Celsius and Fahrenheit

From Fahrenheit to Celsius:

$$T_C = \frac{5}{9}(T_F - 32)$$

From Celsius to Fahrenheit:

$$T_F = \frac{9}{5} T_C + 32$$

Remarks:

- $-40\,^\circ C = -40\,^\circ F$
- Mercury (Hg) solidifies at $\approx -39\,^\circ C$
- Siberia is very cold, new cold records were set in November 2016.
- "quick and dirty" conversion method:

$$T_C \approx \frac{1}{2}(T_F - 30)$$

- body temperature: $98.6\,^\circ F = 36.8\,^\circ C$, but your fingers, nose and ears can be colder. High fever: $104\,^\circ F = 40\,^\circ C$.
- Birds are warmer than mammals.
- Paper ignites at $451\,^\circ F$. (Ray Bradbury)
- Oven temperatures in the kitchen: 325–$425\,^\circ F$.

Electric power line

$L_0 = 170\ \text{km} = 170{,}000\ \text{m}$ at $T_0 = 14.8°C$

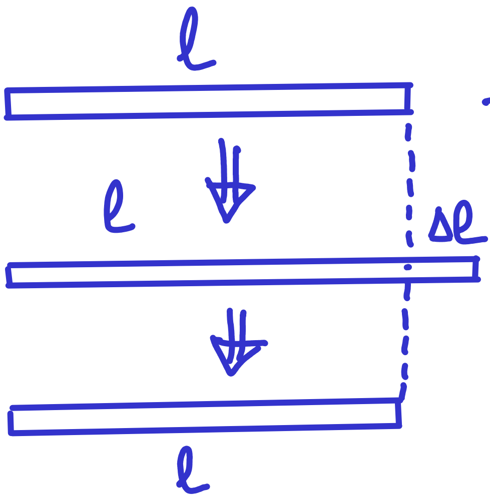
$T_{summer} = 41.1°C \Rightarrow \Delta T_1 = 26.3°C$

$T_{winter} = -32.9°C \Rightarrow \Delta T_2 = -47.7°C$

$\Delta L = \alpha L_0 \Delta T$; $\alpha = 1.62 \cdot 10^{-5}\ 1/°C$

$\left.\begin{array}{l} \Delta L_1 = 72.4\ \text{m} \\ \Delta L_2 = -131.4\ \text{m} \end{array}\right\}$ These are large changes, but the initial length of the power line was large: $L_0 = 170{,}000\ \text{m}$.

Force due to increase in temperature



heat expansion:

$$\Delta \ell = \alpha \ell \Delta T$$

compression:

$$\frac{F}{A} = E \frac{\Delta \ell}{\ell + \Delta \ell} \cong E \frac{\Delta \ell}{\ell}$$

(because $\ell \gg \Delta \ell$)

$$\underbrace{\frac{\Delta \ell}{\ell} = \alpha \Delta T \quad \text{and} \quad \frac{F}{A} \cdot \frac{1}{E} = \frac{\Delta \ell}{\ell}}$$

$$\alpha \Delta T = \frac{F}{A} \cdot \frac{1}{E}$$

$$\alpha \Delta T E A = F$$

$\alpha \approx 10^{-5}$ 1/K
$E \approx 10^{11}$ Pa

The force is going to be huge!

Huge forces can develop due to thermal expansion / contraction.

($1\,cm^2 = 10^{-4} m^2$ because $1\,cm = 10^{-2} m$)

Three liquids

$m_1 \,;\, c_1 \,;\, T_1$

$m_2 \,;\, c_2 \,;\, T_2$ $\longrightarrow$ $T_f = ?$

$m_3 \,;\, c_3 \,;\, T_3$

final temp.

$Q_1 + Q_2 + Q_3 = 0$ } Conservation of energy:

Some of the liquids will warm up, some of them will cool down. The algebraic sum of the heats is zero.

