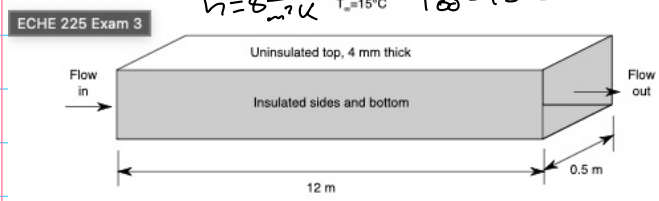
5. $(\lambda T)_{max\ pow} = 2897.8\ \mu m \cdot K$

$\lambda = \frac{2897.8\ \mu m \cdot K}{700°C + 273.15} = 2.98\ \mu m$

Duct



$h = 8 \frac{W}{m^2 K}$ $T_\infty = 15°C$ $T_\infty = 15°C$

PVC Duct

$k = 0.25 \frac{W}{mK}$

walls: thickness = $4\ mm = 0.004\ m$

$L = 12\ m$

width = $0.5\ m$

height = $0.2\ m$

$h = 30 \frac{W}{m^2 K}$

Air

$c_p = 1.0 \frac{kJ}{kg K} = 1000 \frac{J}{kg K}$

6. $R_{cond,\ top}$

$R_{cond} = \frac{L}{kA_c} = \frac{0.004\ m}{(0.25 \frac{W}{mK})(12\ m \cdot 0.5\ m)} = 0.00267 \frac{K}{W}$

7. $R_{conv,\ inside}$

$A_s = (12\ m \cdot 0.5\ m) = 6\ m^2$ walls insulated, heat loss only from top

$R_{conv} = \frac{1}{hA_s} = \frac{1}{(30 \frac{W}{m^2 K})(6\ m^2)} = 0.00556 \frac{K}{W}$

8. $R_{conv,\ exposed}$

$A_s = (12\ m \cdot 0.5\ m) = 6\ m^2$

$R_{conv} = \frac{1}{hA_s} = \frac{1}{(8 \frac{W}{m^2 K})(6\ m^2)} = 0.0208 \frac{K}{W}$

9. $\dot{Q}$ from top,

$R_{total} = 0.00556 + 0.0208 + 0.00267 = 0.02903 \frac{K}{W}$

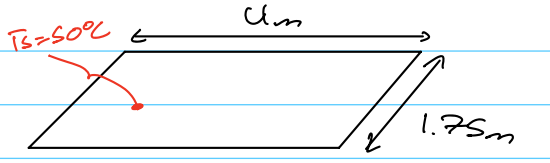
$\dot{Q} = \frac{\Delta T}{R_{total}} = \frac{28 - 15}{0.02903 \frac{K}{W}} = 447.8\ W$

10. $T_i = 29°C$
$T_e = 27°C$
$\dot{m} = 0.23 \frac{kg}{s}$
} Find $\dot{Q}$

loss
$-\dot{Q} = \dot{m} \cdot c_p (T_e - T_i)$
$= 0.23 \frac{kg}{s} (1000 \frac{J}{kg \cdot K})(27°C - 29°C)$
$= -460 \, W$

$\dot{Q} = 460 \, W$

Air:
$k = 0.026 \frac{W}{m \cdot K}$
$Pr = 0.73$



$u_\infty = 70 \frac{km}{hr} = 19.44 \, m/s$
$T_\infty = 10°C$

$Re_L = 5.1 \times 10^6$

11. $Re_L = 5.1 \times 10^6 > 5 \times 10^5$ turbulent
assume transition from laminar to turbulent
$Nu_L = (0.037 \, Re_L^{4/5} - 871) \cdot Pr^{1/3}$
$= (0.037 (5.1 \times 10^6)^{4/5} - 871) \cdot (0.73)^{1/3}$
$Nu_L = 6954.99$

12. $Nu_L = \frac{Lh}{k_{Sand}} = \frac{(L_m)h}{0.026 \frac{W}{m \cdot K}}$
$h = \frac{(0.026 \frac{W}{m \cdot K})(6954.99)}{L_m} = 45.21 \frac{W}{m^2 K}$

