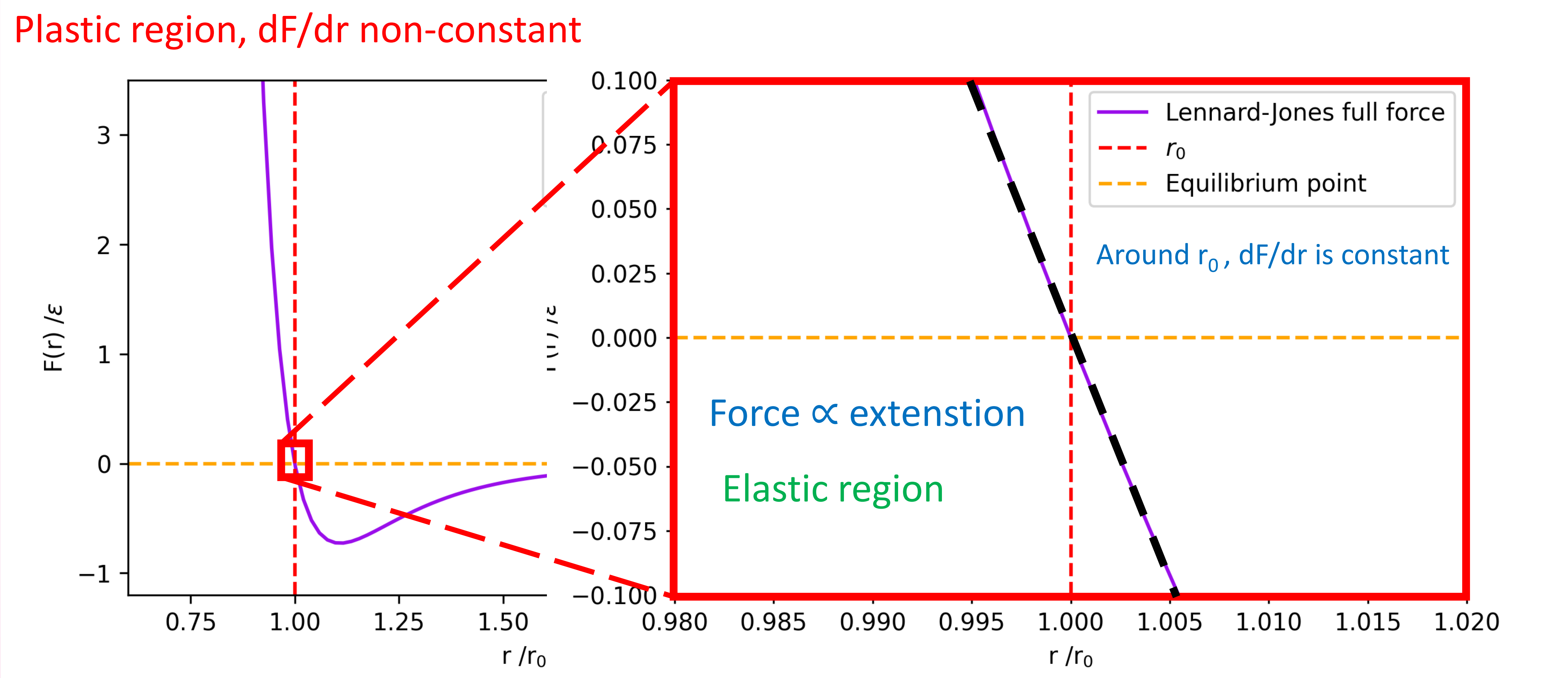
Recap from last lecture



Recap from last lecture

Materials break when the force applied to the material is greater than the maximum attractive force between atoms:

$$\text{Maximum when } \frac{\mathrm{d}F}{\mathrm{d}r} = 0 \Rightarrow F = F_{max}$$

Can define a maximum breaking stress based on this maximum force and the average area occupied by an atom (r_0^2):

