GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2001

Manufacturing
EXAM AREA

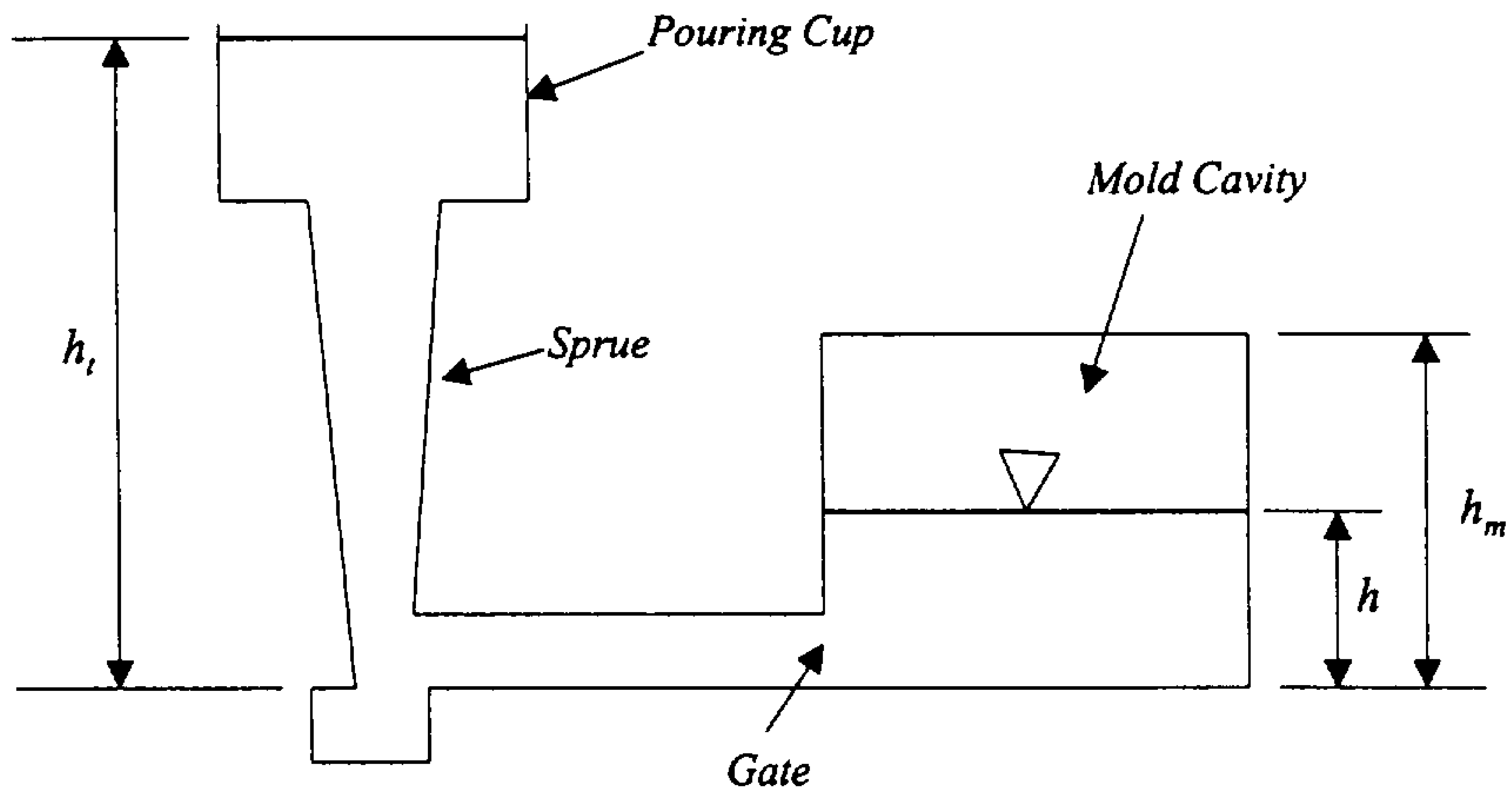
Assigned Number (DO NOT SIGN YOUR NAME)

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

Ph.D. Written Qualifying Examination-Manufacturing Area
George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology
Spring 2000

Note: Answer two, and not more than two, of the following questions:

