Heat

- temperature – measure of kinetic energy of particles

- Heat is a transfer of energy.
  ↳ flows from hot to cold.

An object of mass m, with heat capacity c receives heat Q. Its temperature is raised by ΔT.

$$Q = mc\Delta T$$

Q – heat, J.

m – mass, kg

c – heat capacity, J/kg °C or J/kg K

ΔT – change in temperature, °C or K.

- the specific heat is a quality of the material.
    - ↳ low c = less energy needed to raise temperature some amount.
    - ↳ high c = more energy needed to raise temperature some amount.

1 cal = 4.186 J

- the energy needed to raise 1g of water by 1°C.

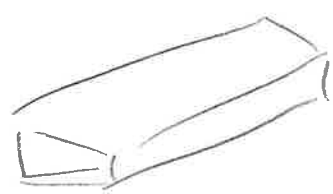
1 Calorie (food) = 1000 cal (thermal)
=
1 kcal

Heat problem

a) Calculate the heat required (in J and calories) to raise the temperature of a 5 kg block of copper 60 °C.

b) Calculate the energy needed to heat the equivalent mass of water the same amount.

a)



$m_{cu} = 5\ kg$

$c_{cu} = 387\ J/kg\,°C$

$\Delta T = 60\ °C$

$$Q = mc\Delta T$$

$$Q = (5\ kg)(387\ J/kg\,°C)(60\ °C)$$

$$\boxed{Q = 115,200\ J}$$

$$115,200\ \cancel{J} \times \frac{1\ cal}{4.186\ \cancel{J}}$$

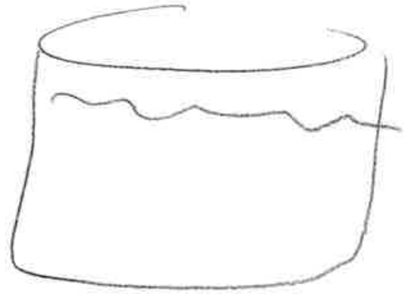
$$\boxed{Q = 27\,520\ cal}$$

b) $Q = mc\Delta T$

$m_w = 5\ kg$

$c_w = 4186\ J/kg\,°C$

$\Delta T = 60\ °C$



$Q = (5\ kg)(4186\ J/kg\,°C)(60\ °C)$

$Q = 1,255,800\ J$

$1,255,800\ \cancel{J} \times \dfrac{1\ cal}{4.186\ \cancel{J}}$

$\boxed{Q = 300,000\ cal}$

Thermal Expansion

- Materials expand with increase of temperature.

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

α - coefficient of linear expansion (1/°C).

L - original length (m)

ΔL - change in length (m)

ΔT - change in temperature (°C)

- Objects expand in 3-dimensions as well.

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

ΔV - change in volume (m^3)

β - bulk modulus (1/°C)

V - original volume

ΔT - change in temperature. (°C)

Calculate the increase in temperature necessary to increase the volume of a brass sphere by 5%.

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$$\frac{\Delta V}{V} = 0.05$$

$$\beta = 56 \times 10^{-6}\ 1/°C$$

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

$$\Delta T = \frac{\Delta V}{V} \frac{1}{\beta}$$

$$\Delta T = (0.05) \frac{1}{(56 \times 10^{-6}\ 1/°C)}$$

$$\boxed{\Delta T = 893\ °C}$$

Thermal expansion problem 2

500 mL of an unknown liquid expands to 533 mL when heated by 60 °C. Identify the unknown liquid.

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

$$\beta = \frac{\Delta V}{V} \frac{1}{\Delta T}$$

$$\beta = \frac{(533 - 500)}{(500)} \frac{1}{(60°C)}$$

$$\beta = \frac{33}{500} \frac{1}{60}$$

$$\beta = 0.0011 \ {}^{1}/_{°C}$$

$$\beta = 1.1 \times 10^{-3} \ {}^{1}/_{°C}$$

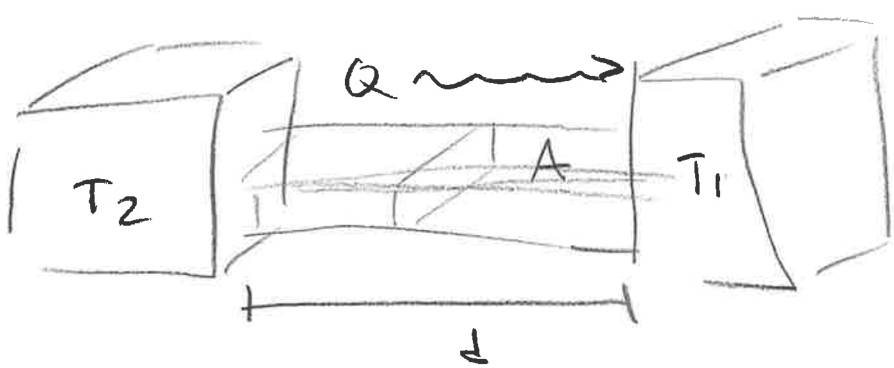
$$\beta = 1100 \times 10^{-6} \ {}^{1}/_{°C}$$

$\boxed{\text{Ethyl Alcohol}}$

Methods of Heat Transfer

1. Conduction - direct contact
2. Convection - flow of hot substance to cold.
3. Radiation - "black body radiation." All objects emit radiation due to their temperature.

