GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2000

Thermodynamics
EXAM AREA

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

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

Problem #1:

The air from a glass tube is completely evacuated before the tip of the tube is fused and sealed, leaving the sealed tube with no air inside. You are invited to break the tip of the tube, allowing air to enter the tube, wait a second or two, and dip the tip of the open end of the tube into a cup of water.

Do you expect the water to rise into the glass tube, or do you expect air bubbles to come out of the tube into the water?

Explain the basis for you expectation using the 1^{st} law of thermodynamics and the ideal gas property relationships.

Problem #2:

A steady flow adiabatic turbine accepts steam at 4 MPa and 500C with negligible velocity and exhausts at 100 kPa with a quality of 98% and a velocity of 150 m/s. Assume the environment is at 25C.

A. Calculate

1) The actual work per unit mass of steam flowing through the turbine.
2) The irreversibility/ unit mass.
3) The reversible work/unit mass
4) The turbine efficiency
5) The effectiveness of the turbine.

B. Explain the industrial significance of each answer above.

Problem #3:

This examiner detests closed-book exams. Oh well. Even faculty members have to obey the rules. Thus I am going to ask you a series of questions---none of which requires a numerical answer. Rather you are to either discuss or describe how you would do a set of computations or you will discuss what you know about certain property relationships.

A. There is new material called **Burdellium**.

Its triple point is (P = 1.0 Pa, T = 10 K)
Its normal boiling point is (P = 100 kPa, T = 100 C)
Its critical point is (P = 2 MPa, T = 400 C)

You are to determine the enthalpy difference between the following two states:

State 1: P = 100 kPa and T = 10 C
State 2: P = 10 MPa and T = 1000 K

Describe exactly how you would compute the enthalpy difference. and/or what additional information is required and how you would use it. Please show all of your work and illustrate your answer with appropriate graphs and sketches.

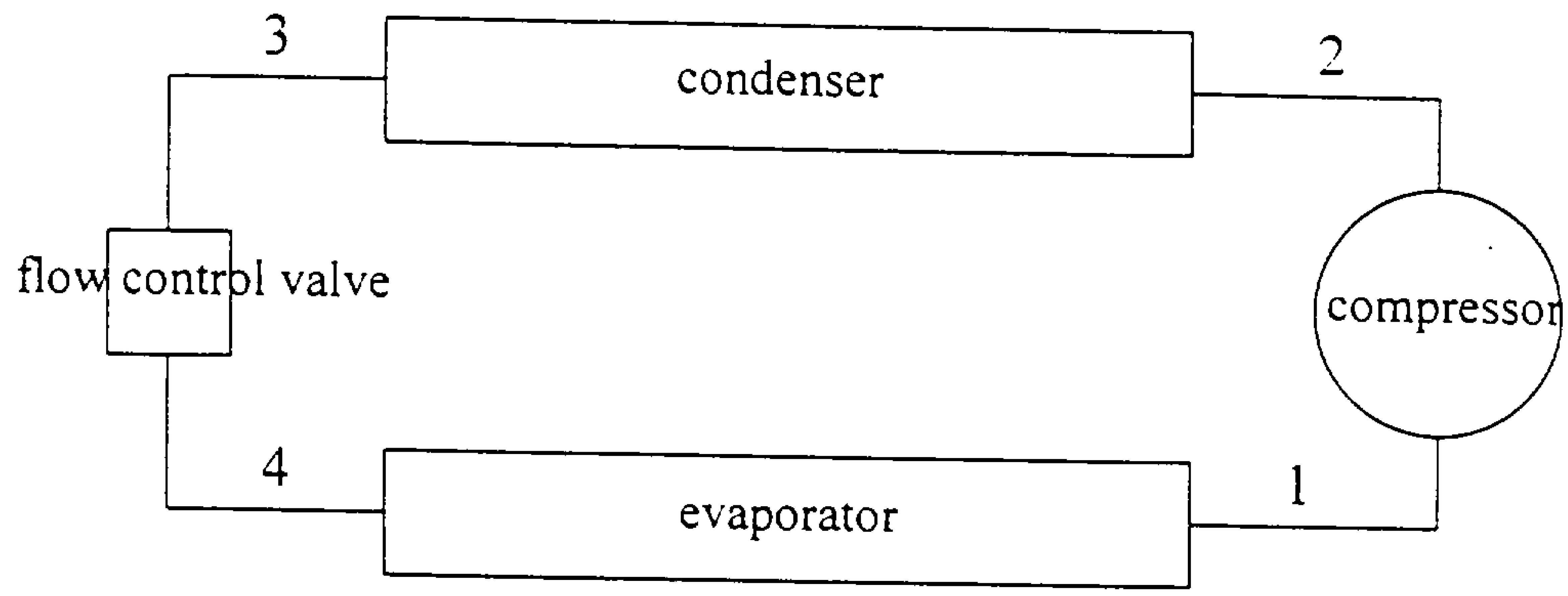
B. What is the "State Principle?" Why is it important? How do you apply it?

C. What is the Clapeyron Equation? Why is it important? How is it used? What are its limitations?

D. Is it possible to have an isentropic but irreversible process? If so---please describe such a process.

Problem #4:

A vapor compression heat pump system sketched below uses R-12 as its working fluid. The compressor is adiabatic. Fluid is assumed to flow through the condenser and through the evaporator with negligible pressure drops. The evaporator operates at 0.50 MPa. and the condenser operates at 1.20 MPa. Fluid leaves the compressor at station 2 at 70 C. Fluid leaves the evaporator at station 1 at 20 C. Use standard assumptions elsewhere in the system. The ambient conditions are 100 kPa and 25 C. Heat is supplied to a heating load at 35 C. Heat is extracted from the ambient atmosphere at 25 C.



Complete the following table of properties:

	station	T (C)	P (MPa)	h (kJ/kg)	s (kJ/kg-K)	ψ (kJ/kg)
1	evap outlet					
2	comp outlet					
3	cond outlet					
4	evap inlet					
RDS	restricted dead state					

ψ is the flow or stream availability or exergy.
The restricted dead state is in thermal and hydraulic or pressure equilibrium with the medium but not mixed or blended with the medium.

Determine the following quantities:

heat from the condenser per unit mass ______________ kJ/kg

heat to the evaporator per unit mass ______________ kJ/kg

work to the compressor per unit mass ______________ kJ/kg

heating COP ______________

(continued-Problem #4)

Also compute the corresponding Carnot cycle heating COP and explain your choice of the temperatures used in this calculation.

Carnot heating COP ____________

Explain the differences between the two COP results.

Complete a combined laws exergy analysis of this system and indicate the exergy flows and exergy destructions on the following diagram. Write the value of fluid stream or flow exergy, in kJ/kg, at each station on the pipelines. Write the amount of exergy destruction, in kJ/kg, inside each component. Indicate any exergy transport by heat with an arrow accompanied by its value in kJ/kg. Indicate the temperature of the control surface anywhere heat leaves or enters the system.