

# Electromagnetic Nature of Thermo-Mechanical Mass-Energy Transfer Demystified

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**Based on electron-shell interactions and well-established phenomena and theories, including Einstein's mass-energy equivalence and thermal radiation, it is deduced here, that for a conduction heat transfer or mechanical work transfer, there has to be underlying electromagnetic energy transfer (i.e., via photon "on-contact" diffusive re-emission and/or propagation) and commensurate mass-transfer through material systems involved, from a mass-energy source to a sink system, since these thermo-mechanical phenomena are neither gravitational nor nuclear interactions.**

## Introduction

It is widely believed that thermal heat conduction and mechanical work transfer are "massless" phenomena [1]. However, based on existing observations of atomic electron-shell interactions and well-established phenomena and theories, including Einstein's mass-energy equivalence [2] and thermal radiation, it is reasoned here that for a conduction heat transfer (e.g., through a wall) or mechanical work transfer (e.g., a rotating shaft), there has to be underlying electromagnetic energy transfer (i.e., via photon "on-contact" diffusive annihilation/reemission and propagation) and commensurate mass-transfer through material systems involved, from a mass-energy source to a sink system. Otherwise, the mass-energy equivalence and the Physics law of forced interactions will be violated, since these thermo-mechanical phenomena are neither gravitational nor nuclear interactions. Actually, the deficiency of classical Fourier heat conduction theory (parabolic differential equation), allowing infinite speed of thermal energy propagation (i.e., a change of temperature at one location is felt at infinity instantaneously), is raised by Hyperbolic Heat Conduction Model (hyperbolic DE) [3], Relativistic Heat Conduction Theory (hyperbolic DE with modified definition of heat flux vector) [4], and more recently by Thermomass Theory [5] (based on Einstein mass-energy equivalence with 'thermon' quasi-particle leading to inertia of heat transfer).

The objective here is to express a *phenomenological-thermodynamicist*, an up-down thought-reasoning view as complement to (and independent from) the *quantum-mechanists*, down-up modeling view [6]. After all, the thought-reasoning experiments are necessary for concepts beyond reach of reliable experimental observations. Lavoisier [7] and his followers reasoned ingeniously, long before the conservation of energy was established, that heat has to be a conserved substance (massless *caloric*) contained in material systems which can be "poured" (transferred) within and between the systems, which is true for "caloric processes" without work interactions. If conversion of all other energy types to heat is accounted (thermal energy

“generation” from all types of “phlogistons”), i.e., conservation of energy in general, then “extended caloric theory” will be valid in general as stated by Clausius [8]. How ironic, Lavoisier may be right, since this treatise reaffirms that ‘*caloric*’ is a transferred “mass-energy substance” after all.

Most physicists are “fully familiar” with the Einstein mass-energy equivalence and use it when required, but somehow stop short to “fully apply” it for the heat-conduction and mechanical energy transfer through material structures, but refer to both as “energy transfers only” (as if “massless”) and keep “silent” if the commensurate mass is transferred, and have not justified the means (i.e. the underlying, fundamental carriers) by which the latter is achieved, if at all [1]. The physicists and other scientists account for mass-energy equivalence for electro-magnetic radiation (including thermal, e.g., from Sun to Earth), and binding electro-chemical and nuclear energy, but somehow, again, are “silent” (without giving a due justification) about thermal heat-conduction and mechanical work transfer through material structures when energy is transferred without (or beyond) any material particle diffusion.

It is reasoned here that during the heat-conduction and mechanical work-transfer there must be propagation of photons (even if “invisible/unobserved”), from a mass-energy source to a sink system in a manner similar to the thermal radiation (and for the same reason: electron-shell thermal and mechanical motion and interactions), but within material structure (“on-contact” photon diffusive re-emission and propagation, or “internal” thermal radiation) for the heat conduction, and similar, but directionally oriented, orderly-photon propagation, in the direction of forced, bulk motion/displacement (in direction of pushing or twisting from higher to lower stresses or “collective stresses,” i.e., forces for solids) in the case of mechanical work transfer, as vividly observed in *fractoluminescence* and *triboluminescence* phenomena. The photons have been giving us a lot of “signs” (almost “poking” our eyes) about their involvement in thermo-mechanical phenomena, but scientists have been “somehow busy” with studying the more “modern” concepts and overlooked the “old” thermo-mechanical energy phenomena that established the fundamental laws of Thermodynamics and nature.

