GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 2003

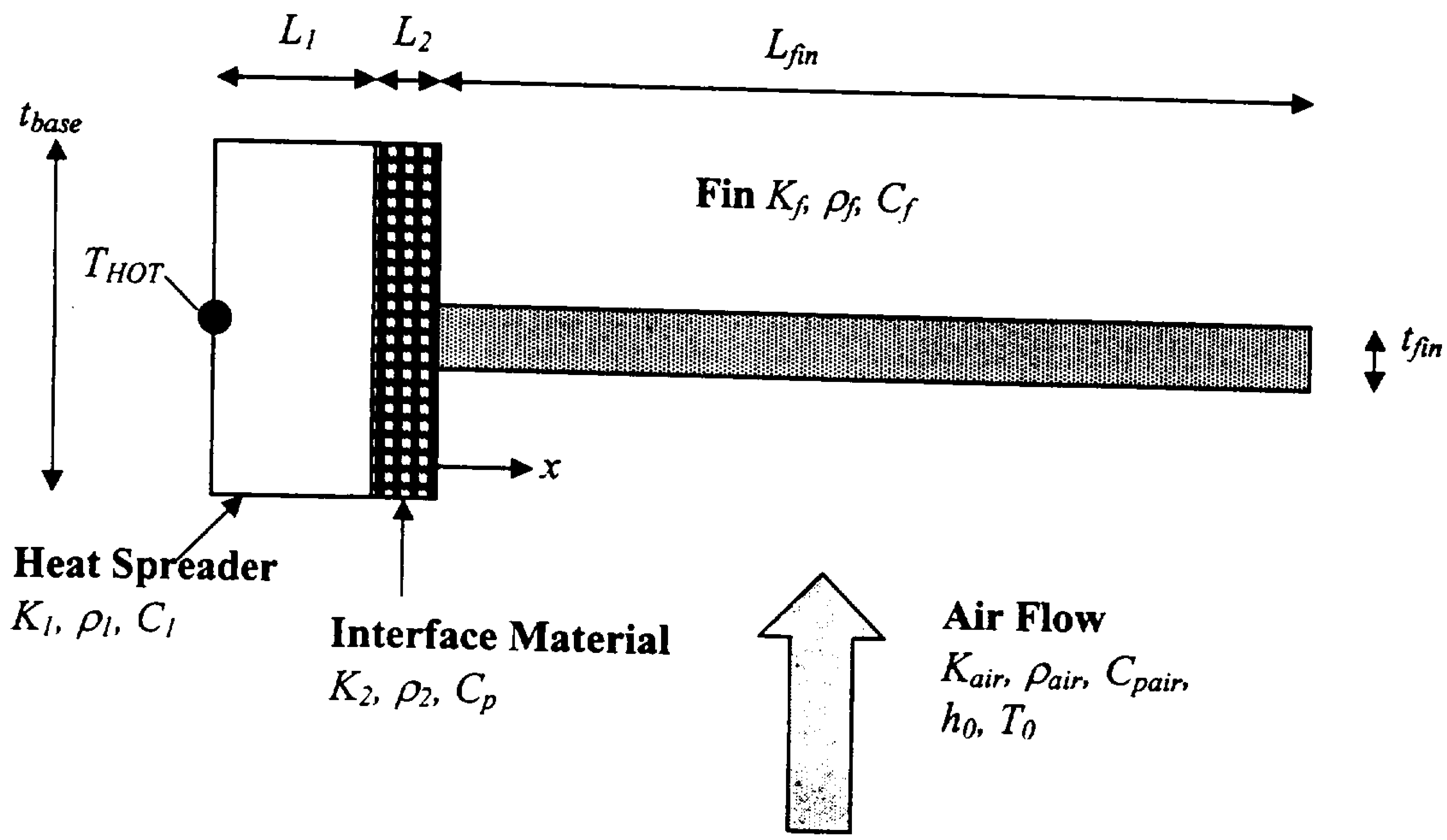
Heat Transfer
EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

* Please sign your **name** on the back of this page —

Problem #1

Consider the following situation, where a fin is extended into an air stream (at temperature T_0) in order to carry heat away from a hot surface (at temperature $T_{HOT} > T_0$). There is a heat spreader and an interface material between the hot surface and the base of the fin. Dimensions are given in the figure below. You can assume a unit depth for everything.



There are three materials in the system: two for the base and one for the fin. The thermal properties of the system are given in the figure.

In this problem, the temperature varies only in the x-direction. You can neglect radiation from the fin, and you can also neglect convection and radiation from the interface/heat spreader materials.

1. *In terms of the parameters given, what time would you use to check the system was in steady-state?*

2. Let's say we are observing the system at a time much later than the time constant you specified above. *Sketch the temperature distribution in the x-direction, between the surface at T_{HOT} and the end of the fin for each of the following three cases:*
   a. *$k_1 > k_2$ and a short fin with an adiabatic tip*
   b. *$k_1 < k_2$ and a temperature $T_{HOT} > T_{tip} > T_0$ at the end of the non-adiabatic tip*
   c. *$k_1 < k_2$ and a very long fin*

