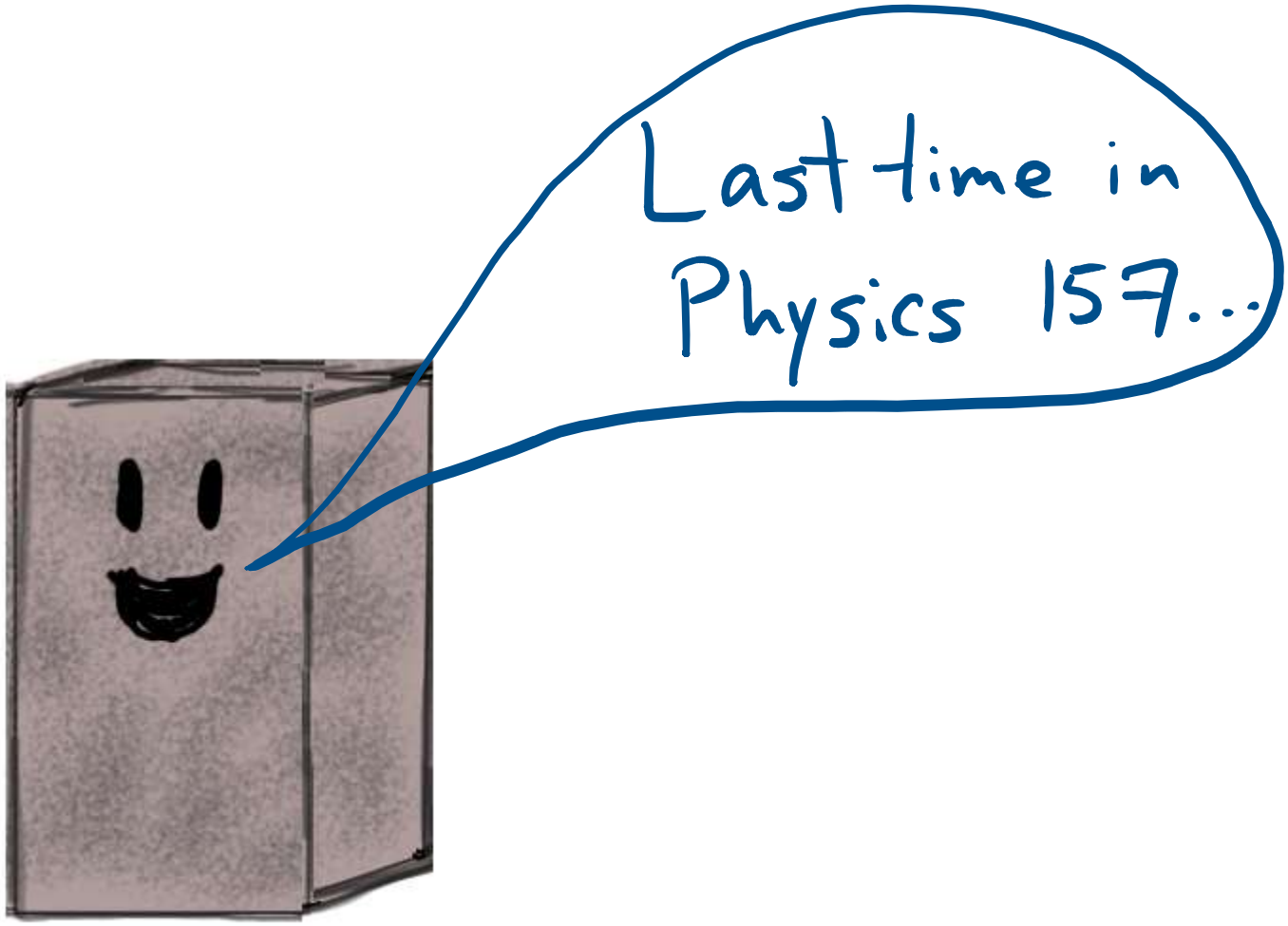
# Don't eat the marshmallows!

**Clicker:** A steel ball does not quite fit through a hole in a copper plate. If $\alpha_{steel} < \alpha_{copper}$, we could help the ball fit through the hole by

A. Heating the system
B. Cooling the system
C. Either A or B will work
D. Neither A nor B will work

$$\Delta L = \alpha L_o \Delta T$$

**EXTRA:** does the hole get larger or smaller when we heat the system? Why?


Last time in
Physics 157...