## **The Nature of Thermal Mass-Energy Transfer**

Two illustrative systems are presented on Figure 1, with a steady-state, mass-energy transfer from a mass-energy source on the left to a sink system on the right. At the lower part of the Figure a steady-state, mass-energy transfer from a gas turbine to an electric generator, via rotating turbine shaft is depicted. The objective here is to reason the fundamental mass-energy carriers during the steady-state mechanical energy transfer through the rotating shaft, to be discussed later. In the upper part of Figure 1, the system is chosen to demonstrate steady-state, mass-energy transfer from a high-temperature heat source (e.g., an infinite thermal reservoir) through a vacuum chamber on the left (i.e., via photonic electromagnetic thermal radiation) to an amorphous and opaque heat-conduction plate (i.e., to avoid phonon and free-electron contribution to heat conduction, to be explained later), to be finally transferred to a low temperature heat sink (an infinite thermal

reservoir) through a vacuum chamber on the right (i.e., via photonic electromagnetic thermal radiation), thus maintaining the steady-state mass-energy transfer. The system is adiabatically insulated on the side to prevent any heat loss to the rest of the surroundings. The objective here is to reason the underlying, fundamental mass-energy carriers during the steady-state heat conduction through the plate.

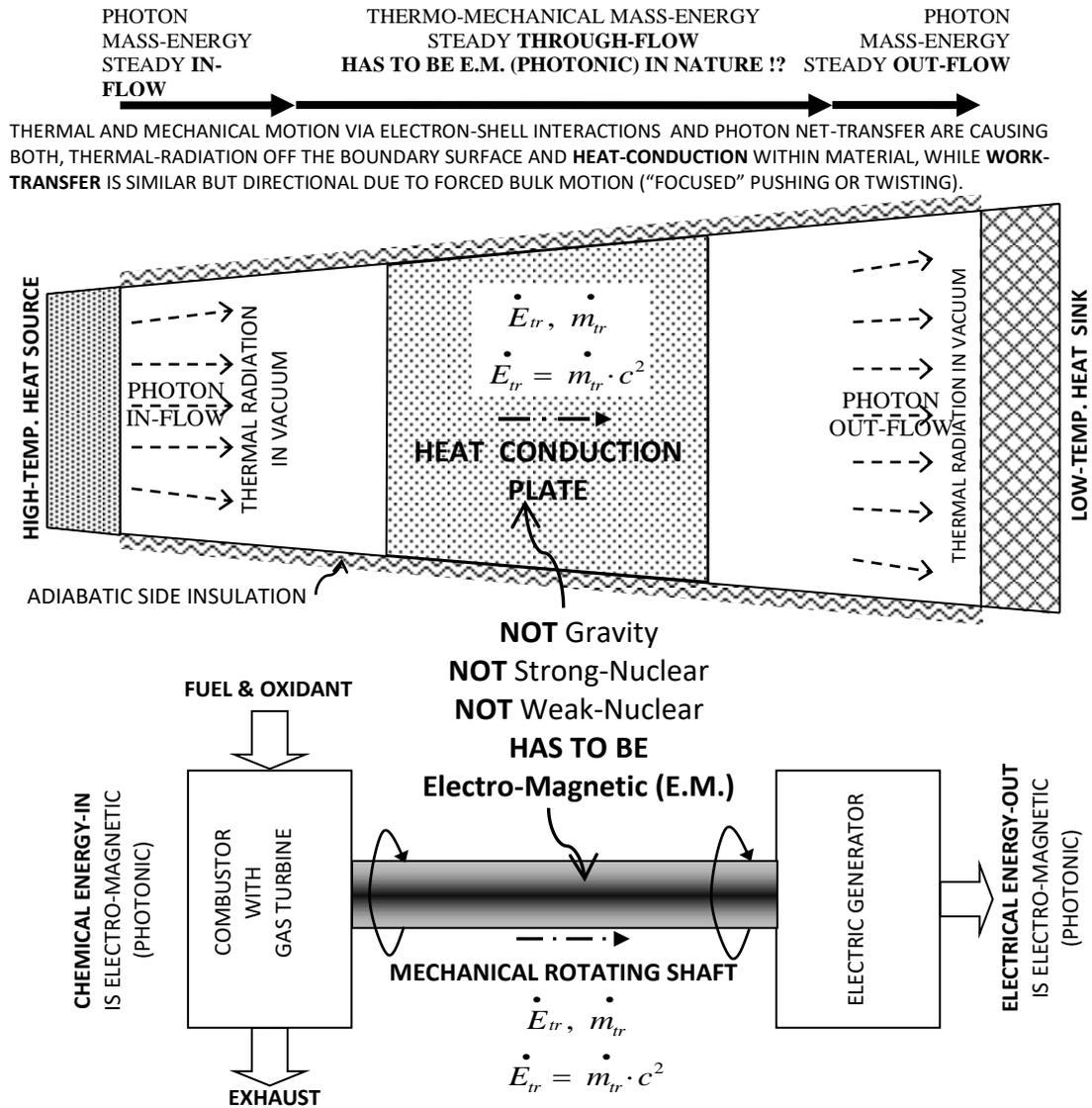
For the steady-state operation of the above process, there will be a constant energy flow, i.e., a constant energy transfer rate,  $\dot{E}_{tr}$ , from the left to the right as depicted on Figure 1. Since the Einstein mass-energy equivalence is universally valid, then there will be a commensurate mass flow (as from the Sun to Earth), i.e., the constant mass transfer or propagation rate,  $\dot{m}_{tr}$ , or more accurately the *mass-energy* propagation rate, i.e.:

