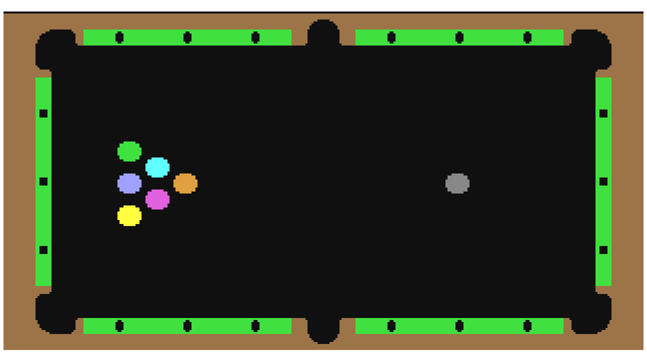
Gas dependance on entropy, entropy of a monochromatic radiation at low density and volume dependence of entropy; a list of “trivial” concepts when it comes to dealing with light and black body radiation. This list is so trivial, that the average person’s reaction to reading it is one of indignation in the simplicity of the list. Actually even third year Physics students find quite the degree of difficulty in grasping these concepts, a situation sure to be remedied by the conclusion of this article.

Entropy appears with scary frequency in the list. This is because entropy is the fundamental tool for the exploration of light as a particle or collection of particles. That’s great but what exactly is entropy? Simply put entropy is the order of a particular system. Think of a game of billiards or pool. The table will represent the system as a whole and the balls the components within the system. When the balls are racked the entropy, order, of the system is at its lowest; in fact, it is at zero. The more ordered the arrangement of any system, the lower its entropy. As the rack is broken the balls scatter and the entropy increases. With the entropy rising so too does the total energy of the system. Bear in mind that we are holding the volume constant through all of this.

The entropy does not solely rely on the order of the balls. The volume also plays a vital role in determination of the system’s entropy. Remember the table itself? The table and the balls comprise the system, but the size of the table is defined as the volume of said system. Imagine now that all of the rack has been broken and all the balls have settled into their spots, but for sum odd reason the table suddenly doubles in size. What does this do to the entropy of the system? The entropy will decrease as there is now more space to fill. From this it can be seen that as volume increases, entropy decreases: this is known as an inverse relationship.



Zero Entropy.

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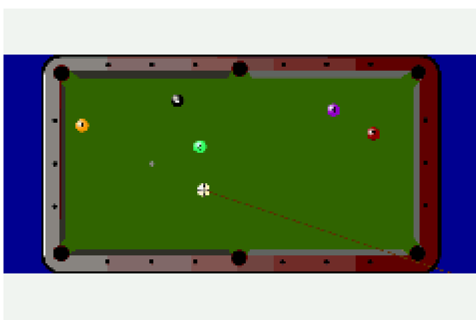
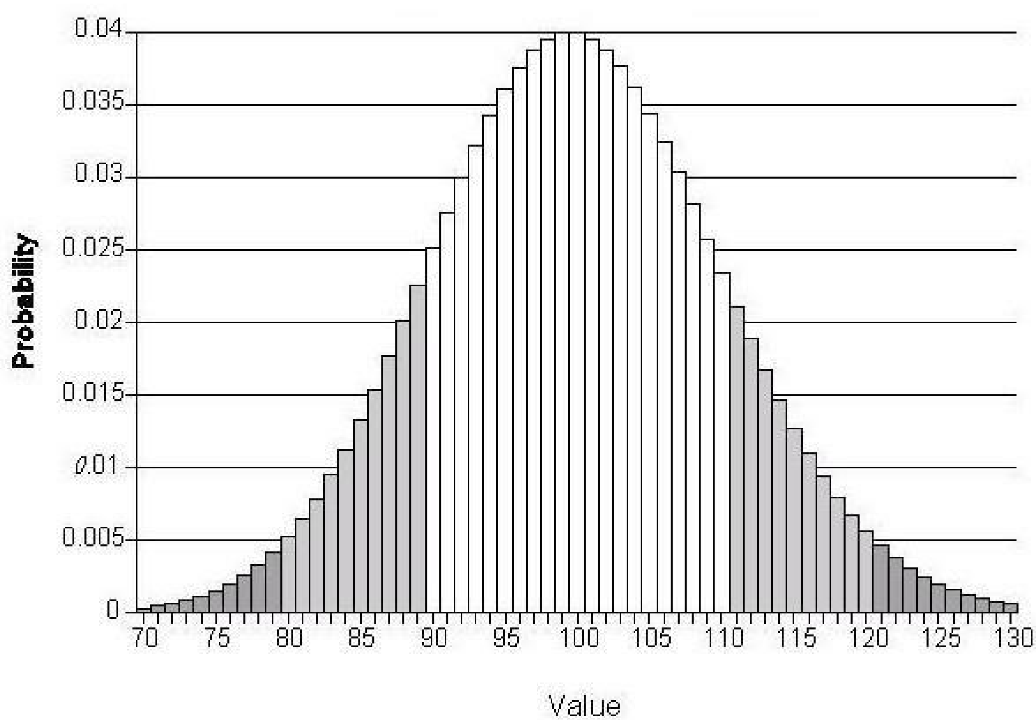
Low Entropy. The balls are clustered.