Define Kelvin scale by:

$$T = \text{const.} \times P$$

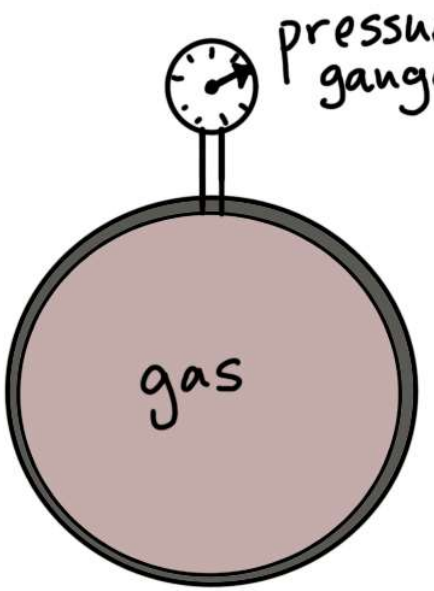
const. ↑ depends on particular thermometer

P ↑ pressure

and

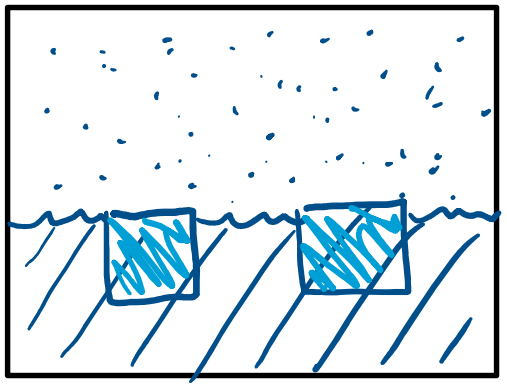
$$T = 273.16\,K$$

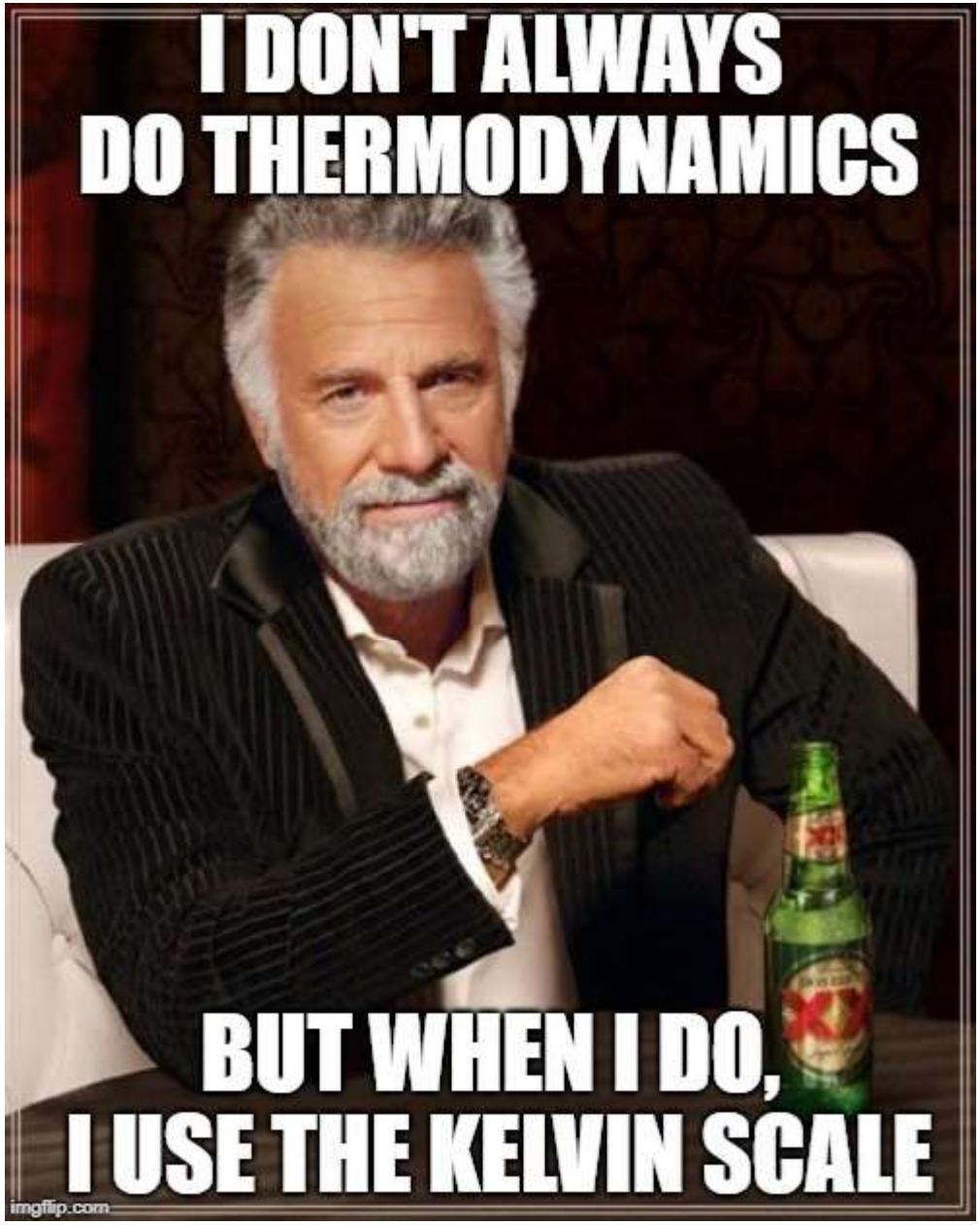
at triple point of water



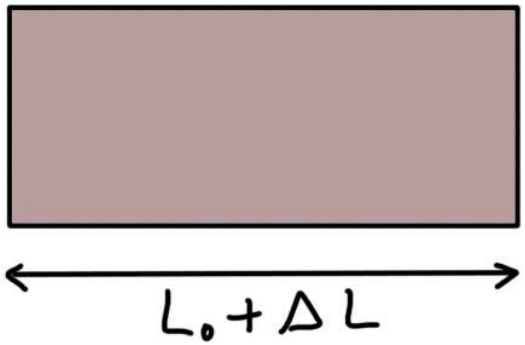

constant volume gas thermometer:

$$T_C = T_K - 273.15$$




I DON'T ALWAYS
DO THERMODYNAMICS
BUT WHEN I DO,
I USE THE KELVIN SCALE
imgflip.com

