0-2-1 [UN] What do you call a system that has (a) no mass interaction, (b) no heat interaction, (c) no mass and energy interaction?

SOLUTION

(a) No mass interaction: Closed system

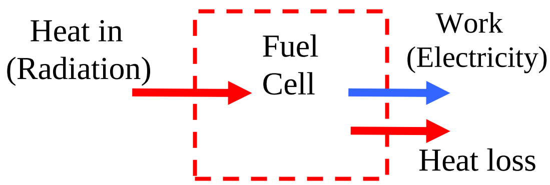
(b) No heat interaction: Adiabatic system

(c) No mass and energy interaction: Isolated system

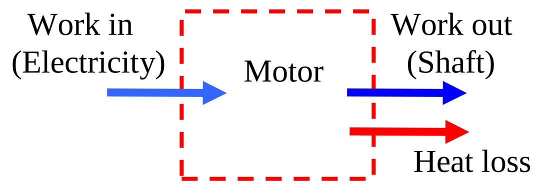
0-2-2 [UE] As shown in the figure below, electric current from the photovoltaic (PV) cells runs an electric motor. The shaft of the motor turns the paddle wheel inside the water tank. Identify the interactions (mass, heat, work) for the following systems: (a) PV cells, (b) motor, (c) tank, and (d) the combined system that includes all these three subsystems.

SOLUTION

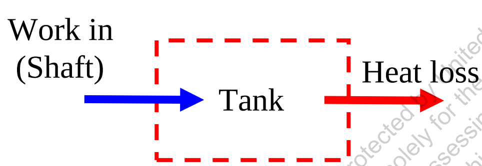
(a) PV Cell:



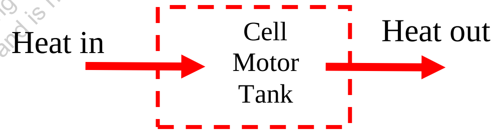
(b) Motor:



(c) Tank:



(d) Combined System:



0-2-3 [XK] On a hot day, a student turns on the fan and keeps the refrigerator door open in a closed kitchen room, thinking that it would cool down the hot kitchen. Treating the room as a closed insulated system, identify the possible energy interactions between the room and the surroundings. Also determine the sign (positive: 1; negative: -1; none: 0) of (a) Q and (b) W_{ext}, if any.

SOLUTION

(a) Mass Transfer: None. The system is closed.
Heat Transfer: None. Q = 0; the room is assumed to be perfectly insulated.

(b) External Work Transfer: Electricity to power the refrigerator and the fan is transferred into the room. $W_{ext} = W_{el}$ is negative: -1 (WinHip: Work in negative; heat in positive).

0-2-4 [XX] An external force drags and accelerates a rigid body over a surface. Treating the body as a thermodynamic system, determine the sign (positive: 1; negative: -1; none: 0) of (a) W_{ext} , and (b) Q across its boundary. Assume friction to be present.

SOLUTION

(a) Mass Transfer: None

Work Transfer: Mechanical work (W_M) is done by the external pull (or push) force which is completely transferred into the system. The sign must be **negative** (WinHip). However, this is not the only external work transfer as the body must overcome the drag force created by friction. The mechanical work done to overcome frictional drag is **positive** because energy is lost from the system. The W_{net} goes into accelerating the system. $W_{\text{ext}} = W_{\text{M,pull}} - W_{\text{M,friction}}$ is negative: -1

(b) Heat Transfer: The frictional work done by the system is immediately converted into heat at the interface. Part of the heat enters the system (sign is positive, WinHip), which makes the system hotter. Q is positive: 1

0-2-5 [XP] During the free fall of a rigid body (system), identify the interactions between the system and its surroundings.

SOLUTION

Mass Transfer: None.

Work Transfer: It may be tempting to treat the work done by gravity as boundary work. However, this is already accounted for in the potential energy expression due to gravitational force. Therefore, external work transfer in this case is 0. The body also does work on the surrounding air (to overcome frictional drag), which is positive by WinHip sign convention.

Heat Transfer: None since the body can be assumed to be at the same temperature as the surrounding atmosphere.