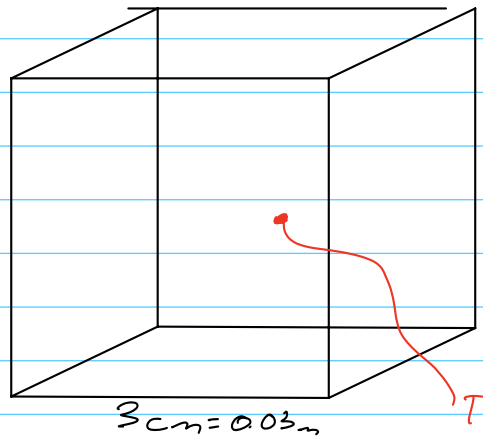
13. $\dot{Q}_{conv} = h \Delta T A_s$
$= (45.21 \frac{W}{m^2 K})(50°C - 10°C)(L_m \cdot 1.75m)$
$= 12658.8 \, W$

$\dot{Q}_{conv} = 12.66 \, kW$

14. $\dot{Q}_{emitted} = \varepsilon \sigma A_s (T_s^4 - T_\infty^4)$
$= 0.8 (5.67 \times 10^{-8} \frac{W}{m^2 K^4})(L_m \cdot 1.75m)(50 + 273.15)^4$
$= 3462.48 \, W$

$\dot{Q}_{emitted} = 3.46 \, kW$

Cube (3cm sides)



$T_\infty = 25°C$ in oil & $h = 120 \frac{W}{m^2 K}$

$T_e = 80°C$

Titanium cube

$V = (0.03m)^3 = 2.7 \times 10^{-5} m^3$

$A_s = 6(0.03m)^2 = 5.4 \times 10^{-3} m^2$

$\rho = 4506 \frac{kg}{m^3}$

$k = 19.5 \frac{W}{mK}$

$c_p = 0.544 \frac{kJ}{kgK} = 544 \frac{J}{kgK}$

Oil

$\rho = 875 \frac{kg}{m^3}$

$k = 0.12 \frac{W}{mK}$

$c_p = 1.91 \frac{kJ}{kgK} = 1910 \frac{J}{kgK}$

15. LSA valid?

$B_i = \frac{h L_c}{k} = \frac{hV}{kA_s} = \frac{(120 \frac{W}{m^2K})(2.7 \times 10^{-5} m^3)}{(19.5 \frac{W}{mK})(5.4 \times 10^{-3} m^2)} = 0.0308 < 0.1$ ✓

Conclusion: Lumped capacitance method is valid

16. $Q_{total} = m c_p [T(t_{final}) - T_i]$

$m = 4506 \frac{kg}{m^3} \cdot (2.7 \times 10^{-5} m^3) = 0.121662 kg$

$Q_{total} = 0.121662 kg (0.544 \frac{kJ}{kgK})(80°C - 600°C) = -35.05 kJ$

$Q_{total} = 35.05 kJ$

17. $\frac{T(t) - T_\infty}{T_i - T_\infty} = e^{-bt}$ $\quad b = \frac{hA_s}{\rho V_c}$

$t = -\frac{1}{b} \cdot \ln\left[\frac{T(t) - T_\infty}{T_i - T_\infty}\right] \rightsquigarrow t = -\frac{1}{0.00979} \cdot \ln\left[\frac{80 - 25}{600 - 25}\right]$

$= 239.72 sec \cdot \frac{1 min}{60 sec}$

$t = 3.995 min$

$T(t) = 80°C$

$T_\infty = 25°C$

$T_i = 600°C$

$b = \frac{(120 \frac{W}{m^2K})(5.4 \times 10^{-3} m^2)}{4506 \frac{kg}{m^3} \cdot (2.7 \times 10^{-5} m^3)(544 \frac{J}{kgK})}$

$= 0.00974 \frac{1}{s}$