# Thermal expansion:


$$\Delta L = \alpha L_0 \Delta T$$

$\alpha$: coefficient of linear expansion

- assumes $\frac{\Delta L}{L}$ is small
- $\alpha$ can depend on T

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ball + hole both expand, but hole expands more since $\alpha_{Cu} > \alpha_{steel}$

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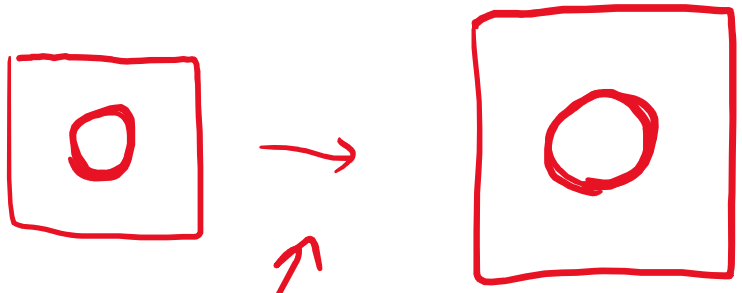


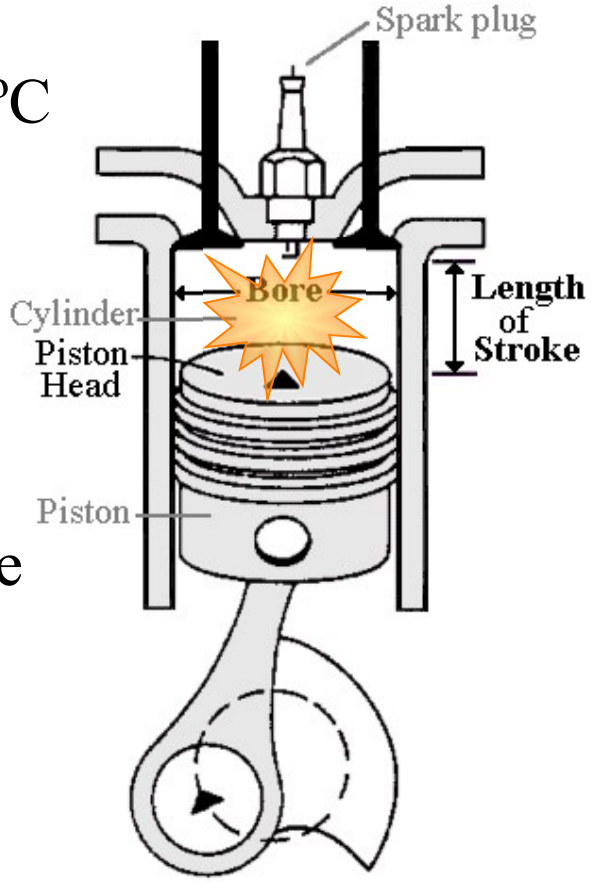
**EXTRA:** does the hole get larger or smaller when we heat the system? Why?