0-2-6 [XC] An electric adapter for a notebook computer (converting 110 volts to 19 volts) operates 10^{o}C warmer than the surrounding temperature. Determine the sign (positive: 1; negative: -1; none: 0) of (a) W_{ext} and (b) Q interactions.

SOLUTION

(a) Mass Transfer: None

Work Transfer: Electrical work is transferred into the system (adapter) and is transferred out of the system (at a different voltage). $\dot{W}_{ext} = \dot{W}_{el,out} - \dot{W}_{el,in}$ and must be negative: -1 as some of the electrical work is dissipated into heat (making the adaptor warm).

(b) Heat Transfer: As the adapter gets warmer, heat is transferred out due to the temperature difference between the adapter and its surroundings; therefore the sign is negative (WinHip). Q is negative: -1.

0-2-7 [XV] A block of ice dropped into a tank of water as shown (see accompanying animation) begins melting. Identify the interactions for the (a) ice as a system, (b) water in the tank as a system, and (c) water and ice together as a system.

SOLUTION

(a) **Ice as the system:**

Mass Transfer: As the ice melts mass is transferred away from the ice (as a system).

Work Transfer: As the ice shrinks in size, boundary work (by pressure of liquid water) is transferred into the system. W_{ext} is negative by WinHip convention.

Heat Transfer: For melting to occur, heat must enter the ice (positive, WinHip). Q is positive.

(b) **Liquid water as the system:**

Mass Transfer: As the ice melts mass is transferred into the liquid body.

Work Transfer: As the water expands in size, boundary work (by pressure at the ice water interface) is transferred into the ice (work done by liquid). W_{ext} is positive by WinHip convention.

Heat Transfer: For melting to occur, heat must leave the water. Q is negative (WinHip).

(c) **Combined system:**

Mass Transfer: The combined system has no mass transfer.

Work Transfer: There is no work transfer at the boundary of the combined system. $W_{ext} = 0$.

Heat Transfer: If the water initially had the same temperature as the surroundings, heat will be gained by the combined system (positive, WinHip) as the melting of the ice reduces the water temperature. Eventually, transfer of heat from the surroundings will make the system temperature equal to that of the surroundings.

0-2-8 [XQ] A gas trapped in an insulated piston-cylinder assembly expands as it is heated by an electrical resistance heater placed inside the cylinder. Treating the gas and the heater as the system, identify the interactions with its surroundings and the sign (positive: 1; negative: -1; none: 0) of (a) Q and (b) W_{net}.

SOLUTION

(a) Mass Transfer: None

Heat Transfer: For the insulated system there is no heat transfer. Q is 0.

(b) Work Transfer: As the gas expands, boundary work (W_B of $pd\mathcal{V}$ kind) (positive, WinHip) is done by the system which is transferred into the surroundings through the piston.

Work is also transferred into the system through the electrical heater (W_{el}), which must be negative (WinHip).

The fact that the system gets hotter indicates a net transfer of work into the system. $W_{ext} = W_B - W_{el}$ is most likely negative: -1.

0-2-9 [XT] A piston-cylinder device contains superheated vapor at atmospheric pressure. The piston is pulled by an external force until the pressure inside drops by 50%. Determine the sign (positive: 1; negative: -1; none: 0) of W_B, treating the vapor trapped inside the cylinder as the system. Where does the work done in pulling the piston go?

SOLUTION

Work Transfer: The boundary work (W_B) is positive: 1 because the vapor will continue to push on the piston and cylinder walls despite external force. Work is also done by the external pull force. Now this raises the interesting question of where does these work go? Both these components of work go into displacing the atmosphere, that is, into the surrounding air. $W_{ext} = W_B$ is positive (HIPWOP).

0-2-10 [XY] A warm cup of coffee gradually cools down to room temperature. Treating the coffee as the system, determine the sign (positive: 1; negative: -1; none: 0) of Q during the cooling process.

SOLUTION

Heat Transfer: The heat transfer from the coffee is negative as heat is lost (WinHip). Q is negative: -1.

0-2-11 [XF] A hot block of solid is dropped in an insulated tank of water at the temperature of the surroundings. Determine the sign (positive: 1; negative: -1; none: 0) of Q treating (a) the block as the system, (b) the water as the system and (c) the entire tank (with the block and water).

