GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2003

Manufacturing
EXAM AREA

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

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

Problem #1

The following eight questions are related to the attached phase diagram (Figure 1).

1) Calculate the quantity of liquid (not the liquid composition) present (in percent) when an alloy having a composition of 50% A and 50% B is cooled to 1100°C. Please show all of your work. A good way to begin is to label all of the phase fields.

2) For this same 50% A – 50% B alloy, what is the composition of the solid at 1100°C?

3) For this same 50% A – 50% B alloy, what is the composition of the liquid at 1100°C?

4) For this same 50% A – 50% B alloy, sketch the cooling curve (temperature vs. time) from 1200 to 800°C.

5) For the same 50% A – 50% B alloy, assuming that the alloy is cooled sufficiently slowly so that the solidification follows the phase diagram, what would be the composition of the last bit of liquid to solidify and at what temperature would it solidify?

6) For this same 50% A – 50% B alloy, what phase (or phases) is (are) present at 800°C?

7) Would you expect this same 50% A – 50% B alloy to be harder and stronger than pure B, i.e. 100% B? Explain your answer in as much detail as you can, mentioning mechanisms.

8) Sketch the cooling curve for 100% B (not the alloy) from 1200 to 800°C.

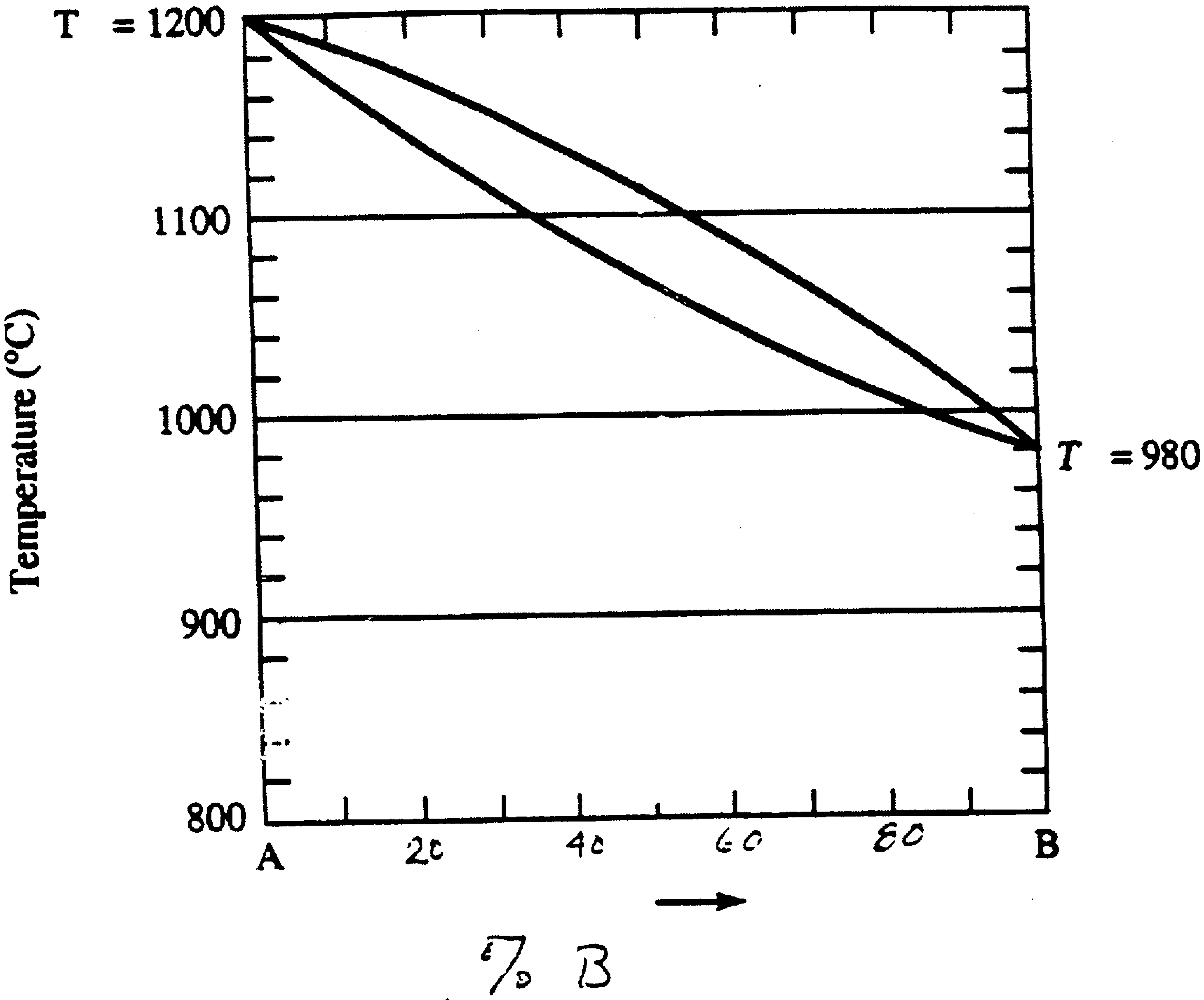
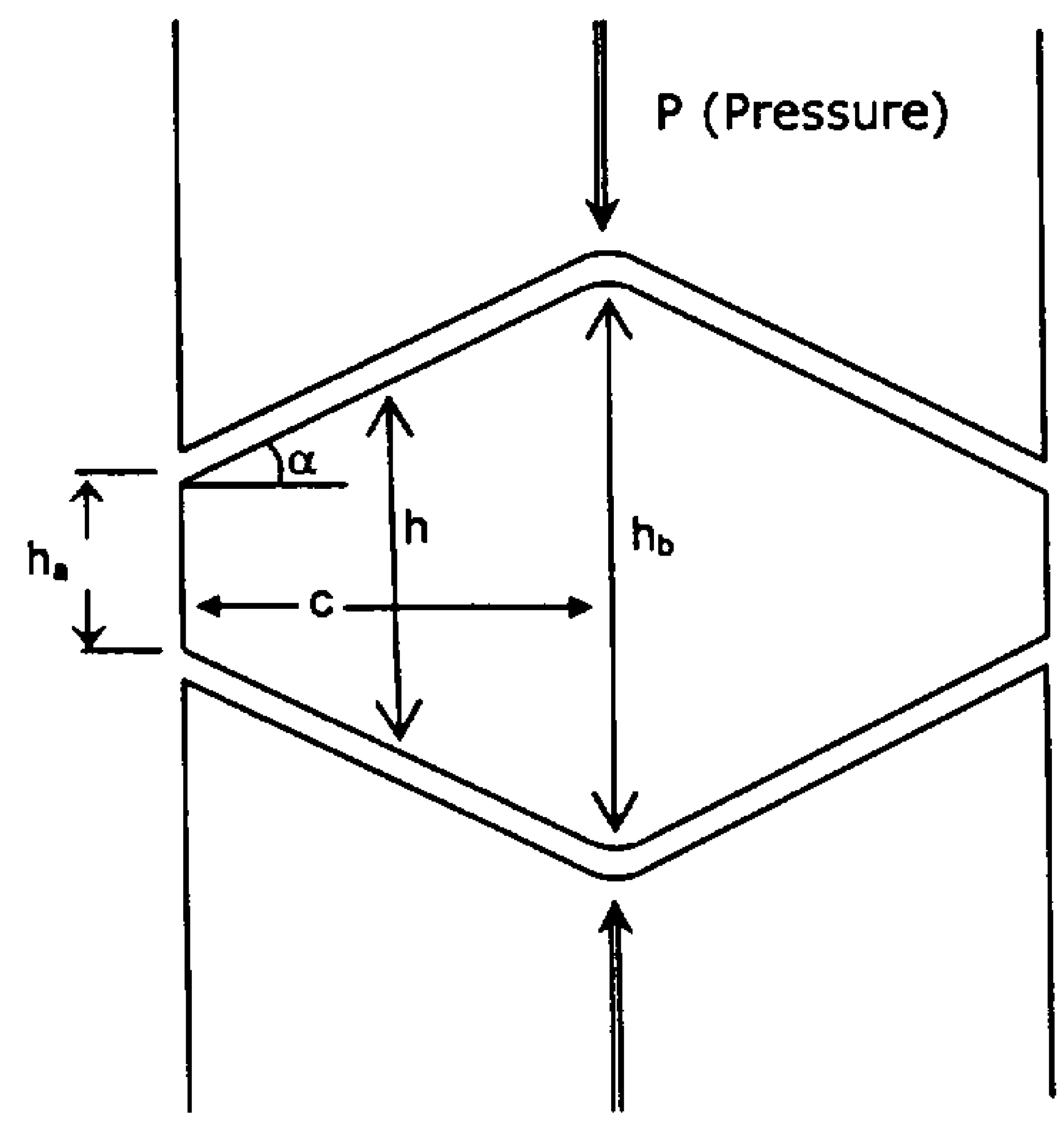


