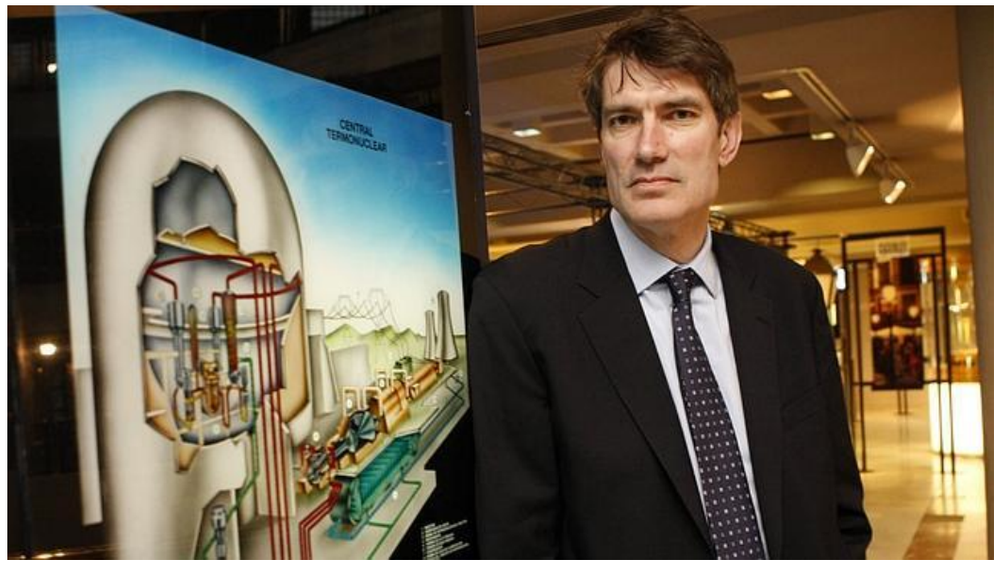
For $20 billion in cash I could build you a working fusion reactor. It would be big, and maybe not very reliable, but 25 years ago we didn't even know if we'd be able to make fusion work. Now, the only question is whether we'll be able to make it affordable.

