The thermodynamics of global warming

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Abstract: Macroscopic temperature of solid matter results from sub-microscopic oscillation of all the bonds holding atoms and molecules together. Current understanding of thermodynamics, however, was devised long before scientists understood that matter consists of atoms and molecules. Current understanding works reasonably well for small differences in temperature but fails catastrophically for global warming where Sun is 5759 ºC hotter than Earth. Kinetic energy of radiation equals frequency of oscillation times a scaling constant. Since frequency is a broad continuum of frequencies, energy is a broad continuum of energies that cannot accurately be described by an amount of watts per square meter as currently assumed throughout climate studies. What climate scientists currently assume is energy of radiation is actually intensity, caused by amplitude of oscillation. Heat flows by resonance simultaneously at all frequencies and is not additive as currently assumed. Heat simply does not physically flow in the ways assumed by greenhouse-warming theory.

Introduction: Thermodynamics is the study of heat in motion. Heat is what a body of matter must absorb to increase its temperature and lose to decrease its temperature. Temperature is "that which exists when heat ceases to flow between systems in thermal contact", essentially the zeroth law of thermodynamics (Grossman, 2014). Temperature is a macroscopic, intensive, physical property of a body of matter or of a volume of gas. Temperature at the macroscopic level is the result of kinetic energy of oscillation that is pervasive at the atomic level: 1.) kinetic energy of oscillation of all the bonds holding solid matter together or 2.) kinetic energy of translation of all the atoms and molecules making up a gas. The higher the average kinetic energy, the higher the temperature. As kinetic energy approaches zero, temperature approaches absolute zero kelvins.

The purpose of this paper is to review the physical evidence for what causes temperature, what heat is physically, how radiation is emitted and absorbed, how heat flows within matter and throughout air and space, and what determines the rate of heat transfer. Physics is about what is physically happening in Nature. The closest things to truth in physics are direct observations of what is physically happening—direct observations that do not require assumption of some theory in order to observe or interpret. This paper is based on direct, fundamental observations that are both physically intuitive and typically easy to make. This paper may be more easily understood by people not trained in physics because they can think based on direct observation rather than in terms of the physics of heat that we all learned in school, which, unfortunately, contains some mistaken assumptions detailed in this paper.

The most important mistake is confusing intensity or brightness of radiation with energy of radiation in the formulation of Planck's law. The second most important mistake is thinking that intensive kinetic energies of oscillation of submicroscopic systems within matter should be added together rather than averaged. Understanding these issues helps us realize why greenhouse-warming theory is not only mistaken, it is not even physically possible. The world has warmed on average 0.9 °C since 1950 (Jones et al., 1999) but increasing concentrations of greenhouse gases cannot physically be the cause. Heat simply does not flow in the ways assumed by greenhouse-warming theory.

The physical properties of radiation: We all observe that visible light when passed through a prism consists of a very broad spectrum of colors. Physicists measure these colors in the laboratory as frequencies of oscillation extending from dark red at 405 terahertz (trillion cycles per second) through orange, yellow, green, blue, and indigo, to dark violet at 790 terahertz. Newton (1704) showed that these separated colors, when passed through a second prism, become white light again demonstrating that all these colors coexist in white light. We observe clearly that these colors do not interact or interfere with each other in any way in air and space except in the immediate presence of matter. Furthermore, physicists measure that these visible frequencies of oscillation are but a tiny part of the electromagnetic spectrum consisting of frequencies of oscillation ranging from extremely low frequency radio signals of less than one cycle per second to gamma rays at frequencies of more than 10^{20} cycles per second.

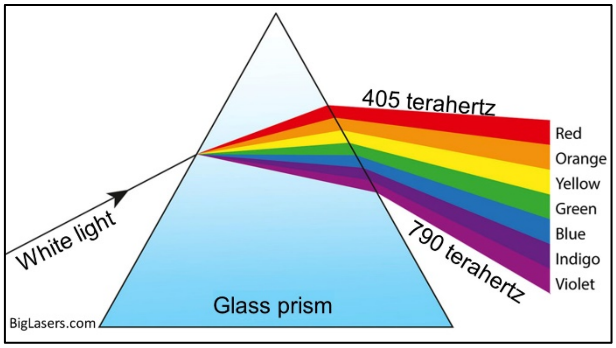

Figure 1. When white light is passed through a prism, it is separated into a rainbow of colors. The color spectrum, shown in bands for simplicity, is actually a gradually changing continuum of colors.

Many people think of light in terms of wavelength, but that is based on the assumption that light travels as a wave and that the frequency measured is wave frequency, which is defined as the velocity of light divided by wavelength. But that is mathematics, not physics. Waves are the deformation of matter. Michelson and Morley (1887) showed definitively that the luminiferous aether, the matter through which light waves were thought to travel, does not physically exist. Wave theory became especially popular after Newton (1704) showed it can explain observations of reflection, refraction, diffraction, interference, and polarization of light. But these phenomena can be explained in other ways as discussed below.

