A 132, 136, 140
B 133, 137, 140
C 134, 138, 140
D 135, 139, 140

[redacted] 75

vapor state and the piston rests against the stops. With the piston against the stops, the water is further heated until the pressure is 600 kPa. On the *P*-*v* and *T*-*v* diagrams sketch, with respect to the saturation lines, the process curves passing through both the initial and final states of the water. Label the states on the process as 1, 2, and 3. On both the *P*-*v* and *T*-*v* diagrams, sketch the isotherms passing through the states and show their values, in °C, on the isotherms.

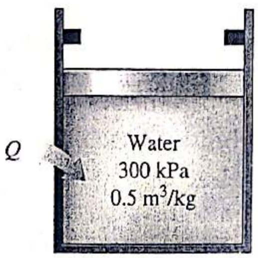

FIGURE P3–130

3–131 0.2-kg of argon is compressed from 6895 kPa and 149°C to 13,790 kPa in a piston-cylinder device which executes a polytropic process for which $PV^{1.6}$ = constant. Determine the final temperature treating the argon as (*a*) an ideal gas and (*b*) a Beattie-Bridgeman gas.

Fundamentals of Engineering (FE) Exam Problems

3–132 A rigid tank contains 2 kg of an ideal gas at 5 atm and 40°C. Now a valve is opened, and half of mass of the gas is allowed to escape. If the final pressure in the tank is 2.2 atm, the final temperature in the tank is

(*a*) 71°C (*b*) 44°C (*c*) −100°C
(*d*) 20°C (*e*) 172°C

3–133 The pressure of an automobile tire is measured to be 190 kPa (gage) before a trip and 215 kPa (gage) after the trip at a location where the atmospheric pressure is 95 kPa. If the temperature of air in the tire before the trip is 25°C, the air temperature after the trip is

(*a*) 51.1°C (*b*) 64.2°C (*c*) 27.2°C
(*d*) 28.3°C (*e*) 25.0°C

3–134 A 300-m³ rigid tank is filled with saturated liquid–vapor mixture of water at 200 kPa. If 25 percent of the mass is liquid and 75 percent of the mass is vapor, the total mass in the tank is

(*a*) 451 kg (*b*) 556 kg (*c*) 300 kg
(*d*) 331 kg (*e*) 195 kg

3–135 Water is boiled at 1 atm pressure in a coffee maker equipped with an immersion-type electric heating element. The coffee maker initially contains 1 kg of water. Once boiling started, it is observed that half of the water in the coffee maker evaporated in 10 minutes. If the heat loss from the coffee maker is negligible, the power rating of the heating element is

(*a*) 3.8 kW (*b*) 2.2 kW (*c*) 1.9 kW
(*d*) 1.6 kW (*e*) 0.8 kW

3–136 A 1-m³ rigid tank contains 10 kg of water (in any phase or phases) at 160°C. The pressure in the tank is

(*a*) 738 kPa (*b*) 618 kPa (*c*) 370 kPa
(*d*) 2000 MPa (*e*) 1618 kPa

3–137 Water is boiling at 1 atm pressure in a stainless steel pan on an electric range. It is observed that 2 kg of liquid water evaporates in 30 min. The rate of heat transfer to the water is

(*a*) 2.51 kW (*b*) 2.32 kW (*c*) 2.97 kW
(*d*) 0.47 kW (*e*) 3.12 kW

3–138 Water is boiled in a pan on a stove at sea level. During 10 min of boiling, it is observed that 200 g of water has evaporated. Then the rate of heat transfer to the water is

(*a*) 0.84 kJ/min (*b*) 45.1 kJ/min
(*c*) 41.8 kJ/min (*d*) 53.5 kJ/min
(*e*) 225.7 kJ/min

3–139 A 3-m³ rigid vessel contains steam at 4 MPa and 500°C. The mass of the steam is