SOLUTION

(a) **Block as the system:**
Mass Transfer: No mass transfer.
Work Transfer: No work transfer. $W_{\text{ext}} = 0$.
Heat Transfer: As the hot block cools down, it loses heat. Q is negative: -1 (WinHip).

(b) **Liquid water as the system:**
Mass Transfer: No mass transfer.
Work Transfer: No work transfer. $W_{\text{ext}} = 0$.
Heat Transfer: Heat lost by the block is gained by the water, so Q is positive: 1 (WinHip).

(c) **Combined system:**
Mass Transfer: The combined system has no mass transfer.
Work Transfer: There is no work transfer at the boundary of the combined system. $W_{\text{ext}} = 0$.
Heat Transfer: Q will flow from the block to the water. However, the tank is insulated, so heat transfer for the combined system is zero. Q = 0.

0-2-12 [XM] An insulated tank containing high pressure nitrogen is connected to another insulated tank containing oxygen at low pressure. Determine the possible interactions as the valve is opened and the two gases are allowed to form a mixture by treating (a) one of the tanks as a system and (b) two tanks together as a single system.

SOLUTION

(a) **One tank as the system:**

Mass Transfer: When one tank is treated as the system, there is mass transfer through the port (the flow may be created by a pressure difference and/or by diffusion).

Work Transfer: Only flow work (W_F) is present, which is not part of external work.

Heat Transfer: If the two gases are at the same temperature, there is no heat transfer. $Q = 0$.

(b) **Both tank forming the system:**

Mass Transfer: None.

Work Transfer: None. $W_{ext} = 0$.

Heat Transfer: None. $Q = 0$.

0-2-13 [XJ] A fluid is accelerated by an insulated nozzle attached at the end of a pipe. Identify the interactions, treating the nozzle as an open system.

SOLUTION

Mass Transfer: At the inlet and exit.

Work Transfer: Only flow work ($\dot{W}_F$) is present, which is not part of external work.

$W_{ext} = 0$.

Heat Transfer: No heat transfer. $\dot{Q} = 0$.

0-2-14 [CO] An insulated steam turbine produces Q and W_{sh} as steam flows through it, entering at a high pressure and a high temperature and leaving at a relatively low pressure. Identify the interactions between the turbine (as an open system) and its surroundings and determine the sign (positive: 1; negative: -1; none: 0) of (a) Q and (b) W_{ext}.

SOLUTION

(a) Mass Transfer: At the inlet and exit ports.
Heat Transfer: No heat transfer. $Q = 0$.

(b) Work Transfer: Flow work ($\dot{W}_F$) is present, but it is not part of external work. Shaft work is the only external work output of turbine. $\dot{W}_{ext}$ is positive: 1 (WinHip).

0-2-15 [CB] Identify the possible interactions of a steam turbine with poor insulation with its surroundings and determine the sign (positive: 1; negative: -1; none: 0) of (a) Q and (b) W_{ext}.

SOLUTION

(a) Mass Transfer: At the inlet and exit ports.
Heat Transfer: Assuming a higher temperature than the surrounding and because of poor insulation, there will be heat loss. $\dot{Q}$ is negative: -1 (WinHip).

(b) Work Transfer: Flow work ($\dot{W}_F$) is present, but it is not part of external work. Shaft work is the only external work output of turbine. $\dot{W}_{\text{ext}}$ is positive: 1 (WinHip).

0-2-16 [CS] The pressure of a liquid flow is raised by a pump driven by an electrical motor. Identify the interactions treating (a) the pump as an open system and (b) the pump and the motor as a combined system.

SOLUTION

(a) **When only considering the pump:**

Mass Transfer: At the inlet and exit ports.

Work Transfer: Flow work ($\dot{W}_F$) is present, but it is not part of external work. Shaft work is the only external work (input) for the pump. $\dot{W}_{\text{ext}}$ is negative (WinHip).

Heat Transfer: Heat loss. $\dot{Q}$ is negative (WinHip). Friction in the pump increases the temperature of the liquid (slightly), which causes the heat transfer into the cooler surroundings.

(b) **When the motor is included within the system:**

Mass Transfer: At the inlet and exit ports.

