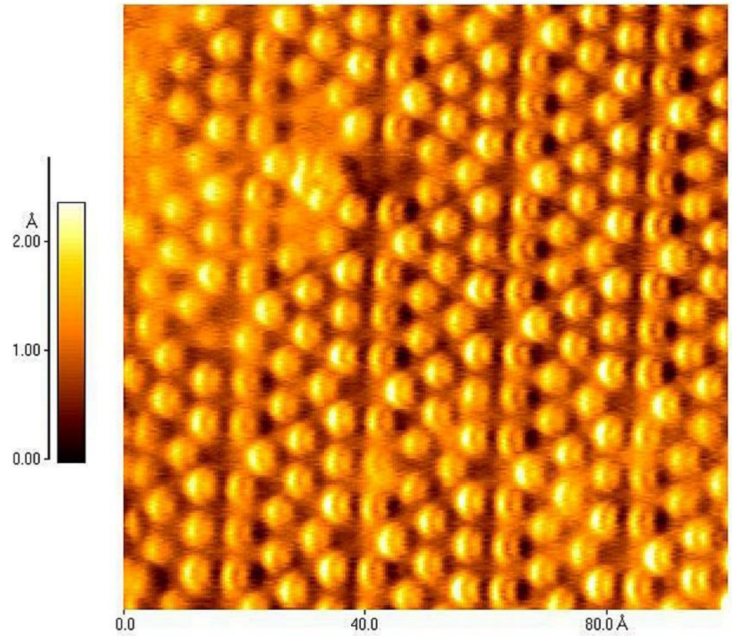