High entropy. The balls are spread out.

With this new understanding of entropy the nature of light, monochromatic radiation, can now be further explored. Entropy is considered a thermodynamic property. Thermodynamics can be decomposed to, thermo (heat) and dynamics (power) and generally deal with studying the nature of gases as their fundamental properties are altered on the macroscopic level. To explain this, the idea of entropy has to be exploited. When dealing with gaseous systems, entropy defines the temperature of the system. Temperature is simply the change in the collective energy of the system. At the macroscopic level an ideal, homogeneous gas simply occupies a space and as the entropy changes, so too does the temperature and volume. In this case it is a direct relationship. As the entropy increases so too will the other system properties. In the case of light the idea of volume basically remains the same. Temperature relates to intensity and entropy is simply entropy. Through this analog it is easy to see that the properties of light can be derived from simple thermodynamic principles. This begs the question; can this new idea of light be pushed even further?

A gas is able to be examined as a collection of fundamental particles or molecules. Now the situation is different as it has been shifted away from the macroscopic level to the microscopic. The situation is not as simple anymore; now special attention has to be paid to the individual components of the system. At the microscopic level the fundamental definition of entropy stays the same but the derivation or determination is now a bit more complex. That is entropy now becomes a function of probability. This is so because it is impossible to pin-point the exact position and velocity of any particle at an instant of time. The solution to this is simple, make an educated guess. This may make the situation much simpler than it really is but in essence that is what probability is all about. For each guess, probability, there exists another plausible situation or probability. This gives rise to distributions. A distribution is a collection of all probabilities and is best explained in the form of a graph. As the distribution peaks the probability is at a high level and conversely the distribution dips at a low probability.



<u>A Poisson distribution. A simple example of a probability distribution graph.</u>

To illustrate this with respect to the topic of light and molecules consider a system in terms of its fundamental particles. Pick any number of molecules from varying positions in the system. Any number of particles chosen would be acceptable but try to limit it to an easy number to manage, and be sure that they are sufficiently far away from each other that any interactions between the molecules can be ignored. Now take each molecule and move it to a higher level of entropy, just like moving boxes from the basement to the attic. For the sake of argument, say a few boxes get dropped on the staircase in the process of moving. After moving, compare the probability of the boxes laying on the stairs or making it to the attic. The conclusion is that it all depends on how many stairs the boxes have to be moved up. The more stairs, the higher the probability that boxes will be dropped on the stairs; fewer stairs the higher the probability that the boxes make it to the attic. Relating this back to the physics sense, the staircase represents the system's volume; the boxes, of course, are the molecules and the act of moving the boxes is the rise in entropy. Putting this all together, as the entropy of the system increases the probability of a molecule existing in a specific energy state depends on the volume of the system.

This leads us to the understanding that light can be treated as a sum of its fundamental particles. Through these simple thermodynamic principles Einstein was able to develop a working, practical model for the treatment of light as a collection of fundamental particles or molecules. This model allowed him to establish the photoelectric effect and show that light, monochromatic radiation could be treated not only as a waveform but as a particle, thereby helping to verify Plank's earlier works.

References

Einstein A. "Conerning an heuristic point of view toward the emission and transformation of light." 1905.

Dr. Chitra Rangan