The primary physical property of thermal radiation, which is radiation emitted by a body of matter because of its temperature, is a very broad spectrum of frequencies of oscillation where each frequency does not change with distance traveled, even galactic distances, except for Doppler effects. The second physical property of thermal radiation is intensity of oscillation at each frequency of oscillation—how bright that frequency appears. Intensity of oscillation at each frequency of oscillation is observed to increase with increasing temperature of the radiating body and decrease inversely proportional to the square of the distance travelled. All frequencies throughout the electromagnetic spectrum coexist at all times and at all locations. What varies in time and space is the intensity of oscillation at each frequency ranging on a logarithmic scale from completely insignificant to dominant.

Planck's empirical law describes the physical properties of radiation: In the 1890s, several radiation physicists passed white sunlight through a glass prism, spatially separating white light into a spectrum of colors as in Figure 1. Then they moved various sensors through each band of color, carefully measuring the intensity or brightness of each color as a function of the temperature of the source of the radiation. They did the same for infrared radiation using a prism made out of halite because infrared radiation does not have enough energy to pass through glass.

Planck (1900) was able to devise an equation that calculates the observed intensity or brightness at each frequency of oscillation as a function of temperature of the emitting body, plotted for three temperatures in Figure 2. This equation, now known as Planck's empirical law, was determined by trial and error in order to explain extensive observations. It was not originally based on theory.

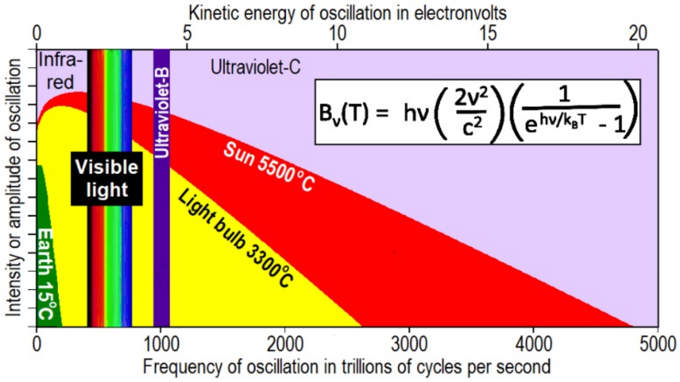

Figure 2. Planck's empirical law calculating the intensity of radiation at each frequency of oscillation as a function of the temperature of the radiating body.

In the 1890s and still today, physicists thought their sensors were measuring energy of radiation rather than intensity or brightness, so Planck plotted flux of energy in watts per square meter on the y-axis. What is fascinating, however, is that Planck, in order to satisfy dimensional analysis for his equation, postulated that energy of radiation (E) is equal to the Planck constant (h) times frequency (v, the Greek letter nu). Planck's "energy elements" became known as "energy quanta" (Einstein, 1905b) and ultimately as photons (Lewis, 1926). But if energy equals a constant times frequency, then energy must be plotted parallel to frequency on an alternative x-axis as shown at the top of Figure 2.

In 1900, Planck considered $E=hv$ to be a "mathematical trick or convenience" and his empirical law to be a "fortunate guess" (Gearhart, 2008). He never appears to have thought carefully about what energy of radiation is physically. Nevertheless, in 1918, Planck earned the Nobel Prize in Physics for "his discovery of energy quanta." In 1931, he admitted that introducing the "energy element" in 1900 was "a purely formal assumption and I really did not give it much thought except that no matter what the cost, I must bring about a positive result" (Kragh, 2000). In other words, Planck, a theoretical physicist, was obsessed with the mathematics rather than thinking about what was actually physically happening in Nature.

Perhaps the most important direct observation from Planck's empirical law is that the physical properties of radiation from Sun shown in red, yellow, and green are very different from the physical properties of radiation from Earth shown in green. Frequencies of oscillation radiated by Sun can exceed 5000 trillion cycles per second, while frequencies of oscillation emitted by Earth are nearly all less than 200 trillion cycles per second. Energies of oscillation radiated by Sun can exceed 20.7 electronvolts, while energies of oscillation emitted by Earth are nearly all less than 0.7 electronvolts. The intensity of the brightest frequencies of oscillation emitted by Sun are four orders of magnitude (10,000 times) greater than the intensities of the brightest frequencies of oscillation emitted by Earth (Figure 2).

Greenhouse-warming theory assumes that the physical properties of solar and terrestrial radiation are the same except that there is a greater amount of flux of solar radiation measured in watts per square meter. That assumption is clearly mistaken. There is no such thing as amount of radiation in Planck's empirical law when properly formulated. Temperature is the result of a very broad spectrum of frequencies of oscillation. The higher the temperature of the radiating body, the higher the frequency content, the higher the energy content, the higher the maximum amplitude of oscillation and the higher the intensity or brightness.

We all know when we stand in sunlight, we get very warm and even sunburned. While standing at night bathed in infrared radiation from Earth, we do not get very warm and we will never get sunburned no matter how long we stand there. Sunburn is caused by ultraviolet-B radiation with energies around 4.0

electronvolts. Earth does not emit ultraviolet-B radiation and does not even emit any significant intensity of visible light. The physical properties of radiation from Earth shown in green are but a tiny subset of the physical properties of radiation from Sun shown in red, yellow, and green. Current thinking of solar and terrestrial radiation as being identical except for amount grossly overestimates the thermal effects of low-energy, terrestrial, infrared radiation absorbed by greenhouse gases compared to the thermal effects of solar visible and ultraviolet radiation. By $E=h\nu$, any intensity of ultraviolet-B radiation has 50 times more energy than any intensity of infrared radiation absorbed most strongly by carbon dioxide. The thermal effect of radiation is not about amount of total energy flux specified in watts per square meter as currently thought. It is about the amplitude of oscillation at each frequency of oscillation, which is determined by the temperature of the source of the radiation as calculated by Planck's empirical law.