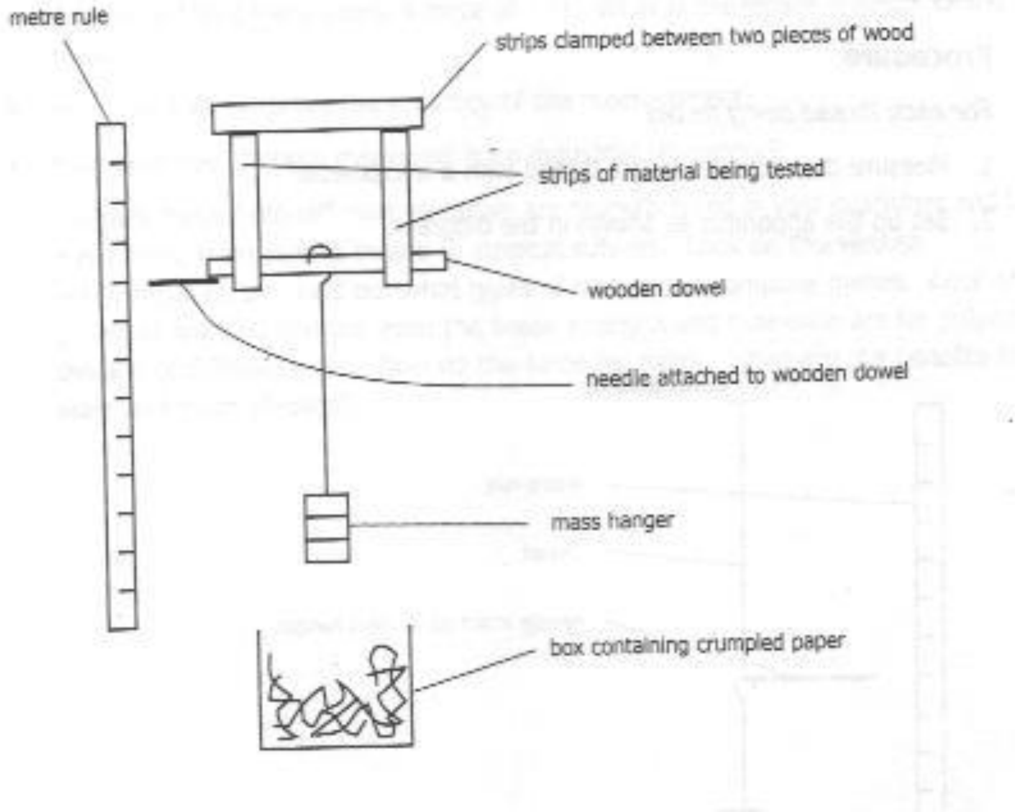
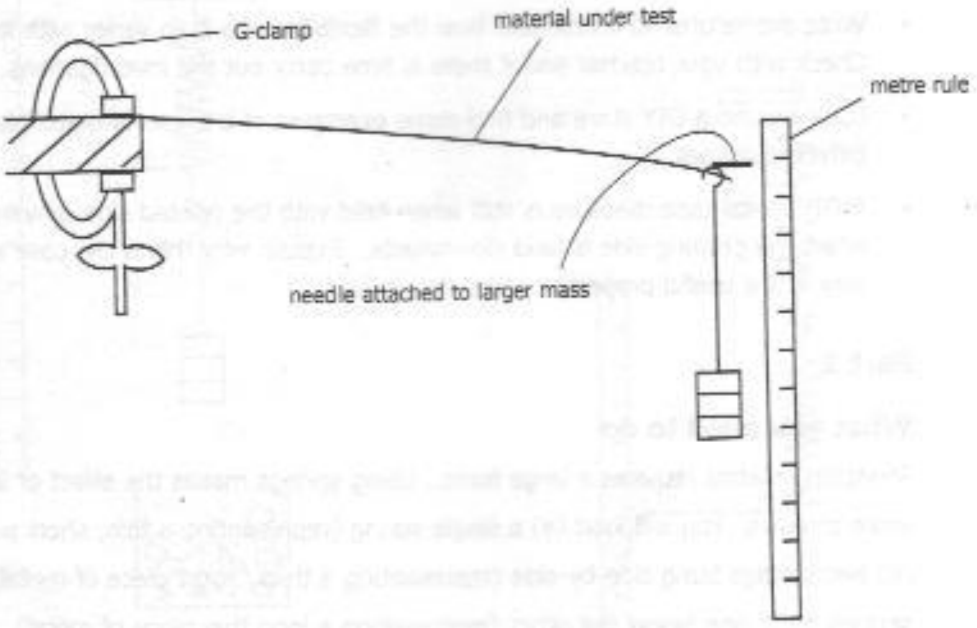