$$\dot{E}_{tr} = \dot{Q}_{rad} = \dot{Q}_{plate} \text{ or } \dot{m}_{tr} = \dot{m}_{rad} = \dot{m}_{plate} \quad (1)$$

Where,  $\dot{E}_{tr} = \dot{m}_{tr}c^2$  is the energy rate (or commensurate mass rate,  $\dot{m}_{tr} = \dot{E}_{tr}/c^2$ ) transferred in general;  $\dot{Q}_{rad} = \dot{m}_{rad}c^2$  is thermal-energy rate (or commensurate mass rate,  $\dot{m}_{rad} = \dot{Q}_{rad}/c^2$ ) transferred by thermal radiation (by photons) through vacuum chambers;  $\dot{Q}_{plate} = \dot{m}_{plate}c^2$  is heat-conduction rate (or commensurate net-mass propagation rate,  $\dot{m}_{plate} = \dot{Q}_{plate}/c^2$ , transferred by thermal heat-conduction through the heat-conduction plate, without any material particle *net*-diffusion.

When thermal energy is transferred (known as heat transfer), without material particle net-transfer, in direction of decreasing temperature gradient (known as heat conduction), see Figure 2(a), then more-energized particles (atoms or molecules) at higher temperature ( $T_A$ ) will be interacting (colliding) with neighboring less-energized particles at lower temperature ( $T_R$ ), thus transferring their electron-shell energy by propagating photons (with annihilation and reemission) from one electron shell to another during the particle localized interactions. Depending on material structure, the heat conduction may be enhanced by free-electrons (like in metals) or by “collective” mechanical vibration of solid crystalline structure (like in crystals), both caused by thermal motion of atoms and molecules, the latter known as thermal *phonons* (not elementary particles but quasi-particles). However, the both (thermal free-electrons and thermal phonons) are due to electromagnetic photon “on-contact propagation” during atomic electron shell or free electron thermal interactions, resulting in photon net-propagation as underlying fundamental carriers of thermal energy transfer due to temperature gradient.