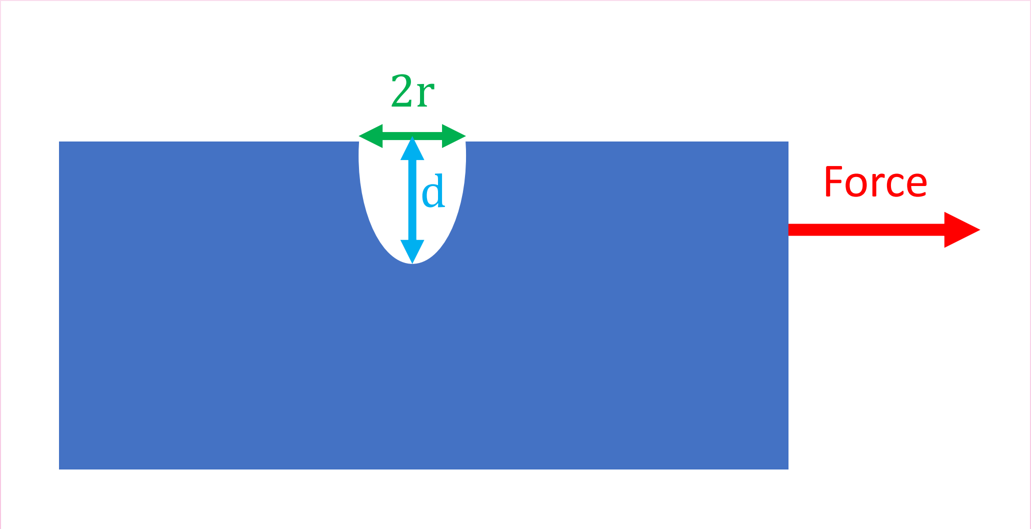
Macroscopic

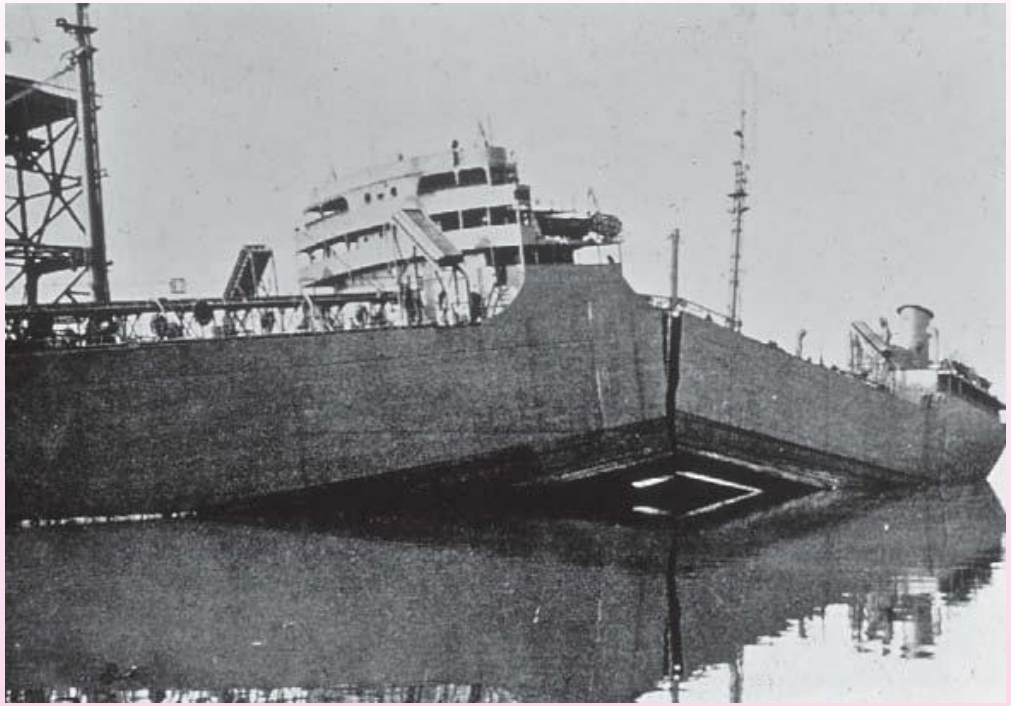
$$\text{Breaking stress} = \frac{F_{max}}{r_0^2} = \frac{F_{break}}{A} = 0.037\,Y$$

Microscopic

Recap from last lecture

Stress increases if there is a crack in the material by a factor of $\left(1+2\sqrt{\frac{d}{r}}\right)$





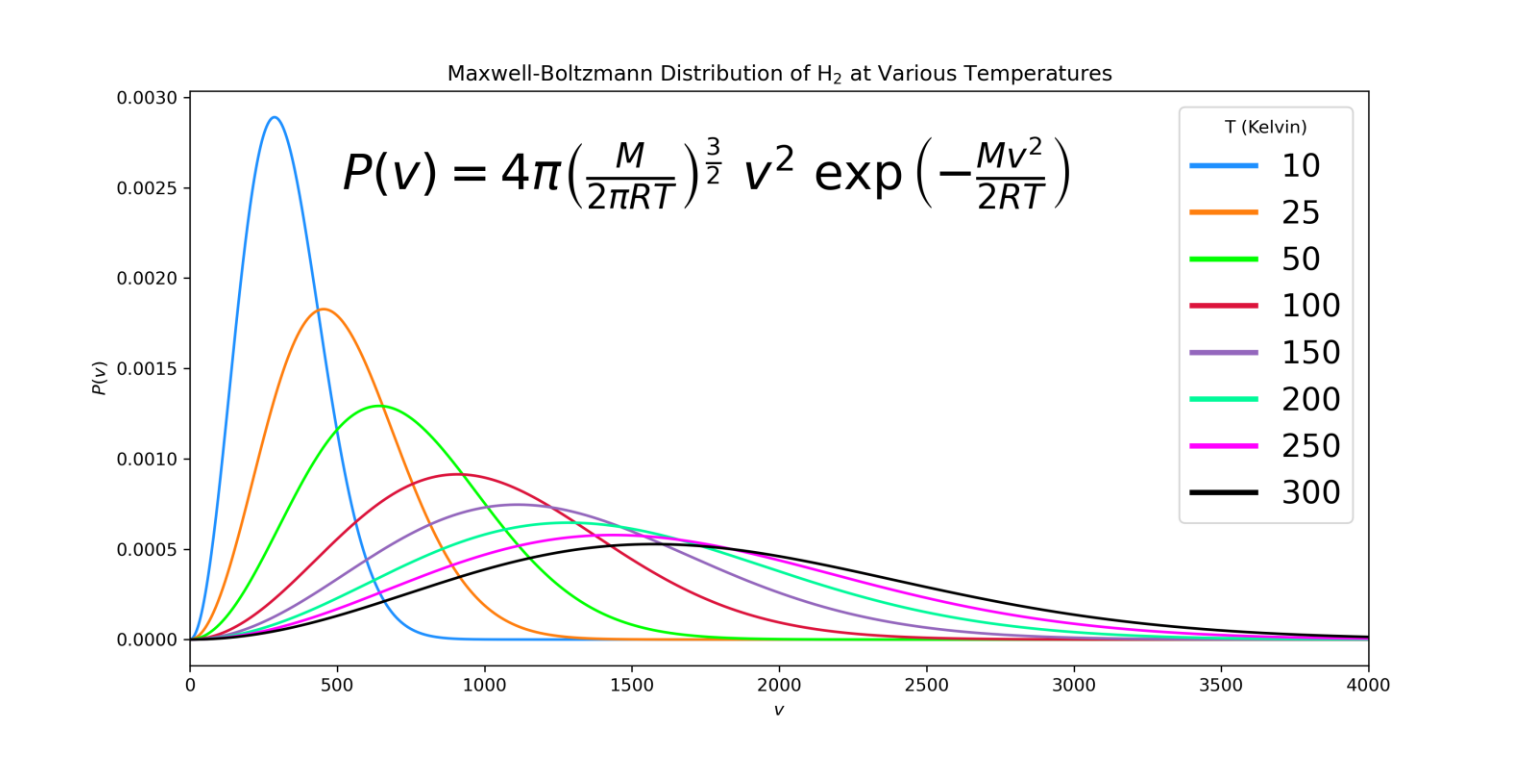
https://metallurgyandmaterials.files.wordpress.com/2015/12/liberty-ship-failure.jpg

