the mechanics of fluids and ensuing general integrals or theorems. In order application of these equations may be fully definitive, it is necessary that the following additional *phenomenological laws* be taken into account: state equation, Newton's law for viscosity, Fourier's law for heat conduction, Fick's law for diffusion, etc.

2. Some Information on the Molecular Structure of Substance

Depending on the quantitative relationship between the kinetic energy of the motion of molecules and potential energy of intermolecular dynamic interaction, there originate different molecular structures and types of internal motion of molecules.

Essential in *solid bodies* is the molecular energy of the interaction of molecules due to which the latter are arranged in regular crystal lattices with stable equilibrium positions at lattice nodes. Thermal motions in a solid body consist of small vibrations of molecules about lattice nodes with a high frequency (of order 10^{12} Hz) and amplitude proportional to spacings between these nodes. Both "short-range" and "long-range" orders are effected in the molecular structure of a solid body. To solid bodies also belong substances in amorphous state which do not have crystalline structure but which possess "short-range" order closely resembling that in liquids (see below). Amorphous states are not very stable and change easily to crystalline states.

In contrast to a solid body, both "short-range" and "long-range" orders are absent in gases. The molecules of a gas move in a random motion, with their interaction being reduced only to collisions. The interaction of molecules in the intervals between collisions is neglected, and this corresponds to the smallness of the potential energy of the dynamic interaction of molecules as compared with the kinetic energy of their random motion. The mean distance between two consecutive collisions of molecules determines the "free path length". The "free path" velocity of molecules is commensurable with the speed of propagation of small disturbances (speed of sound) in this state of gas.

As to their molecular structure and thermal motion, liquid bodies occupy an intermediate position between solid and gaseous bodies. According to the current views, a certain molecule, acting as a central one, collects around itself a group of neighboring molecules that slightly vibrate with a frequency close to that mentioned earlier for vibrations of solid body molecules in a lattice and with an amplitude of the order of mean distance between molecules. The central molecule either remains stationary (in a liquid at rest), or migrates at a speed coinciding in magnitude and direction with the local mean velocity of the macroscopic motion of liquid. In the molecular structure of a liquid the potential energy of molecular interaction is comparable in order with the kinetic energy of their thermal motion, with the "short-range" order being present and the "long-range" order not. The evidence for the vibrations of molecules in liquids is provided by the well-known "Brownian motion" of tiny solid particles introduced into liquid. Vibrations of these particles can be easily seen under a microscope and may be looked upon as the result of collision of solid particles with the molecules of liquid.

The difference between molecular structures and thermal motions of solid, liquid and gaseous bodies reveals itself clearly in the phenomenon of diffusion consisting in the propagation of one substance (inclusion) into the other (carrier). Diffusion of one gas in another (for example, the propagation of odor in air) due to intensive molecular motion leads to rapid penetration of odor into the farthest corners in a room. Conversely, the diffusion of a liquid in a liquid occurs much more slowly because of weak migration of central molecules with groups of molecules bound around them. The best example is provided by the historical experiment of Reynolds who introduced a thin jet of dye into a (laminar) water flow slowly moving through a cylindrical pipe. The jet remained nearly the same in thickness over almost *the mechanics of fluids and ensuing* general integrals or theorems. In order application of these equations may be fully definitive, it is necessary that the following additional *phenomenological laws* be taken into account: state equation, Newton's law for viscosity, Fourier's law for heat conduction, Fick's law for diffusion, etc.

2. Some Information on the Molecular Structure of Substance

Depending on the quantitative relationship between the kinetic energy of the motion of molecules and potential energy of intermolecular dynamic interaction, there originate different molecular structures and types of internal motion of molecules.

Essential in *solid bodies* is the molecular energy of the interaction of molecules due to which the latter are arranged in regular crystal lattices with stable equilibrium positions at lattice nodes. Thermal motions in a solid body consist of small vibrations of molecules about lattice nodes with a high frequency (of order 10^{12} Hz) and amplitude proportional to spacings between these nodes. Both "short-range" and "long-range" orders are effected in the molecular structure of a solid body. To solid bodies also belong substances in amorphous state which do not have crystalline structure but which possess "short-range" order closely resembling that in liquids (see below). Amorphous states are not very stable and change easily to crystalline states.

