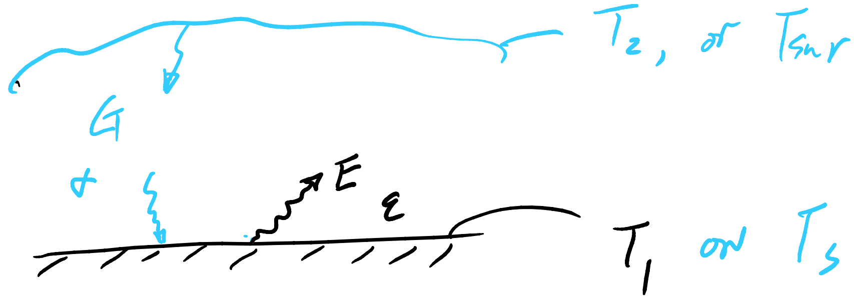
Radiation HT

$$q = \varepsilon \cdot A \cdot \sigma \cdot (T_s^4 - T_{sur}^4) \quad \text{or} \quad q'' = \varepsilon \cdot \sigma \cdot (T_s^4 - T_{sur}^4)$$



$$q''_{1-2} = E - \alpha \cdot G = \underbrace{\varepsilon \cdot \sigma \cdot T_1^4}_{E} - \alpha \cdot \sigma \cdot T_2^4 = \varepsilon \cdot \sigma \cdot (T_1^4 - T_2^4)$$

grey body: $\varepsilon = \alpha$

$$q''_{2-1} = q''_{1-2}$$

$$q = \varepsilon \cdot A \cdot \sigma (T_1^4 - T_2^4)$$

$$= \varepsilon \cdot A \cdot \sigma (T_1^2 + T_2^2)(T_1^2 - T_2^2)$$

$$= \varepsilon \cdot A \cdot \sigma \cdot (T_1^2 + T_2^2)(T_1 + T_2)\underbrace{(T_1 - T_2)}_{\Delta T}$$

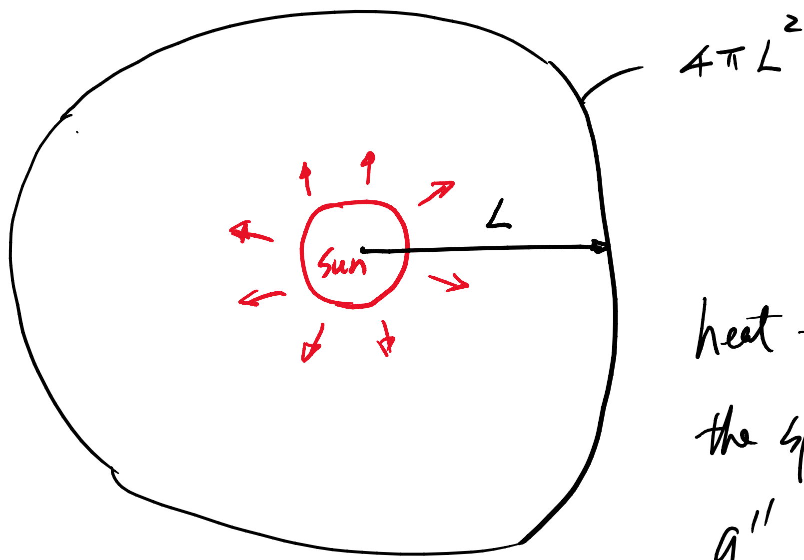
$$= \underbrace{\varepsilon \cdot \sigma \cdot (T_1^2 + T_2^2)(T_1 + T_2)}_{h_r} \cdot A \cdot \Delta T$$

heat transfer coefficient from radiation.

$$q_r = h_r \cdot A \cdot \Delta T$$

where, $h_r = \varepsilon \cdot \sigma \cdot (T_1^2 + T_2^2)(T_1 + T_2)$

$\doteq 4 \varepsilon \cdot \sigma \cdot T_m^3$, $T_m = \dfrac{T_1 + T_2}{2}$

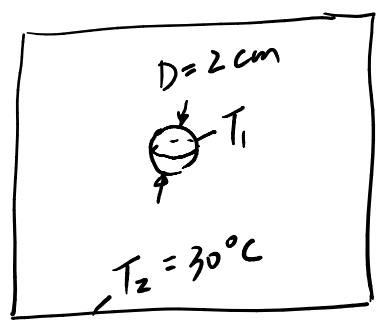


$$q_{sun} = \varepsilon \cdot \sigma \cdot A_{sun} \cdot T_{sun}^4$$

heat flux projected on the spheric surface

$$q''_L = \frac{\varepsilon \cdot \sigma \cdot A_{sun} \cdot T_{sun}^4}{4\pi L^2}$$

e.g.



$q = 300$ mW

In vacuum. No conduction.