https://www.trirentall.net/wp-content/uploads/2022/06/shutterstock_2059472675.jpg

Temperature

What is temperature?

A statistical collection of energies for particles that make up the system for which we are measuring the temperature

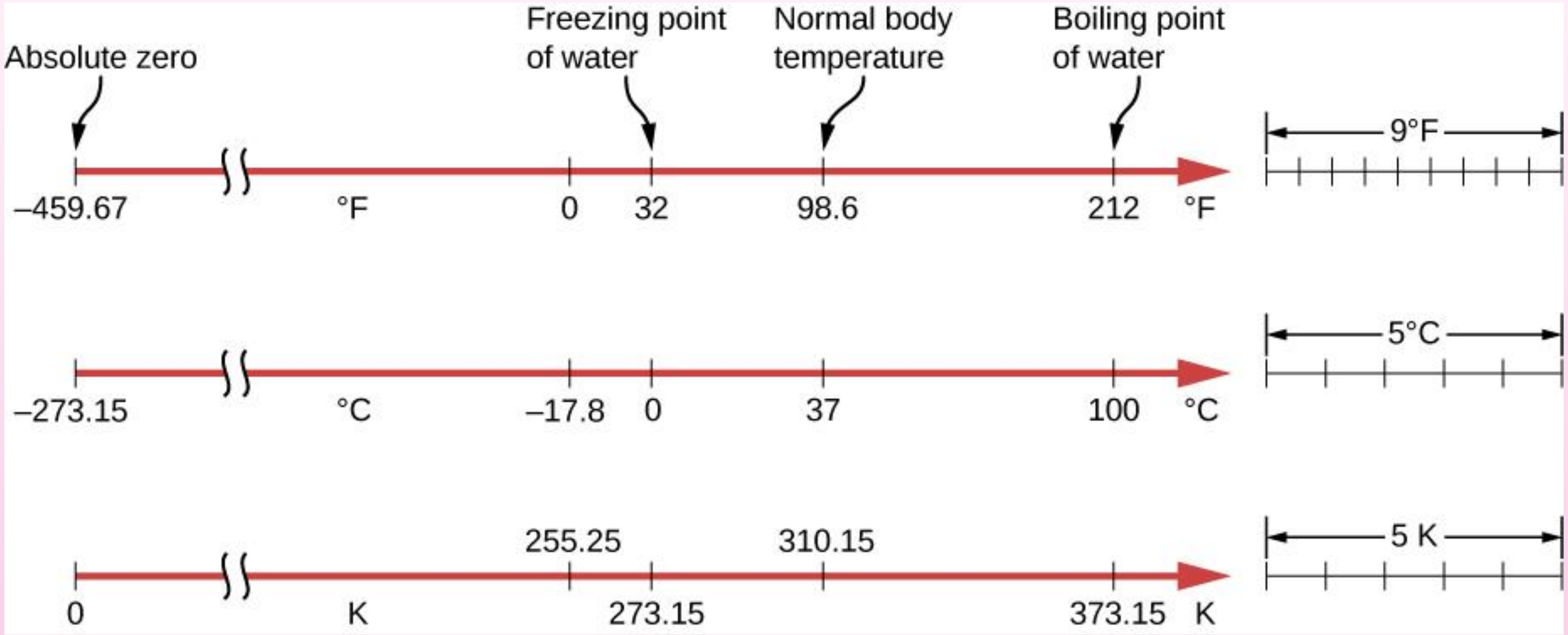


Temperature scales

Fahrenheit
(°F, F-tier)

Celsius
(°C, B-tier)

Kelvin
(K, S-tier)



https://phys.libretexts.org/@api/deki/files/7851/CNX_UPhysics_18_02_Scales.jpg?revision=1