During any heat transfer process there must be a net-propagation of photons through a boundary (in addition to free electrons or other material particle diffusion within, if any, which are only carriers of electromagnetic photons) and the equivalent mass will be transferred ( $m_{tr}=E_{tr}/c^2$ ) from one material system to another (regardless of the amount), thus in the process, effectively propagating photon electro-magnetic energy and inertial mass (total relativistic mass), in direction of decreasing temperature (opposite direction of the temperature gradient), from a mass-energy source to a sink system.

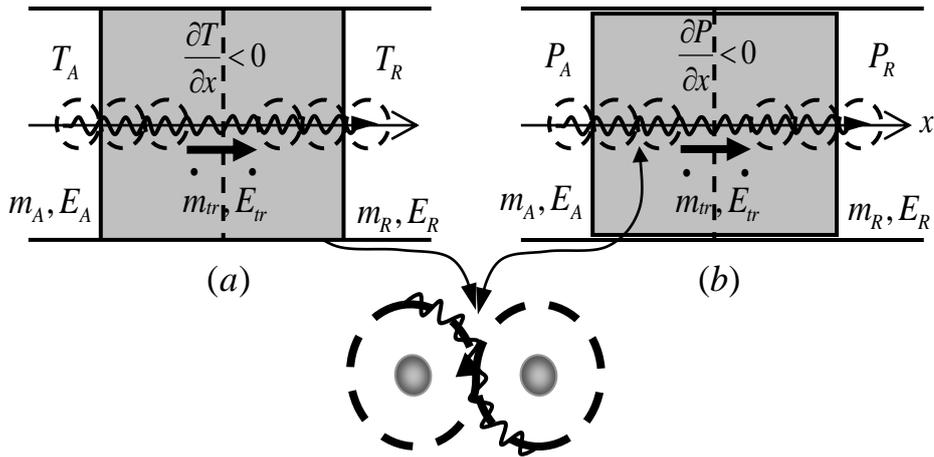


**FIG. 1. Electromagnetic nature of thermo-mechanical mass-energy transfer due to photon diffusive re-emission and propagation:** Based on atomic electron-shell interactions and the Einstein mass-energy equivalence, during “believed-massless” heat conduction or mechanical work transfer there has to be electromagnetic, photonic mass-energy propagation through involved material structures from a mass-energy source to a sink system. Steady-state, mass-energy transfer is depicted through heat conduction plate (above) and rotating shaft (below). Energy transfer (i.e., Einstein’s mass-energy equivalency transfer,  $\dot{E}_{tr} = \dot{m}_{tr}c^2$ ) has to be electromagnetic by photon transfer, either as photon electromagnetic waves on-long range through space/vacuum ( $\dot{Q}_{rad} = \dot{m}_{rad}c^2$ ), or photon “on-contact” transfer (annihilation/re-emission) within material structures, e.g., through heat conduction plate (above) and turbine shaft work (below), since it is neither gravitational nor nuclear (strong or weak) interaction. Otherwise, Einstein’s mass-energy equivalency and the fundamental force/interactions will be violated. Thermal conduction is due to chaotic thermal electron-shell collisions and may be enhanced by free-electrons or crystal-lattice structure vibration (phonons), both phenomena due to underlying photon propagation (similar to electro-chemical phenomena). The mechanical work transfer is due to electron-shell directional pushing/twisting as the most efficient (“focused”) energy transfer (i.e., mechanical super conductor). If it is fully investigated and understood, it has potential for development of hybrid synthetic-materials with superior thermal conductivity like diamond and others, for critical and new applications.