Steve Cowley



Arizona State University
SES 194

Energy in Everyday Life

Crystal Thermometers

Frank Timmes

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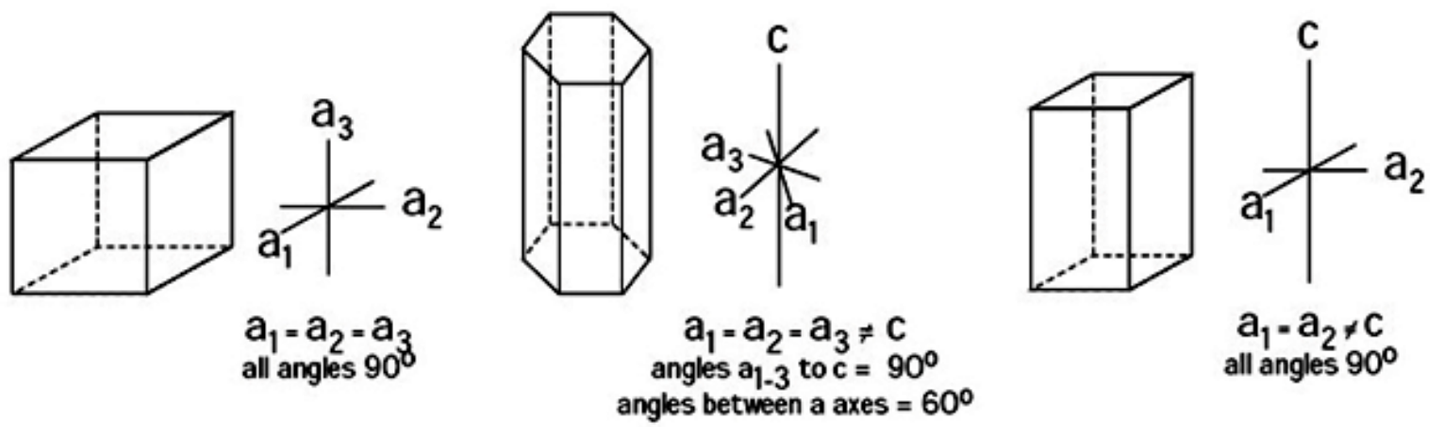
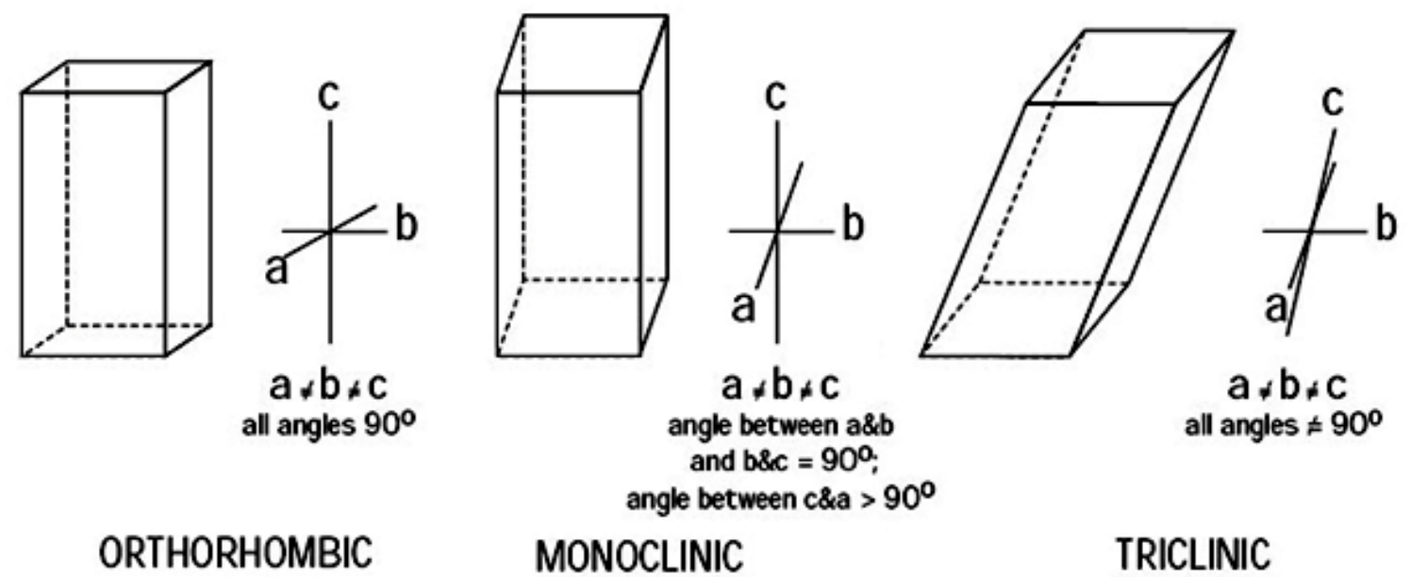
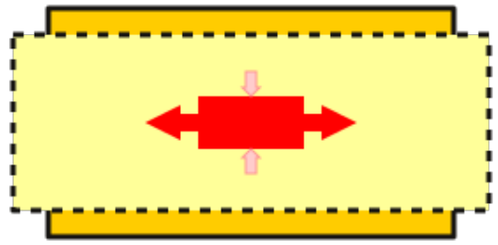
Crystal Oscillator Thermometers

A crystal is a solid in which the constituent atoms, molecules, or ions are packed in a regularly ordered, repeating pattern extending in all three spatial dimensions.



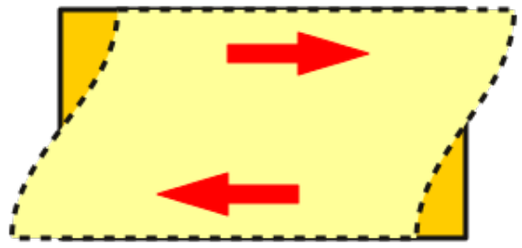


When a voltage is applied to a thin slice of, say, a quartz crystal, it changes its shape.



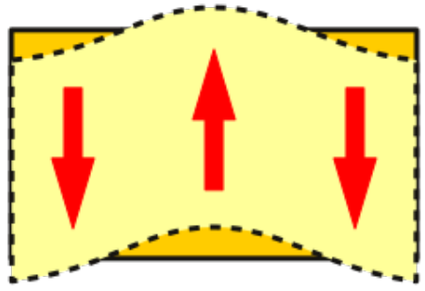
Longitudinal mode

When an oscillating voltage is applied, the crystal can vibrate at a very specific frequency, like a tuning fork.

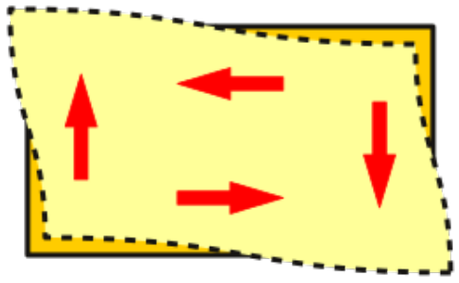


Thickness shear mode

A rise or fall in temperature causes the crystal to expand or contract, changing the frequency of vibration.



Flexural mode



Face shear mode

Measuring the change in frequency, which can be done very accurately, can be calibrated to the temperature.

More than two billion crystals are manufactured annually. Most are used for consumer devices such as wristwatches, clocks, radios, computers, and cellphones.

Coupled with a communication signal, an ingested crystal oscillator thermometer can measure a body's internal temperature as it passes through body.