Illusions of Elastic Collisions in the Sciences: An Essay

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Abstract—Employing the concept of elastic collisions rather than the reality of inelastic collisions simplifies much of the theoretical sciences. The consequences are completely ignored/unrealized by the majority, hence must be addressed. At the crux of the problem is arguably the illusion of elastic collisions in kinetic theory, but this extends to other realms of physics including statistical theory, Lagrangian mechanics and the Navier-Stokes equations.

Index Terms—Avogadro's Hypothesis, Ideal Gas Law, Inelastic Collisions, Kinetic Theory, Langrangian Mechanics, Navier-Stokes Equation.

I. INTRODUCTION

This author has previously provided an improved kinetic theory [1,2]. A theory that is a superior match to known/accepted empirical findings for gas's heat capacities [3,4,5,6,7,8]. A theory, which realizes that a gas molecule has its energetics imposed upon it by the surrounding wall molecules, i.e. a gas molecule has both its rotational and translational energies imposed upon it by collisions with the cohesively bound more-massive wall molecules. A theory where a polyatomic gas's vibrational energy is obtained by the adsorption and re-radiation of surrounding blackbody radiation.

Importantly, it’s a theory where, when in thermal equilibrium:

1) Wall molecules adsorb as much blackbody/thermal radiation as they radiate.
2) Polyatomic gas molecules adsorb as much blackbody/thermal radiation as they radiate.
3) Inelastic intermolecular collisions produce thermal radiation and this becomes part of the system's thermal/blackbody radiation.
4) A gas's vibrational energy is exchanged with the wall molecule's vibrational energy with the net energy exchange being zero.
5) The gas molecules receive an imposed mean amount of given kinetic energy (translational plus rotational) from the more massive vibrating wall molecules during their inelastic collisions.

Note in the above the term thermal/blackbody radiation is used because at this point, we do not know if the radiation, which is a result of inelastic intermolecular collisions is blackbody or not.

Interestingly, numerous explanations for equipartition's failure in describing heat capacities have been presented [3]-[13]. Importantly, this author's kinetic theory does not rely upon any of the exceptions that plague the traditionally accepted equipartition based kinetic theory. For example, the traditional assertion that a monatomic gas has no rotational energy because the molecule's radius is too small is incorrect. The reality is that a small radius molecule can have the same rotational energy as a larger molecule; it is just that the smaller molecule's rotational velocity must be significantly greater than that of the larger molecule.

Furthermore, it now accepted that electron-photon collisions are inelastic [15]-[18], so why would one even consider that the vast majority of intermolecular collisions are anything but inelastic? Certainly, the understanding that intermolecular collisions are inelastic fits well with this author's kinetic theory.

Of interest is the fact that inelastic intermolecular collisions also help explain our witnessed pressure-temperature relations (P-T relations), which remains poorly explained by traditionally accepted thermodynamics [19]. Specifically, as the pressure increases, then so to does the number and/or magnitude of intermolecular collisions increase; hence the greater the thermal energy that is produced. Since, the witnessed blackbody/thermal radiation will be greater, then in turn so to will be the measured temperature. Of course, this sentiment understands that higher temperatures tend to create greater mean molecular velocities, and/or intramolecular vibrations.

Equally, inelastic collisions help to explain viscous dissipation. Herein, gases that are forced through small orifices will tend to heat up.

Moreover, blackbody/thermal radiation from inelastic collisions now becomes part of a system's temperature. Of course, since the energy of blackbody/thermal radiation is generally very small when compared to a system's molecule's kinematics, one now begins to understand why the traditional assertion that temperature only involves molecular kinematics, still provides good approximations for what has been witnessed.

Obviously, the fact that the massive wall molecules impose their kinetic energies onto the smaller gas molecules helps explain why the “illusion of elastic collisions” existed, hence leading to the traditional assertions. The other part being that the enclosed system's surrounding walls adsorb and re-radiate any heat/thermal energy that results from any inelastic collisions within that system, i.e. becomes part of that system’s temperature.

II. IMPLICATIONS TO THE SCIENCES

The realization that intermolecular collisions are inelastic has broad consequences to many realms of the sciences. First of all, the statistical ensembles used to define concepts like entropy are based upon elastic collisions. Interestingly, this author has questioned whether or not entropy based statistical thermodynamics is necessary. Specifically, it is this author's belief that such a theory is based upon a powerful mathematical language that approximates but does not fully explain what is witnessed. For example, many

Published on January 23, 2020.

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DOI: http://dx.doi.org/10.24018/ejers.2020.5.1.1693
known inefficiencies/irreversibility can be explained in terms of lost work rather than the second law in its currently accepted form, i.e. lost work ($PdV$) is given clarity as the work done by expanding systems onto the surrounding atmosphere [19]-[21].