(*a*) 3 kg (*b*) 9 kg (*c*) 26 kg
(*d*) 35 kg (*e*) 52 kg

3–140 Consider a sealed can that is filled with refrigerant-134a. The contents of the can are at the room temperature of 25°C. Now a leak develops, and the pressure in the can drops to the local atmospheric pressure of 90 kPa. The temperature of the refrigerant in the can is expected to drop to (rounded to the nearest integer)

(*a*) 0°C (*b*) −29°C (*c*) −16°C
(*d*) 5°C (*e*) 25°C

Design and Essay Problems

3–141 In an article on tire maintenance, it is stated that tires lose air over time, and pressure losses as high as 90 kPa per year are measured. The article recommends checking tire pressure at least once a month to avoid low tire pressure that hurts fuel efficiency and causes uneven

(3-132) rigid tank → constant Volume ($V_2 = V_1$)

$m_2 = \frac{1}{2} m_1 = 1$ kg $\qquad \frac{V_1}{v_1} = \frac{1}{2}\frac{V_2}{v_2} = 1$

$\frac{P_2 V_2}{R_2 T_2} = \frac{1}{2}\frac{P_1 V_1}{R_1 T_1} \qquad \frac{1}{2}\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad T_1 = 40 + 273.15 = 313.15$

$\frac{1}{2} * \frac{5(101.3)}{313.15} = \frac{2.2(101.3)}{T_2} \rightarrow T_2 = 275.6 \text{ K} = 2.42°C$

(3-136) $V = 1 m^3 \quad m = 10$ kg $\quad T = 160°C. \quad P = ??$

$v = \frac{V}{m} = \frac{1}{10} = 0.1 \; m^3/kg$

Table A-4 → saturated mixture

$P = P_{sat} = 618.23$ kPa [b]

3-140 $\quad P_2 v_2 = R_2 T_2$

$90 \, v_2 = 0.08149 \, T_2$ --- ①

$P_1 v_1 = R_1 T_1$

$P_1 v_1 = 0.08149 * (273.15 + 25)$

[redacted]

[redacted]

5–30 The diffuser in a jet engine is designed to decrease the kinetic energy of the air entering the engine compressor without any work or heat interactions. Calculate the velocity at the exit of a diffuser when air at 100 kPa and 20°C enters it with a velocity of 500 m/s and the exit state is 200 kPa and 90°C.

4.5

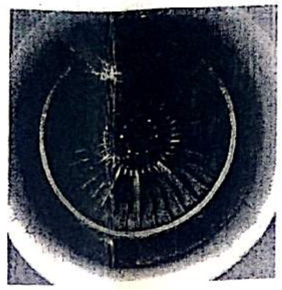

FIGURE P5–30

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$\dot{E}_{in} = \dot{E}_{out}$

$\dot{Q}_{in} + \dot{W}_{in} + \dot{m}\theta_{in} = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}\theta_{o}$

diffuser → steady

$\dot{m}_{in}(ke_{in} + pe + h_{in}) = \dot{m}_{out}(ke + pe + h)$

$\frac{U_{in}^2}{2} + h_{in} = \frac{U_{out}^2}{2} + h_{out}$

$h_{in} \cong 295.17$ kJ/kg

$h_{out} \cong 361$ kJ/kg

$\frac{U_{in}^2}{2} + 295.17 = \frac{500^2}{2} + 361$ kJ/kg

$V_{in} \cong 617.78$ m/s

5–199 Steam is compressed by an adiabatic compressor from 0.2 MPa and 150°C to 0.8 MPa and 350°C at a rate of 1.30 kg/s. The power input to the compressor is

(a) 511 kW (b) 393 kW
(c) 302 kW (d) 717 kW
(e) 901 kW

$\dot{m}_{in}\theta_{in} + W_{in} = \dot{m}_{out}\theta_{out}$

$1.3(h_{in}) + W_{in} = 1.3 * (h_{out})$

$W_{in} = 511.03$ kJ

$\dot{W}_{in} = \frac{\dot{W}_{out}}{\dot{m}}$

$h_{in} = 2769.1$ (kJ/kg)

