ROSE-HULMAN Institute of Technology
DEPARTMENT OF MECHANICAL ENGINEERING

ME302-Heat transfer
Mini-exam 2

Solutions
Name

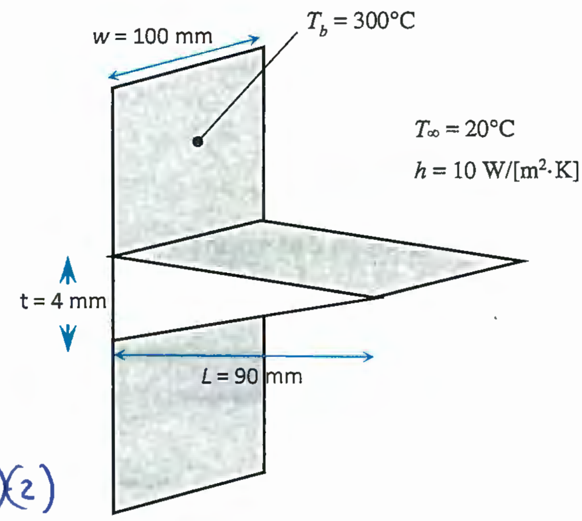
Grade: ______/20

Problem 1 (9 pts)

A straight triangular fin made of an aluminum alloy (k = 50 W/m-K) is exposed to a convective environment as shown in the figure. The fin is attached to a wall maintained at T_b = 300°C. Dimensions and other information are given in the figure. Ignore heat any heat transfer from the front and back faces of the fin.

(a) [5 pts] If the fin efficiency is 74%, find the rate of heat transfer from the fin in W.

(b) [4 pts] Find the fin effectiveness.



(a) $\dot{Q} = \eta_f \dot{Q}_{MAX}$ $\quad \dot{Q}_{MAX} = hA_{fin}(T_b - T_\infty)$

$$A_{fin} = \sqrt{L^2 + \left(\frac{t}{2}\right)^2} \cdot W \cdot 2$$

$$= \left(\sqrt{0.090^2 + 0.002^2} \cdot m\right)(0.100\ m)(2)$$

$$= 0.018\ m^2$$

$$\dot{Q} = \left(0.74 \cdot 10 \frac{W}{m^2 \cdot K}\right)(0.018\ m^2) \cdot (300 - 20)°C$$

$$= 37.3\ W$$ ← ANS

(b) $$\varepsilon = \frac{\dot{Q}_{fin}}{\dot{Q}_{no\ fin}} = \frac{\eta_f h A_{fin} (T_b - T_\infty)}{h A_b (T_b - T_\infty)} = \eta_f \frac{A_{fin}}{A_{b}}$$

$$= \eta_f \frac{A_{fin}}{t \cdot w} = 0.74 \frac{0.018\ m^2}{(0.004\ m)(0.100\ m)}$$

$$= 33.3$$ ← ANS

Problem 2 [3 pts]

(a) True | (False) The fin equation represents conservation of energy for a system consisting of an entire fin. ✗

(b) (True) | False The solution to the fin equation can be used to find how temperature changes a long a fin.

(c) (True) | False The solution to the fin equation can be used to find the rate of heat transfer from a fin.

Problem 3 (4 pts)

Answer the following questions.

(a) [1 pt] Insulation of thickness L is added to a plane wall. The *total* thermal resistance of the wall/insulation combination will

- o A. decrease
- o B. stay the same
- o C. increase
- o D. Cannot be determined

(b) [1 pt] Insulation of thickness L is added to the outside diameter of a hot water pipe. The *total* thermal resistance of the pipe/insulation combination will

- o A. decrease
- o B. stay the same
- o C. increase
- o D. Cannot be determined

$r_{NEW} < r_{crit}$?

(c) [1 pt] The handle of a metal spoon is 7.0 cm long and modeled as a fin. You calculate the parameter m to be m = 0.879 cm^{-1}. Is the infinitely long finite boundary condition a reasonable assumption?

- o A. Yes
- o B. No
- o C. Cannot be determined

$L_{fin} >> \frac{1}{m}$

(d) [1 pt] For the spoon in part (c), is the insulated tip with a corrected fin length boundary condition a reasonable assumption?

- o A. Yes
- o B. No
- o C. Cannot be determined

Always a good choice

Problem 4 (4 pts)

An aluminum (k=230 W/m-K, ρ=2600 kg/m³, c=901 J/kg-K) cube with side length L=2.00 mm is initially at a temperature of T_1 = 60°C. Suddenly it is placed in a convective environment with T_∞=20°C and h_∞=80 W/m²-K where are faces are exposed to the convective fluid.

(a) [2 pts] Can you assume that temperature gradients are negligible with the aluminum? Justify your answer *quantitatively*.

(b) [2 pts] The time constant is calculated to be TC = 9.8 seconds. Estimate the temperature of the aluminum 30 minutes after it is exposed to the environment.

(a) $Bi = \frac{h L_{CHE}}{K} = \frac{h \forall / A_{sur}}{K} = \frac{h \cdot L^3/(6L^2)}{K} = \frac{hL}{6K} = \frac{80 \frac{W}{m^2 \cdot K} \cdot 0.002\,m}{6 \cdot 230 \frac{W}{m \cdot K}}$

$= 0.000116 \ll 0.1$ Temperature gradients are negligible.

(b) 30 min = 1800 s >> TC

$T_{final} \approx T_\infty = 20°C$ ← ANS