The second most important direct observation from Planck's empirical law is that the higher the temperature of the radiating body, the higher the intensity at each and every frequency and the higher the frequencies with the greatest intensities. To make a body warmer by absorbing radiation, therefore, that radiation must come from a hotter body of matter that contains higher intensity at each and every frequency. Thus, a body cannot physically be warmed in any way by absorbing its own radiation because its own radiation does not contain higher intensity at each and every frequency. Earth's surface and atmosphere simply cannot physically be warmed by increasing concentrations of greenhouse gases absorbing radiation from Earth.

Many climate scientists think greenhouse gases, by absorbing terrestrial radiation, slow the cooling of Earth. This is mistakenly thinking of heat as an amount—the more you absorb the hotter you get. As stated above, there is no such thing as amount of radiation in Planck's empirical law when properly formulated. What increases with increasing temperature are amplitudes of oscillation at each and every frequency of oscillation.

The third most important direct observation from Planck's empirical law is that heat, which we define as what must be absorbed by a body of matter to make that body hotter, is physically a continuum of frequencies of oscillation, each with an associated amplitude of oscillation calculated by Planck's empirical law. Thus, the heat that Earth must absorb to be raised to the temperature of the filament of an incandescent light bulb is shown by the continuum shaded yellow in Figure 2.

What is oscillating? We observe that the chemical bonds holding matter together are not rigid. We think of them as oscillating between electrodynamic forces of repulsion when the atoms get too close together and electrodynamic forces of attraction as the atoms move apart as approximated by the Morse potential (Morse, 1929) shown in Figure 3, or by the more detailed Morse/Long range potential (Le Roy et al., 2009). Oscillations of bonds are frictionless and therefore can last essentially forever. As temperature increases, the frequencies, energies, and amplitudes of oscillation all increase until the energy of oscillation reaches a threshold (Emax) equal to the energy holding the bond together. At this level of energy, the molecular bond is essentially shaken apart—the molecule is dissociated. When two atoms collide, the bond can be reestablished provided the resulting energy of oscillation is less than Emax.

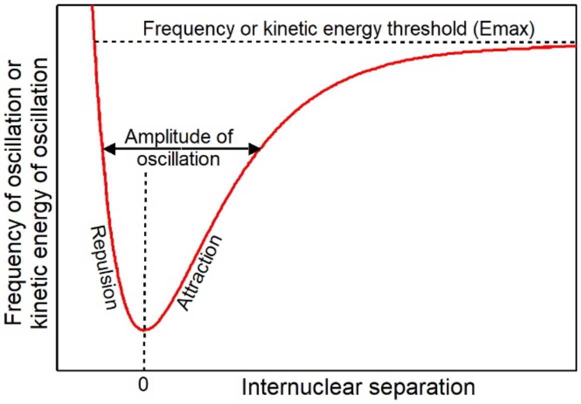

Figure 3. Oscillation of a molecular bond between forces of repulsion and forces of attraction. The molecule is dissociated when the frequency, which is also kinetic energy, is above Emax.

Note in Figure 3 that a bond oscillator is asymmetric, also known as anharmonic, because repulsion acts over a shorter distance than attraction. Bond length is observed to increase with increasing temperature. This asymmetry explains why the volume of most materials is observed to increase with increasing temperature.

We observe from Planck's empirical law that radiation has two physical properties: a broad spectrum of frequencies of oscillation and an intensity or brightness at each frequency. We observe that a frictionless oscillator has two physical properties: a frequency of oscillation and an amplitude of oscillation. Clearly the y-axis of Planck's empirical law should be intensity or brightness when referring to radiation or amplitude of oscillation when referring to the source of the radiation. I simply plot orders of magnitude on the y-axis because I think it would be best for the absolute values of amplitude to be calibrated in the laboratory. They could vary in detail with chemical composition. Energy should not be plotted on the Y-axis as assumed by Planck and most physicists today because we now know that kinetic energy of oscillation of frictionless oscillators is simply another way of looking at frequency of oscillation as shown on the upper x-axis for $E=h\nu$ in Figure 2.

These frequencies of oscillation and associated amplitudes of oscillation contained within thermal radiation and described by Planck's empirical law must be the frequencies of oscillation and the amplitudes of oscillation of molecular bonds on the surface of the emitting body that are collectively transmitting the radiation. Oscillation of charge on the surface of matter is well-observed and well-understood to transmit its frequency of oscillation via line of sight through air and space. This is how a radio transmitter works. The radio transmitter causes oscillation of charge on its antenna at the frequency assigned by the government to that radio station. You tune your radio receiver to receive just that exact frequency.

These frequencies and amplitudes of oscillation must also exist below the surface of the radiating body, interacting via conduction. In this way, Planck's empirical law shows the frequencies of oscillation and associated amplitudes of oscillation of bonds that must exist within a body of matter at thermal equilibrium for that body to physically possess a specific temperature.

