## Chapter 3

# Pressure in fluids in the presence of gravity

*In association with Ugo Besson, the main author of the study*[1]

## 1. QUESTIONS ABOUT THE MERITS OF A MICROSCOPIC APPROACH

So much has been written about the word "model" that one hesitates to use it. It has nevertheless been used here and there in the previous chapters, primarily to draw attention to the distinction between something constructed from a description of reality on the one hand and an ordinary object on the other. The words "theory" or "theoretical" very soon appear if a more elaborate definition of the term "model" is attempted, since it is difficult to imagine an object without doing anything with it and that is when a theory is required. Here we will be trying to devise a model for the study of fluids in equilibrium in the presence of gravity, and the theory involved will be Newtonian theory, whether for static or kinetic analysis; the latter will also bring a statistical approach to the study of the dynamics of the particles involved.

As we said earlier, content analysis and analysis of the common ideas of pupils are both essential when devising a teaching scheme that will have any chance both of being suitable for the intended public and of meeting the desired objectives.

[1] The experiment was conducted in association with Jacques Lega, University of Louvain la Neuve.

Let us assume, without going into further details for the moment, that pupils have problems with the study of fluids (liquids and gases).

No one involved in educational research or responsible for drawing up syllabuses, in France in particular[2], seems to dispute the advantage of introducing teenagers to a microscopic particulate model involving empty space between the particles in question[3].

The status of such an approach is not immediately obvious: should the particulate model of kinetic theory be introduced as a subject of knowledge in its own right, as a tool for a better understanding of macroscopic phenomena, as a pretext for introducing students to the idea of modelling, or as a combination of two or three of these?

The analysis and proposal presented here have been made primarily to provide a tool for understanding macroscopic phenomena. This also means that they seek to introduce students to modelling as an approach, which is not the same thing as introducing a particular model. In the case of a microscopic model that considers particle kinetics, there may be a risk of confusing two objectives, namely that of introducing the *existence* of particles, which will quickly be said to be molecules – will anyone doubt that? –, and the use of a model for explanatory purposes. To be more precise, the merits of the second aspect, in terms of effectiveness in teaching, are often simply taken to be the obvious consequence of the general value of a model adopted in the scientific community[4].

But as a theoretical tool for providing explanations, a particulate model with empty space between the particles in question may be a problem for beginners in science. In the absence of any consideration given to the movement of the particles, such a model does seem to lend itself to analysis of the compressibility of fluids[5], but then there is the question of resistance to compression, which, as we all know, does not start with a sudden "contact" between motionless particles. If we now introduce particle kinetics in the hope that pupils will take that aspect on board, not as a subject of knowledge in its own right but as a means of understanding and therefore predicting phenomena involving fluids, the difficulties must not be underestimated. "Moving to the microscopic

[2] See the *Seconde* (fifth year of secondary schooling in France, equivalent to grade 10) syllabus issued in 2000: MEN 1999.

[3] Some proposals introduce particle movement from the outset, others do not. See for exemple Brook *et al.* 1984, Larcher, Chomat & Méheut 1988, Andersson & Bach 1996, Vollebregt 1998.

[4] The same could be said of the analysis of friction in mesoscopic terms, namely via surface asperities, were it not for an evaluation of the effects of teaching proposals using that very aspect: see Chapter 2.

[5] See note 2.

level", as people often say, not only changes the scale of the analysis but is also and more importantly a complete change in the type of explanation and its relationship to time. A permanent effect – the interactive forces between the gas and the walls of the container – is linked to events[6] whose duration is not considered[7], namely collisions between the molecules of the fluid and those of the container. These two types of time sequence can only be reconciled by taking a statistical approach. Such conceptual gymnastics are not obviously accessible, to say the least, and some difficulties can be expected, especially in secondary education. Moreover, understanding the transmission of physical information, so to speak, between particles during a disturbance is something of a conceptual feat. In any case, at the time of writing, after fifteen years of experimentation, there is still no entirely convincing evidence of the merits of such an approach for a better understanding of the thermo-elastic properties of gases, even though that work took no account of gravity. If we now want to introduce the effect of gravity, if only to make what pupils are taught the least bit relevant to any interest they might have in their environment, it is very difficult to use a microscopic model to tackle the following questions at an elementary level: why do the molecules of the atmosphere not just form a pathetic heap on the ground? And if they don't do that despite all the space there is between them, why don't they have the same density at different altitudes? Why do some planets not have an atmosphere? Similar questions relating to liquids are just as difficult to answer if we have at one and the same time to consider both an interparticulate void – much smaller than in the case of gases it is true – and molecular interactions and kinetics[8].

[6] At least that is how they are often described. In her attempt to distinguish "objects and events" from "theories and models", Tiberghien (1997) fails to say how far such a distinction is practicable once you are no longer at a macroscopic level. We all know that in elementary particle physics, for example, the term "event" is commonly used to refer to collisions, the same term used to describe the impact between two billiard balls. Likewise, the question in the title of Diu's book (1997): "*Les atomes existent-ils vraiment*?" [Do atoms really exist?] leaves one wondering what useful purpose is served by continuing to deny that these mental constructs are objects when they can nevertheless, to put it succinctly, be "photographed" and people try to "immobilise" them, etc.

[7] Their frequency, that is the number of such events per unit time, is considered, however.

[8] The accepted theory, in the form of the equipartition of energy theorem, states that, for a given pure body in thermodynamic equilibrium at a given temperature, the distribution of velocities is the same regardless of the interactions between particles (see for example Diu *et al.* 1989, p303), and therefore the contribution to the pressure

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