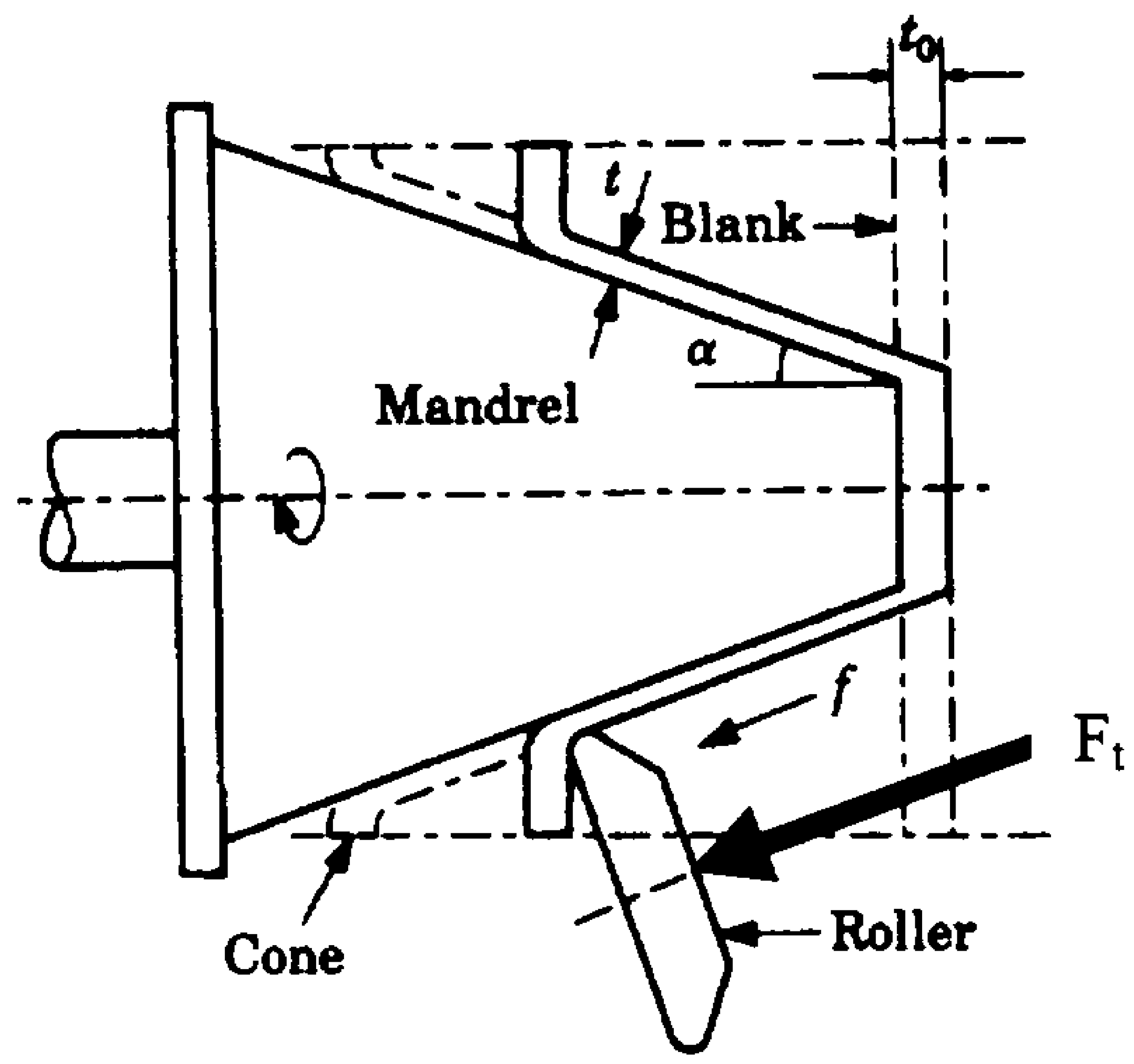
1. Consider the mold shown in the figure below for sand casting a rectangular block of metal.



(a) Discuss the fundamental scientific principles on which sprue design is based <u>and</u> the primary reason for using a tapered sprue.

(b) Derive an equation for the time required to fill the mold cavity upto height h_m, given that the cross-sectional areas of the gate (i.e. where the runner meets the mold cavity) and the mold cavity are A_g and A_m, respectively. Note that h in the figure represents the instantaneous height of the molten metal in the mold cavity. Clearly list all assumptions you make.

2. In shear spinning, an axi-symmetrical conical shape can be generated by using a roller to <u>shear</u> a sheet of metal against a mandrel (see figure). Parts made by this process include rocket motors.



In shear spinning over a conical mandrel, the thickness of the spun part is given by

$$t = t_o \sin\alpha$$

where t_o is the initial thickness of the material, and α is the angle of the mandrel.

The force responsible for supplying energy is the tangential force, F_t.

(a) Show that the thickness equation given above is true (i.e., derive it). Discuss the extreme limits of the equation ($\alpha = 0$, $\alpha = 90^o$). (Hint: the metal is sheared in the process, not stretched. An analogy would be the card model in cutting.)

(b) Derive an expression for F_t, in terms of the material properties ($\sigma = K\varepsilon^n$), the feed rate, f, and the geometry of the part (t_o) and of the mandrel (α).

(c) Discuss the expression you derived in (b) in terms of its limitations (i.e., why would it underestimate the true force?).

3. A manufacturing engineer is conducting experiments to develop the process parameter values for machining a block of medium carbon steel on a shaper using a single point Carbide tool. After a particular test, he finds that the cutting edge is plastically deformed. He attributes this to significant loss in the hardness of the carbide tool due to excessive heat generated in the process.

(a) Draw a neat sketch of the orthogonal cutting geometry (recall that shaping is an orthogonal process) and label the following: major heat source(s), approximate location of the maximum cutting temperature, and arrows indicating where the heat from the source(s) is dissipated (use large and small arrows to indicate the relative magnitudes of heat dissipation).

(b) Derive a simple equation to calculate the mean temperature of the chip, $\bar{\theta}_{chip}$, in terms of the power generated in the heat source(s) identified in part (a), density of the workpiece material ρ, workpiece specific heat c_p, cutting speed V, undeformed chip thickness t, the width of cut w, and the ambient room temperature θ_0. List all the assumptions you make in deriving the equation.

(c) Given that the engineer has the following alternate tool materials available: Al_2O_3 and Polycrystalline Diamond (PcD), discuss their suitability as replacements for the Carbide tool currently used by the engineer with a focus on their relative mechanical/thermal /chemical properties. Some of the typical properties of the tool materials are given in the table.

	Carbide	Al_2O_3	PcD
Room temp. hardness (GPa)	10	18	85
Compressive Strength (MPa)	5500	3000	4800
Thermal conductivity (W/mK)	75	10	560
Chemical reactivity with carbon steels	Moderate to Strong	None	Moderate