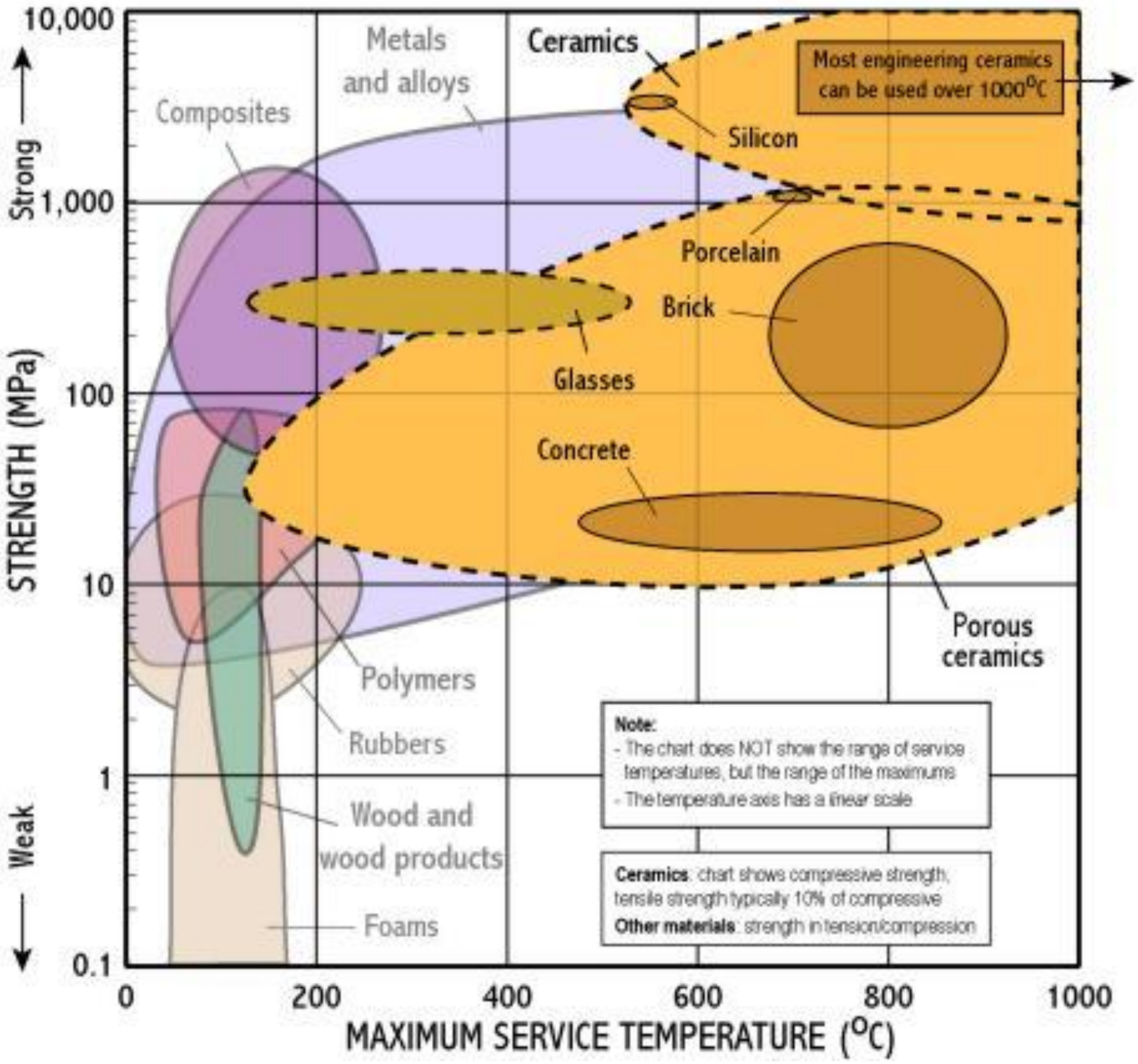