°F -> °C: $(x - 32) \times \frac{5}{9}$

°C -> K: $(x + 273.15)$

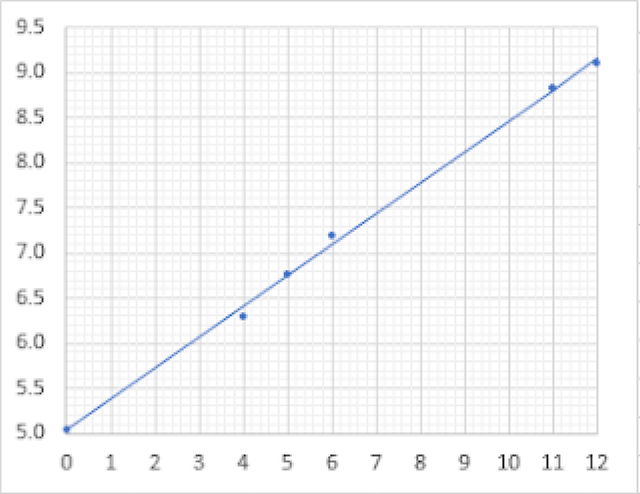
Note the lack of a degrees sign

Temperature scales (cursed)

Rankine (like Fahrenheit meets Kelvin, but even less useful because not even Americans use it): $°R = °F + 459.67$

Temperature scales (cursed)

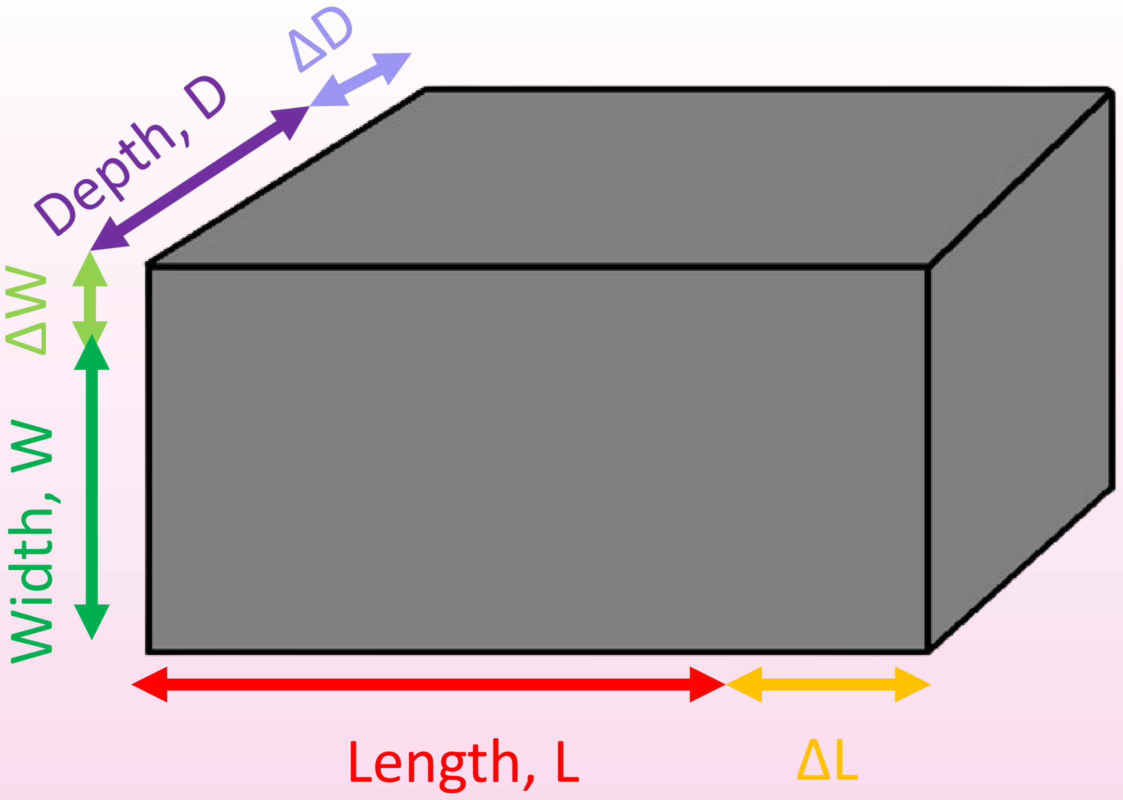
Newton scale:



https://httprover2.blogspot.com/2017/06/newtons-temperature-scale.html

0		the heat of air in winter at which water begins to freeze. This point may be accurately determined by pressing the thermometer into melting snow.
0,1,2		the heats of air in winter
2,3,4		the heats of air in spring and autumn
4,5,6		the heat of air in summer
6		the heat at midday about the month of July
12	1	the greatest heat which a thermometer takes up when in contact with the human body
14	1¼	the greatest heat of a bath which one can endure for some time when the hand is dipped in and is kept in constant movement
17	1½	the greatest heat of a bath which one can endure for some time when the hand is dipped in and is kept still
20		the heat of a bath in which liquid wax slowly becomes solid and assumes transparency
24	2	the heat of a bath in which solid wax melts and is conserved in liquid state without boiling
28	2¼	intermediate point between the boiling point of water and the melting point of wax
34		the heat at which water boils vehemently (the temperature at which water begins to boil is given as an additional value in the description, as 33)
40		melting point of an alloy of one part lead, four parts tin and five parts bismuth
48	3	melting point of an alloy of equal parts of bismuth and tin
57	3¼	melting point of an alloy of one part bismuth and two parts tin
68	3½	melting point of an alloy of one part bismuth and eight parts tin
81		melting point of bismuth
96	4	melting point of lead
114	4¼	heat of bodies that can barely be seen glowing at night
136	4½	heat of bodies that can be seen glowing by twilight
161		heat of bodies that can be seen glowing by daylight
192	5	heat of iron glowing as brightly as possible

