CONTENT CHAPTER 1

In-Text Concept Questions

1.a

Make a control volume around the turbine in the steam power plant in Fig. 1.2 and list the flows of mass and energy that are there.

Solution:
We see hot high pressure steam flowing in at state 1 from the steam drum through a flow control (not shown). The steam leaves at a lower pressure to the condenser (heat exchanger) at state 2. A rotating shaft gives a rate of energy (power) to the electric generator set.
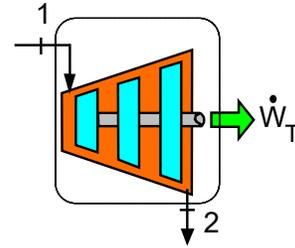
1.b

Take a control volume around your kitchen refrigerator and indicate where the components shown in Figure 1.3 are located and show all flows of energy transfers.

Solution:

The valve and the cold line, the evaporator, is inside close to the inside wall and usually a small blower distributes cold air from the freezer box to the refrigerator room.

$\dot{Q}_{leak}$

$\dot{Q}$

$\dot{W}$

cb
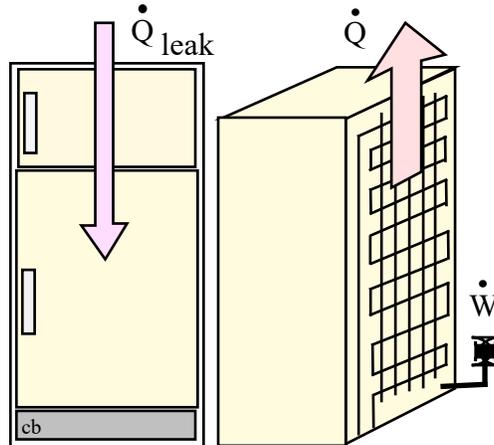
The black grille in the back or at the bottom is the condenser that gives heat to the room air.

The compressor sits at the bottom.

1.c

Why do people float high in the water when swimming in the Dead Sea as compared with swimming in a fresh water lake?

As the dead sea is very salty its density is higher than fresh water density. The buoyancy effect gives a force up that equals the weight of the displaced water. Since density is higher the displaced volume is smaller for the same force.

1.d

Density of liquid water is $\rho = 1008 - T/2$ [kg/m³] with T in °C. If the temperature increases, what happens to the density and specific volume?

Solution:

The density is seen to decrease as the temperature increases.

$$\Delta\rho = -\Delta T/2$$

Since the specific volume is the inverse of the density $v = 1/\rho$ it will increase.

1.e

A car tire gauge indicates 195 kPa; what is the air pressure inside?

The pressure you read on the gauge is a gauge pressure, ΔP, so the absolute pressure is found as

$$P = P_o + \Delta P = 101 + 195 = 296 \text{ kPa}$$

Figure 1.21
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1.f

Can I always neglect ΔP in the fluid above location A in figure 1.13? What does that depend on?

If the fluid density above A is low relative to the manometer fluid then you neglect the pressure variation above position A, say the fluid is a gas like air and the manometer fluid is like liquid water. However, if the fluid above A has a density of the same order of magnitude as the manometer fluid then the pressure variation with elevation is as large as in the manometer fluid and it must be accounted for.

1.g

A U tube manometer has the left branch connected to a box with a pressure of 110 kPa and the right branch open. Which side has a higher column of fluid?

Solution:

Since the left branch fluid surface feels 110 kPa and the right branch surface is at 100 kPa you must go further down to match the 110 kPa. The right branch has a higher column of fluid.
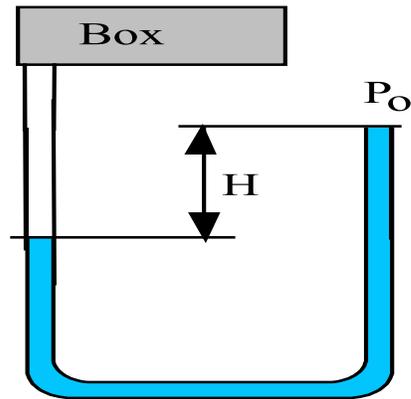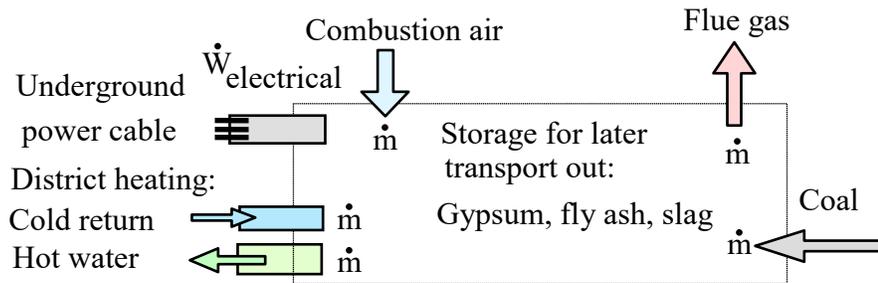
Concept Problems

1.1

Make a control volume around the whole power plant in Fig. 1.1 and with the help of Fig. 1.2 list what flows of mass and energy are in or out and any storage of energy. Make sure you know what is inside and what is outside your chosen C.V.