$\eta = 50\%$

i> bright, $\varepsilon = 0.035$, $T_1 = ?$

ii> black anodized, $\varepsilon = 0.8$, $T_1 = ?$

$$q_{1-2} = \varepsilon \cdot \sigma \cdot A_s \cdot [T_1^4 - T_2^4)$$

✓ ✓ ✓ ✓ ? ✓

$$\frac{q_{1-2}}{\varepsilon \cdot \sigma \cdot A_s} = T_1^4 - T_2^4 \Rightarrow T_1^4 = \frac{q_{1-2}}{\varepsilon \cdot \sigma \cdot A_s} + T_2^4$$

$$T_1(\varepsilon) = \sqrt[4]{\frac{q_{1-2}}{\varepsilon \cdot \sigma \cdot A_s} + T_2^4}$$

where, $q_{1-2} = 300 \cdot 10^{-3} \cdot (1-\eta) = 3\times10^{-1} \cdot (0.5) = 0.15$ W

$A_s = 4\pi r^2 = \pi D^2 = \pi \cdot (2\times10^{-2})^2 = 4\pi \cdot 10^{-4}$ m^2

$T_2 = 30 + 273.15 = 303.15$ K

$A_s = 4\pi r^2 = \pi D^2 = \pi \cdot (2\times10^{-}\,)^2 = 4\pi \cdot 10^{-}\ m^2$

$T_2 = 30\,^\circ C = 30 + 273.15 = 303.15\ K$

$T_1(0.035) = 599\ K = 326\,^\circ C$ ✗

$T_2(0.8) = 342\ K = 69\,^\circ C$

∇T : temp. gradient.

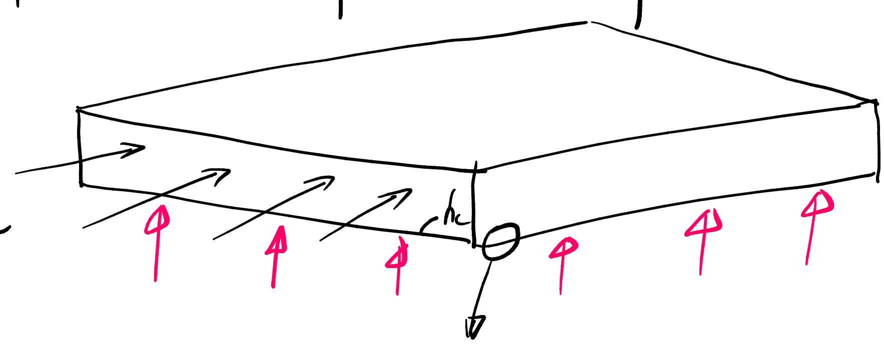
ΔT : temp. diff.

Summary of heat transfer modes

Mode	Mechanism	Eq.	Quantities
conduction	Diffusion	$q'' = -k \cdot \frac{dT}{dx}$ $q'' = \frac{q}{A}$	A: normal to ∇T k: $\frac{W}{m\cdot K}$ or $\frac{W}{m\cdot {}^\circ C}$ $\frac{dT}{dx} = \nabla T$, Temp. gradient.
Convection	B.L. + collective motions of fluids.	$q'' = h_c \cdot (T_s - T_\infty)$ Re ΔP, $q'' = \frac{q}{A_s}$	A_s: wetted areas h_c: $\frac{W}{m^2\cdot K}$ $\propto \frac{k}{\delta}$ → thickness
radiation	E.M. wave	$q'' = \varepsilon \cdot \sigma \cdot (T_1^4 - T_2^4)$ $\varepsilon = \alpha$, grey body	T: MUST "Kelvin" $\sigma = 5.67\times10^{-8}\ \frac{W}{m^2\cdot K^4}$

$h_c = 100\ \frac{W}{m^2\cdot K}$

e.g.

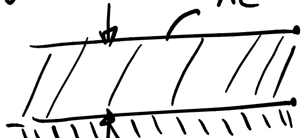


cold air

$T_f = 30\,^\circ C$

$\delta = 10$ mm

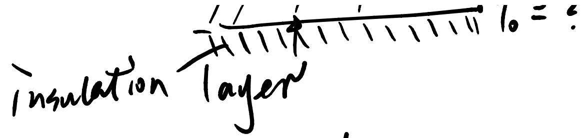
h_c $T_i = 85\,^\circ C$



$k = 20\ \frac{W}{m\cdot K}$

$T_0 = ?$

insulation layer



i> $q''_{heating} = ?$

$$q'' = h_c \cdot (T_i - T_f) = 5.5\ \frac{kW}{m^2}$$

ii> $T_0 = ?$

$$q'' = k\,\frac{T_0 - T_i}{\delta} \Rightarrow T_0 = \frac{q'' \cdot \delta}{k} + T_i$$

$$= 87.75\,^\circ C.$$