hole grows in proportion to plate (same as if hole were filled)

**Clicker:** In some car engines, the piston is aluminum ($\alpha = 2.4 \times 10^{-5}$), while the cylinder is cast iron ($\alpha = 1.2 \times 10^{-5}$). If the engine needs to operator between 0°C and 120°C, which of these is not a good design:

A) The piston barely fits in the cylinder at 120°C

B) The piston barely fits in the cylinder at 0°C




**EXTRA:** what do we need to worry about if the engine gets too hot? Too cold?

$$\Delta L = \alpha L_0 \Delta T$$

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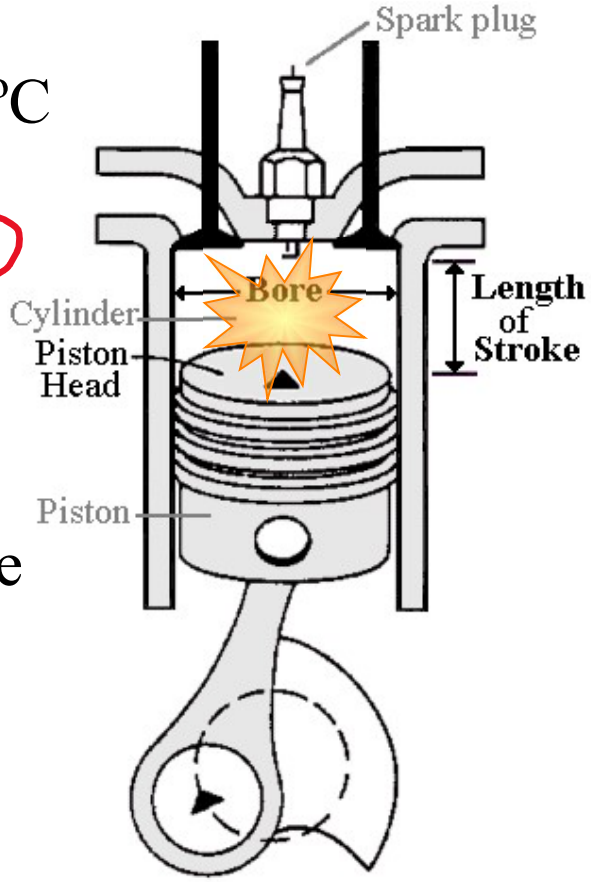
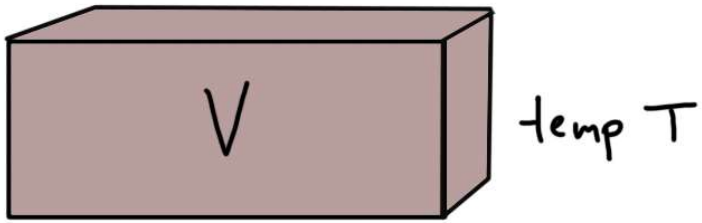
piston expands more than cylinder as engine heats up → wouldn't be able to move at higher temps.

