# Indian Institute of Technology Kanpur

## Thermodynamics (ESO201A)
## Instructor: Jishnu Bhattacharya

## Tutorial 3

**3–6C** What is the difference between the critical point and the triple point?

**3–26** Complete this table for refrigerant-134a:

| $T$, °C | $P$, kPa | $v$, m³/kg | Phase description |
|---|---|---|---|
| −4 | 320 | | |
| 10 | | 0.0065 | |
| | 850 | | Saturated vapor |
| 90 | 600 | | |

**3–43** Water initially at 200 kPa and 300°C is contained in a piston-cylinder device fitted with stops. The water is allowed to cool at constant pressure until it exists as a saturated vapor and the piston rests on the stops. Then the water continues to cool until the pressure is 100 kPa. On the $T$-$v$ diagrams sketch, with respect to the saturation lines, the process curves passing through both the initial, intermediate, and final states of the water. Label the $T$, $P$ and $v$ values for end states on the process curves. Find the overall change in internal energy between the initial and final states per unit mass of water.

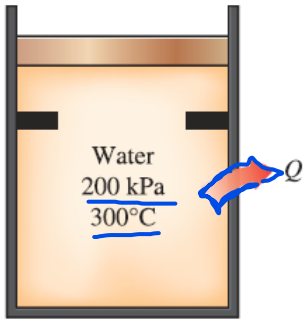


**FIGURE P3–43**

**3–65C** Under what conditions is the ideal-gas assumption suitable for real gases? Low pressure and high temperature

**4–1C** An ideal gas at a given state expands to a fixed final volume first at constant pressure and then at constant temperature. For which case is the work done greater?

**4–24** A piston–cylinder device contains 50 kg of water at 250 kPa and 25°C. The cross-sectional area of the piston is 0.1 $m^2$. Heat is now transferred to the water, causing part of it to evaporate and expand. When the volume reaches 0.2 $m^3$, the piston reaches a linear spring whose spring constant is 100 kN/m. More heat is transferred to the water until the piston rises 20 cm more. Determine (*a*) the final pressure and temperature and (*b*) the work done during this process. Also, show the process on a *P*-*V* diagram. *Answers:* (*a*) 450 kPa, 147.9°C, (*b*) 44.5 kJ

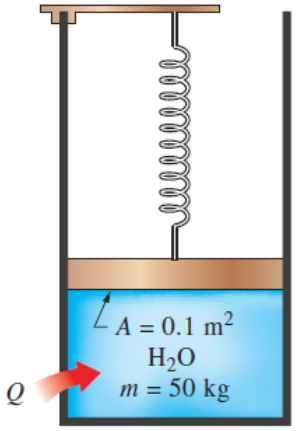


**FIGURE P4–24**

**4–34** An insulated piston–cylinder device contains 5 L of saturated liquid water at a constant pressure of 175 kPa. Water is stirred by a paddle wheel while a current of 8 A flows for 45 min through a resistor placed in the water. If one-half of the liquid is evaporated during this constant-pressure process and the paddle-wheel work amounts to 400 kJ, determine the voltage of the source. Also, show the process on a *P*-*v* diagram with respect to saturation lines. *Answer:* 224 V

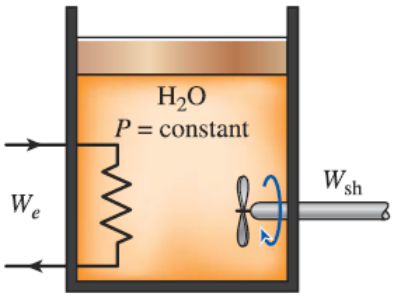


**FIGURE P4–34**

## Additional Homework Problems

**3–14C** Does $h_{fg}$ change with pressure? How?

**3–41** 10-kg of R-134a at 300 kPa fills a rigid container whose volume is 14 L. Determine the temperature and total enthalpy in the container. The container is now heated until the pressure is 600 kPa. Determine the temperature and total enthalpy when the heating is completed.

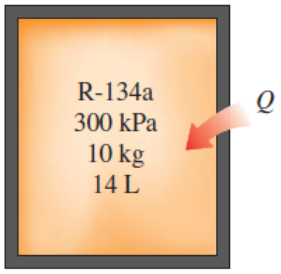


**FIGURE P3–41**

**3–75** A 1-m$^3$ tank containing air at 10°C and 350 kPa is connected through a valve to another tank containing 3 kg of air at 35°C and 200 kPa. Now the valve is opened, and the entire system is allowed to reach thermal equilibrium with the surroundings, which are at 20°C. Determine the volume of the second tank and the final equilibrium pressure of air. *Answers:* 1.33 m$^3$, 264 kPa

**3–80C** How are the reduced pressure and reduced temperature defined?

**4–29** A 0.5-m$^3$ rigid tank contains refrigerant-134a initially at 160 kPa and 40 percent quality. Heat is now transferred to the refrigerant until the pressure reaches 700 kPa. Determine (*a*) the mass of the refrigerant in the tank and (*b*) the amount of heat transferred. Also, show the process on a *P*-*v* diagram with respect to saturation lines.

**4–57C** Is it possible to compress an ideal gas isothermally in an adiabatic piston–cylinder device? Explain.

**4–66** Argon is compressed in a polytropic process with $n = 1.2$ from 120 kPa and 10°C to 800 kPa in a piston–cylinder device. Determine the work produced and heat transferred during this compression process, in kJ/kg.

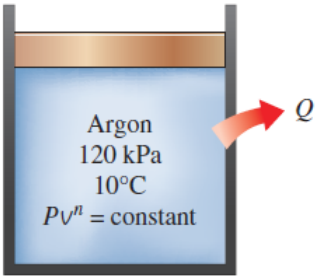


**FIGURE P4–66**