Reply to creationwiki page "Pseudoscience in the American Journal of Physics"

Dan Styer, Department of Physics and Astronomy, Oberlin College; 20 December 2013

The `creationwiki` article above, by "Davidmihjn", claims that my paper "Entropy and evolution" (*American Journal of Physics* **76** (11) November 2008, pages 1031–1033) is "irrational." The twelfth paragraph (of thirteen in the article) describes why: My paper uses the microcanonical expression for entropy $S = k_B \ln W$, but "This is absurd because the Boltzmann constant $[k_B]$ comes from observations about atomic systems."

In fact, living things are made up of atoms, so the microcanonical expression for entropy is perfectly reasonable and applicable. The insinuation that the Boltzmann constant applies only to "atomic systems" is also false. For example, black body radiation is not made up of atoms, yet the entropy of black body radiation of volume V and temperature T involves Boltzmann's constant through

$$S = k_B^4 \left(\frac{32\,\pi^5}{45\,c^3 h^3} \right) V T^3.$$

(Here c represents the speed of light and h represents Planck's constant.)

The above suffices to show why Davidmihjn's critique is without substance. However I cannot resist pointing out some of the article's other errors concerning thermodynamics and statistical mechanics:

1. Claim: "Another basic variable is heat, which is what causes temperature to change."

   Fact: Heat is not a state variable. There are two ways to transfer energy into (or out of) a system – heat and work. Once the energy transfer happens, there is no way to distinguish whether the transfer happened through heat or through work. Furthermore, either heat or work might or might not cause temperature to change. (For example, given a bowl of water and ice at equilibrium at atmospheric pressure and temperature 0 Celsius, addition of either heat or work will melt the ice and not raise the temperature.)

2. Claim: Temperature and "average kinetic energy of molecules" are related through $KE = (3/2)k_B T$.

   Fact: This relation holds only for a classical monatomic gas of non-interacting point particles. For a classical diatomic gas of non-interacting molecules, the relation is instead $KE = (5/2)k_B T$. For non-classical systems, and for interacting molecules, still other formulas apply.

3. Claim: "The second law of thermodynamics is that a gas will fill up the entire container it is in because that is the most probable distribution of gas molecules. It is possible, but improbable, for all of the molecules to be huddled in one corner of the container."

   Fact: The second law of thermodynamics applies to all equilibrium systems, not just gases. There is an easy way to make all the molecules huddle in one corner... simply decrease the temperature until the gas turns to a liquid.

4. Claim: "The second law only applies to systems of non-interacting particles or entities."

   Fact: The Clausius–Clapeyron relation demonstrates conclusively that the second law of thermodynamics applies at phase transitions. Phase transitions are caused by interactions between particles. Clearly the second law *does* apply to systems of interacting particles.

5. Claim: "entropy increases only for isolated systems not affected by outside forces or inputs."

   Fact: The entropy of a system affected by outside forces or inputs might decrease, remain constant, or increase.

6. Claim: "All these authors are making the same assumption viz. that all one needs is sufficient energy flow into a closed system (or open system, where mass flow is allowed) and this will be the means of increasing the probability of life developing in complexity and new machinery evolving."

   Fact: None of the authors mentioned make this assumption. In fact, in the last paragraph of my paper I point out specifically that claims like the one above are irrelevant. "The second law of thermodynamics permits but does not require evolution. For example, the second law of thermodynamics holds on the Moon, yet biological evolution doesn't occur there."