**EXTRA:** what do we need to worry about if the engine gets too hot? Too cold?

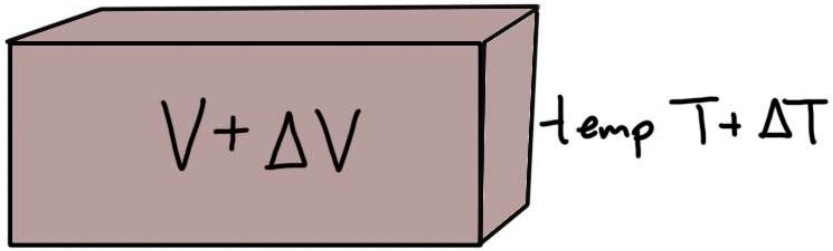



$$\Delta L = \alpha L_0 \Delta T$$

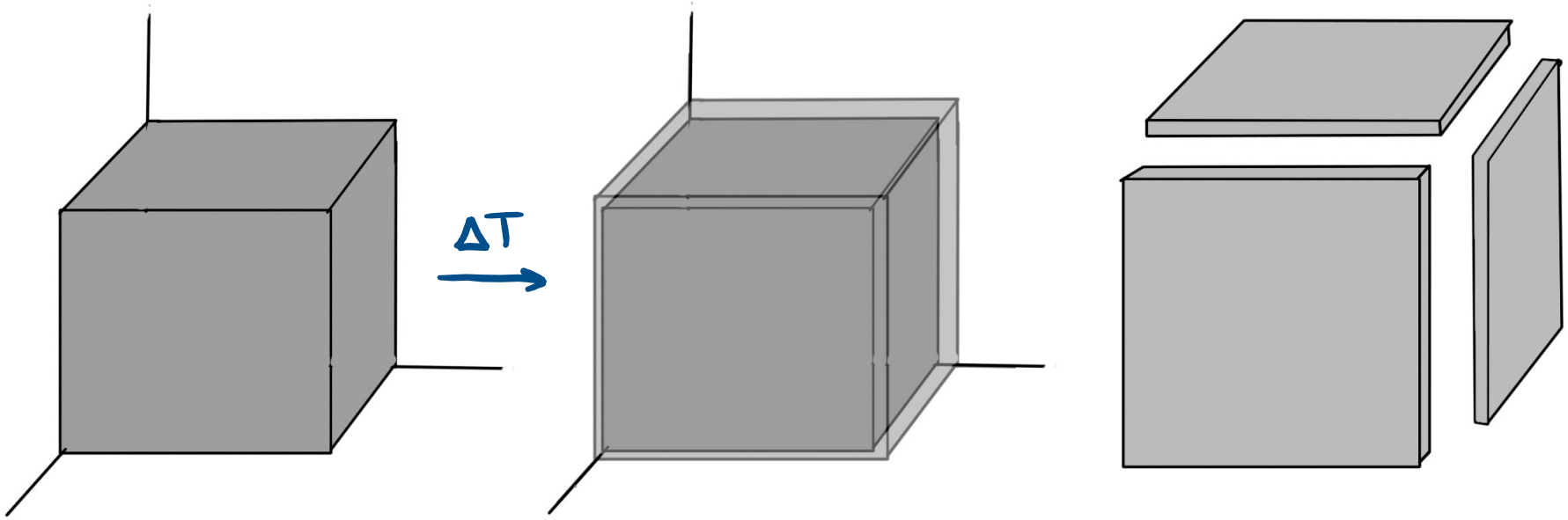
# Volume expansion:




$$\Delta V = \beta V_o \Delta T$$




also applies to liquids

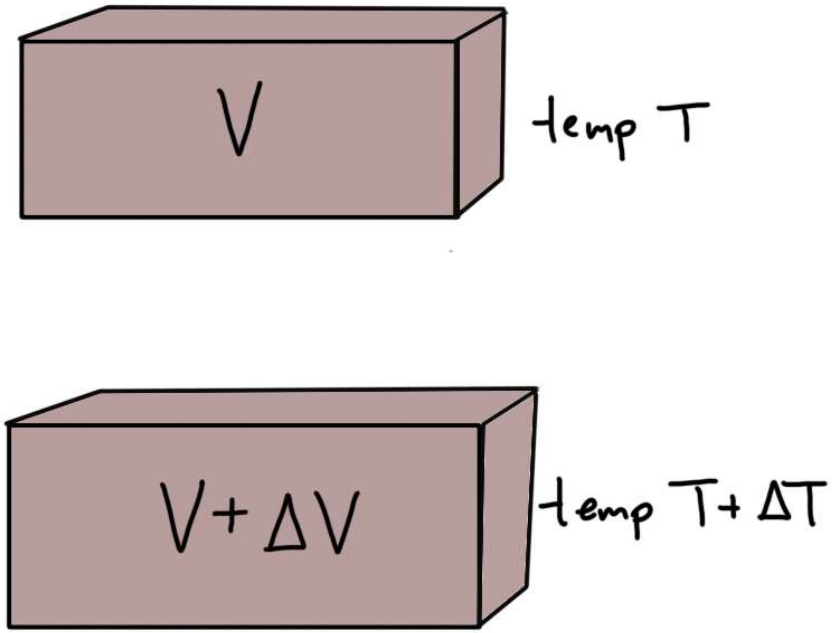



Clicker: When heated, each side of a cube of material expands by 0.1%. As a percentage of the original volume of the cube, the extra volume (shown in the third picture) after the expansion is

