Heat as Energy

[A discussion between J. Ghitis and a physics teacher.]

Teacher (T): "We have already seen that the average kinetic energy of the molecules in a gas is proportional to the absolute temperature of the gas."

J. Ghitis (JG): Each of the molecules of a fluid--gas or liquid--possesses its own kinetic energy resulting from its movement as an object. Thus, each molecule has the momentum of mass times velocity. There is no absolute temperature of the fluid, but of each molecule, thus an average temperature of the total molecules of the fluid in a container. The kinetic energy of each molecule as an object may be referred to as "macrokinetic.".

If a fluid is forced to move, its kinetic energy increases proportionally to its movement, even though its heat (measured as temperature) remains unchanged. What you say is almost true only when the fluid is static, i.e., when its inertia is determined only by its mass.

Completely different is the case of "microkinetic" energy, which is the "vibrational momentum" present exclusively in the outermost electrons of atoms, which is manifested as what we call "heat" and is topically measured as "temperature". Such energy is received by the outermost electrons of each atom from a source of external energy, such as chemical or luminous. The temperature of a whole object cannot be measured, so that when a given degree is stated, it refers to the presumed temperature of the object when assumed that all its atoms' electrons have the same microkinetic (vibrational) energy. We can see the agitation of water at boiling temperature, and know what will happen if we touch it. What we might not know is that such agitation is actually the manifestation of convection, and that its (macro) momentum is relatively insignificant. It is the microkinesis (micromomentum) of the outer electrons in the water atoms that causes damage to our skin. Does the wall of the container show agitation at that same boiling temperature? No, yet it causes a more extensive burning, because its dense material contains more atoms, and therefore more external electrons, than the fluid inside. The few air molecules in a hot oven cause no significant damage to a hand that avoids touching its walls.

T: In a gas, the atoms are moving randomly. In a solid, the atoms can move randomly about their equilibrium positions. In addition, the solid as a whole can move with a given velocity and have ordered kinetic energy. Only the kinetic energy associated with the random motion of the atoms is proportional to the absolute temperature of the solid. The average kinetic energy associated with the random motion of a any substance is proportional to the absolute temperature of the substance.

JG: Again, it is the microkinetic energy of the vibrating electrons of the atoms heated from an external source that determines the temperature of the solid. The "ordered" kinetic energy of a solid as a whole is of the macrokinetic order, being the (macro) momentum of the solid.

I postulate that the need to conceive macro- and micro- kinesis as different physical entities is evident.

T: Thermal energy is disordered energy. Temperature is a measure of this internal, disordered energy. While in ideal gases the disordered energy is all kinetic energy, in solids it is a combination of kinetic and potential energy. If we model the atoms in a solid as being held together by tiny springs, the random kinetic energy of each atom constantly switches between kinetic energy and elastic potential energy.

JG: What on earth is "disordered energy?" Order and disorder are anthropic concepts, not physical realities. Thermal energy is the microkinetic energy of vibrating atomic outermost electrons. Temperature is a standardized measurement in "degrees" of the heat intensity of the site examined. Not all a patient's organs have the temperature of his mouth. I can not fathom the meaning of your other phrases.

T: How can we heat things up? You can add thermal energy to an object by doing work on the object. If you rub an object, the force of sliding friction does work, and changes ordered kinetic energy into thermal energy. If fuel burns, chemical energy is converted into thermal energy.

JG: When made to increase their vibrations, the outermost electrons of an object manifest their augmented heat content, which is actually their microkinetic energy, which in turn acts on their neighbor atoms' outermost electrons. One does not "do" work: it is the displacement of an object--even an atom--by applying force to it, that is called work. Work is what energy does. Thus, energy is kinesis, whether at the micro- (electron) or at the macro- (atomic and molecular) realm. The effect of the force applied as friction is to excite the external electrons, which increase their vibrations, i.e., their microkinesis, which is micromomentum, manifested by what we call heat and measure topically as temperature.

Anything that can burn contains the potential energy that made the thing. This energy is called "chemical." When burning, the released energy is dissipated in
The question rises: what is meant by 'intensity' of electron's vibration? For the reason that vibrations (very fast oscillations) vary in frequency and in composition the molecules. Such microkinetic energy decreases as it excites lesser energetic electrons, until the intensities become equal, i.e., reach equilibrium.

Without moving, work cannot be done. Energy in the guise of heat is not exchanged, but transferred (dissipated) by the external electrons of the atoms falling, or a compressed spring.

The word "work" you use here is confusing. The whole paragraph hence should be, "Intense heating increases the kinetic energy of captive molecules to the point of dissociation into their component atoms." By 'captive' I mean that the heated molecules are in no position to dissipate their electronic excessive vibrations through transfer or by infrared photon generation.

The question rises: what is meant by 'intensity' of electron's vibration? For the reason that vibrations (very fast oscillations) vary in frequency and in...
Thus, heat cannot "flow." The "work" done (by each of the hotter molecules) might be called "microwork." A very confusing paragraph: "Charged" and "vibrating" are undefined, as is "electromagnetic radiation" and "random kinetic energy." The last phrase sounds as if heat were a transportable object.