This may be experimentally confirmed in nuclear reaction processes: If a nuclear reaction is carried out in a “sealed” opaque box, then energy and/or rest mass will be conserved within the box if energy is not transferred out. However, after the energy is transferred through the opaque wall (by heat conduction) to the surroundings and the sealed box is cooled to its initial temperature, then its inherited rest mass is reduced and all energy transferred will increase the surroundings’ rest mass by the same amount. Therefore, the rest-mass is transferred via heat conduction through the wall. The energy carriers have to be the electromagnetic photons’ propagation from atomic-to-atomic electron-shell throughout the opaque wall of the box, and then to the surroundings. This experimentally “proves” that “massless” photons transfer the invariant body-rest-mass through a wall from one body to another during what is commonly regarded as “massless” heat conduction (similarly as is accomplished by photons from the Sun to Earth). Therefore, all thermal conduction energy transfers are “*thermo-luminescence-kind*” (visible or invisible), carried by the photon diffusion and re-emission, i.e., “on-contact” mass-energy propagation, which may be considered as an “internal” thermal radiation. The ordinary thermal radiation off a body boundary surface through a transparent-to-radiation space (like a vacuum) is due to the same cause, i.e., generated by thermal interactions of material structure, as is the case for thermal conduction within a material structure described above, which also justifies the existence of thermal equilibrium (establishment of equal temperature) between heat conduction and thermal electromagnetic radiation, regardless if the bodies are in contact or far away.

### **The Nature of Mechanical Mass-Energy Transfer**

Similar, but more elusive, is happening during mechanical energy transfer (known as work transfer), see Figure 1 (bottom part), Figure 2(b), and Figure 3. On Figure 1 (bottom part) a rotating shaft from a gas-turbine to electric-generator in a typical power-plant is presented. Megawatts of energy rate are “flowing” thorough the shaft’s cross-section, and then after conversion in an electrical-generator, as electrical energy through the powerlines, in a steady-state operation. The question arises as to how those megawatts of the energy rate are steadily flowing through the rotating shaft’s cross-section and what are underlying fundamental carriers, see Figure 3? To this author’s knowledge, there is no answer to the latter important question in the open literature. It is reasoned here, based on existing and well-established knowledge, and thus tacitly proved, that it has to be the “ordered” flow, virtually frictionless streaming, of electromagnetic photons through the electron shells of the stressed-structure, forcefully displacing “stealth energy” under load as a virtual mechanical-superconductor. After all it is the same (amount of) energy carried later by charged electrons in power lines. Without any charge-potentials and dissipative effects to be measured, such super-conductive mechanical-energy flow in the rotating shaft is illusive until somehow disrupted (e.g., in a structural break-down, with conversion of such “stealth” energy to overwhelming and dangerous heat and sound), or it is manifested later after conversion to electrical energy.



**Fig. 2. Thermo-mechanical mass-energy transfer by photon “on-contact propagation.”** (a) Heat transfer by photon diffusive annihilation and reemission, in direction of decreasing temperature (opposite direction of temperature gradient), and (b) work transfer by photon propagation, in direction of decreasing stress (opposite direction of stress gradient); from Acting-source (A) to Reacting-resisting-sink (R) systems.

## ... Mechanical Work Transfer ...

... Again, during any work transfer process **there must be a net-propagation of photons** (in addition to free electrons or other material particle motion, if any) and the **equivalent mass will be transferred** ( $m_{tr} = E_{tr}/c^2$ ) from one material system to another, thus in the process effectively propagating the photon ‘inertial’ mass (total relativistic mass), in direction of decreasing stresses for fluids, or in direction of decreasing “collective stresses” (i.e. forces) for solids, even if it is too small to be measured.

**What are (???) the “energy carriers” for huge steady-state energy transfer (in 100’s of MJ/s) thru rotating shaft, from power-plant turbine to electric generator?**

**How come ???**

**Fig. 3. Mechanical mass-energy transfer by photon “on-contact, streaming propagation.”** Work transfer in direction of decreasing stress (opposite direction of stress gradient); from Acting-source (A) to Reacting-resisting-sink (R) system. Since it is not gravitational nor nuclear interaction, it has to be the “ordered” flow, virtually frictionless, on-contact streaming, of electromagnetic photons through the electron shells of the stressed-structure, forcefully displacing “stealth energy” under load as a virtual mechanical-superconductor.