Thermal kinetic energy is not additive: Grossman (2014) explains "by measuring temperature, we're measuring how fast the atoms in the material are moving. The higher the average velocity of the atoms, the higher the temperature of the material".

In gases, all atoms and molecules move independently until they collide. Then they typically change direction of independent motion unless a new molecule is formed by the collision. Kinetic energy of translation of an individual gas atom or molecule is the energy an atom or molecule possesses by virtue of being in motion and is equal to one-half its mass times its velocity of translation squared. Temperature of a gas, according to the kinetic theory of gases, is proportional to the average kinetic energy of translation of all atoms and molecules making up the gas. Average kinetic energy of translation is proportional to the average velocity of motion squared.

Note that kinetic energy of motion in a gas is a physical property of a specific atom or molecule and that this kinetic energy only affects how this specific atom or molecule interacts with others. While it is mathematically possible to add up all the kinetic energies of all the atoms and molecules contained within a gas to get the total energy contained within a gas, this sum is not physically meaningful—it has no basis in physical reality because the physical and chemical interactions are at the molecular level, not at the level of the whole gas. The gas may be in a container that is not moving and, therefore, has no kinetic energy of translation. Kinetic energies of translation can be averaged together to characterize the statistical distribution of kinetic energies throughout the gas, but they cannot meaningfully be added together to calculate a total amount of kinetic energy per unit volume or the total amount of kinetic energy flowing through a surface each second in units of watts per square meter as is currently done when using greenhouse warming theory.

In matter, all atoms and molecules are interconnected by bonds. The only motion possible within a body of solid matter is oscillation of these bonds. These bonds are very short, with lengths and amplitudes of oscillation typically measured in picometers (10^{-12} meters). Each mode of oscillation of each bond is observed to oscillate at a characteristic resonant frequency of oscillation typically measured at room temperature in terahertz, which are trillions (10^{12}) of cycles per second. The frequencies and amplitudes of these oscillations are observed to be dependent on the physical properties of the bond and on temperature. Planck's empirical law shows the higher the temperature of the material, the higher the amplitudes of oscillation at each and every frequency of oscillation and the higher the frequencies of oscillation with the greatest amplitudes of oscillation.

Kinetic energy of oscillation in solid matter is the energy a bond possesses by virtue of the atoms joined by the bond being in motion relative to each other. This oscillatory energy is fully described and quantified as the frequency of oscillation. The higher the frequency, the faster the atoms are moving. Planck's "energy elements" ($E=h\nu$), now widely accepted as the Planck-Einstein relation, tell us that the kinetic energy of oscillation (E) of each mode of oscillation of a bond simply equals the frequency of oscillation (ν) times the Planck scaling constant (h), which is the number of joules or electronvolts of energy possessed by one bond oscillating at a frequency of one cycle per second. The higher the frequency of oscillation, the higher the velocity of the atoms involved, the higher the kinetic energy of oscillation, and the higher the temperature. The value of Planck's constant can be estimated easily using light emitting diodes in a high-school physics laboratory (Rute and Sérgio, 2014).

Again, it makes no physical sense to add together these individual kinetic energies of bond oscillation ($E=h\nu$) because each kinetic energy is a property of only one discrete mode of oscillation of one discrete oscillator. Furthermore, frequencies (ν) are not additive. All frequencies coexist and cannot, physically, be added together. If you add red light at a frequency of 450 terahertz to blue light at a frequency of 650 terahertz, you do not get ultraviolet light at a frequency of 1100 terahertz. You simple have some red light coexisting with some blue light. It makes no physical sense to mathematically add frequencies together or integrate kinetic energy as a function of frequency. Frequencies of oscillation are not additive, and energies of oscillation cannot be additive as currently assumed.

Furthermore, temperatures are not additive. If you take two bodies of matter that are identical in every way except temperature and connect them together, the resulting temperature is the average of the two initial temperatures, not the sum. That means that the physical processes that result in temperature cannot be additive. We should think of them as averative, a word I am coining to emphasize that the resulting temperature is somewhere between the two initial temperatures.

The rate that heat flows is proportional to the difference in temperature: All curves of warming or cooling of matter are asymptotic to the final temperature as shown in Figure 4 for warming. The black curve plots the warming measured when shining a light on a small piece of thin black metal. The red line shows the warming calculated by multiplying a constant times the final temperature minus the current temperature. The greater the difference in temperature, the faster the body is warmed, but it takes a very long time to completely warm the body as the temperature difference approaches zero.