Thermal expansion



As a solid is heated (not melted), it expands

$$\frac{\Delta L}{L} = \frac{\Delta W}{W} = \frac{\Delta D}{D} = \alpha_L \Delta T$$

Linear expansion coefficient

Change in temperature

Area expansion coefficient

Volume expansion coefficient

Area: $\frac{\Delta A}{A} = \alpha_A \Delta T = 2\alpha_L \Delta T$

Volume: $\frac{\Delta V}{V} = \alpha_V \Delta T = 3\alpha_L \Delta T$

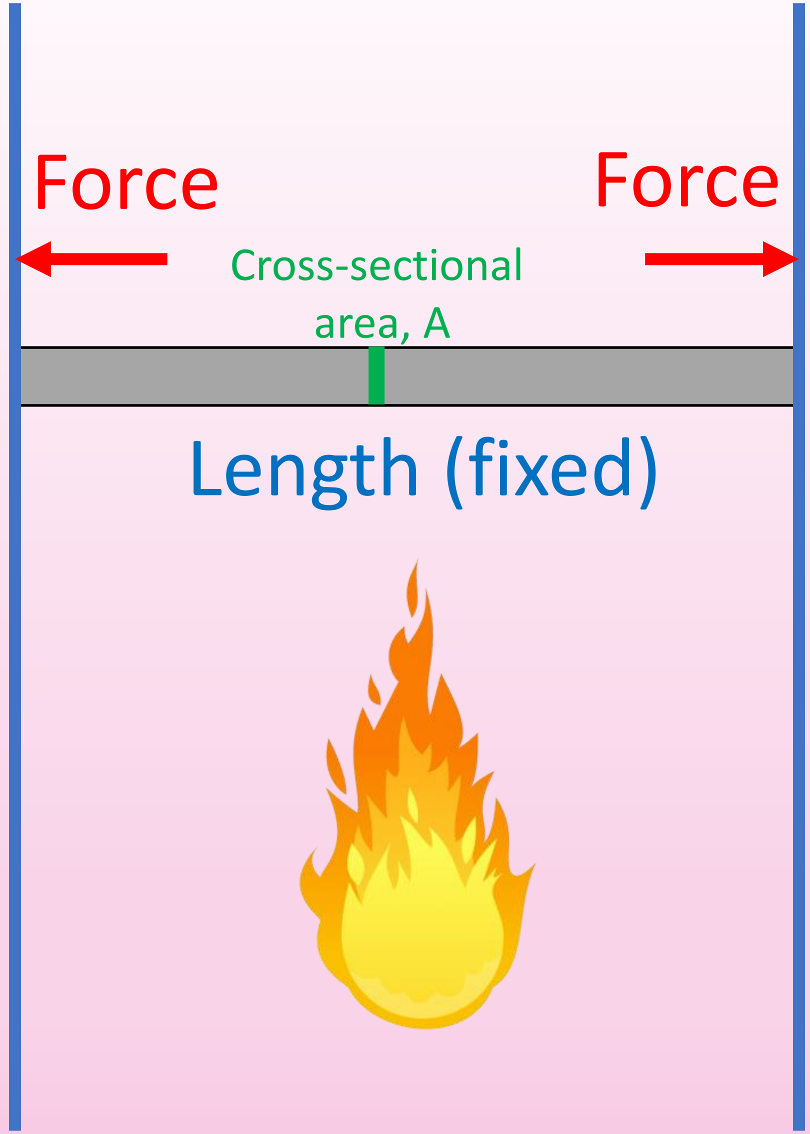
Thermal expansion

Q: An aluminium rod is heated from 20°C to 120°C, and expands to a length of 4 metres. How long was the rod originally? The rod has linear expansion coefficient $\alpha = 2.3 \times 10^{-5}$ K^{-1}

