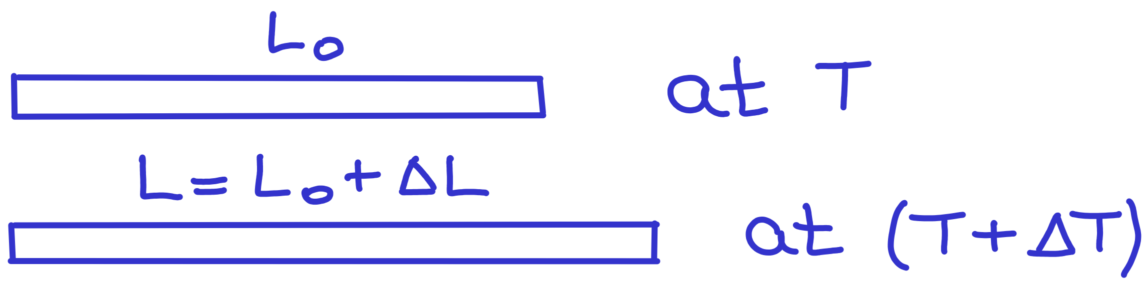
Thermal expansion: linear



$\Delta L \sim \Delta T$
$\Delta L \sim L_0$ $\Big\} \Rightarrow$ $\Delta L = \alpha L_0 \Delta T$

$L = L_0 (1 + \alpha \Delta T)$

α : coefficient of linear expansion

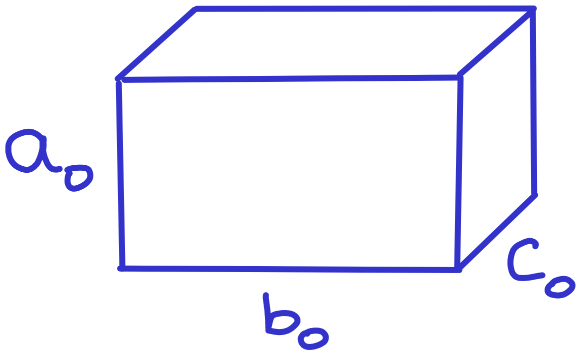
$$\alpha = \frac{\Delta L / L_0}{\Delta T} \qquad [\alpha] = \frac{1}{K}, \text{ or } \frac{1}{°C}$$

α : fractional or relative increase in length per unit change in temperature.

Examples:

Aluminium	:	2.39×10^{-5} 1/°C
Copper	:	1.62×10^{-5} 1/°C
Steel	:	1.17×10^{-5} 1/°C
Invar	:	0.12×10^{-5} 1/°C

Thermal expansion : volumetric



$V_0 = a_0 b_0 c_0$ at T

$a = a_0(1+\alpha\Delta T)$

$b = b_0(1+\alpha\Delta T)$

$c = c_0(1+\alpha\Delta T)$

$$V = abc = a_0 b_0 c_0 (1+\alpha\Delta T)^3 =$$

$$= V_0\left(1 + 3\alpha\Delta T + \underbrace{3(\alpha\Delta T)^2}_{} + \underbrace{(\alpha\Delta T)^3}_{}\right)$$

these two terms are very small

$$V \cong V_0(1 + \underbrace{3\alpha}_{=\beta}\Delta T)$$

$$V = V_0(1+\beta\Delta T) \qquad \Delta V = \beta V_0 \Delta T$$

$$\beta = \frac{\Delta V / V_0}{\Delta T} \qquad [\beta] = \frac{1}{K}, \text{ or } \frac{1}{°C}$$