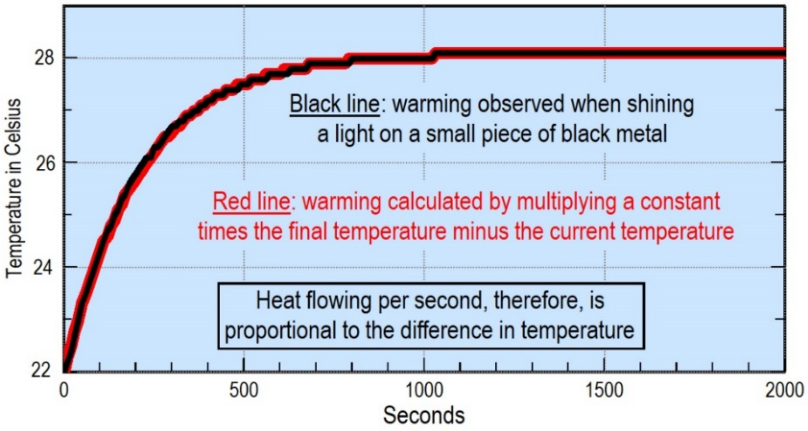

Figure 4. Heat flowing per second is proportional to the difference in temperature at that moment.

You get this same asymptotic shape when you approach a wall by moving half the distance between you and the wall during each unit of time. You get very close to the wall soon, but you will never theoretically reach the wall.

Currently atmospheric scientists assume that the rate of flow of heat is proportional to the temperature, not to the temperature difference. Furthermore, they assume that greenhouse gases absorbing infrared radiation from Earth slow the rate that heat can flow from Earth into space, so that the same amount of radiation from Sun makes Earth hotter. This seems logical, but it is not the way heat flows. As shown by the red curve above, if Earth gets hotter, more heat will flow into space during each second. Heat flows at a rate that is proportional to the difference in temperature, not proportional to temperature as currently assumed.

Secondly, temperature is not about amount of thermal energy. There is no such thing in Planck’s empirical law when formulated properly as amount of energy flowing with units of watts per square meter. Temperature is increased by absorbing greater amplitudes of oscillation at each frequency of oscillation radiated by a hotter body. As discussed above, kinetic energy of translation and kinetic energy of oscillation apply to specific atoms, molecules, or bonds. It is not physically meaningful to sum up the total amount of kinetic energy per unit volume or passing through some surface per unit time.

Planck’s empirical law (Figure 2) shows us that when heat flows, what is physically flowing is amplitude of oscillation at each and every frequency simultaneously. But how does amplitude of oscillation flow and how does the warming system know what the final temperature will be for calculating the red line shown in Figure 4?

Amplitude of oscillation flows by resonance: Temperature in matter, as calculated by Planck's empirical law, is the result of oscillation of all the bonds holding a piece of solid matter together. The most important physical property of oscillating systems beyond frequency of oscillation and amplitude of oscillation is resonance, also known as sympathetic oscillation. When two discrete molecular-bond-scale oscillators are oscillating at the same frequency and are within line-of-sight of each other or mechanically connected in some way, they are observed to share amplitude of oscillation. The oscillator with the largest amplitude of oscillation loses amplitude of oscillation to the oscillator with the least amplitude of oscillation. In the simplest case, both oscillators end up with the average of the initial amplitudes of oscillation. But in undamped systems with no friction such as bond oscillators, the increase in amplitude can be larger if that specific frequency is a natural resonant frequency of that specific oscillator.

For example, molecules of carbon dioxide, absorb less than 16% of the frequencies (Ångström, 1900) contained in the broad spectrum of radiation emitted by Earth, producing spectral lines of absorption shown in Figure 5 for the main absorption band between 17 and 23 terahertz (Gordon et al., 2017). These lines are located at the resonant frequencies of all the different modes of oscillation and all the different harmonics or overtones for all the bonds holding the one carbon and two oxygen atoms together. These spectral lines are so distinctive that they can be used to identify the specific gas located from near at hand to distant galaxies.

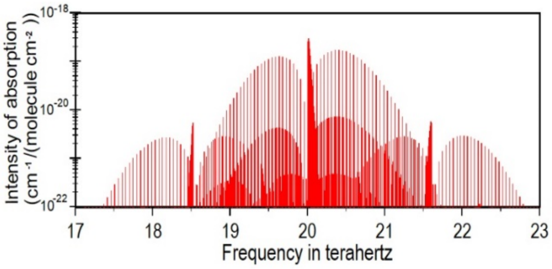

Figure 5. Spectral lines of absorption by a molecule of carbon dioxide in the frequency range of 17 to 23 terahertz, commonly referred to as centered around 14.9 micrometers wavelength.

Note that harmonics or overtones of oscillation are at higher frequencies, which are higher energies. Currently we think of higher energies as the result of moving an electron to a higher energy orbit causing the Planck-Einstein relation to become E=nhv where n is an integer (Bohr, 1913). The same observations can be explained much more simply as harmonics or overtones of an oscillating system.

Thus, amplitude of oscillation flows by resonance between two discrete oscillators oscillating at the same frequency, which because E=h*v* means oscillating at the same energy. Within matter, resonance can occur by physical touching of oscillators. Across air and space, we observe that resonance occurs via line of sight between oscillations of charge. Resonance appears to happen almost instantly over any distance. Thus, what we think of as the velocity of light may just be the very small fraction of a second that it takes for resonance to happen.

Resonance is what Einstein called “spooky action at a distance” (Born et al., 1971) where something happening over here is mysteriously coupled to something happening over there, but there is no visible evidence of any connection between them. The concept of action at a distance in classical physics or quantum entanglement in quantum mechanics may simply be trying to explain resonance, a fundamental physical property of oscillating systems.