Solution:

Boiler building

Smoke stack

Coal conveyor system Storage gypsum

cb

flue gas

Coal storage

Turbine house

Dock

Combustion air

Flue gas

$\dot{W}_{electrical}$

Underground power cable

$\dot{m}$

Storage for later transport out:

$\dot{m}$

District heating:

Cold return

$\dot{m}$

Gypsum, fly ash, slag

Coal

Hot water

$\dot{m}$

$\dot{m}$

$\dot{m}$
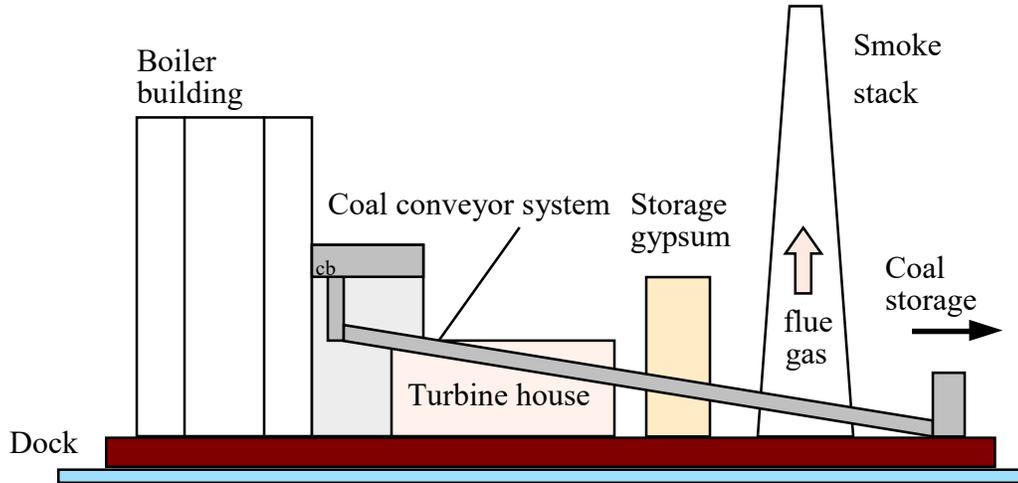
1.2

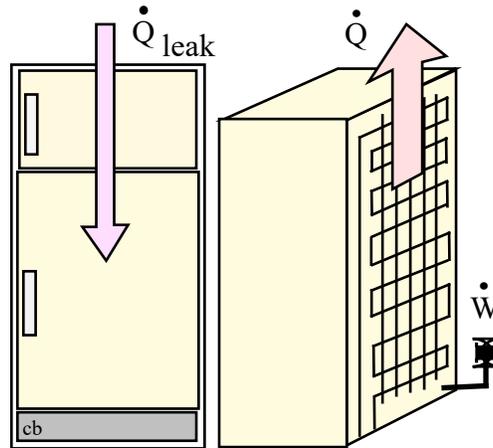Make a control volume around the refrigerator in Fig. 1.3. Identify the mass flow of external air and show where you have significant heat transfer and where storage changes.

The valve and the cold line, the evaporator, is inside close to the inside wall and usually a small blower distributes cold air from the freezer box to the refrigerator room.

$\dot{Q}_{leak}$

$\dot{Q}$

$\dot{W}$

cb

The black grille in the back or at the bottom is the condenser that gives heat to the room air.

The compressor sits at the bottom.

The storage changes inside the box which is outside of the refrigeration cycle components of Fig. 1.3, when you put some warmer mass inside the refrigerator it is being cooled by the evaporator and the heat is leaving in the condenser.

The condenser warms outside air so the air flow over the condenser line carries away some energy. If natural convection is not enough to do this a small fan is used to blow air in over the condenser (forced convection). Likewise the air being cooled by the evaporator is redistributed inside the refrigerator by a small fan and some ducts.

Since the room is warmer than the inside of the refrigerator heat is transferred into the cold space through the sides and the seal around the door. Also when the door is opened warm air is pulled in and cold air comes out from the refrigerator giving a net energy transfer similar to a heat transfer.

1.3

Separate the list P, F, V, v, ρ, T, a, m, L, t, and **V** into intensive, extensive, and non-properties.

Solution:

Intensive properties are independent upon mass: P, v, ρ, T
Extensive properties scales with mass: V, m
Non-properties: F, a, L, t, **V**

Comment: You could claim that acceleration a and velocity **V** are physical properties for the dynamic motion of the mass, but not thermal properties.

1.4

 A tray of liquid water is placed in a freezer where it cools from 20°C to -5°C. Show the energy flow(s) and storage and explain what changes.

Inside the freezer box, the walls are very cold as they are the outside of the evaporator, or the air is cooled and a small fan moves the air around to redistribute the cold air to all the items stored in the freezer box. The fluid in the evaporator absorbs the energy and the fluid flows over to the compressor on its way around the cycle, see Fig. 1.3. As the water is cooled it eventually reaches the freezing point and ice starts to form. After a significant amount of energy is removed from the water it is turned completely into ice (at 0°C) and then cooled a little more to -5°C. The water has a negative energy storage and the energy is moved by the refrigerant fluid out of the evaporator into the compressor and then finally out of the condenser into the outside room air.

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1.5

The overall density of fibers, rock wool insulation, foams and cotton is fairly low. Why is that?

Solution:

All these materials consist of some solid substance and mainly air or other gas. The volume of fibers (clothes) and rockwool that is solid substance is low relative to the total volume that includes air. The overall density is

$$\rho = \frac{m}{V} = \frac{m_{solid} + m_{air}}{V_{solid} + V_{air}}$$

where most of the mass is the solid and most of the volume is air. If you talk about the density of the solid only, it is high.