Å
2.00
1.00
0.00
0.0
40.0
80.0 Å


metre rule
strips clamped between two pieces of wood
strips of material being tested
wooden dowel
needle attached to wooden dowel
mass hanger
box containing crumpled paper

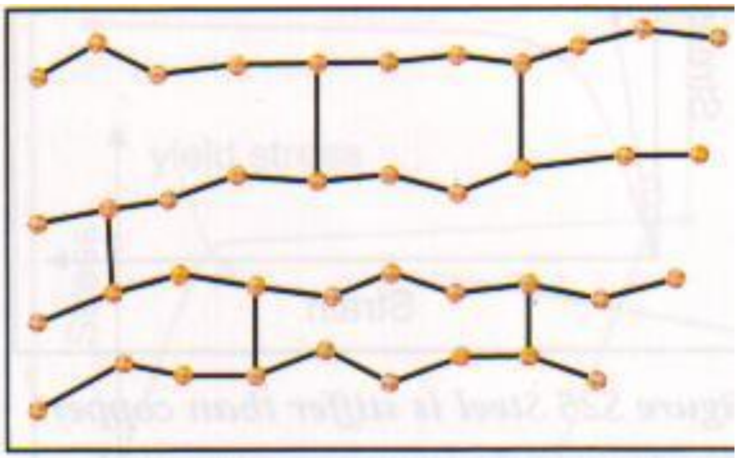

G-clamp
material under test
metre rule
needle attached to larger mass



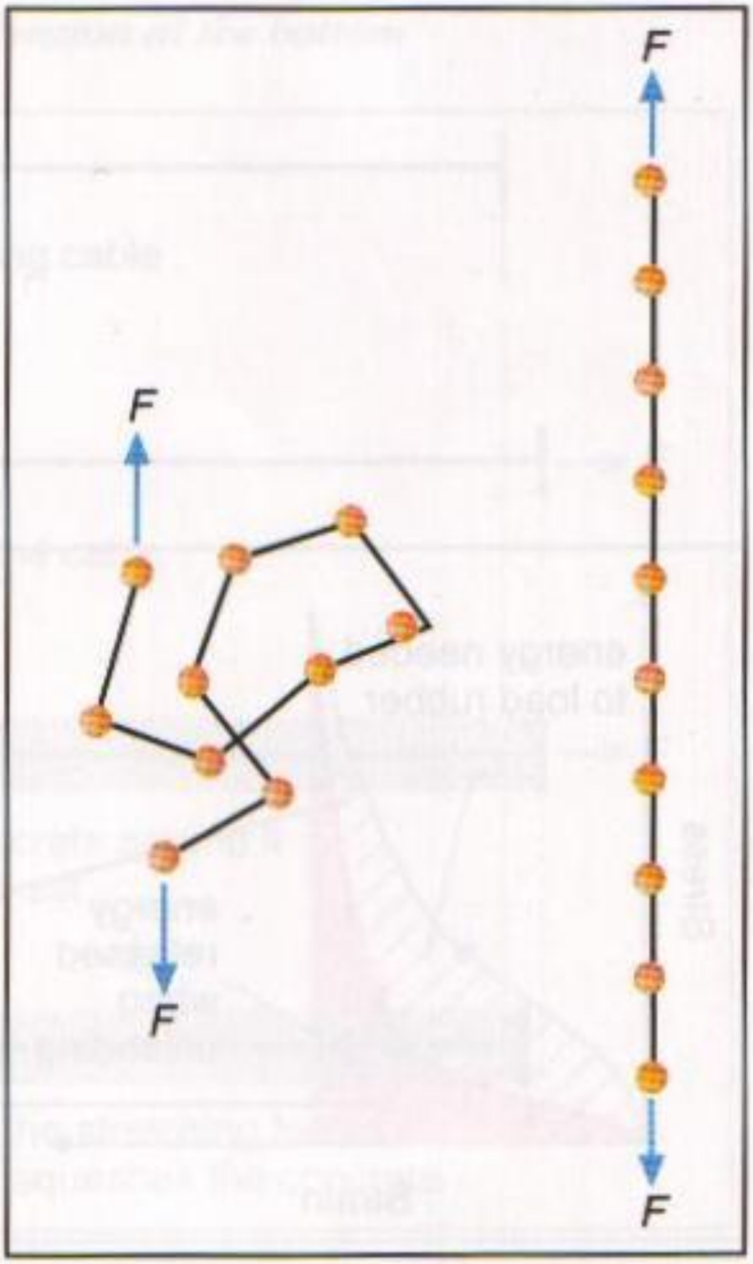
Note:
- The chart does NOT show the range of service temperatures, but the range of the maximums
- The temperature axis has a linear scale

Ceramics: chart shows compressive strength, tensile strength typically 10% of compressive