Heat flows by resonance occurring simultaneously at each and every frequency of oscillation. Physically, heat is a very broad spectrum of frequencies of oscillation of all the bonds holding matter together where the difference in amplitude of oscillation is defined by the difference in temperature between the emitting and the absorbing bodies of matter as quantified by Planck’s empirical law. The greater the difference in temperature, the greater the difference in amplitudes at every frequency, the greater the heat transferred per second. The current way of calculating heat as a flux defined as a single number of watts per square meter that is supposed to apply to all frequencies of oscillation bears no resemblance to what is happening physically at the molecular level.

Heat travels by resonance simultaneously at each and every frequency, averaging or at least moving amplitudes of oscillation at each frequency of oscillation towards each other. Thus, heat is what I call averative. Heat is not additive, as currently assumed, because it makes no physical sense to add frequencies together, to add amplitudes of oscillation together for different discrete oscillators at each frequency of oscillation, or to add kinetic energies together for all independent oscillators.

At each frequency of oscillation, at each energy level, amplitude of oscillation can only be transferred by resonance from higher amplitude to lower amplitude, which means from higher temperature to lower temperature (Figure 2), essentially the second law of thermodynamics (Grossman, 2014).

Tiny bond oscillators are frictionless because they are the result of electrodynamic forces of attraction and repulsion. Therefore, the only way we know to increase or decrease the kinetic energy of oscillation contained in the bond is by resonance.

The only other way to access the kinetic energy of oscillation contained within a bond is to break that bond, to dissociate that bond, so that the molecular pieces fly apart at high velocity, converting bond energy of oscillation completely and efficiently into increased kinetic energy of motion, which increases the temperature of a gas, conserving energy, essentially the first law of thermodynamics (Grossman, 2014). Air in the stratosphere is heated when ultraviolet solar radiation dissociates oxygen, ozone, and many other gas molecules. For each type of molecule, there is a specific level of energy of oscillation ($E=h\nu$) contained in solar radiation that causes resonance of the bond at a high enough amplitude of oscillation to shake that molecule apart—sufficient to dissociate that molecule.

Infrared radiation absorbed most strongly by greenhouse gases has 50 to 60 times less energy than the energy required to dissociate oxygen. Greenhouse-gases cannot be dissociated by the terrestrial infrared energy that they absorb. It has never been shown experimentally that greenhouse gases absorbing terrestrial infrared energy can cause significant heating of air as explained at JustProveCO2.com.

Thus, all matter contains kinetic energy of oscillation stored in the bonds holding matter together. The shorter the length of the bond, the higher the natural frequencies of oscillation and, therefore, the higher the energies of oscillation. Atomic bonds are thus much higher energy than molecular bonds. This insight gives us a physically intuitive way to understand mass-energy equivalence proposed by Einstein (1905a) in the equation $E=mc^2$, where total kinetic energy (E) contained within a body of matter equals mass (m) times the velocity of light squared (c^2). The energy stored in all the molecular and atomic bonds contained in a unit of mass is very high, approximated by the largest commonly used physical constant we know squared in order to look like the equation for kinetic energy of translation ($E=\frac{1}{2}mv^2$). This energy is only accessible by the flow of heat, by dissociation of molecular bonds, or by dissociation of atomic bonds such as in a chain reaction we know as the atomic bomb. Finding controlled ways to access a portion of the energy stored in all bonds within solid matter will lead to the ultimate source of energy to power our economies and our lifestyles.

Simultaneous resonance at every frequency of oscillation provides a way for myriads of bond oscillators on the surface of a body of matter to transfer heat to myriads of bond oscillators on a cooler body of matter within line of sight. If we put a sensor in between, the bonds on the front surface of the sensor resonate with the bonds on the surface of the emitter and the bonds on the back surface of the sensor resonate with the bonds on the surface of the cooler absorber as determined by the temperature of the sensor. The sensor reads a value that changes as we move it in three spatial dimensions. We think of these values as mapping out a field. The field does not need to physically exist but thinking about this “field” can help us figure out how resonance actually works.

Resonance provides a physical explanation for how, physically, a warming system "knows" the final temperature as plotted in Figure 4, how, physically, amplitudes of oscillation and temperatures are averaged, and how, physically, Planck curves keep their shape. Resonance explains why heat can only flow from hot to cold. Resonance shows that a body of matter does not emit the same radiation in every direction. Resonance is point to point. For example, Earth absorbs heat, amplitude of oscillation, from a hotter Sun, but it loses a lot of heat to much colder deep space.

Resonance explains why air temperatures are warmer on cloudy evenings. Bonds on the surface of Earth are resonating with bonds in the cloud, which is much warmer than deep space. The temperature difference is smaller, which means the flow of heat from Earth's surface is slower as in Figure 4.

There is still much to learn about the details of resonance, but clearly resonance plays the primary role in the transfer of heat, light, and electromagnetic radiation both through matter and through air and space.

Resonance is all around us: Resonance is how we see. Each of our eyes contains six to seven million cone cells in sets of three that resonate to visible light in slightly different ways shown by the solid lines in Figure 6 labelled Red, Green, and Blue. Our brain processes the three slightly different neurological signals to detect ten million different shades of color. All cone cells resonate simultaneously, each with a single oscillating molecular bond within your field of view, allowing you to see a whole scene in full color.