$$c_1 m_1 \cdot \underbrace{(T_f - T_1)}_{\Delta T_1} + c_2 m_2 \underbrace{(T_f - T_2)}_{\Delta T_2} + c_3 m_3 \underbrace{(T_f - T_3)}_{\Delta T_3} = 0$$

$$c_1 m_1 T_f + c_2 m_2 T_f + c_3 m_3 T_f =$$
$$= c_1 m_1 T_1 + c_2 m_2 T_2 + c_3 m_3 T_3$$

$$T_f = \frac{c_1 m_1 T_1 + c_2 m_2 T_2 + c_3 m_3 T_3}{c_1 m_1 + c_2 m_2 + c_3 m_3}$$

$$T_f = \frac{C_1 T_1 + C_2 T_2 + C_3 T_3}{C_1 + C_2 + C_3} \quad ; \quad C = c \cdot m$$

mass

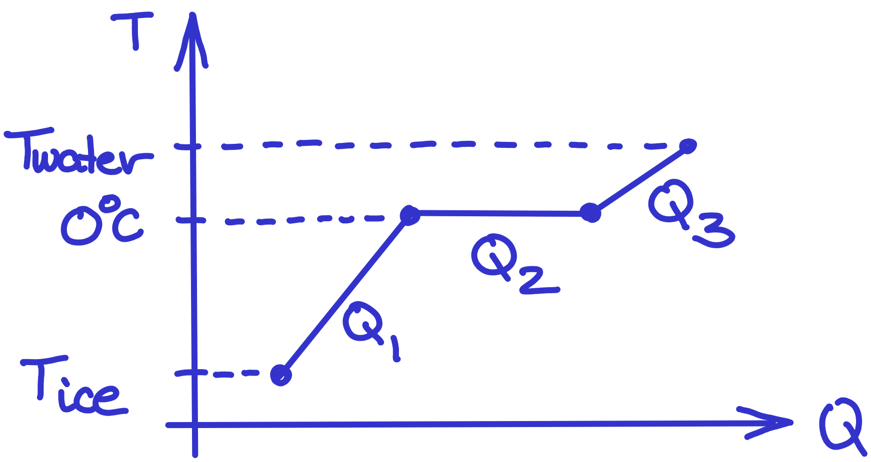
specific heat

heat capacity

The final temperature is the weighted average of the individual initial temperatures. The weights are the heat capacities.

→ Remember center of mass?

Melting ice



$m = 955g = 0.955kg$

$T_{ice} = -25°C$

$T_{water} = 60°C$

$c_{ice} = 2220 \frac{J}{kg°C}$

$c_{water} = 4186 \frac{J}{kg°C}$

$L_f = 333{,}000 \frac{J}{kg}$

$$Q_{tot} = Q_1 + Q_2 + Q_3$$

$$Q_{tot} = \underbrace{c_{ice} \cdot m \cdot (0°C - T_{ice})}_{\text{warming up the ice from } T_{ice} \text{ to } 0°C} + \underbrace{L_f \cdot m}_{\text{melting the ice to water}} +$$

$$+ \underbrace{c_{water} \cdot m (T_{water} - 0°C)}_{\text{warming up the water from } 0°C \text{ to } T_{water}}$$

Speeding water

$\boxed{\begin{array}{c}\text{water}\\ c\,;m\end{array}}$

$T_i = 15°C$

$T_f = 90°C$

$\Delta T = T_f - T_i$

$m = 550\,g = 0.55\,kg$

$c = 4.186\ \frac{J}{g\,°C} =$

$= 4{,}186\ \frac{J}{kg\,°C}$

What if $\Delta KE = Q$ was possible?

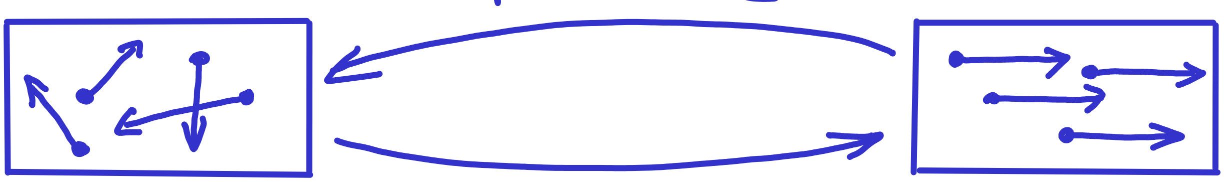
$$cm\Delta T = \frac{1}{2}mv^2$$

$$\sqrt{2c\Delta T} = v$$

$$v = \sqrt{2 \cdot 4{,}186 \cdot 75} \cong 792\ m/s$$

This speed is higher than the speed of sound in air!