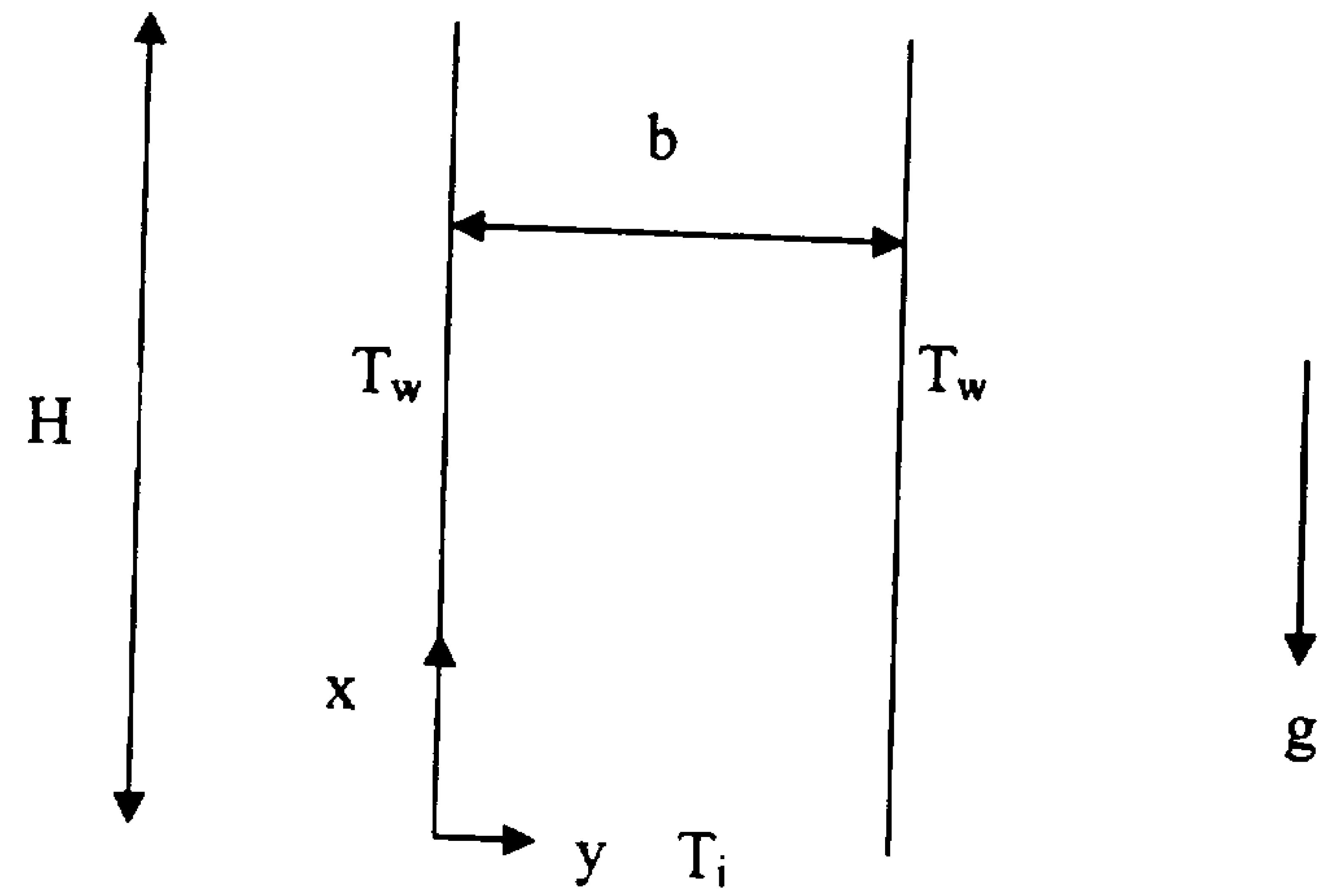
3. *What criteria would you use to determine that the fin is "long" or "short" compared to the length over which heat leaves the fin?*

4. *For an infinitely long fin, what is the heat flux away from the surface T_{HOT}. Please provide your answer in terms of the properties and geometry given, the convection coefficient h, and the temperature T_0.*

5. Let's say you determine that that fin is sufficiently hot that radiation from the fin is important. The fin is a black body, and exchanges thermal radiation with only the air, which is also a blackbody. *Write the **differential equation** that describes the temperature field in the fin, $T(x)$.* You do not need to solve the DEQ.

Problem #2

Consider a vertical channel formed by two smooth parallel plates of height **H**, spaced a distance **b** apart in air. The plates are very long in the direction normal to the plane of the paper. Each plate is at a temperature $\mathbf{T_w}$, which is higher than $\mathbf{T_i}$, the air temperature at the channel inlet. Assume the resulting natural convection flow to be laminar.



1. (35%) Show the expected profile of the x-component of the velocity, **u**, across the channel at four different x locations from the entrance to the exit. Do this for three cases: H/b>>1, H/b =1, H/b<<1.

2. (35%) Write down the equations and boundary conditions needed to determine u and v components of the flow velocity in general. Write down the appropriate simplified versions of these equations for the cases H/b>>1 and H/b<<1 far away from the leading edge (x=0).

3. (30%) Solve for the x-component of the velocity, **u**, far away from the leading edge for H/b>>1.

Problem #3

The roof of a house measures 1x1 m^2 in area. The sky temperature is 300K, and the sun temperature is 5800K, the distance between the earth and the sun is 1.5 x 10^{11} m (note the sun diameter is 1.4x10^9 m and the earth diameter is 1.3x10^7 m). **Determine the steady-state temperature of the roof at noon. State clearly any assumptions you make in your analysis.**

Properties of the roof are: $\varepsilon_\lambda = 0.1$ $\lambda < 6$ μm and $\varepsilon_\lambda = 0.5$ $\lambda > 6$ μm and the roof is a diffuse surface.

Fractional Blackbody Emission Power Functions

λT (μmK)	F(0-λ)
1000	0.00032
1200	0.00213
1400	0.00779
1600	0.01972
1800	0.03934
2000	0.06673
2200	0.10089
2400	0.14026
2600	0.18312
2800	0.22790
3000	0.27323
3200	0.31810
3400	0.36174
3600	0.40361
3800	0.44338