However, there are other issues that should be addressed. Consider the Lagrangian mechanics and/or Navier-Stokes energy equations. Both equations start off being written in terms of equating forces to momentum changes. They are then often transformed into energy change. Unwittingly, they both start out based upon conservation of momentum, and then are often transformed into conservation of energy-based equations. In other words, their fundamentals were developed around the Utopian illusions of elastic collisions [22]. The reality of inelastic collisions will limit and/or challenge their acceptance.

The idea of conservation of a system's energy is often extended via the concept of a system's potential plus kinetic energy being conserved. Herein the notion of energy conservation is limited to systems that do not readily lose thermal energy/heat into its surroundings. Certainly a system of gas surrounded by walls that adsorbs and re-radiates thermal/blackbody radiation back into the system, i.e. many experimental systems, can be approximated as a system wherein energy is conserved. Note again for emphasis; any collision induced thermal/blackbody radiation now becomes part of the system’s temperature.

### III. AVOGADRO’S HYPOTHESIS

Traditional equipartition-based kinetic theory implies that at a given temperature all gases possess the same mean translational energy. This seemingly verified Amedeo Avogadro's (1776-1856) hypothesis, which states, “Equal volumes of different gases measured at the same temperature and pressure contain an equal number of molecules” (circa 1811). An implication being that when comparing two gases in thermal equilibrium they will both have the same mean translational energy, per unit area.

To further exasperate the situation, equal pressure implies that the gases also possess the same mean momentum per unit volume i.e. mechanical equilibrium, or, if you prefer, the same pressure. This brings us to a conveniently forgotten concern of Avogadro’s hypothesis that its conservation of energy guise seemingly confounds the conservation of momentum. Specifically, in order for gases of differing mass to have both the same kinetic energy and mean momentum requires specified mathematics that push the plausibility of universal logic to its limits.

It must be emphasized that the illusion of elastic collisions in kinetic theory is limited to sufficiently dilute gases wherein gas-wall molecule collisions dominate the system's dynamics. For the case of a dense gas wherein gas-gas molecule collisions begin to dominate; herein it is accepted that both the ideal gas law and Avogadro’s hypothesis falter. When dealing with high-density gases, i.e. stellar interiors, one has to use the polytropic equation in order to relate volume to pressure.

Although not fully accepted/understood, the need for using the polytropic equation, rather than the ideal gas is actually based upon inelastic inter-gaseous molecular collisions. Consider a high density gas in an experimental system: Herein gas-gas molecule collisions dominate over gas-wall molecule collisions, hence the wall molecules no longer impose their kinetic energy onto the majority of contained gases. Therefore, the gases still adhere to conservation of momentum but no longer have that illusion of elastic collisions. Note: If the neighboring gas molecules adsorb and/or contain any inelastic collision induced radiation, then the illusion of elastic collisions may exist.

It now becomes sensible to realize that both the ideal gas law and Avogadro's hypothesis are actually limited to sufficiently dilute systems that give the illusion of elastic collisions. E.g. systems most often used in experiments to analyze kinetic theory, as well as both the ideal gas law and Avogadro's hypothesis [1,2].

### IV. NAVIER-STOKES EQUATION

It should be pointed out that in its fundamental forms the Navier-Stokes equations are limited to incompressible fluids. This alone, limits it to more ideal than realistic fluid flows, i.e. one certainly can approximate certain liquids such as pure water as incompressible, but many liquids that contain dissolved gases which can be components within the liquid that are compressible.

Ignoring the issues of compressibility, Navier-Stokes relations give reasonable approximations for simple systems wherein the illusion of elastic collisions exists. This primarily applies to systems wherein any heat generated during inelastic collisions is readily adsorbed by surrounding molecules. Again such generated heat maybe re-radiated back into the system, or remain as part of the system's molecular vibrations.

For example, in most laminar flowing bodies of water; the neighboring liquid molecules would readily adsorb generated heat. Hence the heat will fundamentally remain part of the system. However, there is also the following question; would cohesively bound liquid molecules actually physically collide in a manner that is similar to unbound gas molecules? The answer is probably not. No matter the answer, one can readily envision that the concept of elastic collisions may provide a good approximation that simplifies any system analysis.

Another example might be a contained flow of gas. Certainly, in many such systems either the neighboring gas molecules and/or the system's walls would have the capacity to contain any inelastic collision-generated heat/thermal energy. Again, the conceptualization of elastic collisions simplifies the analysis hence allowing the use of Navier-Stokes relations to approximate what is witnessed.