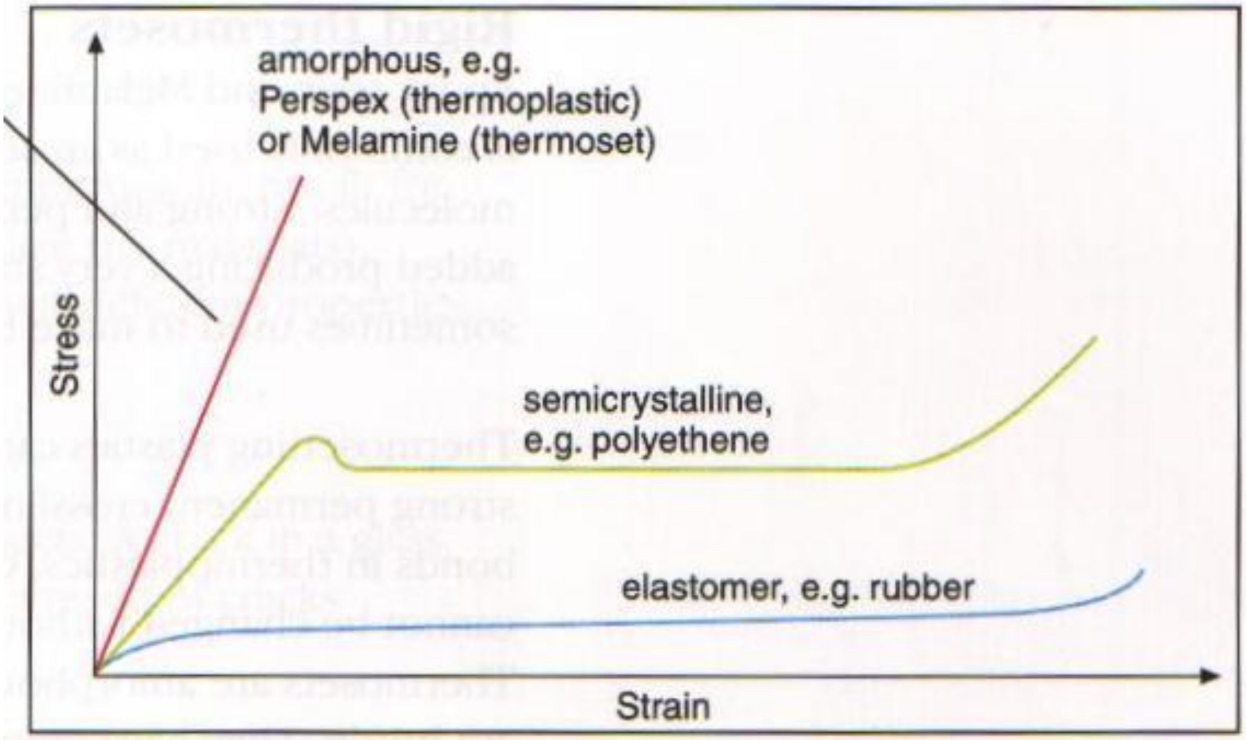
Other materials: strength in tension/compression



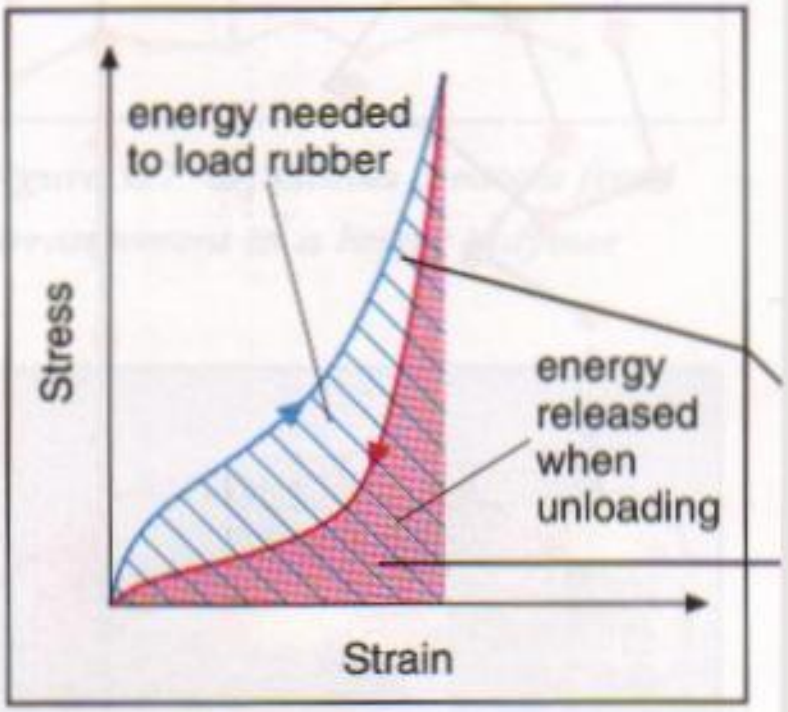
Crosslinks create a fixed arrangement in a linear polymer



It is easier to stretch a coiled molecule than a straight one



Stress–strain graph for a range of polymers



Stress–strain graph for rubber: the work done on the rubber to stretch it is greater than the work done by the rubber as it returns to its original shape

Royal Holloway
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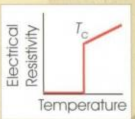
Superconductivity

sponsored by OXFORD INSTRUMENTS

Many metals and compounds become superconducting at low temperatures

Superconductors



- Superconductors have zero electrical resistance below a transition temperature T_C.
- Superconductivity is destroyed above a critical magnetic field.
- Superconductors exclude magnetic fields (the Meissner effect) and levitate magnets.