Conduction



$$T_2 > T_1$$

$$\frac{Q}{t} = \frac{kA\,(T_2 - T_1)}{d}$$

Q - heat (J)

t - time (s)

k - thermal conductivity (W/m°C)

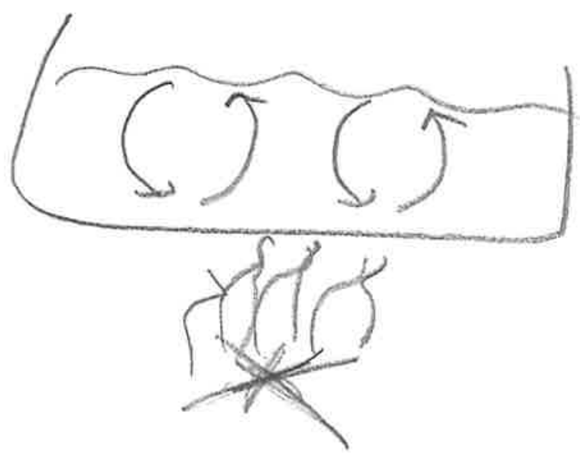
A - cross-sectional area (m^2)

d - distance (m)

T_2 - hot object (°C)

T_1 - cold object (°C)

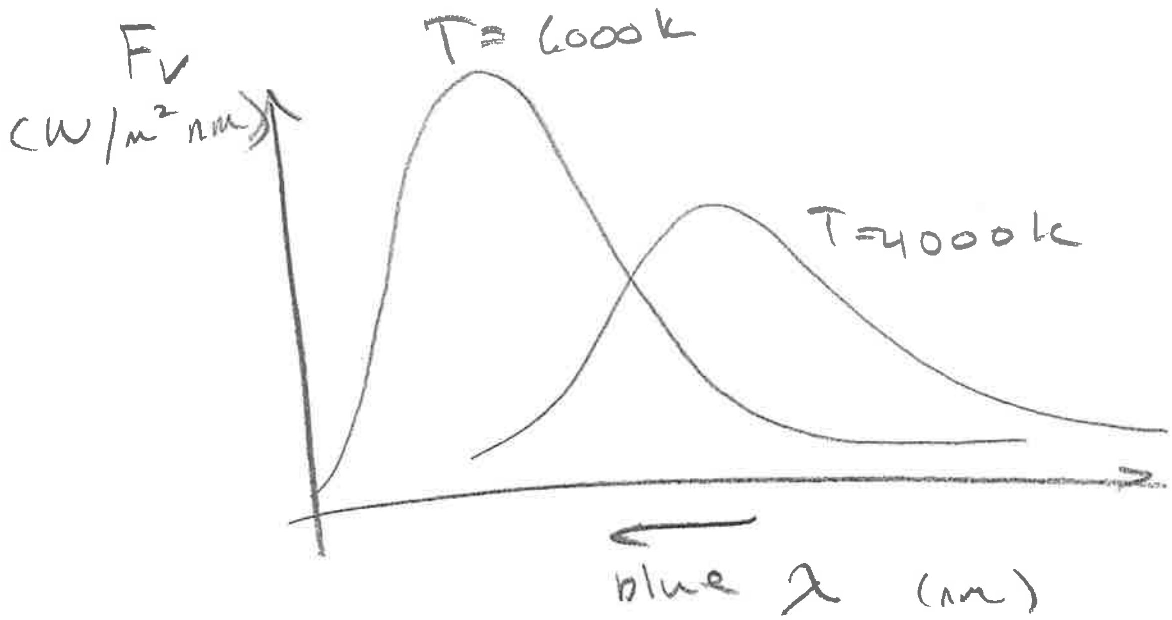
Convection



- hot rises and cold sinks.
- heat is transferred from the hot material as it rises and interacts with cold material.

Radiation

- All objects emit thermal radiation due to their temperature.
- Caused by atomic and molecular kinetic energy released as electromagnetic radiation.



- Peak thermal radiation depends on temperature

$$\lambda_{max} = \frac{2.898 \times 10^{-3}\ m\ K}{T\ (K)}$$

λ_{max} – peak wavelength   T – temperature (in K)

Thermal radiation

a) The surface of the sun has a temperature of 5870 K. Find the peak wavelength of the thermal emission.

b) the human body temperature is 37°C. Find the peak wavelength of the thermal emission.

a) $$\lambda_{max} = \frac{2.898 \times 10^{-3}\ m\,K}{5870\ K}$$

$$\lambda_{max} = 5.01 \times 10^{-7}\ m \quad \text{(green light)}$$

b) $$\lambda_{max} = \frac{2.898 \times 10^{-3}\ m\,K}{(37 + 273 K)}$$

$$\lambda_{max} = \frac{2.898 \times 10^{-3}\ m\,K}{310\ K}$$

$$\lambda_{max} = 9.35 \times 10^{-6}\ m \quad \text{(infrared)}$$

$$\frac{Q}{t} = A\sigma e T^4$$

Q - heat (J)

t - time (s)

A - surface area (m^2)

e - emissivity (0 - 1)

T - temperature (K)