$h_{out} = 3162.2$ kJ/kg

$\dot{m}_{in}\theta_{in} = \dot{m}_{out}\theta_{out} + W_{out} + \frac{\dot{Q}_{out}}{\dot{m}}$

5–198 Steam expands in a turbine from 4 MPa and 500°C to 0.5 MPa and 250°C at a rate of 1350 kg/h. Heat is lost from the turbine at a rate of 25 kJ/s during the process. The power output of the turbine is

(a) 157 kW (b) 207 kW
(c) 182 kW (d) 287 kW
(e) 246 kW

$\frac{1350}{3600} \cdot (h_{in}) = \frac{1350}{3600}(h_{out}) + W_{out}$

$0.375(3446) = 0.375(3484.5) + W_{out}$

$W_{out} = 4375$

W_{out}

[redacted]

Fundamentals of Engineering (FE) Exam Problems

6–154 The label on a washing machine indicates that the washer will use \$85 worth of hot water if the water is heated by a 90 percent efficient electric heater at an electricity rate of \$0.09/kWh. If the water is heated from 18 to 45°C, the amount of hot water an average family uses per year is

(*a*) 11.6 tons (*b*) 15.8 tons (*c*) 27.1 tons
(*d*) 30.1 tons (*e*) 33.5 tons

6–155 A 2.4-m high 200-m^2 house is maintained at 22°C by an air-conditioning system whose COP is 3.2. It is estimated that the kitchen, bath, and other ventilating fans of the house discharge a houseful of conditioned air once every hour. If the average outdoor temperature is 32°C, the density of air is 1.20 kg/m^3, and the unit cost of electricity is \$0.10/kWh, the amount of money "vented out" by the fans in 10 hours is

(*a*) \$0.50 (*b*) \$1.60 (*c*) \$5.00
(*d*) \$11.00 (*e*) \$16.00

6–156 The drinking water needs of an office are met by cooling tab water in a refrigerated water fountain from 23 to 6°C at an average rate of 10 kg/h. If the COP of this refrigerator is 3.1, the required power input to this refrigerator is

(*a*) 197 W (*b*) 612 W (*c*) 64 W
(*d*) 109 W (*e*) 403 W

6–157 A heat pump is absorbing heat from the cold outdoors at 5°C and supplying heat to a house at 25°C at a rate of 18,000 kJ/h. If the power consumed by the heat pump is 1.9 kW, the coefficient of performance of the heat pump is

(*a*) 1.3 (*b*) 2.6 (*c*) 3.0
(*d*) 3.8 (*e*) 13.9

6–158 A heat engine cycle is executed with steam in the saturation dome. The pressure of steam is 1 MPa during heat addition, and 0.4 MPa during heat rejection. The highest possible efficiency of this heat engine is

(*a*) 8.0% (*b*) 15.6% (*c*) 20.2%
(*d*) 79.8% (*e*) 100%

6–159 A heat engine receives heat from a source at 1000°C and rejects the waste heat to a sink at 50°C. If heat is supplied to this engine at a rate of 100 kJ/s, the maximum power this heat engine can produce is

(*a*) 25.4 kW (*b*) 55.4 kW (*c*) 74.6 kW
(*d*) 95.0 kW (*e*) 100 kW

13

Form A

6–160 A heat pump cycle is executed with R–134a under the saturation dome between the pressure limits of 1.4 and 0.16 MPa. The maximum coefficient of performance of this heat pump is

(*a*) 1.1 (*b*) 3.8 (*c*) 4.8
(*d*) 5.3 (*e*) 2.9

6–161 A refrigeration cycle is executed with R-134a under the saturation dome between the pressure limits of 1.6 and 0.2 MPa. If the power consumption of the refrigerator is 3 kW, the maximum rate of heat removal from the cooled space of this refrigerator is