However, what happens in more complex systems e.g. the case of turbulence around an airplane wing? Such turbulence represents a chaotic system. Certainly, from a thermal energy perspective, many chaotic systems will venture far from any idealistic systems that can be approximated via solutions based upon elastic collisions.

Moreover, the varieties of thermal energy created by turbulent/chaotic inelastic collisions may mean that neither the Lagrangian mechanics, nor the various forms of the Navier-Stokes equations could possibly retain their ability to approximate what is witnessed. Furthermore, around an airplane wing there is little to no system containment for any
collision-generated heat. Moreover, the mean free path for thermal photons would be too large for one to apply any notion of thermal containment by surrounding atmospheric molecules. And without thermal containment, one cannot approximate what is witnessed by some system that adheres to the conservation of energy.

Next, consider turbulent flow of a gas within a pipe. Any notion of heat generated by differential pressures, e.g. chaotic inelastic collisions, being homogeneous would generally be lost. The loss of homogeneity may even apply if the system is capable of containing such heat. So, this brings up another requirement for simplification, that being, the system remains reasonably homogeneous. Herein the term “reasonably homogeneous” does not necessitate that the system be absolutely homogeneous throughout, but rather that it can be sub-divided into sufficiently small homogeneous volumes where only infinitesimally small variations exist between the neighboring volumes. Of course, the greater the said variations, the less accurate the analysis will be.

It is of interest that the Clay Mathematics Institute has funded a significant award for explaining why the Navier-Stokes equations fail in turbulent systems. Understanding their failure is not complicated, however arriving at a set of equations that define such chaotic systems may verge on the impossible. Specifically, mathematically classifying events that are absolutely unique, in that no two events will ever be similar, could become an adventure in futility.

V. TRUE ELASTIC COLLISIONS

Elastic collisions are readily witnessed. For example, in the game of billiards; when the cue ball hits another ball dead on, the cue ball can pass all of its momentum and kinetic energy onto the other ball. In other words, the result is the cue ball has no velocity after the collision, while the other ball has the same velocity that the cue ball had before impact.

Another interesting device that clearly demonstrates elastic collisions is Newton's Cradle. Here several similar steel balls on equal length strings are strung in series. One lifts the first ball and elastic collisions are passed from ball to ball, ending in the last ball swinging like a pendulum, only to return and reverse the process of elastic collisions.

What is easily forgotten in these two examples is that the elastic collision requires that the balls be of equal mass and that the collision occurs dead-on, i.e. through the ball's center mass, along the direction of motion. If one alters the angle of the collision or performs the experiment with balls of differing masses, then the collision is no longer elastic.

The above does pose the question as to why? This should become a fundamental question to answer

VI. CONCLUSION

The illusion of elastic collisions has allowed for a simplification of the analysis of many systems and/or events. However, it has also unwittingly plagued the scientific community.

The reality is that the vast majority of collisions are inelastic. This applies to most collisions at both the macro and micro scale. It is herein understood that too many aspects of physics have been wrongly taught with elastic collisions as a major part of their construct.

The above includes but is not limited to:
1) Equipartition-based kinetic theory
2) Many statistical ensembles
3) Navier-Stokes equations
4) Lagrangian mechanics
5) Avogadro's hypothesis
6) Ideal gas law

We accept that the conceptualization of elastic collisions generally simplifies theory in much the same manner as treating a flowing fluid as incompressible, as it’s often done when applying the Navier-Stokes equations at their fundamental level. But there are inherent weaknesses to such ideologies. For example, Avogadro's hypothesis and its accompanying ideal gas law have their place in general instruction, but they are limited to ideal systems i.e. closed experimental systems where the gases are sufficiently dilute.

Systems and/or events where the blackbody/thermal energy/radiation due to inelastic collisions are not contained within the system cannot be readily approximated by a theoretical system wherein energy is conserved. Chaotic systems/event such as turbulence are prime examples of where traditional analysis i.e. Navier-Stokes equation, fails all due to a lack of understanding.

Understanding that the vast majority of collisions are inelastic will certainly alter how the sciences deal with many realistic systems i.e. systems that cannot be roughly approximated by the idealism of elastic collisions.

And the question as to why elastic collisions are so rare may now begin to befuddle the sciences.

ACKNOWLEDGMENT

I would like to thank Lloyd and Gail Mayhew for their assistance in putting this paper together. A further thanks goes out to Dr. Dennis Allen for a paper that he sent me that discussed reference [22 (pg 76)], which helped initialize the ideas presented herein.

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DOI: http://dx.doi.org/10.24018/ejers.2020.5.1.1693