Figure 1

Problem #2

You are most likely familiar with open die forging where a metal is hammered between flat dies. This type of geometry is typically used in classroom examples to show how an analysis might be performed. However, many forging operations are done with shaped dies. This problem asks you to demonstrate your ability to extend the 'flat die' geometry to 'curved dies'.

Suppose the die is shaped as shown below:



Set up the equations (using the slab analysis) for stress versus position on the workpiece, solve the equations, and produce a figure showing this variation.
(Hint: Use the tresca criteria: $\sigma_{largest} - \sigma_{smallest} = \sigma_{yield}$) to deduce the stresses within the workpiece in terms of h_a, h_b, α and μ , the coefficient of friction).

Problem #3

You are extruding a polymer rod, which has a radius of R. At processing temperature, the polymer has a Newtonian viscosity μ.

The extrusion die has a length of L, and a radius of R (you can ignore die swell, so the diameters are the same).

The screw in the extruder has an axial length l, normal pitch of flights w, helix angle θ, and depth of flight B. The barrel of the extruder has inner radius r.

1) Determine the relationship between the speed of the screw and the output rate of the rod.

2) Determine the effect of doubling the screw speed and the output rate of the rod.

Additional information for part (3): The polymer has a surface tension in air of γ_p, and the die has a surface tension in air of $10\gamma_p$. You may ignore the effect of surface tension in the screw, as well as gravity.

3) Determine the effect of surface tension on the change in screw speed necessary to maintain a constant output rate of polymer rod, as compared to your answer for part (1). Is the value for screw speed in part (3) greater or smaller than that in part (1)?

$$\gamma_{SL} + \gamma_{LV} \cos\theta = \gamma_{SV}$$

$$\gamma_{AB} = \gamma_A + \gamma_B - 2\sqrt{\gamma_A \gamma_B}$$