Feynman Fluid Mechanics

Bouncing up the mother drop from water surface trailing three child droplets behind

by

Feynman, R.P., Leighton, R.B., Sands, M, & Beiser A.

edited by

Takeo R.M. Nakagawa & Ai Nakagawa

Advanced College of Symbiosis, Hakusan Press

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Magnolia at the backyard on 22 March 2021

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Contents

1. Introduction

The book is made by extracting and editing the two chapters, 40 the flow of dry water pp.40-1~12 and 41 the flow of wet water pp.41-1~12 in "The Feynman lectures on Physics" by Feynman, R.P., Leighton, RB., sand, M. Addison-Wesley Publishing Company, Reading. Massachusetts・Menlo Park・California・London・Sydney・ Manila (1970). The chapter 3, which is written by Beiser(1963), is added to connect the conventional fluid mechanic equation, Navier-Stokes equation (Navier 1827, Stokes 1845) with Tsugé correlation equation(Tsugé 1974). The former is for the laminar flow, while the latter is for the turbulent flow, where the kinetic theoretical approach to track the locus of each the fluid particle is required.

This is a lecture note to be used for senior level students and professional physicists and engineers as an online lecture by the instructors in Advanced College of Symbiosis, Hakusan in Japan. This Note should be only for internal use for private learners.

On this ground, this book has been published by a publisher who belongs to a non-profit organization. Of course, the editors are volunteers, who are interested in educating promising youngsters.

2. The Flow of Dry Water

2-1 Hydrostatics

The subject of the flow of fluids fascinates everybody. We can all remember playing in the bathtub or in mud puddles with the strange stuff. As we get older, we watch streams, waterfalls, and whirl-pools, and we are fascinated by this substance which seems alive relative to solids. The behavior of fluids is in many ways very unexpected and interesting. The efforts of a child to dam a small stream flowing in the street and his surprise at the strange way the water works its way out has its analog in our attempts over the years to understand the flow of fluids. We have tried to dam the water up by getting the laws and the equations that describe the flow.

We suppose that the elementary properties of water are already known by the readers. The main property that distinguishes a fluid from a solid is that a fluid cannot maintain a shear stress for any length of time. If a shear is applied to a fluid, it will move under the shear. Thicker liquids like honey move less easily than fluids like air or water. The measure of the ease with which a fluid yields is its viscosity.

In this chapter, we will consider only situations in which the viscous effects can be ignored! Let us begin by considering hydrostatics, the theory of liquids at rest. When liquids are at rest, there are no shear forces (even for viscous liquids). The law of hydrostatics, therefore, is that the stresses are always normal to any surface inside the fluid. The normal force per unit area is called the pressure. From the fact that there is no shear in a static fluid it follows that the pressure stress is the same in all directions (Fig.2-1).

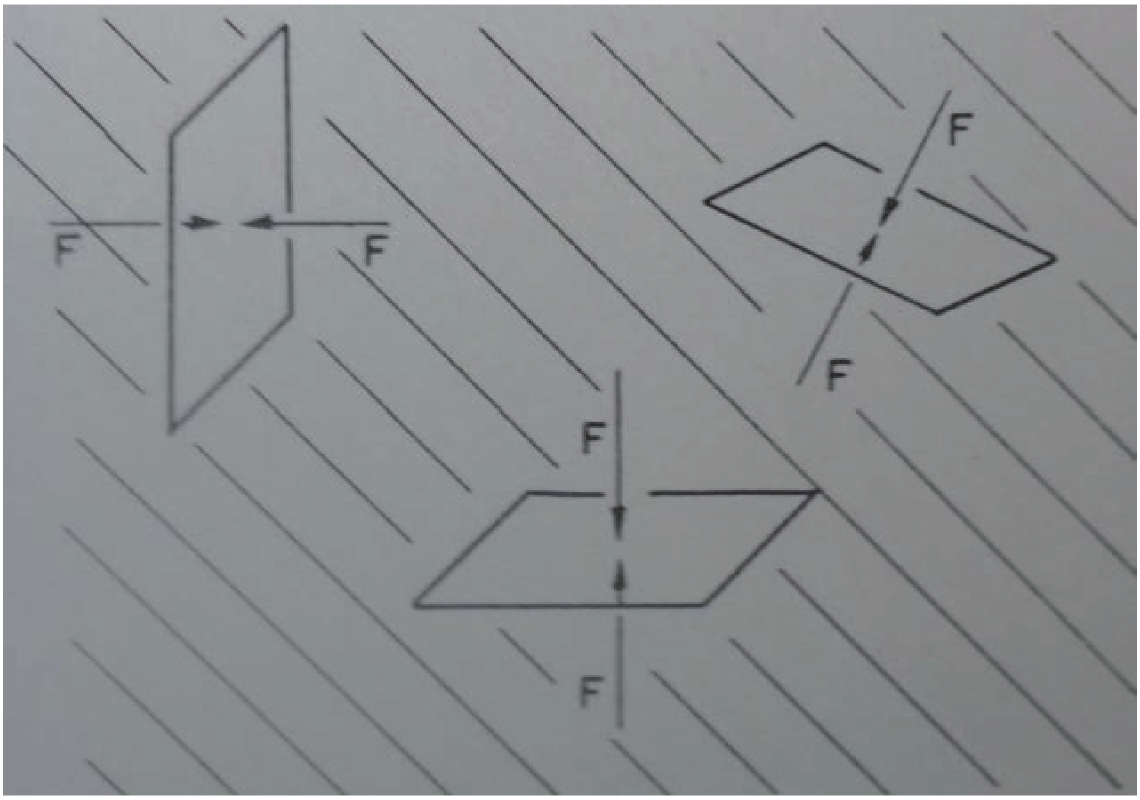

Fig.2-1 In a static fluid, the force per unit area across any surface is normal to the surface and is the same for all orientations of the surface.

The pressure in a fluid may vary from place to place. For example, in a static fluid at the earth's surface, the pressure will vary with height, because of the weight of the fluid. If the density of ρ of the fluid is considered constant, and if the pressure at some arbitrary zero level is called p_0(Fig.2-2), then the pressure at a height h above this point is $p=p_0-\rho gh$, where g is the gravitational force per unit mass. The combination

$p+\rho gh$

is, therefore, a constant in the static fluid. This relation is familiar to you, but we will now derive a more general result of which it is a special case.

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