Abd El Hafid Boussouf University Center – Mila
Institute of Science and Technology
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Heat Transfer Final Exam

Closed Notes, Show All Work, Overall pages 2/2 + Appendix

Problem n° 01 (08 points):

A transformer (**10×6.2×5 cm^3**) will be cooled by attaching a (**10×6.2 cm²**) black-anodized heat sink (**ε = 0.90**) to its top surface. The heat sink has **7** fins (**η = 0.95**), each fin has (**5×2×100 mm^3**) (high × thick × long).

A fan blows air at **T_∞ = 25 °C** parallel to the passages between the fins. The heat sink is to dissipate **12 W** of heat and the base temperature of the heat sink is not to exceed **T_s = 60 °C** to maintain safe operation.

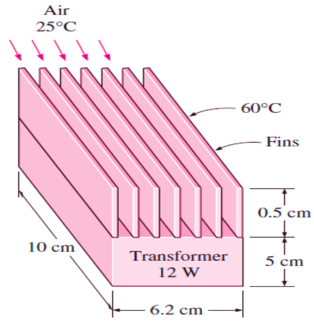

Figure – 1

Assuming the fins and the base plate to be nearly isothermal and the flow is laminar over the entire finned surface of the transformer, give:

1) The energy balance on the finned surface in terms of: $\mathbf{Q_{total}}$, $\mathbf{q_{conv}}$ and $\mathbf{q_{rad}}$

Figure – 2 example of heat sink

Determine:

2) The total surface area ($\mathbf{A_{s,\ total}}$) for heat transfer
3) The radiation heat transfer rate ($\mathbf{q_{rad}}$)
4) The heat transfer coefficient (**h**)
5) The minimum free-stream velocity ($\mathbf{U_{min}}$) the fan needs to supply to avoid overheating.

Figure – 3 example of transformer with heat sink

Data:

The properties of air at the film temperature of **42.5 °C** are:

k =	**0.02681**	(W/m².°C)
ν =	**1.726 x 10^{-5}**	(m²/s)
Pr =	**0.7248**	

Flow regime	Local *Nusselt* number	Average *Nusselt* number	Conditions
Laminar	$Nu_x = \frac{h_x.x}{k} = 0.332Re_x^{0.5}Pr^{\frac{1}{3}}$	$Nu = \frac{h.L}{k} = 0.664Re_L^{0.5}Pr^{\frac{1}{3}}$	$Re_x < 5\times10^5$ $Pr > 0.6$
Turbulent	$Nu_x = \frac{h_x.x}{k} = 0.0296Re_x^{0.8}Pr^{\frac{1}{3}}$	$Nu = \frac{h.L}{k} = 0.037Re_L^{0.8}Pr^{\frac{1}{3}}$	$5\times10^5 \le Re_L \le 10^7$ $0.6 \le Pr \le 60$

Problem n° 02 (04 points):

A **5-m-long** and **3-m-high** house wall is constructed of two layers of **18-mm-thick** sheetrock (**$k_{sheetrock}$ = 0.15 W/m.K**) placed **178 mm** apart. The space between the sheetrock is filled with fiberglass insulation (**$k_{fiberglass}$ = 0.02 W/m.K**).

The house is maintained at **25 °C** and the ambient temperature outside is **4 °C**. Taking the heat transfer coefficients at the inner and outer surfaces of the house to be **8.3** and **34 W/m².K**, respectively,

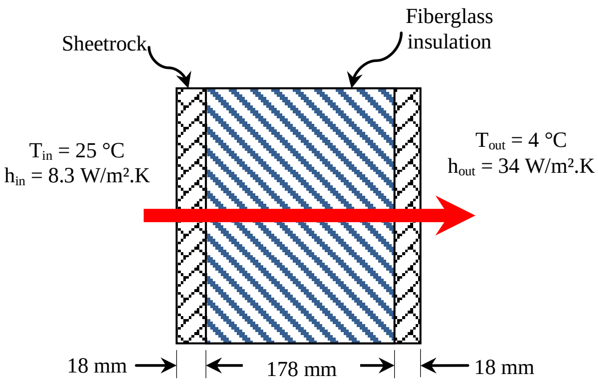

Figure – 4

1) Draw the thermal resistance circuit for this wall
2) Determine the thermal resistance of the wall
3) Calculate the heat transfer rate through the wall.

Problem n° 03 (08 points):

Consider a stainless steel spoon (**k_{ss} = 8.7 Btu/h.ft.°F**) partially immersed in boiling water at **200°F** a kitchen at **75°F**. The handle of the spoon has a rectangular cross section of **0.08 in. × 0.5 in.**, and extends **7 in.** in the air from the free surface of the water.

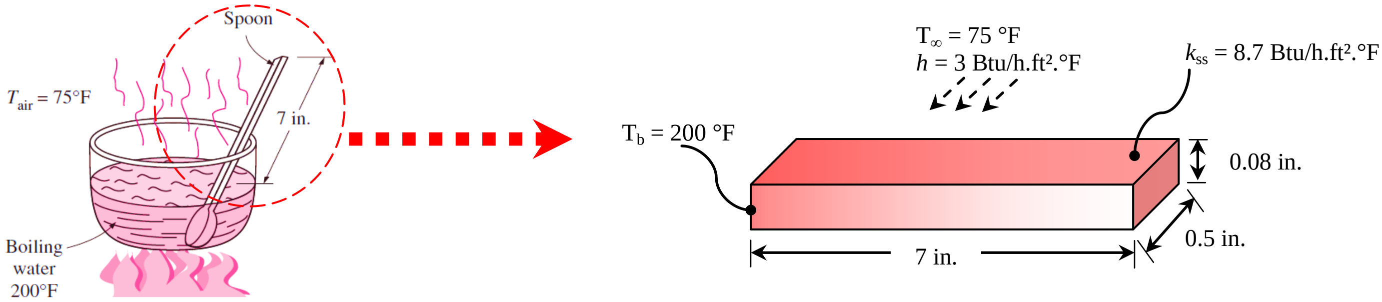

Figure – 5

If the heat transfer coefficient at the exposed surfaces of the spoon handle is **3 Btu/h.ft².°F**, and assuming that the heat transfer from the tip of the spoon is negligible

1) Give the variation of temperature $\frac{T(x) - T(\infty)}{T(b) - T(\infty)}$ along the spoon ;
2) Determine the temperature difference (**$\Delta T = T_b - T_{tip}$**) across the exposed surface of the spoon handle ;
3) Determine the fin heat transfer rate (**q_f**).

Use **APPENDIX** in next page.

Dr. Mohamed BOUTI
Good Luck,