9. 7 kg of neon is stored in a rigid tank at three times atmospheric pressure and a temperature of 70°C. 30 kJ of heat is added to the neon. What is most nearly the final temperature of the neon?

(A) 70°C

(B) 73°C

(C) 74°C

(D) 77°C

10. A device expends 130 kJ of energy while pressurizing 10 kg of water initially at 17°C. The isentropic efficiency of the device is 50%. Inefficiencies are represented by a heat loss from the device casing. What is most nearly the final temperature of the water?

(A) 18°C

(B) 19°C

(C) 20°C

(D) 21°C

11. An adiabatic pump receives 1.5 kg/s of 15 kPa water and discharges it at 15 MPa. The specific volume of the entering water is 0.001055 m^3/kg. Consider the water to be incompressible. The isentropic efficiency of the pump is 0.82. Velocity and elevation changes are insignificant. The water does not increase in temperature significantly. Most nearly, what is the minimum electrical power required to drive the pump?

(A) 13 kW

(B) 20 kW

(C) 23 kW

(D) 30 kW

12. An engine operates at a constant temperature of 90°C. Through a reversible process, the engine's work output is 5.3 kJ, and the heat loss is 4.7 kJ. What is most nearly the change in entropy during the process?

(A) 0.013 kJ/K

(B) 0.014 kJ/K

(C) 0.015 kJ/K

(D) 0.016 kJ/K

13. In a heat treating process, a 2 kg metal part (specific heat = 0.5 kJ/kg·K) initially at 800°C is quenched in a tank containing 200 kg of water initially at 20°C. What is most nearly the total entropy change of the process immediately after quenching?

(A) 2.3 kJ/K (decrease)

(B) 0.65 kJ/K (decrease)

(C) 0.90 kJ/K (increase)

(D) ~~1.4~~ 1.6 kJ/K (increase)

SOLUTIONS

1. The generators are driven by hydraulic turbines. Since the process is adiabatic, and since velocity and elevation changes are insignificant, all of the terms in the steady flow energy equation drop out except work and enthalpy. The turbine work per unit mass is

$$w_{\text{turbine}} = h_i - h_e$$

In the absence of compressed water tables (giving enthalpies of subcooled and compressed water), the turbine work must be calculated from more basic principles. Enthalpy is defined as $h = pv + u$, so the turbine work per unit mass is

$$w_{\text{pump}} = h_i - h_e = p_i v_i - p_e v_e$$

Since the water is incompressible, the specific volume is unchanged. The turbine work per unit mass is

$$w_{\text{pump}} = v_i(p_i - p_e)$$

The power generated by turbines is

$$\begin{aligned} \dot{W} &= \dot{m} v_i (p_i - p_e) \\ &= \left(900\ \frac{\text{Mg}}{\text{s}}\right)\left(0.001\ \frac{\text{m}^3}{\text{kg}}\right)(900\ \text{kPa} - 200\ \text{kPa}) \\ &= 630\ \text{MW} \end{aligned}$$

The answer is (B).

2. The first law is

$$Q - W = \Delta U$$

Q is the heat transfer into the system across the system boundary. W is the energy transferred across the system boundary to the surroundings in the form of work. ΔU is the change in energy stored within the system in the form of internal energy. This expression shows that the energy transferred across the system boundary comes from a change in stored energy.

The answer is (B).

3. The energy equation is based on the first law of thermodynamics.

The answer is (C).

12. The change in entropy is

$$\Delta S_{\text{out}} = \frac{Q_{\text{out}}}{T_{\text{reservoir}}} = \frac{4.7\ \text{kJ}}{90^\circ\text{C} + 273^\circ} = 0.013\ \text{kJ/K}$$

The answer is (A).

13. Calculate the final temperature, T_f.

$$(mc\Delta T)_{\text{metal}} + (mc\Delta T)_{\text{water}} = 0$$

$$(2\ \text{kg})\left(0.5\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}}\right)(800^\circ\text{C} - T_f) + (200\ \text{kg})\left(4.18\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}}\right)(20^\circ\text{C} - T_f) = 0$$

$$T_f = 20.93^\circ\text{C} \quad (21^\circ\text{C})$$

For a solid or liquid, the total entropy is

$$\Delta S = mc \ln \frac{T_2}{T_1}$$

So, considering a system consisting of the metal part and the water in the quenching tank,

$$\Delta S_{\text{metal}} = mc \ln \frac{T_2}{T_1} = (2\ \text{kg})\left(0.5\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}}\right) \ln \frac{21^\circ\text{C} + 273^\circ}{800^\circ\text{C} + 273^\circ} = -1.295\ \text{kJ/K}$$

$$\Delta S_{\text{water}} = mc \ln \frac{T_2}{T_1} = (200\ \text{kg})\left(4.18\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}}\right) \ln \frac{21^\circ\text{C} + 273^\circ}{20^\circ\text{C} + 273^\circ}$$

= ~~2.655~~ [2.848] kJ/K

$$\Delta S_{\text{total}} = \Delta S_{\text{metal}} + \Delta S_{\text{water}}$$

= −1.295 kJ/K + ~~2.655~~ [2.84] kJ/K

= ~~1.36~~ [1.55] kJ/K (~~1.4~~ [1.6] kJ/K)

The answer is (D).