(*a*) 0.45 kJ/s (*b*) 0.78 kJ/s (*c*) 3.0 kJ/s
(*d*) 11.6 kJ/s (*e*) 14.6 kJ/s

6–162 A heat pump with a COP of 3.2 is used to heat a perfectly sealed house (no air leaks). The entire mass within the house (air, furniture, etc.) is equivalent to 1200 kg of air. When running, the heat pump consumes electric power at a rate of 5 kW. The temperature of the house was 7°C when the heat pump was turned on. If heat transfer through the envelope of the house (walls, roof, etc.) is negligible, the length of time the heat pump must run to raise the temperature of the entire contents of the house to 22°C is

(*a*) 13.5 min (*b*) 43.1 min (*c*) 138 min
(*d*) 18.8 min (*e*) 808 min

6–163 A heat engine cycle is executed with steam in the saturation dome between the pressure limits of 7 and 2 MPa. If heat is supplied to the heat engine at a rate of 150 kJ/s, the maximum power output of this heat engine is

(*a*) 8.1 kW (*b*) 19.7 kW (*c*) 38.6 kW
(*d*) 107 kW (*e*) 130 kW

6–164 An air-conditioning system operating on the reversed Carnot cycle is required to remove heat from the house at a rate of 32 kJ/s to maintain its temperature constant at 20°C. If the temperature of the outdoors is 35°C, the power required to operate this air-conditioning system is

(*a*) 0.58 kW (*b*) 3.20 kW (*c*) 1.56 kW
(*d*) 2.26 kW (*e*) 1.64 kW

6–165 A refrigerator is removing heat from a cold medium at 3°C at a rate of 7200 kJ/h and rejecting the waste heat to a medium at 30°C. If the coefficient of performance of the refrigerator is 2, the power consumed by the refrigerator is

(*a*) 0.1 kW (*b*) 0.5 kW (*c*) 1.0 kW
(*d*) 2.0 kW (*e*) 5.0 kW

6–166 Two Carnot heat engines are operating in series such that the heat sink of the first engine serves as the heat source of the second one. If the source temperature of the first engine is 1300 K and the sink temperature of the second engine is 300 K and the thermal efficiencies of both engines are the same, the temperature of the intermediate reservoir is

(*a*) 625 K (*b*) 800 K (*c*) 860 K
(*d*) 453 K (*e*) 758 K

6–167 Consider a Carnot refrigerator and a Carnot heat pump operating between the same two thermal energy reservoirs. If the COP of the refrigerator is 3.4, the COP of the heat pump is

(*a*) 1.7 (*b*) 2.4 (*c*) 3.4
(*d*) 4.4 (*e*) 5.0

6–168 A typical new household refrigerator consumes about 680 kWh of electricity per year and has a coefficient of performance of 1.4. The amount of heat removed by this refrigerator from the refrigerated space per year is

(*a*) 952 MJ/yr (*b*) 1749 MJ/yr (*c*) 2448 MJ/yr
(*d*) 3418 MJ/yr

158| highest efficeincy → carnot conditions

swap ↓

$$\eta = \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H} = 1 - \frac{T_L}{T_H} = 1 - \frac{(179.88 + 273.15)}{(143.61 + 273.15)}$$

$$= 1 - \frac{416.76}{453.03}$$

$= 8\%$ [a]

159| max power → carnot

$$\eta = \frac{W}{Q_H} = 1 - \frac{T_L}{T_H} \qquad Q_H = 100$$

$$\eta = 1 - \frac{50 + 273.15}{1000 + 273.15} = 0.746 = \frac{W}{100} \rightarrow W = 74.6 \text{ KW}$$

[c]

162| Heat Pump

$$cop = \frac{Q_H}{W} = \frac{m\,C_p\,(T_2 - T_1)}{W * t} = 3.2$$

$$3.2 = \frac{1200\,(0.718)\,(22 - 7)}{5 * t}$$

$$t = \frac{1200\,(0.718)\,(15)}{5\,(3.2)} = 807.75 \text{ second} \quad /60$$

$$\frac{807.75}{60} = 13.46 \text{ min}$$ [a]