Thermal stress

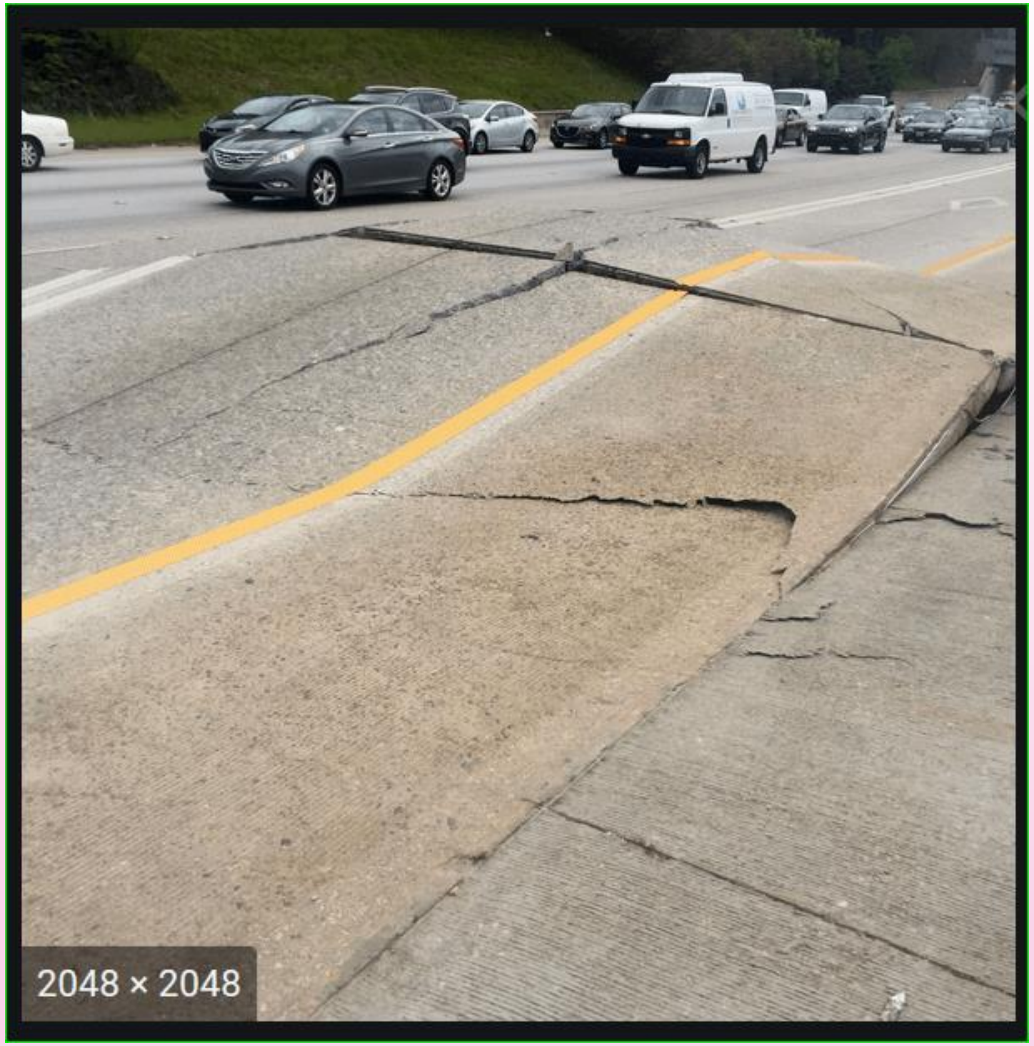
If we prevent a rod from expanding under heat (say, by compressing it between two walls), then rod exerts a force on the walls

