State Examinations Commission – Physics Higher Level, 2004.

Question 7

Define (i) specific heat capacity, (ii) specific latent heat. (12)
500 g of water at a temperature of 15 °C is placed in a freezer. The freezer has a power rating of 100 W and is 80% efficient.
(i) Calculate the energy required to convert the water into ice at a temperature of –20 °C .
(ii) How much energy is removed every second from the air in the freezer?
(iii) How long will it take the water to reach a temperature of –20 °C? (27)
Allowing a liquid to evaporate in a closed pipe inside the freezer cools the air in the freezer. The vapour is then pumped through the pipe to the outside of the freezer, where it condenses again. Explain how this process cools the air in the freezer. (12)
The freezer causes the room temperature to rise. Explain why. (5)
(specific heat capacity of ice = 2100 J kg^{-1} K^{-1}; specific heat capacity of water = 4200 J kg^{-1} K^{-1}; specific latent heat of fusion of ice = 3.3×10^5 J kg^{-1})

Define (i) specific heat capacity, (ii) specific latent heat. (12)

Basic textbook definition

500 g of water at a temperature of 15 °C is placed in a freezer. The freezer has a power rating of 100 W and is 80% efficient.

(i) Calculate the energy required to convert the water into ice at a temperature of –20 °C.

Energy required = energy to cool water from 15 to 0 °C + energy to freeze water at 0 °C + energy to cool ice from 0 to –20 °C.

$= (m.c.\Delta\theta)_{water} + (m.l_f) + (m.c.\Delta\theta)_{ice}$
$= (0.5 \times 4180 \times 15) + (0.5 \times 3.3 \times 10^5) + (0.5 \times 2100 \times 20)$
$= 2.17 \times 10^5$ J

(ii) How much energy is removed every second from the air in the freezer?

100 W => 100J removed each second.
However, if the freezer is only 80% efficient, then it removes 80 J of energy from inside each second.

(iii) How long will it take the water to reach a temperature of –20 °C? (27)

To remove 2.17×10^5 J at a rate of 80 J per second takes $(2.17 \times 10^5)/80 = 2{,}717$ s.

Allowing a liquid to evaporate in a closed pipe inside the freezer cools the air in the freezer. The vapour is then pumped through the pipe to the outside of the freezer, where it condenses again. Explain how this process cools the air in the freezer. (12)

The liquid evaporating inside the freezer takes the latent heat of vaporization it requires from the air inside the freezer thereby cooling it. When it condenses again in the pipe outside of freezer it dumps the heat (latent heat of vaporization) it gained inside, into the surroundings. It then passes once more through a compressor into the pipe on the inside where the process repeats itself, leading to a gradual removal of heat from inside the freezer.

The freezer causes the room temperature to rise. Explain why. (5)

The heat removed inside the fridge is deposited in the room causing it to warm slightly. Also, the fridge is not 100% efficient and would generate heat within the coils of the motor, which would also warm the room slightly.