MOLECULAR IMPULSES

The System of Study: Let us postulate a system of study consisting of a ***p***-population of gaseous atmospheric molecules in random motion in proximity space. The surface of interest is a sphere having a hard surface producing perfectly elastic collisions. This sphere is surrounded by the ***p***-population.

Definition of Impulse: An impulse is a brief expression of force. Its duration is often measured in nanoseconds or less. Moreover, the magnitude of this impulse force usually varies throughout its duration. Molecular impulse may be thought of as the change in molecular momentum over time. Impulse is force, is measured in ***newtons,*** and has the dimensions MLT^{-2}.

$$\varphi_i = \Delta \underset{\leftrightarrow}{\rho} = \frac{d\underset{\leftrightarrow}{\rho}_i}{dt} = \int_{initial\ contact}^{final\ contact} \underset{\leftrightarrow}{\rho}_i \qquad \text{IMP01}$$

Here, φ_i is the molecular impulse in newtons and $\underset{\leftrightarrow}{\rho}_i$ is the molecular impulse momentum in kilogram-meters per second.

Impulse and Momenta: A molecule in motion bears momentum. When that motion terminates in an impact with our surface of interest, that momentum becomes impulse. Momenta that do not become impulses are not the subject of this essay.

When a molecule impacts upon a surface of interest, its momentum changes. This is true whether that surface is the surface of another molecule or a surface of some other kind. It is also true whether the impacting molecule rebounds from, adheres to, or is absorbed by that surface. The momentum changes in every case.

Let us define the pre-impact momentum as:

$$\underset{\leftrightarrow}{\rho}_i = m_i v_i \qquad \text{IMP02}$$

We go on to define the post-impact momentum as:

$$\underset{\leftrightarrow}{\rho}_{-i} = m_{-i} v_{-i} \qquad \text{IMP03}$$

The change in momentum is the impulse, as is shown in IMP01. Equation IMP01 is the universal impulse equation. It is valid for ideal gases and for real gases, in the laboratory and in the free atmosphere, under conditions of equilibrium and under conditions of non-equilibrium. It is valid in still air and in moving air. It is even valid on moving objects in moving air.

Impulses in Ideal Gases: In classical mechanics, the impulse received by the surface during an elastic collision will be,

$$\varphi_i = \Delta\underset{\rightarrow}{\rho} / \Delta t = 2m_i v_i \qquad \text{IMP04}$$

Here, $\Delta\underset{\rightarrow}{\rho} / \Delta t$ is the change in momentum over time and has the dimensions of force. The parameter v_i is the molecule's individual impulse speed toward and normal to the surface.

The impulse received by the molecule will be,

$$\varphi_{-i} = \Delta\underset{\leftrightarrow}{\rho}_{-i} / \Delta t = 2m_i v_{-i} \qquad \text{IMP05}$$

Here, nothing has changed except the direction of molecular movement. The minus signs in the subscripts indicate that the molecule is now moving away from the surface of interest. They have nothing to do with the magnitude of the parameter.

These two impulses created during the time of impact will (in an ideal gas and in classical mechanics) be equal in magnitude and opposite in direction. They therefore cancel out mathematically, and the magnitude of the total system momentum before the collision is the same as the magnitude of the total system momentum after the collision.

Thus, in ideal gases:

$$\bar{\varphi}_i = 2\bar{m}_i \bar{v}_i \qquad \text{IMP06}$$

Constraints in Real Gases: During a molecular collision, for Equation IMP06 to be valid, certain constraints must be observed. These include:

$\bar{f}_i = \bar{f}_{-i}$ The number of rebounds must equal the number of impacts. In real gases, this is not always the case. Obviously, it is not the case when either evaporation or condensation is occurring. In addition, living things sometimes absorb more molecules than they emit and sometimes emit more than they absorb. Inanimate surfaces often absorb and emit gas molecules as chemical and electromagnetic processes occur.

$\bar{m}_i = \bar{m}_{-i}$ The mean molecular mass must be the same both before and after impact. Again, this is not always the case with real gases—especially water vapor. Both net condensation and net vaporization change the mean molecular mass of the atmospheric system where they are taking place. Moreover, during a molecular collision, ionization phenomena may occur, and the colliding molecule may gain or lose one or more electrons. This, or course, changes the molecular mass. In addition, polymer molecules may gain or lose segments; and monomers become dimers and dimers disassociate into monomers. Ozone degrades into oxygen and oxygen associates into ozone. Finally, atmospheric chemistry takes place with some abundance: oxidation, reduction, nitrification, and so on all take place at one time or another. Only the noble gases are immune from chemical activity.

$\bar{v}_i = \bar{v}_{-i}$ The mean molecular impulse speed must be the same both before and after impact. Again, this is not always the case with real gases. The most common exception is the simple process of heat conduction. Hot molecules impacting upon a cold surface lose kinetic energy to that surface; and come away with reduced speeds. Just the opposite happens with cold air and hot surfaces.

Finally, there may be an exchange of kinetic energy between the internal energies of the molecules (rotational, vibrational, and librational energies) and the external energies of translation. This does not happen with every collision, but the law of equipartition of energy requires that it must happen occasionally.

Significance of Molecular Impulses: It is these molecular impulses that are transferred to the surface of a manometer or barometer or thermometer or any other contact-type sensor. Sensing instruments that function by exposing the sensing surface to the molecules of the atmosphere receive and measure molecular impulses and only molecular impulses.

A barometer or a manometer measures the transfer of molecular impulses and translates these impulses by design into readings of pressure. An anemometer measures the transfer of molecular impulses and translates these impulses by design into readings of wind velocity. A thermometer measures the transfer of molecular impulses and their attendant kinetic energies and translates these impulses by design into readings of temperature.

All of these devices sense molecular impulses and only molecular impulses. This concept will be developed more fully in the sections on the nature of gas pressures and the nature of gas temperatures.

Molecular Impulses in Moving Air: When the wind blows, the values of many atmospheric parameters change significantly. These changes will be functions of the wind speed and the wind direction relative to the surface of interest. Phenomena related to fluid flows are discussed in advanced papers in this collection.

Still Air Parameters: The essay Still Air Parameters gives the following values for molecular impulses in still air with no net evaporation or condensation. The system temperature is 25° C, and the system pressure is 1,000 hectopascals. The system vapor pressure is 10 hectopascals.

Mean molecular impulse: $\varphi_i =$ 2.20 x 10^{-23} newtons per impact.

REFERENCES

Internal References: References to other essays in this collection are linked in the essay text by hyperlinks. You may follow these hyperlinks or ignore them, as you choose.

External References: These are papers by other authors that contain statements or data that are specifically incorporated into this essay. This paper has no external references.

General References: These are works that I have read carefully and whose views have helped to shape the views presented in this collection. None of these authors are have any responsibility for my many unconventional views and opinions.

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