disorder   always possible   order



$U = E_{th}$

$Q = \Delta E_{th}$

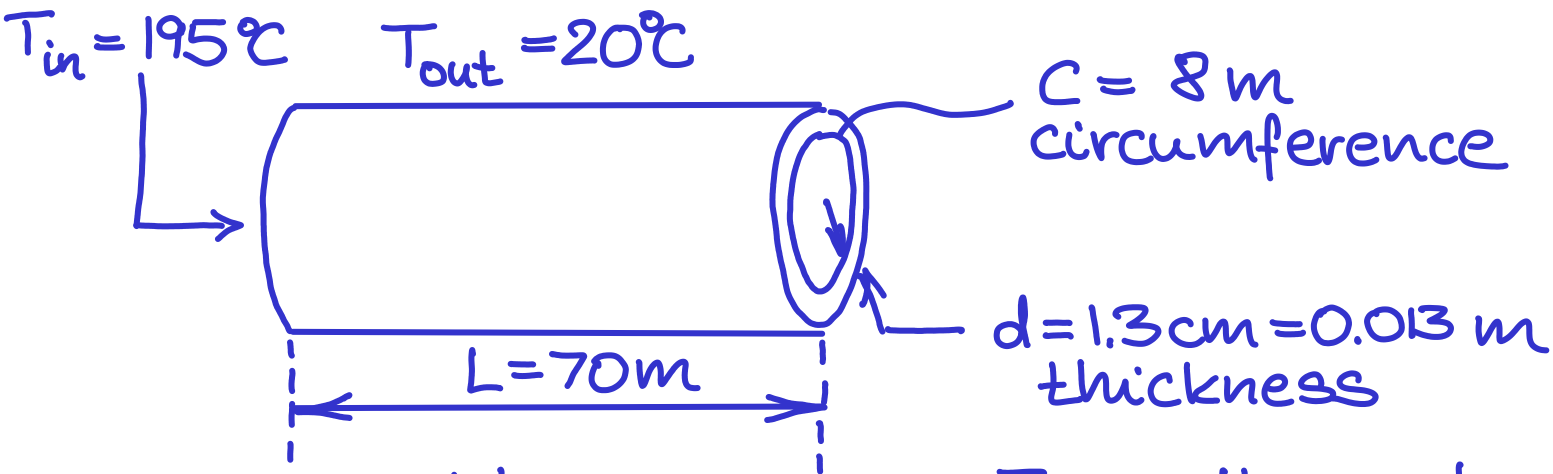
$Q = cm\Delta$

partially possible, $KE = \frac{1}{2}mv^2$

limitation: η

heat engine efficiency

Steam pipe



$$k = 0.27 \frac{W}{m \cdot °C} \quad \text{or} \quad 0.27 \frac{J}{s\,m\,°C}$$ thermal conductivity

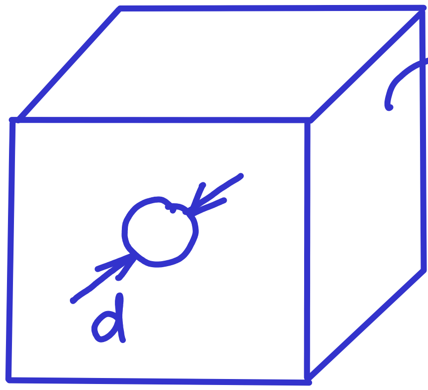
since $d \ll C$ therefore $A = L \cdot C$

$$Q = k \cdot \frac{\Delta T \cdot A \cdot t}{d} \qquad t = 1\,s$$

$$Q = 0.27 \cdot \frac{(195-20) \cdot 70 \cdot 8 \cdot 1}{0.013} = 2.04\,MJ$$

This is the heat loss in one second. It is signifant. This steam pipe needs more insulation!

Power emitted by a hole



$T = 1040K$ inside
$d = 20mm = 2cm$
$A = \pi r^2 = \frac{\pi d^2}{4}$
$\varepsilon = 1$: black body

$\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$; $b = 2.898 \times 10^{-3}\ m \cdot K$

$$P = \sigma \varepsilon A T^4 = 5.67 \times 10^{-8} \cdot 1 \cdot \frac{\pi \cdot 0.02^2}{4} \cdot 1040^4$$

$$\lambda_{max} \cdot T = b \Rightarrow \lambda_{max} = \frac{b}{T}$$

$$\lambda_{max} = \frac{2.898 \times 10^{-3}\ m \cdot K}{1040\ K} = 2.79 \times 10^{-6}\ m =$$

$= 2.79\ \mu m = 2790\ nm$ } far infrared

(visible light : 400-700 nm)