**DEFINITIONS**

**CONDUCTION**

T: The atoms in a solid vibrate about their equilibrium positions. As they vibrate, they bump into their neighbors. In those collisions they exchange energy with their neighbors. If the different regions of a solid object or of several solid objects placed in contact with each other have the same temperature, then all atoms are just as likely to gain energy as to lose energy in the collisions. Their average random kinetic energy does not change. If, however, one region has a higher temperature than another region, then the atoms in the high temperature region will, on average, lose energy in the collisions, and the atoms in the low temperature region will, on average, gain energy. In this way heat flows through a solid by conduction.

JG: By definition, metals are good conductors. In fact, several artificial molecules made of nonmetallic atoms are good conductors, and are therefore called metals. I find the paragraph unclear.

**CONVECTION**

T: Convection transfers heat via the motion of a fluid which contains thermal energy. In an environment where a constant gravitational force \( F = mg \) acts on every object of mass \( m \), convection develops naturally because of changes in the fluid's density with pressure. When a fluid, such as air or water, is in contact with a hotter object, it picks up thermal energy by conduction. Its density decreases. For a given volume of the fluid, the upward buoyant force equals the weight of this volume of cool fluid. The downward force is the weight of this volume of hot fluid. The upward force has a larger magnitude than the downward force and the volume of hot fluid rises. Similarly, when a fluid is in contact with a colder object, it cools and sinks. When a volume of fluid such as air or water starts to move, the surrounding fluid has to rush in to fill the void. Otherwise large pressure differences would develop. This sets up a convection current and the looping path that follows is a convection cell. Since fluid can not pile up at some point in space without creating a high pressure area, it will flow in a closed loop. Convection can be increased if the fluid is forced to circulate. A fan, for example, forces the air to circulate.

JG: Heated gases or fluids move upwards because their component molecules are less compact. In so doing, the "conduction" of heat is facilitated. This phenomenon is called convection.

**RADITATION**

JG: Note that radiation is considered to be the third manner for heat to be transferred. It is quite easy to understand that when objects interact in terms of heat, the hottest heats the coldest until both reach the same temperature (equilibrium). In the process of heating by radiation, the hot object emits an energy which is not microkinetic, but radiating (photon). The object loses microkinetic energy in this way, with no relationship to the eventual fate of the photonic energy. Thus, there is no equilibrium.

T: Nuclei and electrons are charged particles. When charged particles accelerate, they emit electromagnetic radiation and lose energy. Vibrating particles are always accelerating since their velocity is always changing. They therefore always emit electromagnetic radiation. Charged particles also absorb electromagnetic radiation. When they absorb the radiation the accelerate. Their random kinetic energy increases. In thermal equilibrium, the amount of energy they lose to radiation equals the amount of energy they gain from radiation. But hotter objects emit more radiation than they absorb from their cooler environment. Radiation can therefore transport heat from a hotter to a cooler object.

JG: A very confusing paragraph: "Charged" and "vibrating" are undefined, as is "electromagnetic radiation" and "random kinetic energy." The last phrase sounds as if heat were a transportable object.

T: Electromagnetic radiation refers to electromagnetic waves which travel through space with the speed of light. The quantity that is "waving" is the electromagnetic field, an esoteric but quite measurable entity. A wave is characterized by a wavelength.
JG: EM radiation are both waves and particles. They travel at the speed of light by definition, because in physics light refers to all EM.

T: The wavelength is the distance from crest to crest or from trough to trough. We classify electromagnetic waves according to their wavelengths. The visible part of the spectrum may be further subdivided according to color, with red at the long wavelength end and violet at the short wavelength end.

JG: Each "color" (an anthropic definition), is composed of a large number of "hues," which are each one of the waves that are classified as color. The boundary hues are very difficult to distinguish by the human retina Thus, hues define the different energies of colors. Those that are toward the right side of the spectrum are shorter and more energetic (more per unit of time, viz, have a higher frequency). This rule applies to all EM waves, i.e., to all "light." However, the effects of the radiations--emitted from a given electron--on other atoms' electrons depend not only on energy, but also on the "shape" of the wavelength. Thus, for instance, infrared radiations are more calorific than the more energetic "color" ones. Here is an example of how the "shape" of the wave is more effective than its frequency. In a greenhouse, infrared radiations cannot penetrate nor exit the walls. "Color" radiations can, and they start the heating process, which is intensified by the emitted--and "trapped"--infrared, until the electrons' microkinetic energy called heat reaches equilibrium. This is the point where as much "heat" is lost through the walls of the enclosed space as it is generated by the described "heating" process.

T: Hot objects emit radiation with a distribution of wavelengths. But the average wavelength of the radiation decreases as the temperature of the object increases. Most thermal radiation lies in the infrared region of the spectrum. We cannot see this radiation, but we can feel it warming our skin. Different objects emit and absorb infrared radiation at different rates. Black surfaces are generally good emitters and absorbers, while silvery metal surfaces are poor emitters and absorbers.

JG: It was while studying a black box that Planck conceived light as composed of units, thus starting quantum theory. Infrared radiations, as all EM radiations in nature, are composed of "hues," i.e., of many wave length frequencies. The more energetic ones borderline the colored ones, and yet, their wave shape is not so appropriate for "heating" as are the middle range ones. By the same token, the lesser-energetic EM radiations called microwaves are more "shape-appropriate" to heat in a way proper to them.

That humans and other biological systems can or cannot see, and react in peculiar ways to EM radiations, is a result of evolution constrained by the physical laws applying to the different elements and derivatives that compose matter.

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