Work Transfer: the work transfer is now due to wires going into the motor and electrical work. $\dot{W}_{\text{ext}}$ is negative (WinHip).

Heat Transfer: Heat loss. $\dot{Q}$ is negative (WinHip). Friction in the pump increases the temperature of the liquid (slightly), which causes the heat transfer into the cooler surroundings.

0-2-17 [CH] An insulated compressor raises the pressure of a gas flow. The temperature of the gas is also increased as a result. Identify the possible interactions between the compressor and its surroundings and determine the sign (positive: 1; negative: -1; none: 0) of (a)Q and (b) W_{ext}.

SOLUTION

(a) Mass Transfer: At the inlet and exit ports.
Heat Transfer: No heat transfer. $\dot{Q} = 0$.

(b) Work Transfer: Flow work ($\dot{W}_F$) is present, but it is not part of external work. Shaft work is the only external work (input) for the compressor. $\dot{W}_{ext}$ is negative: -1 (WinHip).

0-2-18 [CN] In a heat exchanger (see accompanying animation) a flow of hot air is cooled by a flow of water. Identify the interactions treating (a) the entire heat exchanger as the system and (b) one of the streams as the system.

SOLUTION

(a) **Entire device as the system:**

Mass Transfer: At the inlet and exit ports.

Work Transfer: Flow work ($\dot{W}_F$) is present at the inlets and exits, but they are not part of external work. $\dot{W}_{\text{ext}} = 0$.

Heat Transfer: No heat transfer. $\dot{Q} = 0$.

(b) **System boundary around the hot air stream:**

Mass Transfer: At the inlet and exit ports.

Work Transfer: Flow work ($\dot{W}_F$) is present at the inlets and exits, but they are not part of external work. $\dot{W}_{\text{ext}} = 0$.

Heat Transfer: $\dot{Q}$ is negative (WinHip).

(c) **System boundary around the cool water stream:**

Mass Transfer: At the inlet and exit ports.

Work Transfer: Flow work ($\dot{W}_F$) is present at the inlets and exits, but they are not part of external work. $\dot{W}_{\text{ext}} = 0$.

Heat Transfer: $\dot{Q}$ is positive (WinHip).

0-2-19 [CG] A pressure cooker containing water is heated on a stove. Determine the interactions and signs (positive: 1; negative: -1; none: 0) of (a) Q and (b) W_{ext}, if any, as steam is released.

SOLUTION

(a) Mass Transfer: At the exit port.
Heat Transfer: $\dot{Q}$ is positive: 1 (WinHip).

(b) Work Transfer: No external work. Flow work ($\dot{W}_F$) is present at the exit, but is not included in the external work expression. $\dot{W}_{ext} = 0$.

0-2-20 [CI] As you blow up a balloon, what are the interactions and the sign (positive: 1; negative: -1; none: 0) of (a) Q and (b) W_{ext}, if any, between the balloon as a system and its surroundings?

SOLUTION

(a) Mass Transfer: Air is blown into the balloon at the inlet.
Heat Transfer: No heat transfer. $\dot{Q} = 0$.

(b) Work Transfer: Boundary work ($\dot{W}_{ext} = \dot{W}_B$) is done by the balloon to displace the atmosphere. Flow work ($\dot{W}_F$) is present at the inlet, but it is not part of the external work expression. $\dot{W}_{ext} = \dot{W}_B$ is positive: 1 (HIPWOP).

0-2-21 [CZ] Air rushes in to fill an evacuated insulated tank as the valve is opened. Determine the interactions and the sign of Q and W_{ext}, if any, treating (a) the tank as the system and (b) the tank and the outside air that eventually enters as the system.

SOLUTION

(a) **Tank as the system:**

Mass Transfer: Air enters the system.

Work Transfer: Flow work ($\dot{W}_F$) is present at the inlet, but is not included in the external work expression. $\dot{W}_{\text{ext}} = 0$.

Heat Transfer: No heat transfer. $\dot{Q} = 0$.

(b) **Tank and air as the system:**

Mass Transfer: None.

Work Transfer: Boundary work is present and is negative as the air is pushed into the tank. Since the inlet is internal to the combined system, we therefore do not consider what happens there.

Heat Transfer: No heat transfer. $\dot{Q} = 0$.