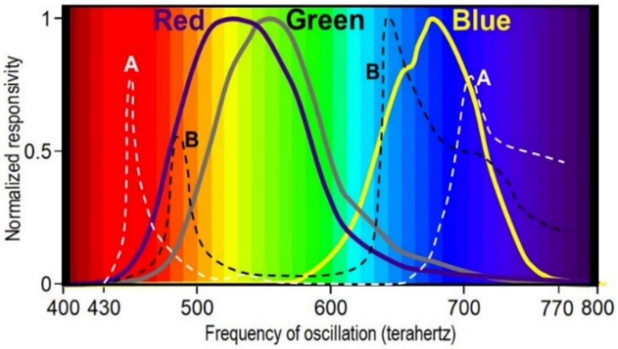

Figure 6. Sets of three cones in your eyes respond in slightly different ways to Red, Green, and Blue light as shown by the solid curves (en.wikipedia.org/wiki/Cone_cell). A leaf appears green because chlorophyll A and B absorb most red and blue light as shown by the dashed lines, leaving only oscillations in the frequency range of green on the surface to resonate with the cells in your eyes (en.wikipedia.org/wiki/Chlorophyll_a).

We hear by resonance when the tiny hair-like cells in our inner ear resonate at different frequencies of air pressure, transmitting that precise frequency to our brains. Scientists are beginning to realize, similarly, that a small number of sensor types involving resonance may be what enables animals to recognize a very wide range of smells and tastes (Burr, 2004; Bushdid et al., 2014; Carney, 2019; Piesse, 2015). We feel temperature by resonance. Resonance appears to be the primary way living things interact with their physical and social environments.

Amplitude of oscillation, intensity of radiation, is well observed to decrease with the square of the distance travelled. This decrease can be understood in terms of the apparent density of molecular-bond-scale oscillators on the surface of near and distant bodies. Over short distances, there is a one-to-one correspondence between oscillators. As distance increases, the distant object looks smaller and smaller. Fewer and fewer molecules on the distant surface are available to resonate with each molecule on the near surface. Thus, the amplitude transferred by resonance must then be shared by conduction with more and more similar oscillators on the distant surface as they reach thermal equilibrium. In this way, the rate of amplitude transfer slows with the square of increasing distance.

Einstein (1905b), when trying to understand the photoelectric effect, suggested that there was a light quantum ($E=h\nu$), which we now understand is simply the level of energy or frequency high enough to release an electron on a fresh, unoxidized metal surface in the photoelectric effect (Hertz, 1887). Similarly, $E=h\nu$ is utilized to specify the level of energy that causes dissociation or ionization.

We can also use this simple equation to describe all energies of radiation that are occurring simultaneously. All frequencies of oscillation (ν) form a very broad continuum of frequencies of oscillation. A constant (h) times a continuum is still a continuum. Therefore, all kinetic energies of oscillation (E) is a continuum of energies, all of which must exist for a body of matter to possess a temperature as shown by Planck's empirical law. Again, it is physically impossible to describe this continuum in terms of a single number of watts per square meter as is currently done throughout greenhouse-warming theory.

We clearly observe that frequencies of oscillation in air and space do not interact with each other except in the immediate presence of matter where the bonds holding the surface of matter together facilitate interaction. A bond may absorb a given frequency and then radiate that frequency back into air and space, giving the effect we think of as reflection. The bond may share that frequency via conduction implemented by resonance to other bonds in matter, giving the effects of diffraction or refraction. The orientations of the axes of oscillation gives the effects of polarization. The balance between re-radiation and conduction can determine an interference pattern. There is much to learn about the details of resonance between oscillators that are touching and oscillators that are communicating via line-of-sight through air and space.

Depletion of the ozone layer appears to explain observed global warming in detail: Planck's empirical law (Figure 2) shows the higher the frequency of oscillation, the greater the difference in amplitude of oscillation between Sun and Earth, and, therefore, the greater the warming per unit time. Ultraviolet-B is the highest frequency solar radiation reaching Earth where it causes sunburn, cataracts, skin cancer, and mutations. The ozone layer absorbs most ultraviolet-B, protecting life on Earth from this very energetic radiation. When the ozone layer is depleted, however, more ultraviolet-B radiation is observed to reach Earth, cooling the ozone layer (Randel, 2010; Thompson and Solomon, 2009) and warming Earth as observed. Ultraviolet-B penetrates oceans hundreds of meters and is, therefore, completely absorbed with no portion being radiated back into space at night. Ultraviolet-B also dissociates ground-level ozone pollution causing greater warming of air in populated, industrialized areas in the northern hemisphere as observed (Jones et al., 1999).