A) 0.0000001% B) 0.001% C) 0.1% D) 0.3%

E) There is not enough information

# Volume expansion:



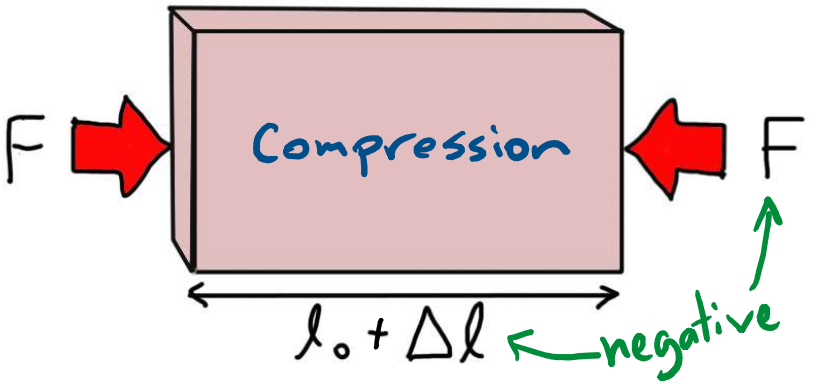

$$\Delta V = \beta V_o \Delta T$$

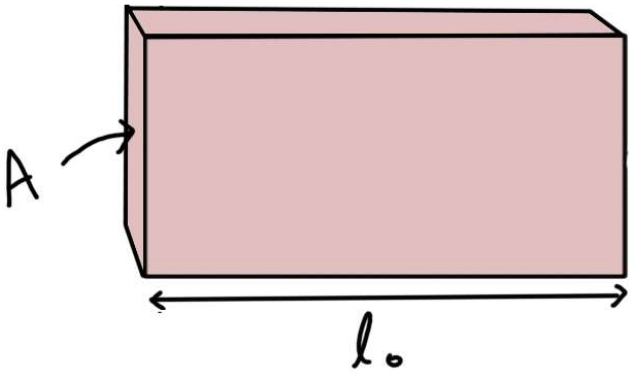
$\beta = 3\alpha$ for solids

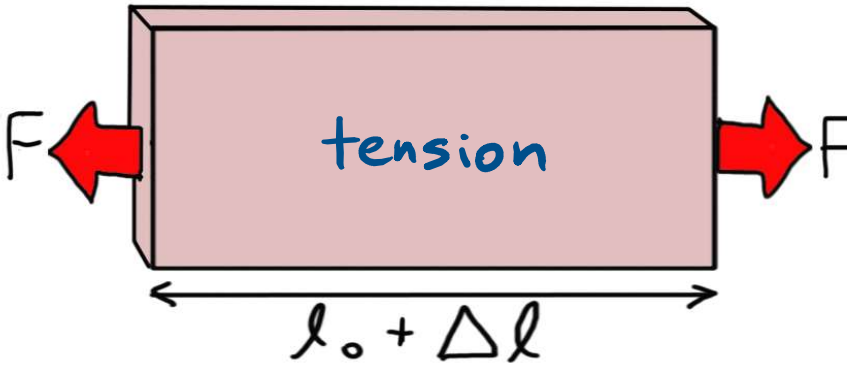
also applies to liquids

Many situations: need to understand thermal expansion together with expansion/compression due to mechanical forces.

# Stress & Strain




$$\frac{F}{A} = Y \frac{\Delta l}{l_o}$$

stress (units of pressure)

Young's modulus

strain

"a basic property of a material (resistance to squishing)"

like $F = k\Delta x$ for spring

# Worksheet: what is the Young's modulus of a marshmallow

Don't eat the marshmallows!

**Clicker**: Which of these is closest to the order of magnitude of the Young's modulus of your marshmallow?

A. $10^2$ Pa
B. $10^4$ Pa
C. $10^6$ Pa
D. $10^8$ Pa
E. $10^{10}$ Pa