CHAPTER 2 – PROBLEMS

1. The length of a spring is changed by (a) applying a force to it or (b) changing its temperature (i.e., thermal expansion). What type of interaction between the system (spring) and system surroundings is required to change the length of the spring in these two ways?

2. Consider an electrical refrigerator located in a room. Determine the sign of the work and heat interactions when the following are taken as the system: (a) the contents of the refrigerator, (b) all parts of the refrigerator including the contents, and (c) everything within the room including the refrigerator during a winter day.

3. Consider an automobile traveling at a constant speed along a road. Determine the sign of the heat and work interactions, taking the following as the system: (a) the car radiator, (b) the car engine, (c) the car wheels, (d) the road, and (e) the air surrounding the car.

4. A personal computer is to be analyzed from a thermodynamic perspective. Determine the sign of the work and heat interactions when the (a) keyboard, (b) monitor, (c) processing unit, and (d) all of these are taken as the system.

5. A man weighing 180 lbf is pushing a cart that weighs 100 lbf with its contents up a ramp that is inclined at an angle of 10° from the horizontal. Determine the work needed to move along the ramp a distance of 100 ft considering (a) the man and (b) the cart and its contents as the system. (-6.25 Btu, -2.23 Btu)

6. A man whose mass is 100 kg pushes a cart whose mass, including the contents, is 100 kg up a ramp that is inclined at an angle of 20° from the horizontal. The local gravitational acceleration is 9.8 m/s². Determine the work needed to move along the ramp a distance of 100 m considering (a) the man and (b) the cart and its contents as the system. (-6.25 Btu, -2.23 Btu)

7. Determine the work required to compress a spring whose spring constant is k = 200 lbf/in a distance of 1 in starting from its free length. (-0.0107 Btu)

8. Determine the work required to compress a spring a distance of 1 cm when the spring constant is 300 N/m and the spring is initially compressed by a force of 100 N.

9. The force required to compress the gas in a piston-cylinder device (e.g., a gas shock absorber) a distance x is given by F = Constant x⁻⁰.⁴ where the constant is determined by the device geometry and k is determined by the gas used in the device. One such device has a constant of 200 lbf-in⁻¹.⁴ and k of 1.4. Determine the work required to compress this device from 4 in to 1 in. (-0.0228 Btu)

10. A gas spring (see Problem 3.5) is arranged to have a constant of 1000 N-m¹.³ and k = 1.3. Determine the work required to compress this spring from 0.3 m to 0.1 m.

11. A man weighing 180 lbf pushes a block weighing 100 lbf along a horizontal plane. The dynamic coefficient of friction between the block and plane is 0.2. Assuming that the block moves at a constant speed, how much work is required to move the block 100 ft considering the (a) the block and (b) the man as the system. (-2.57 Btu, 2.57 Btu)

12. How much work is required to accelerate a 1 lbm body from 0 ft/s to 100 ft/s along a horizontal plane?
13. How much work is required to accelerate a 100 kg body from 0 ft/s to 20 ft/s along a horizontal plane? (-20 kJ)
14. How much work is required to raise a 200 lbm body 10 ft in a location where standard gravitational acceleration exists?
15. How much work is required to raise a 1 kg body 50 m in a location where \( g = 9.8 \text{ m/s}^2 \)? (-0.49 kJ)
16. How much work is required to lower a 20 kg body 20 m in a location where \( g = 9.5 \text{ m/s}^2 \)?
17. A spring loaded piston-cylinder device is filled with 0.5 kg of water vapor that is initially at 400 kPa, 400 °C. Initially, the spring exerts no force against the piston. The spring constant is 0.9 kN/cm and the piston diameter is 20 cm. The water now undergoes a process until its volume is one-half of its initial volume and its pressure has increased. How much work is produced by the water? (-15.4 kJ)
18. Calculate the total work produced by a system undergoing processes 1-3 shown in Figure 1 when \( P_1 = 15 \text{ psia} \), \( P_2 = 300 \text{ psia} \), \( V_1 = 1 \text{ ft}^3 \), \( V_2 = 3.3 \text{ ft}^3 \), and \( V_3 = 2 \text{ ft}^3 \).
19. Calculate the total work produced by a system undergoing processes 1-3 shown in Figure 1 when \( P_1 = 100 \text{ kPa} \), \( P_2 = 400 \text{ kPa} \), \( P_3 = 400 \text{ kPa} \), \( V_1 = 0.5 \text{ m}^3 \), \( V_2 = 1 \text{ m}^3 \), and \( V_3 = 0.75 \text{ m}^3 \).
20. A closed system contains 2 lbm of water that undergoes the reversible process shown in Figure 2. What is the total amount of work produced by this system as it undergoes this process when \( P_1 = 100 \text{ psia} \), \( P_2 = 500 \text{ psia} \), \( v_1 = 2 \text{ ft}^3/\text{lbm} \), and \( v_2 = 4 \text{ ft}^3/\text{lbm} \)?
21. A closed system contains 5 kg of R-134a that undergoes the reversible process shown in Figure 2. What is the total amount of work produced by this system as it undergoes this process when \( P_1 = 100 \text{ kPa} \), \( P_2 = 500 \text{ kPa} \), \( v_1 = 1.3 \text{ m}^3/\text{kg} \), and \( v_2 = 1.6 \text{ m}^3/\text{kg} \)? Would your answer change if the working fluid were water rather than R-134a? (450 kJ, no)