In the late 1960s, CFC gases were manufactured widely for use as refrigerants, spray-can propellants, solvents, and foam-blowing agents. By 1970, ozone began to be depleted especially over polar regions in late winter and global average temperatures began to rise. In 1974, scientists discovered that when CFCs reach the stratosphere, they can be broken down by solar ultraviolet radiation to release atoms of chlorine (Molina and Rowland, 1974). One atom of chlorine, especially in late winter as observed, can destroy more than 100,000 molecules of ozone. In 1985, the Antarctic ozone hole was first discovered (Farman et al., 1985), showing that ozone depletion was more extensive than thought. In 1987, the United Nations passed the Montreal Protocol mandating cutback in CFC production beginning in 1989. By 1993, concentrations of CFCs in the atmosphere stopped increasing. By 1995, ozone depletion stopped increasing. By 1998, average global temperatures stopped increasing. The world was warmed 0.6 °C from 1970 to 1998. Humans, by manufacturing CFCs, had caused the warming. Humans, by passing the Montreal Protocol, had stopped the increase in warming. It will take many decades before the ozone layer is expected to recover to pre-1970 levels (Solomon, 1999). While ozone remains depleted, ocean heat content continue to increase (Levitus et al., 2012).

In 2014, Bárðarbunga volcano in central Iceland extruded the largest basaltic lava flow since 1783. Extensive flows of basaltic lava release large amounts of chlorine and large amounts of heat capable of convecting the chlorine up into the ozone layer. Global warming increased rapidly 0.3 °C from 2014 to 2016, the hottest year on record. Throughout Earth history, extensive extrusion of basalt over areas ranging from tens, to thousands, to millions of square miles were contemporaneous with major global warming, the larger the flow, the greater the warming (Ward, 2016a, b). Considerable detail is provided in webpages, videos, and technical papers at WhyClimateChanges.com.

No significant global warming was observed from 1950 to 1970, from 1998 to 2013, or since 2016, 56% of the time, while atmospheric concentrations of carbon dioxide continued to rise steadily at ever increasing rates. Well observed sudden changes in rates of global warming around 1970, 1998, 2014, and 2016 cannot be explained by this steady rise in concentrations of greenhouse gases.

Summary: Macroscopic temperature of solid matter results from simultaneous oscillation of all the bonds holding atoms and molecules together. Each mode of oscillation of each bond has a frequency of oscillation, a kinetic energy of oscillation that equals the frequency of oscillation times the Planck constant, and an associated amplitude of oscillation that can be calculated as a function of temperature using Planck's empirical law. All frequencies of oscillation, all energies of oscillation, and all amplitudes of oscillation form very broad spectra or continua and all members of these continua must coexist for a body of solid matter to possess a given temperature.

Heat is what a body of solid matter must absorb to increase its temperature and lose to decrease its temperature. Heat flows by resonance at all frequencies simultaneously. The kinetic energy in heat is not additive as currently assumed. It makes no physical sense to add together kinetic energies of oscillation of submicroscopic systems because each kinetic energy applies only to a specific molecular-bond-scale oscillator. Kinetic energies can be averaged, however. The higher the average kinetic energy of oscillation, the higher the temperature of the body.

Since frequency is a broad continuum of frequencies and energy is a broad continuum of energies, energy cannot be described accurately by an amount of watts per square meter as currently assumed throughout climate studies.

The thermal effect of radiation is not determined by the amount of total energy flux specified in watts per square meter as currently thought. It is determined by the amplitude of oscillation at each frequency of oscillation, which can be calculated by Planck's empirical law based on the temperature of the source of the radiation.

Greenhouse-warming theory is based on the assumption that greenhouse gases absorbing infrared radiation from Earth will, in one way or another, cause Earth to get hotter. But this is not physically possible. Planck's empirical law shows that a warmer body has greater amplitude of oscillation at each and every frequency of oscillation and higher frequencies that have the greatest amplitudes of oscillation. A body can only be warmed by radiation when that radiation is emitted by a hotter body that contains higher intensity at each and every frequency. No body of solid matter can physically be warmed in any way by absorbing its own radiation. If it could, we would have an endless supply of free thermal energy.

Greenhouse-warming theory is also based on the widespread assumption that heat is not a physical thing, it is simply a rate of thermal energy per second in watts flowing through a surface area of one square meter. Physicists currently define thermal energy vaguely as internal energy of movement within matter without thinking carefully about the primary role of oscillation and associated resonance. Planck and physicists today mistakenly think of intensity of oscillation as kinetic energy of oscillation. But kinetic energy of oscillation was proposed by Planck to equal frequency times the Planck constant. Today, this Planck-Einstein relation is widely accepted as valid.

Many climate scientists think greenhouse gases, by absorbing terrestrial radiation, slow the cooling of Earth. This is mistakenly thinking of heat as an amount—the more you absorb the hotter you get. As stated above, there is no such thing as amount of radiation in Planck's empirical law when properly formulated. Asymptotic curves of cooling show that the hotter Earth becomes, the more rapidly it loses heat to space. What increases with increasing temperature are amplitudes of oscillation at each and every frequency of oscillation.

Climate scientists today improperly assume that the y-axis of Planck's empirical law is energy per second passing through a surface area. Then they improperly integrate (add together) these energies as a function of frequency to determine total energy expressed improperly as the Stefan-Boltzmann law, which calculates that the total energy per second radiated across a surface of one square meter is proportional to temperature raised to the fourth power.

Heat simply does not physically flow in the ways assumed by greenhouse-warming theory. Greenhouse-warming theory is rapidly becoming the most expensive mistake ever made in science—economically, politically, and environmentally as explained in sixteen short videos at whyclimatechanges.com/most-expensive-mistake/.

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