1. When a hot and cold object are placed in contact heat is observed to flow from the hot object to the cold one. The reason the reverse process is not observed is

   (a) It is impossible for a molecule in the cold object to lose energy to a molecule in the hot object.

   (b) Moving heat from a cold object to a hot object results in the loss of energy, which violates the first law of thermodynamics.

   (c) Moving heat from a cold object to a hot object causes the entropy of both objects to decrease, thus violating the second law of thermodynamics.

   (d) Moving heat from a cold object to a hot object causes the total entropy of both objects to decrease, thus violating the second law of thermodynamics.

   Answer: (d)

2. Which system has greater entropy, a puddle of water on a table next to a disorderly scattering of salt crystals, or the same amount of salt dissolved in a homogeneous solutions with the same amount of water.

   (a) The puddle and the crystals.

   (b) The solution in the glass.

   (c) They both have the same entropy.

   (d) It depends on the nature of the salt crystals.

   Answer: (b)

3. A hot object is brought into contact with a cold object the cold object's entropy increases by 2.5 J/K as it comes into equilibrium with the hot object. By how much does the entropy of the hot object change?

   (a) It decreases by more than 2.5 J/K.

   (b) It decreases by less than 2.5 J/K.

   (c) It increases by 2.5 J/K.

   (d) It decreases by 2.5 J/K.

   Answer: (b). When an object loses heat its entropy drops, but hotter objects lose less entropy than cooler objects, when they lose the same amount of heat.

4. Each of the following processes happens spontaneously, yet appeasers to result in a decrease in entropy (or increase in order). Discuss each item with your group and explain how total entropy has in fact increased in each case.

   (a) An egg which is initially albumen and yolk, develops into a highly structured chick.
   As the chick grows it is converting highly organized chemical energy of the egg into a highly structured body and unorganized heat.

(b) When you wear a wet T-shirt on a hot but windy day your body is cooled down, and hence loses entropy.
The faster moving water molecules in your T-shirt are more likely to escape the T-shirt and become water vapor and be blown away. This leaves behind more slower moving water molecules, which makes the T-shirt colder.

(c) When a grain of sugar is placed in a super-saturated solution of sugar water, sugar crystalizes out of the solution creating an ordered structure out of a homogeneous solution.
In the crystallization process, energy is released – warming the water that is left behind. The water becomes more disordered as the crystals are formed.

5. If we think of a solid as being a collection of oscillators that can oscillate at discrete energy levels, then we can draw an analogy between a solid and a box with bins. Each bin corresponds to an oscillator. Adding discrete units of energy to an oscillator corresponds to adding discrete balls to a bin. The temperature of a solid (the average energy per oscillator), corresponds to the average number of balls per bin in a box. The entropy of the solid corresponds to the information needed to determine the arrangement of balls that are randomly distributed in the bins.

   (a) Consider a box with 2 bins and 1 ball placed in a random location. How many different ways can you arrange the balls in the bins? What is the 'entropy' and 'temperature' of this 'solid'?
   There are two ways to arrange the balls, so the entropy (information in bits) is $\log 2/\log 2 = 1$. The average temperature is the amount of energy per bin, which is $1/2 = 0.5$ units.

   (b) Consider a second box with 2 bin and 3 balls distributed randomly. What is the 'entropy' and 'temperature' of this 'solid'?
   There are 2 ways to have 3 balls per bin, and there are two ways to have 2 balls in one and 1 in another. There are thus 4 arrangements. The entropy in bits is $\log 4/\log 2 = 2$. The average temperature is $3/2 = 1.5$.

   (c) If we now allow the two boxes to come into 'thermal contact' (ie allow the balls to distribute themselves randomly between them), how many different ways are there to arrange the four balls in the four bins (Hint: draw them all out)? How many of those arrangements correspond to possible arrangements of the original boxes? What is the 'entropy' and 'temperature' of the new 'solid'? How do your answers compare to the total 'entropy' and the 'temperatures' of each of the separate 'solids'?.
   If we make thermal contact, there are a total of 4 balls and 4 bins. There are 4 arrangements with 4 balls per bin. There are $4 \times 3 = 12$ arrangements with 3 balls in one bin and 1 ball in another. There are 6 arrangements with 2 balls in one bin and 2 balls in another. There are $4 \times 3 = 12$ arrangements with 2 balls in one bin, and 1 bin with no balls (with one ball in each of the other two bins). Finally there is one arrangement with exactly one ball in each bin. Thus there are a total of 35 arrangements. Of these, $2 \times 4 = 8$ correspond to arrangements of the original boxes. (for each of the two arrangements of the first box there are 4 arrangements of the second box). The entropy of the system is now $\log 35/\log 2 = 5.13$. This is more than the sum of the entropy of the two separate boxes. The temperature is $4/4 = 1$. This half way between the temperatures of the other two boxes.