In contrast to a solid body, both "short-range" and "long-range" orders are absent in gases. The molecules of a gas move in a random motion, with their interaction being reduced only to collisions. The interaction of molecules in the intervals between collisions is neglected, and this corresponds to the smallness of the potential energy of the dynamic interaction of molecules as compared with the kinetic energy of their random motion. The mean distance between two consecutive collisions of molecules determines the "free path length". The "free path" velocity of molecules is commensurable with the speed of propagation of small disturbances (speed of sound) in this state of gas.

As to their molecular structure and thermal motion, liquid bodies occupy an intermediate position between solid and gaseous bodies. According to the current views, a certain molecule, acting as a central one, collects around itself a group of neighboring molecules that slightly vibrate with a frequency close to that mentioned earlier for vibrations of solid body molecules in a lattice and with an amplitude of the order of mean distance between molecules. The central molecule either remains stationary (in a liquid at rest), or migrates at a speed coinciding in magnitude and direction with the local mean velocity of the macroscopic motion of liquid. In the molecular structure of a liquid the potential energy of molecular interaction is comparable in order with the kinetic energy of their thermal motion, with the "short-range" order being present and the "long-range" order not. The evidence for the vibrations of molecules in liquids is provided by the well-known "Brownian motion" of tiny solid particles introduced into liquid. Vibrations of these particles can be easily seen under a microscope and may be looked upon as the result of collision of solid particles with the molecules of liquid.

The difference between molecular structures and thermal motions of solid, liquid and gaseous bodies reveals itself clearly in the phenomenon of diffusion consisting in the propagation of one substance (inclusion) into the other (carrier). Diffusion of one gas in another (for example, the propagation of odor in air) due to intensive molecular motion leads to rapid penetration of odor into the farthest corners in a room. Conversely, the diffusion of a liquid in a liquid occurs much more slowly because of weak migration of central molecules with groups of molecules bound around them. The best example is provided by the historical experiment of Reynolds who introduced a thin jet of dye into a (laminar) water flow slowly moving through a cylindrical pipe. The jet remained nearly the same in thickness over almost the entire working section of the pipe, thus testifying to a slow molecular diffusion typical of laminar motion of water. On transition to a turbulent mode of flow, when the molecular mechanism of diffusion gives place to turbulent mixing of finite macrovolumes of liquid, there arises an intensive turbulent diffusion and the dye rapidly fills the entire flow.

It should be noted that the phenomenon of diffusion is also observed in solid bodies, although it is much weaker here than in liquids. Mutual penetration of molecules can be seen in two specimens of different metals tightly fitted to each other after the lapse of a long period.

The problems of astrophysics associated with the study of ionosphere, "star clouds" and other astronomical objects and especially various physico-technical problems connected with the design of thermonuclear reactors and magnetohydrodynamic generators for direct conversion of thermal into electrical energy spurred a considerable upsurge of interest in the dynamics of ionized gases (plasmas).

In contrast to ordinary electrically neutral gases in which randomly moving molecules display dynamic interaction only ion only on their mutual collision, much more substantial Coulomb interactions originate in plasma due to a high concentration of charged particles. This imparts specific properties to plasma, as e.g. higher electrical conductivity, showing up most vividly on exposure of plasma flows external electrical and magnetic fields.

The exceptional, in their physical importance and applied possibilities, and at the same time very specific properties of plasmas suggested the idea of the fourth (after solid, liquid and gaseous) aggregated state of matter.[1]

---

[1]A detailed survey of the properties of plasma and phenomena occurring in it can be found in the paper by B. B. Kadomtsev "Plasma" (*Physical Encyclopedic Dictionary*, Vol. 4, Moscow, Sov. Entsiklopediya Press, 1965, pp. 15–24) and also in Sects. 1.3–1.4 of the book by Lukiyanov G. A. *Sverkhzvukovye strui plazmy* (*Supersonic Plasma Jets*). Leningrad, Mashinostroeniye Press, 1985, pp. 13–21 and the list of references in it.