During work transfer, See Figures 2(b) & 3, from one *acting* body,  $A$  (twisting or pushing in a certain direction) to another *reacting/resisting* body,  $R$ ; i.e., the particles (atoms and/or molecules via electron-shells) with more momentum at the contact interface (i.e. higher acting stresses,  $P_A$ ) will be pushing the neighboring particles with less momentum (i.e. lower resisting stresses,  $P_R$ ), thus transferring their electron-shell momentum and energy in certain forced-displacement direction by photon propagation from one electron shell to another during the particle localized interactions and displacement in a certain direction, in addition to net-thermal energy transfer if any (the latter depending on temperature gradient). Again, during any mechanical work transfer process there must be a net-propagation of electromagnetic photons (in addition to free electrons or other material particle motion, if any) and the equivalent mass will be transferred ( $m_{tr}=E_{tr}/c^2$ ) from one material system to another, thus in the process effectively propagating the photon inertial mass (total relativistic mass), in direction of decreasing stresses for fluids, or in direction of decreasing “collective stresses” (i.e. forces) for solids, even if it is too small to be measured.

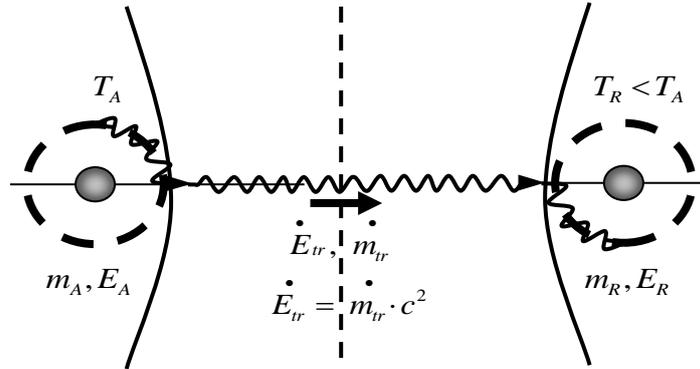
For ideal elastic or perfectly rigid solid, having a steady-state forced motion and transferring mechanical energy without its acceleration (like a stationary-rotating shaft in lower part on Figures 1-3), the mechanical energy and commensurate mass-energy propagation of electromagnetic photons will not accumulate nor accelerate the body but only passing through the body structure without any stress/force gradient through such intermediary, ideal solid body (may be considered as *mechanical superconductor*). However the stress/force gradient will exist at the energy source (where mechanical energy is generated), through imperfect intermediary body, and energy sink (where mechanical energy is dissipated), thus effectively propagating photon mass-energy (with relevant photon conversions and transformations, annihilation and reemission, through material structure, like frequency shifting and others if appropriate, from an energy source to the sink, by accelerating material structure of the mass-energy sink system (e.g., a resisting frictional load) on the expense of decelerating material structure of an acting source system. As reasoned above, during mechanical work transfer, the photon *mass-energy* transfer is always encountered, but rarely observed since it is occurring orderly without dissipation and locally within the material structure (often within virtually infinitesimal distance), except in certain *fractoluminescence* and *triboluminescence* processes, facilitated by material structure “visible” mechanical separation, and especially if conducted in a vacuum, like the “*peeling sticky-tape X-ray phenomenon* [9].” Therefore, all mechanical energy transfers are “*mecha-luminescence-kind*” (visible or invisible), carried by the photon “on-contact” mass-energy propagation.