Thermal stress: $$\frac{F}{A} = Y\alpha_L \Delta T$$



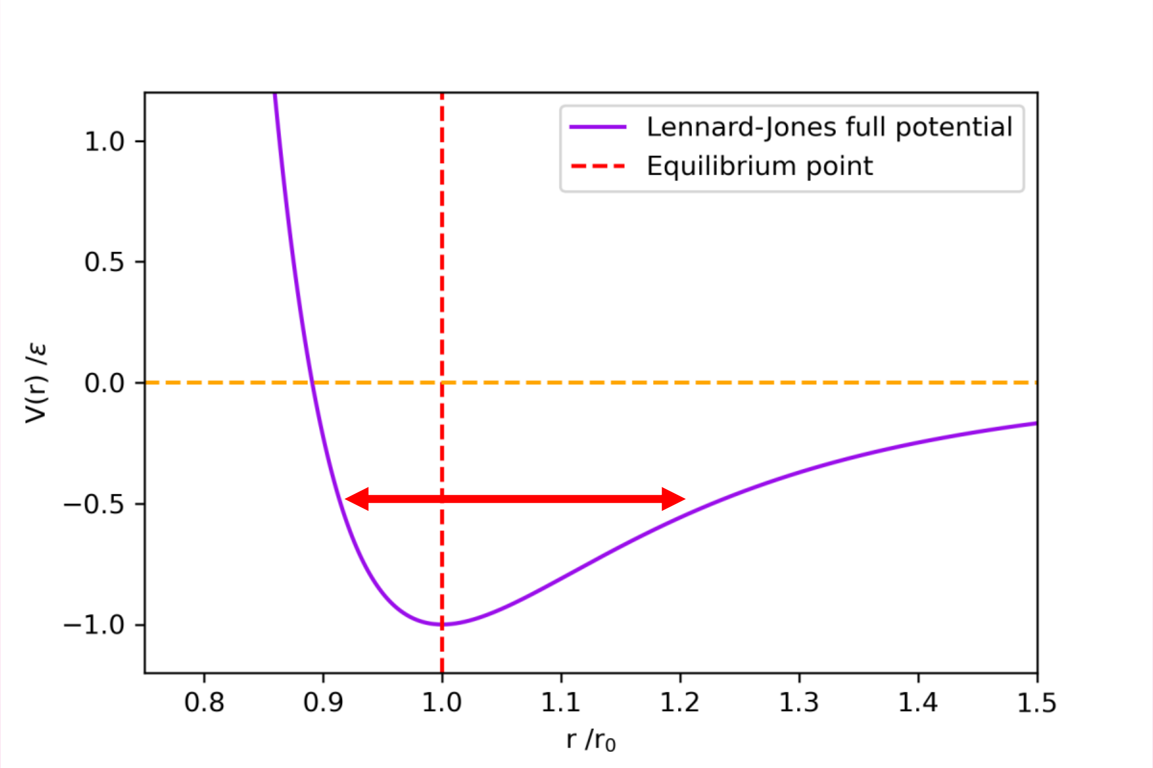
Thermal stress

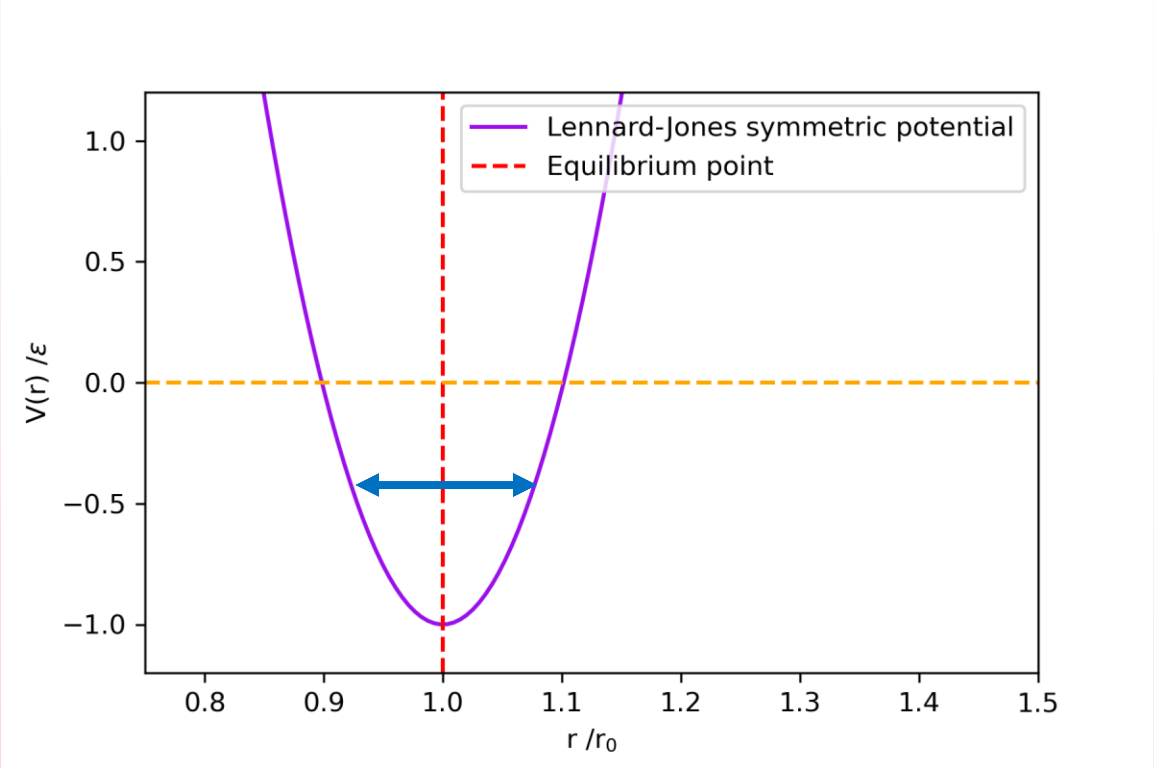
https://www.researchgate.net/publication/303805601/figure/fig2/AS:369544368541698@1465117651748/Thermal-Stress-Induced-Buckle.png



https://res.cloudinary.com/engineering-com/image/upload/v1592495002/tips/ThermalBuckling_m5rh26.png

Lennard Jones meets thermal expansion



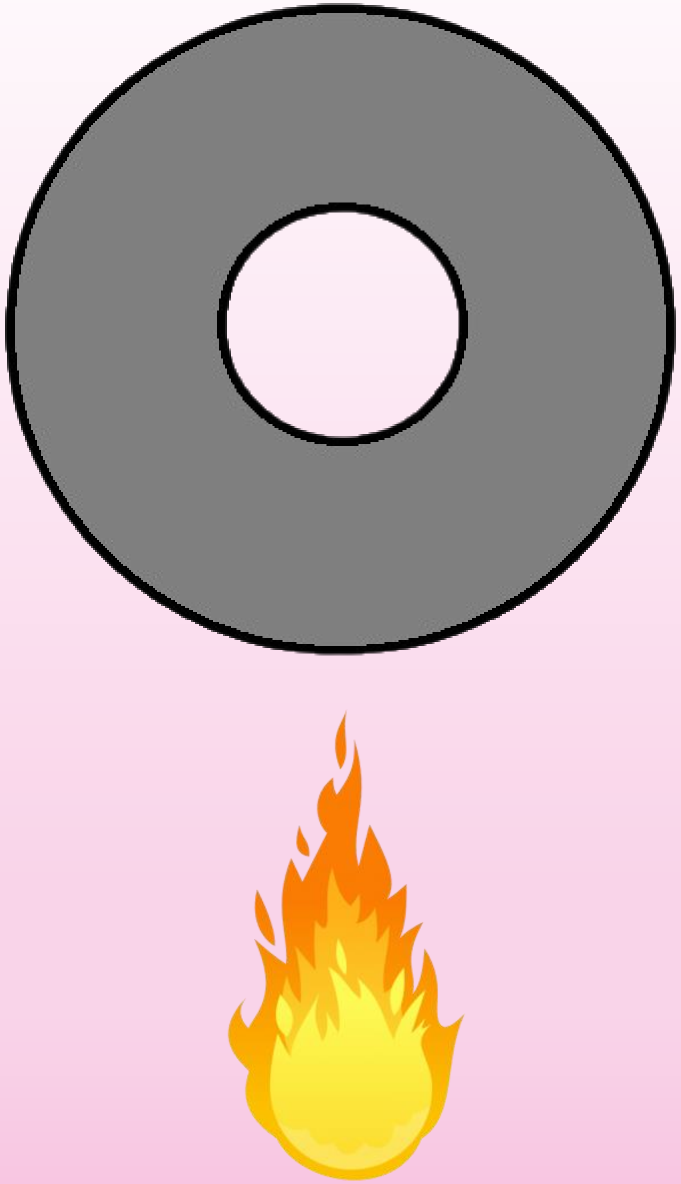


With asymmetric potential (right), as we increase energy (and hence potential) we find the average value of bond length is unchanged (no thermal expansion)