Thermodynamics

46 Manufacturability, Quality, and Reliability

PRACTICE PROBLEMS

1. A shaft with an interference fit has a maximum diameter of 3 cm and a nominal diameter of 2.990 cm. The upper and lower deviations of the shaft are 0.005 cm and 0.003 cm, respectively. What is most nearly the minimum shaft diameter?

(A) 2.990 cm

(B) 2.992 cm

(C) 2.993 cm

(D) 2.995 cm

2. A shaft with a clearance fit has a nominal diameter of 12 mm. The lower deviation and upper deviation are 0.036 mm and 0.028 mm, respectively. What is most nearly the maximum nominal size of the shaft?

(A) 12.028 mm

(B) 12.032 mm

(C) 12.036 mm

(D) 12.064 mm

3. A shaft has a nominal diameter of 15 mm. The shaft diameter is specified with a tolerance range of 14.950 mm to 15.027 mm. What is most nearly the tolerance of the shaft?

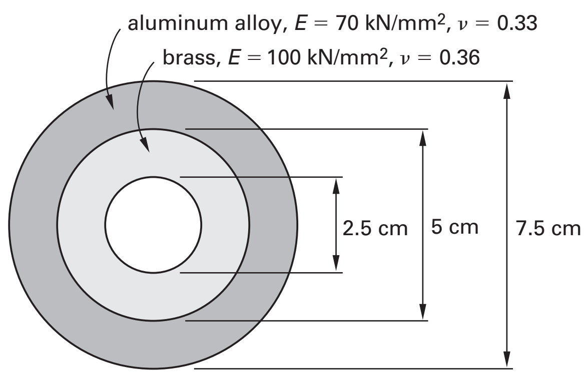
(A) 0.015 mm

(B) 0.023 mm

(C) 0.050 mm

(D) ~~0.073~~ mm 0.077

4. A hollow aluminum cylinder is pressed over a hollow brass cylinder as shown. Both cylinders are 5 cm long. The interference is 0.010 cm. The average coefficient of friction during assembly is 0.25. The pressure on the cylinders is 37 MPa.



What is most nearly the initial axial disassembly force required to separate the two cylinders?

(A) 57 kN

(B) 61 kN

(C) 65 kN

(D) 73 kN

SOLUTIONS

1. The fundamental deviation, δ_F, is the smaller of the upper and lower deviations, which is 0.003 cm.

$$\begin{aligned} d_{\text{min}} &= d + \delta_F = 2.990 \text{ cm} + 0.003 \text{ cm} \\ &= 2.993 \text{ cm} \end{aligned}$$

The answer is (C).

2. For a clearance fit, the fundamental deviation, δ_F, is the upper deviation, δ_u, which is 0.028 mm.

The maximum nominal size of the shaft is

$$\begin{aligned} d_{\text{max}} &= d + \delta_F = 12 \text{ mm} + 0.028 \text{ mm} \\ &= 12.028 \text{ mm} \end{aligned}$$

The answer is (A).

3. The upper deviation is

$$\delta_u = 15.027 \text{ mm} - 15 \text{ mm} = 0.027 \text{ mm}$$

The lower deviation is

$$\delta_l = 15 \text{ mm} - 14.950 \text{ mm} = 0.050 \text{ mm}$$

The shaft tolerance is

$$\begin{aligned} \Delta_d &= |\delta_u - \delta_l| \\ &= |0.027 \text{ mm} - 0.050 \text{ mm}| \\ &= 0.023 \text{ mm} \end{aligned}$$

The answer is (B).

4. The initial force necessary to disassemble the two cylinders is the same as the maximum assembly force.

$$\begin{aligned} F_{\text{max}} &= 2\pi r_{\text{shaft}} \mu p l_{\text{interface}} \\ &= \frac{2\pi(2.5 \text{ cm})(0.25)(37 \text{ MPa})(5 \text{ cm})\left(1000 \ \frac{\text{Pa}}{\text{MPa}}\right)}{\left(100 \ \frac{\text{cm}}{\text{m}}\right)^2} \\ &= 72.65 \text{ kN} \quad (73 \text{ kN}) \end{aligned}$$

The answer is (D).