### **Photon Mass-Energy Transfer**

Questions arise about the nature of a photon and definition of its “rest-mass *transfer*” [10]: Since the photon is a massless, *mass-energy* carrier, while in motion with the speed of light. However, when it is captured

(absorbed) within a material particle or a body at rest, i.e. when its energy is bound (“foiled”) within a body at rest (called here “body-rested” photon *mass-energy*), then the corresponding inertial mass increase of the material particle, could be defined as a photon inertial mass-energy (or *body-rested* mass-energy with regard to the body reference frame), also known as its relativistic mass, that is:

$$m_{ph} = E_{ph}/c^2 = (h \cdot \nu)/c^2 \quad (2)$$



**Fig. 4. Photon mass-energy transfer.** Energy transfer must be accompanied by photon transfer either as electromagnetic waves on-long range through space, or “on-contact propagation” within material structures, or as diffusion or motion of material structures, accompanied with photon mass-energy exchange, thus unifying the mass and energy concepts and a notion of photon rest-mass *transfer*.

The body-rested photon mass-energy ( $m_{ph}$  or equivalently  $E_{ph}$ ), when captured (“foiled”) within a material structure, for example, by an electron [11], it increases the mass-energy of the electron shell (known as higher energy level), but also increases the total inertia of the atom or particle, i.e., increases its inertial mass, and invariant body-rest-mass [12, 13]; and inversely when a material structure releases or emits photons. This concept was used by Einstein to derive its famous mass-energy equivalence correlation (Eq. 2). Furthermore, energy and mass (mass-energy holistic equivalence) may be transferred, not only by direct mass diffusion, but also and ultimately by photons’ electromagnetic radiation, see Figure 4. The latter will turn out to also be indirect mass diffusion, justifying the notion of “massless” photons’ rest-mass *transfer* [10].

Elementary particles and their interactions (always new being discovered) have been, still are, and may always be the principal mysteries in nature. The electrons and nucleons “mysteriously” absorb (annihilate) and emit the photons, which are not conserved (although their total mass-energy is), but somehow “mysteriously” recreated with different frequencies and thus different mass-energies, posing several open questions, which will be subject of another manuscript in-progress [11].

## Conclusion

This treatise may contribute to further generalization of electro-magnetic phenomena, including heat-conduction and mechanical work transfer, and thus “fill the remaining gap” since all other phenomena, excluding gravitational and nuclear interactions, are due to the electromagnetic force interactions, namely all electro-chemical and thermo-mechanical phenomena, the latter as reasoned here. Based on simple, phenomenological, cause-and-effect conservation concepts and the mass-energy equivalence law, it is deduced here that conduction heat transfer and mechanical work transfer within material systems are photonic, i.e., electromagnetic in nature, thus resolving deficiency of the classical Fourier heat conduction law, the latter imply infinite speed of heat space-propagation (not to be confused with finite heat flux rates); however, the heat propagation is limited by the photon ultimate propagation speed of light.

The hypotheses posed here, some thought-provoking, have additional objective to initiate further discussion and constructive criticism, related to the conclusions deduced and open questions posed in this manuscript. If these phenomena are further investigated and understood, it has potential for development of hybrid, synthetic materials with superior thermal conductivity like diamond and many others, for unprecedented applications in existing critical areas as well as emerging and novel applications.