The picture shows a sumo wrestler standing on a levitating magnet platform that floats above a high-temperature superconductor. The superconductor is cooled by liquid air and hidden below the platform.


The newest version of Japan's Bullet Train


The japanese prototype maglev train

Photos courtesy of the Yamanashi Prefectural Maglev Exhibition Centre

Magnetic levitation trains have superconducting magnets in the train itself, cooled by liquid nitrogen or liquid helium. The track has conventional electromagnets to provide levitation and guidance.

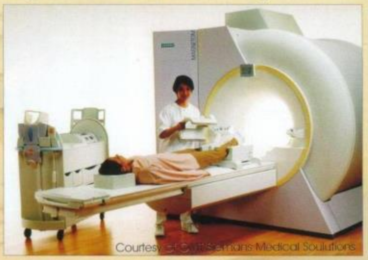
Background courtesy of Oxford Magnet Technology / Siemens Medical Solutions

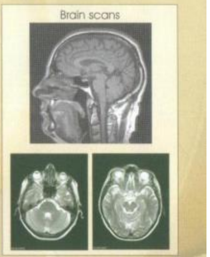
Typical superconductors

- Pure metals such as niobium, $T_C = 9$ K, lead (7.2 K), tin (3.7 K) and zinc (0.88 K).
- Metallic compounds such as Nb_3Sn (18 K) and MgB_2 (39 K).
- High-T_C superconductors such as yttrium barium copper oxide (YBCO) with $T_C = 92$ K.

Superconducting magnets

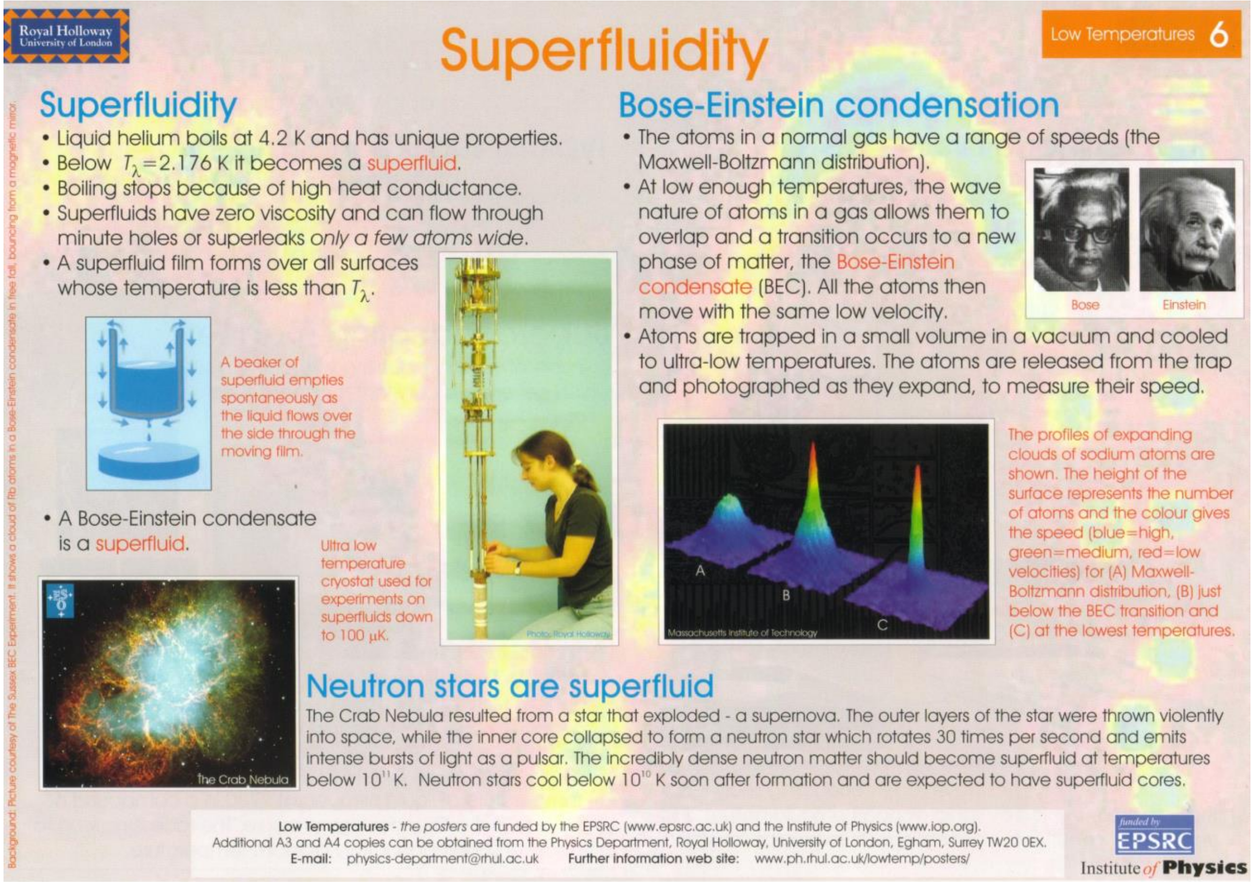
are coils of superconducting wire carrying supercurrents, which generate a constant magnetic field.