With LJ (left), as energy increases so too does average bond length (thermal expansion)

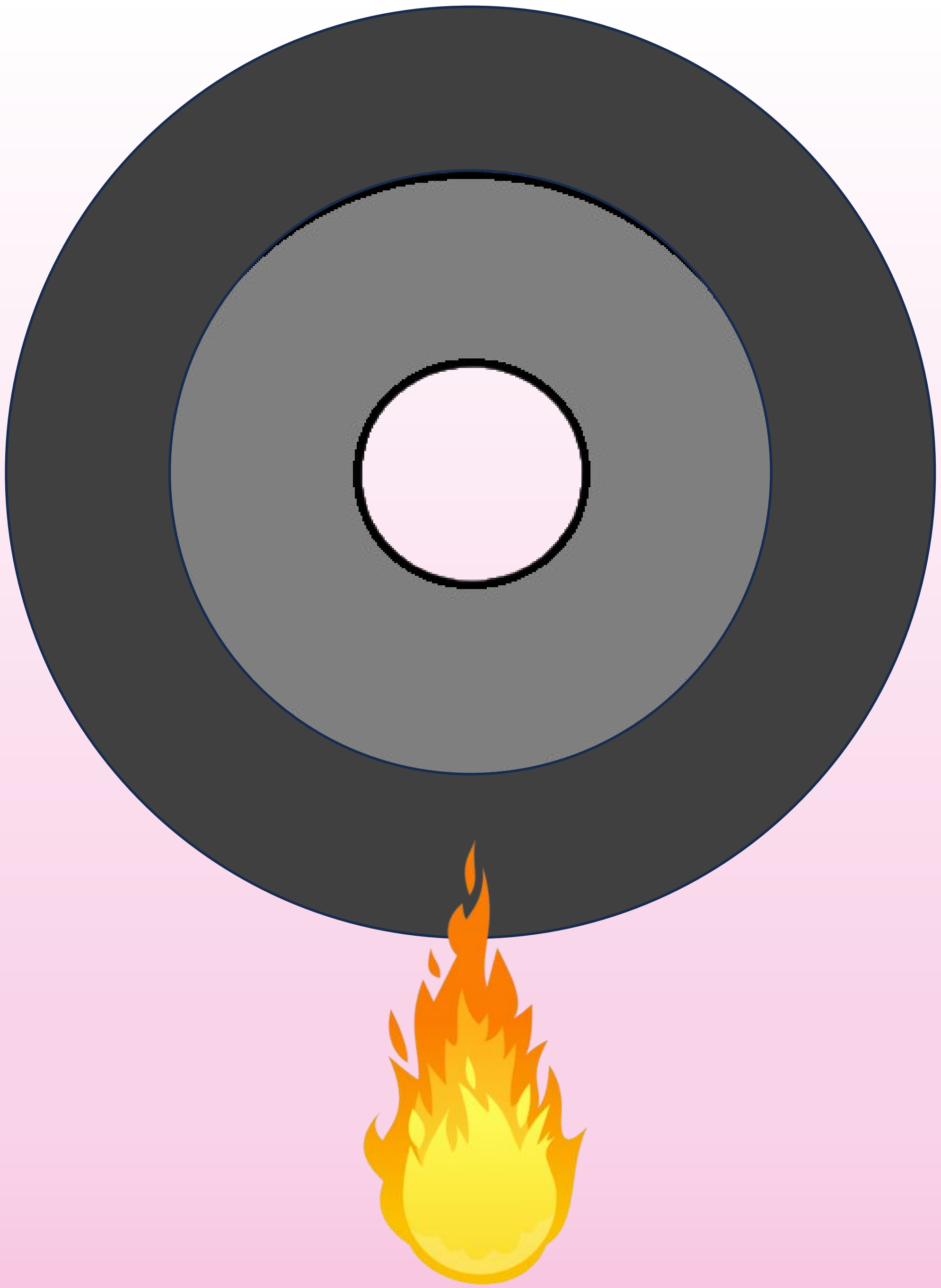
Say we take a metal ring (hole in the middle) and heat it – do we expect the hole in the middle to:

a) Get larger?
b) Get smaller?
c) Stay the same size?



If instead we constrain the metal ring within some circular wall – what will happen now? Do we expect the hole in the middle to:

a) Get larger?
b) Get smaller?
c) Stay the same size?



Summary

Discussed (very briefly) the definition of temperature and various scales used to define it

Looked at thermal expansion and stress, both macroscopically (in terms of its physical effects) and microscopically (in terms of the Lennard-Jones potential)

Learnt that eating mercury did not necessarily pan out for Newton