## References (and Endnotes)

- [1] NOTE that many experts (all I have personally communicated with) “think” that thermal or mechanical energy transfer is massless (or “really have never thought about it”), regardless of “otherwise” implication of Einstein’s mass-energy equivalence. They particularly “balk” about mechanical energy transfer since the solids are virtually mechanical-superconductors (perfect ridged and perfect elastic bodies are) and energy transfer-through is virtually “unnoticeable,” as opposed to dissipative processes. These experts know “how” the heat and work are transferred without any material particle net-diffusion (by exchange of energy and momentum, respectively, between the interacting atoms and molecules), but have “never thought” of “what if anything” is transferred/propagated across a boundary from an energy source to energy sink; they “simply” call it by name, heat or work transfer. I am not aware of any reference to the above effect.
- [2] Einstein, A., *Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?* (1905). English translation: “Does the inertia of a body depends upon its energy-content?” [http://www.fourmilab.ch/etexts/einstein/E\\_mc2/www/](http://www.fourmilab.ch/etexts/einstein/E_mc2/www/)
- [3] Rubin, M.B., “Hyperbolic heat conduction and the second law,” *Int. J. Eng. Sci.* **30** (11), 1665 (1992). [doi:10.1016/0020-7225\(92\)90134-3](https://doi.org/10.1016/0020-7225(92)90134-3).
- [4] Ali, Y.M., Zhang, L.C., “Relativistic heat conduction,” *Int. J. Heat Mass Trans.* **48** (12), 2397 (2005). [doi:10.1016/j.ijheatmasstransfer.2005.02.003](https://doi.org/10.1016/j.ijheatmasstransfer.2005.02.003)
- [5] Guo, Z.Y., “Motion and transfer of thermal mass-Thermal mass and thermon gas,” *Journal of Engineering Thermophysics* **27**(4), 631 (2006).
- [6] NOTE that all interactions in nature are physical (mass-energy interactions) and based on simple cause-and-effect conservation laws, thus deterministic and should be without any exceptional phenomena.

Due to diversity and complexity of large systems, we would never be able to observe deterministic phenomena with full details, but have to use holistic and probabilistic approaches for observation; therefore, our observation methodology is holistic and probabilistic, but phenomena have to be deterministic, not miraculous nor probabilistic.

- [7] [Lavoisier, A., \*Réflexions sur le phlogistique\* \(1783\) <http://www.lavoisier.cnrs.fr/>](http://www.lavoisier.cnrs.fr/)
- [8] Clausius, R. *The Mechanical Theory of Heat* (translated by W.R. Browne), McMillan and Co., London 1879.  
<http://www.archive.org/details/londonedinburghd02lond>
- [9] Camara, C.G., Escobar, J.V., Hird, J.R., Putterman, S.J., “Correlation between nanosecond X-ray flashes and stick–slip friction in peeling tape,” *Nature* **455**, 1089 (2008).  
<http://www.nature.com/nature/journal/v455/n7216/full/nature07378.html>
- [10] NOTE that photon “rest-mass *transfer*” from a body to another body (like from the Sun to Earth), and *body-rest* mass are different from the photon “rest mass,” the latter being zero in a reference frame moving with the photon (with its speed of light). I consider photon total-relativistic mass ( $m_{ph}=E_{ph}/c^2$ ) to be “real” inertial mass when photon *mass-energy* is confined (*body-rested*) within material particle or body. After all, Einstein’s well-known  $mc^2$  equation could be derived using the off-body photon emission which results in the corresponding body-mass deficiency, thus demonstrating the photon *body-rest-mass transfer*. But modern physicists prefer to have photon annihilated/created, and in that “miraculous processes” photon total-relativistic mass is “somehow” transformed to *body-rest* mass and vice versa. Note that for a photon rest mass to be “really” zero the reference system should have the same motion as the photon, meaning a wavy motion with that photon’s frequency and propagation speed of light!
- [11] NOTE that observation or measurement of electron structure, if any, is beyond today’s metrology, i.e. there is no proof that an electron, or any other elementary massive particle, has or does not have a structure. The concept of elementary particle is intrinsically problematic (just because we cannot observe or reason a structure which exhibits certain phenomena, does not mean it does not exist). Past and recent history proved us to be wrong every time. Particularly problematic is the current theory which requires elementary particle annihilation/creation (“miraculous creationism”) while using conservation laws. At the very least (in phenomenological view) the elementary particles should be conserved and be the building structure for other particles and systems.
- [12] NOTE that mass is among the most fundamental concepts in physics, directly (inter)related with gravity and inertia, energy, space and time. Often inconsistent and mixed terminology is source of additional confusion and disagreements [13].
- [13] Okun L.B., “The Concept of Mass,” *Physics Today* **42** (6): 31 (1989).