Courtesy of Siemens Medical Soulutions


Brain scans

Oxford Instruments pioneered superconducting magnets for MRI (magnetic resonance imaging) using NMR (nuclear magnetic resonance), now widely used for whole-body imaging.

The highest known T_C is 164 K (-109°C, well above the temperature of liquid nitrogen at 77 K) in a compound of Hg-Ba-Ca-Cu-O under high pressure. The race is now on to discover superconductivity at room temperature.



Royal Holloway University of London

Low Temperatures 6

Superfluidity

Superfluidity

- Liquid helium boils at 4.2 K and has unique properties.
- Below $T_\lambda = 2.176$ K it becomes a superfluid.
- Boiling stops because of high heat conductance.
- Superfluids have zero viscosity and can flow through minute holes or superleaks *only a few atoms wide*.
- A superfluid film forms over all surfaces whose temperature is less than T_λ.

A beaker of superfluid empties spontaneously as the liquid flows over the side through the moving film.

- A Bose-Einstein condensate is a superfluid.

Ultra low temperature cryostat used for experiments on superfluids down to 100 μK.

Photo: Royal Holloway

Bose-Einstein condensation

- The atoms in a normal gas have a range of speeds (the Maxwell-Boltzmann distribution).
- At low enough temperatures, the wave nature of atoms in a gas allows them to overlap and a transition occurs to a new phase of matter, the Bose-Einstein condensate (BEC). All the atoms then move with the same low velocity.
- Atoms are trapped in a small volume in a vacuum and cooled to ultra-low temperatures. The atoms are released from the trap and photographed as they expand, to measure their speed.

Bose Einstein

A B C

Massachusetts Institute of Technology

The profiles of expanding clouds of sodium atoms are shown. The height of the surface represents the number of atoms and the colour gives the speed (blue=high, green=medium, red=low velocities) for (A) Maxwell-Boltzmann distribution, (B) just below the BEC transition and (C) at the lowest temperatures.

The Crab Nebula

Neutron stars are superfluid

The Crab Nebula resulted from a star that exploded - a supernova. The outer layers of the star were thrown violently into space, while the inner core collapsed to form a neutron star which rotates 30 times per second and emits intense bursts of light as a pulsar. The incredibly dense neutron matter should become superfluid at temperatures below 10^{11} K. Neutron stars cool below 10^{10} K soon after formation and are expected to have superfluid cores.

Background: Picture courtesy of the Sussex BEC Experiment. It shows a cloud of Rb atoms in a Bose-Einstein condensate in free fall, bouncing from a magnetic mirror.

