MOLECULAR MOMENTA

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 the intangible surface of an imaginary sphere surrounded by the ***p***-population.

Definition of Molecular Momentum: Molecular momentum is the simple product of the molecular mass and the molecular speed. Its dimensions are MLT^{-1}.

$$\underset{\leftrightarrow}{\rho} = mv \qquad \text{MMA01}$$

Here, $\underset{\leftrightarrow}{\rho}$ is the mean molecular momentum in kilogram-meters per second[1], m is the mean molecular mass in kilograms, and v is the mean molecular speed in meters per second.

Mean Molecular Momentum in the *p*-Population: In the ***p***-population, mean molecular proximity momentum is denoted as either $\bar{m}_p\bar{v}_p$ (for the subpopulation of molecules that have a component of motion normal to and toward the surface of interest) or $\bar{m}_p\bar{v}_{-p}$ (for the subpopulation of molecules that have a component of motion normal to and away from the surface of interest). Note that molecular mass has no negative subscript. We have no molecules with negative mass.

Mean Molecular Momentum in the *i*-Population: In the ***i***-population, mean molecular impulse momentum is denoted as either $\bar{m}_i\bar{v}_i$ (for the subpopulation of molecules that have a component of motion normal to and toward the surface of interest) or $\bar{m}_i\bar{v}_{-i}$ (for the subpopulation of molecules that have a component of motion normal to and away from the surface of interest).

Distribution of Molecular Proximity Momenta: Since $\bar{m}_p$ has a fixed value, the distribution of molecular proximity momenta follows the distribution of molecular proximity speeds:

[1] The conventional symbol for momentum in physics is "p". However, "p" (in both the upper and lower cases) is used for pressure in the atmospheric sciences. Moreover, pressure is a more important parameter in these sciences than is momentum. Therefore, I am using the Greek lower case ***rho*** ($\underset{\leftrightarrow}{\rho}$) for momentum, with the addition of an underlying double-headed arrow. It looks something like "p", but is different enough not to cause confusion with pressure (***p***). Density (ρ) will still use the customary ***rho*** without the arrow.

$$\frac{d\bar{n}_p}{d\underset{\leftrightarrow}{\rho}} = \sqrt{\frac{2}{\pi}}\,\frac{\bar{n}_p}{\sigma}\exp-\frac{\underset{\leftrightarrow}{\rho}^2}{2\sigma^2} \qquad \text{MMA02}$$

Here, $d\bar{n}_p / d\underset{\leftrightarrow}{\rho}$ is the limited number of molecules (out of $\bar{n}_p$ molecules) that have momenta between $\underset{\leftrightarrow}{\rho}$ and $\underset{\leftrightarrow}{\rho} + d\underset{\leftrightarrow}{\rho}$, and sigma is the standard distribution of the proximity speed distribution.

Distribution of Molecular Impulse Momenta: Since $\bar{m}_i$ has a fixed value, the distribution of molecular impulse momenta follows the distribution of molecular flows:

$$\frac{d\bar{f}_i}{d\underset{\leftrightarrow}{\rho}_i} = \frac{\bar{f}_i}{\sigma^2}\underset{\leftrightarrow}{\rho}_i\,\exp-\frac{\underset{\leftrightarrow}{\rho}_i^2}{\sigma^2} \qquad \text{MMA03}$$

Here, $d\bar{f}_i / d\underset{\leftrightarrow}{\rho}_i$ is the limited number of molecular flows (out of $\bar{f}_i$ flows) that have momenta between $\underset{\leftrightarrow}{\rho}_i$ and $\underset{\leftrightarrow}{\rho}_i + d\underset{\leftrightarrow}{\rho}_i$, and sigma is, once again, the standard distribution of the proximity speed distribution.

Mean Molecular Momenta: For the passive ***p***-population, the mean molecular momentum is:

$$\bar{\underset{\leftrightarrow}{\rho}}_p = \sqrt{\tfrac{2}{\pi}}\,\bar{m}_p\sigma \qquad \text{MMA04}$$

For the interactive ***i***-population, the mean molecular momentum is:

$$\bar{\underset{\leftrightarrow}{\rho}}_i = \sqrt{\tfrac{2}{\pi}}\,\bar{m}_i\sigma \qquad \text{MMA05}$$

Conservation of Molecular Momenta: Conservation of molecular momentum is a useful concept; but we should not take it as revealed truth. Momentum is a vector quantity, having both magnitude and direction. In real world systems, neither the magnitude nor the direction are necessarily conserved. Entropy has its way in the end.

The wind dies down into calm, and the directional preference of the windy molecules is lost in the directionless calm air. Sound waves disappear into the internal motions of the molecules and eventually into the random emission of photons. The rolling stone eventually comes to rest.

Loss of Momentum Magnitude: For atmospheric systems, magnitude is not conserved. The principle of conservation of momentum states that, in the absence of outside forces, the total momentum of an isolated system remains the same. Unfortunately, neither the atmosphere as a whole or any part of it is an isolated system.

Every real atmospheric system continuously emits photons of electromagnetic energy following Wien's Law. Thus, unless replenished from its environment, the total energy content of that atmospheric system diminishes over time. The total momentum must do the same in proportion. For real systems, there is no assurance of any kind that the input of momentum from the environment will equal this momentum loss to the environment.

Loss of Momentum Direction: Direction is not conserved. The Second Law of Thermodynamics mandates that all directional preferences will also diminish over time. Air molecules undergo billions of collisions per second at the range of temperatures and pressures normally encountered in the free atmosphere. The individual molecule's speed and direction of movement may be presumed to change with each collision. Consequently, the individual molecule's momenta change as well.

During these collisions, some of the translatory momenta of the molecules are converted into internal momenta of rotation, vibration, and libration. At the same time, some of these internal momenta are converted into translatory momenta. However, the directional preference of the first conversion is not maintained in the second. In time, all directional preferences are lost as the entropy is maximized in a final state of equilibrium (or quasi-equilibrium). This is the Second Law at work.

Molecular Momenta 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 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.

$\underset{\rightarrow}{\bar{\boldsymbol{\rho}}}$ = 1.75 642 X 10^{-23} kilogram-meters per second for humid air.

$\underset{\underset{\sim}{\rightarrow}}{\bar{\boldsymbol{\rho}}}$ = 1.39 078 X 10^{-23} kilogram-meters per second for water vapor.

$\underset{\underset{\cdot}{\rightarrow}}{\bar{\boldsymbol{\rho}}}$ = 1.76 084 X 10^{-23} kilogram-meters per second for dry air.

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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