β = coefficient of volume expansion

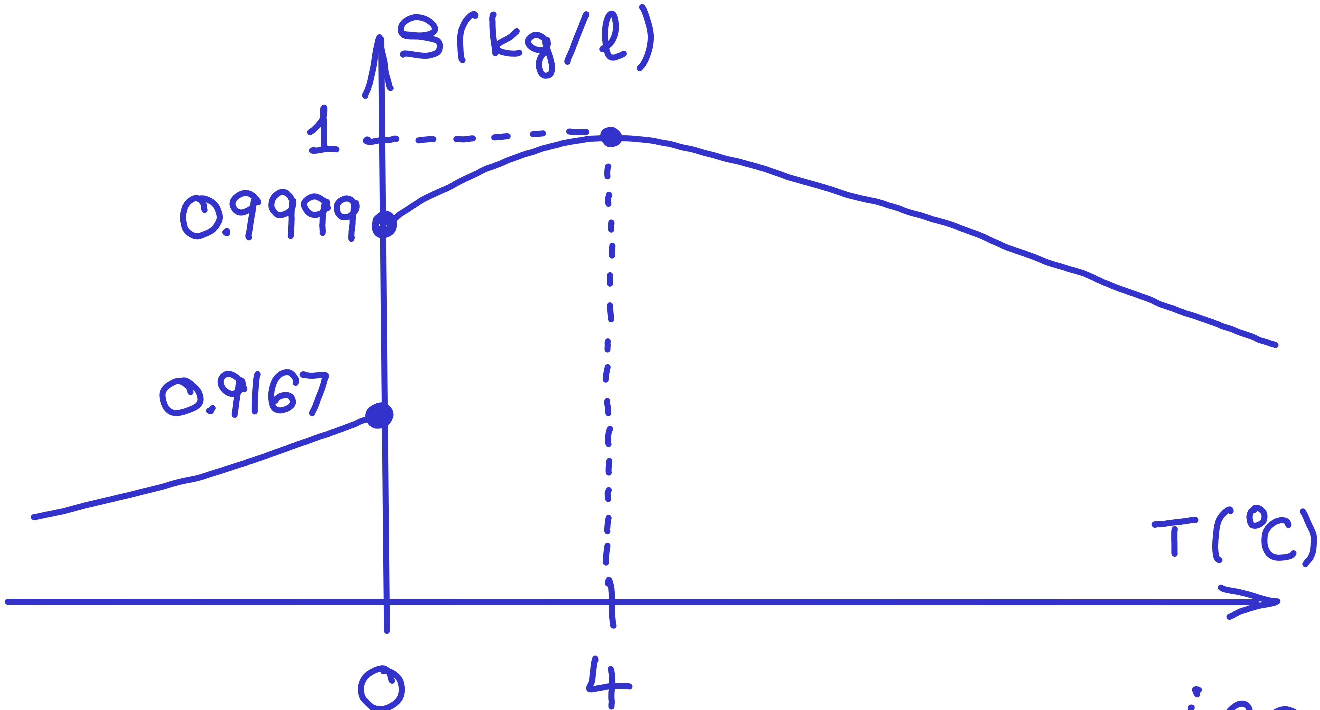
Examples :

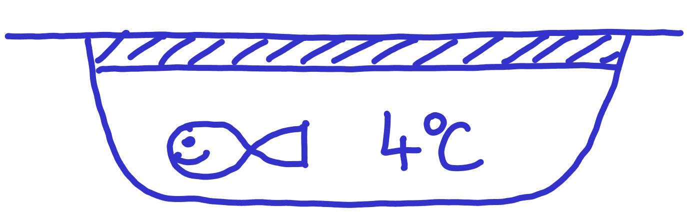
petroleum : 9.6×10^{-4} 1/°C

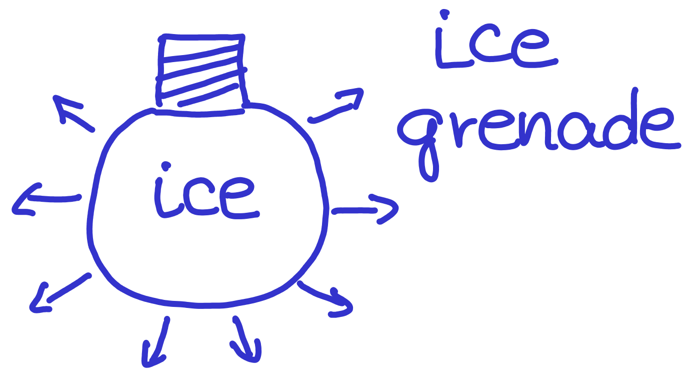
water : 2.0×10^{-4} 1/°C

Warning : water (and ice) is very unusual.

The very unusual behavior of water

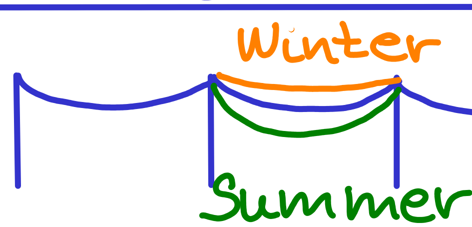




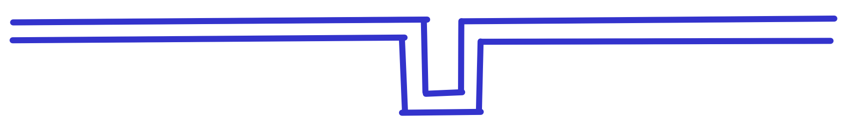


Heat expansion tricks:

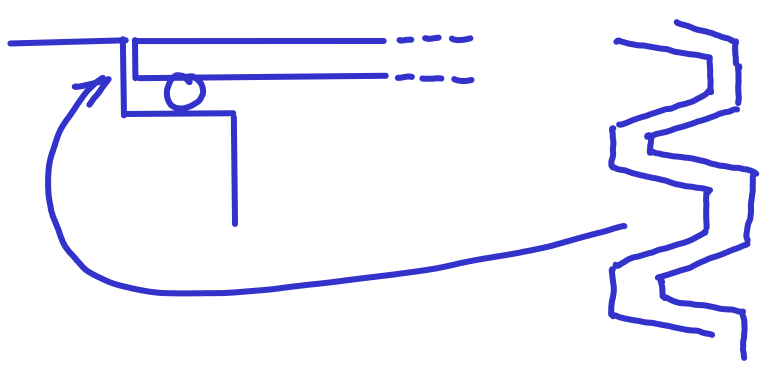
power lines:



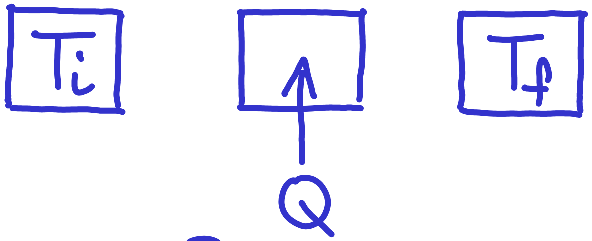
pipes:



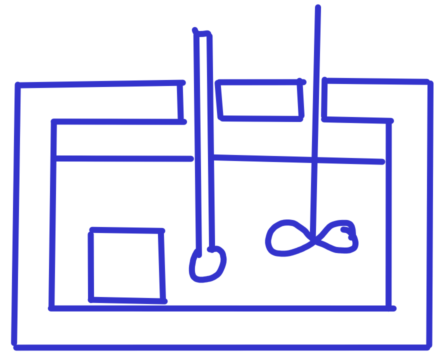
bridges:



Heat and mechanical work



$$Q \overset{?}{\longleftrightarrow} \Delta T = (T_f - T_i)$$



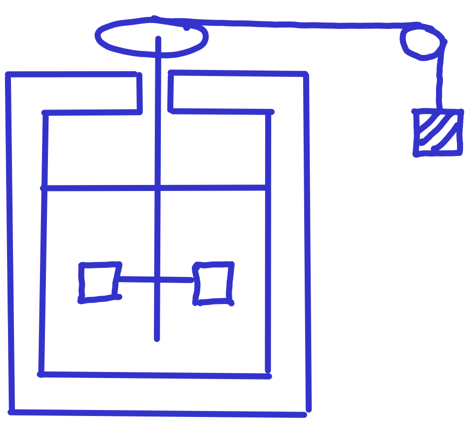
calorimeter

Definition: 1 calorie is the amount of heat which raises the temperature of 1 g water by 1°C.
(Warning: 1 Cal = 1000 cal = 1 kcal.
Reminder: 1 g is the mass of 1 cm^3 water at 4°C temperature.)

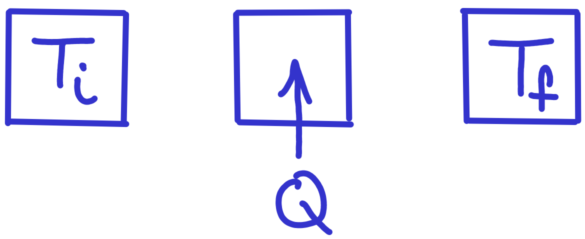
Question: what is the relation between heat Q and mechanical work $W = Fd$?

James Prescott Joule (1818-1899):

1843 : 1 cal = 4.186 J



Heat capacity, specific heat



$$Q = C \cdot \Delta T = C \cdot (T_f - T_i)$$

$$C = \frac{Q}{\Delta T} \quad [C] = J/K$$

C : heat capacity: amount of heat needed to raise the temperature of the object by 1K. (The object can be complex or composite.)

Homogeneous objects : $Q = cm\Delta T$

$$c = \frac{Q}{m\Delta T} = \frac{C}{m} \qquad [c] = \frac{J}{kg\,K}$$

c : Specific heat: amount of heat needed to raise the temperature of a unit mass of material.

water : $1 \frac{cal}{g°C} = 4186.8 \frac{J}{kg\,K}$

Al : $0.215 \frac{cal}{g°C} = 900 \frac{J}{kg\,K}$

Cu : $0.0923 \frac{cal}{g°C} = 386 \frac{J}{kg\,K}$

Molar heat $= c_m = \frac{C}{n}$