Low Temperatures - *the posters* are funded by the EPSRC (www.epsrc.ac.uk) and the Institute of Physics (www.iop.org).
Additional A3 and A4 copies can be obtained from the Physics Department, Royal Holloway, University of London, Egham, Surrey TW20 0EX.
E-mail: physics-department@rhul.ac.uk **Further information web site:** www.ph.rhul.ac.uk/lowtemp/posters/

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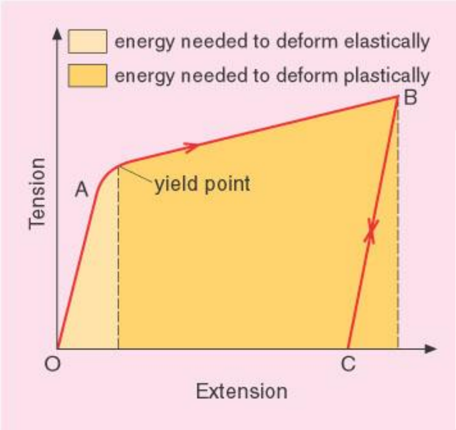

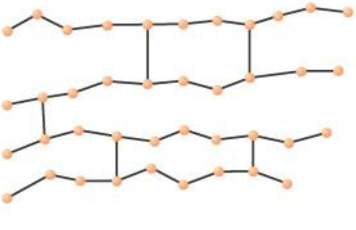

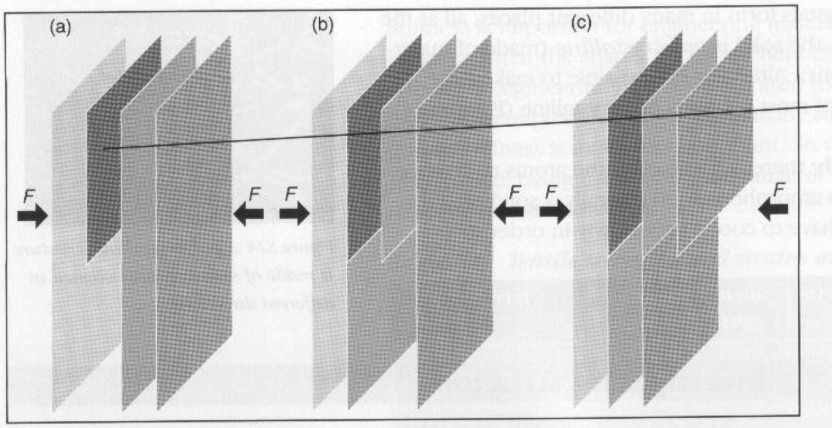

Figure S16 shows a crystal containing an edge dislocation. There is an additional half layer of atoms between two complete layers of atoms.

If you apply forces *F* as shown, the dislocation moves through the crystal, until it eventually stops at a grain boundary.

Figure S16 The edge dislocation moves through the crystal when forces are applied

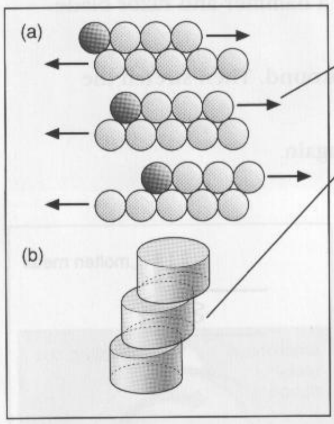

Figure S17 Certain planes of atoms can slip over each other

Slip planes

In this simple crystal structure (Figure S17), the dislocations move along certain planes of atoms, called *slip planes*.

When the atoms are moved repeatedly, certain layers of the crystal slide over each other, without the crystal breaking apart.

Dislocations get in the way of each other

As you work a material and it deforms plastically, the deformation produces more dislocations. As further plastic deformation takes place, the increasing numbers of dislocations moving along intersecting slip planes start to get in the way of each other. So, instead of more dislocations leading to the possibility of more plastic deformation, their tangle makes it harder for plastic deformation to take place. The material has become work-hardened.