

Problems for chapter 1

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1.1

This chapter is much too serious. Have your AI agent explain and summarize §1.4 on density, in the style of a gangster rapper who secretly has a big heart. Read the final result out loud, otherwise it does not count.

1.2

- 1.2.1 Can an incompressible flow also be unsteady?
- 1.2.2 Can a very viscous fluid flow in a turbulent manner?
- 1.2.3 Can a compressible flow also be isothermal?
- 1.2.4 Give an example of an unsteady flow, of a compressible flow, and of a laminar flow.
- 1.2.5 Your colleague tells you not to worry about the pressure changes in your fluid flow, “because it is incompressible”. What do you immediately tell them?
- 1.2.6 A YouTuber explains that air feels colder when you are exposed to the wind because its internal energy (temperature) has been converted to kinetic energy. Why should you definitely not “like and subscribe”?
- 1.2.7 Give the order of magnitude of a “big” density, viscosity, and mass flow.
- 1.2.8 A friend tells you they are going to revolutionize fluid mechanics by doing things *right* and calculating the movement of fluids from scratch, starting with the movement of molecules. What are you going to tell them?

1.3

Which ones are true? Turbulence is fluid motion...

- at multiple scales which is stochastic and polarized.
- at microscopic scales which is harmonic and expensive.
- at industrial scales which is erratic and profitable.
- at multiple frequencies which is unstable and poorly documented.
- at unpredictable scales which is random and inefficient.
- at increasingly small scales which is confused and irreversible.
- at quantum scales which is fractal and self-aware.
- at astronomical scales which is chaotic and underfunded.
- at multiple scales which is chaotic and dissipative.
- at incompatible scales which is nonlinear and emotionally unstable.
- at unnecessarily many scales which is disorderly and antisocial.

1.4

- 1.4.1 In the conceptual experiment of the “brick of fluid” in figure 1.5, what would be the force required to pull the top surface of $20 \times 20 \times 20$ cm cube of honey with a velocity of 25 cm s^{-1} ?
- 1.4.2 To which value should you change the height of the brick if you use water instead, pulling at the same speed and generating the same force?

1.5

If you were to stand up right now, what would be the average pressure under the sole of your shoes, in bars and in Pascals? Find out another non-SI unit for pressure used in the industry and convert the value in that also.

1.6

Describe an experiment you would setup to generate a shear of exactly 150 Pa on the surface of a solid object of your choice.

1.7

In a swimming pool, a window is made of a flat, 2 m-by-2 m glass panel (Figure 1.1). On the left side (atmospheric air), the pressure is uniform at 1 bar.

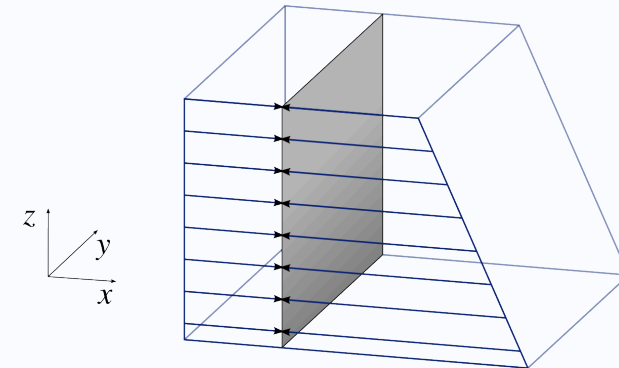


Figure 1.1: Pressure distribution on a flat glass panel that is part of the wall of a swimming pool

Figure CC-0 OC

- 1.7.1 What is the pressure force (i.e. the force resulting from the pressure) exerted on the left side of the plate?
- 1.7.2 Here's a harder question, which we will learn to tackle in chapter 3. On the right side of the plate, the water exerts a pressure which is not uniform: it increases with depth. The relation, expressed in pascals, is: $p_{\text{water}} = 1,3 \cdot 10^5 - 9,81 \cdot 10^3 \times z$. What is the pressure force exerted on the right side of the plate?

1.8

The engine exhaust gases of a student's hot-rod car are flowing quasi-steadily in a cylindrical outlet pipe, whose outlet is slanted at an angle $\theta = 25^\circ$ to improve the good looks of the car and provide the opportunity for an exercise.

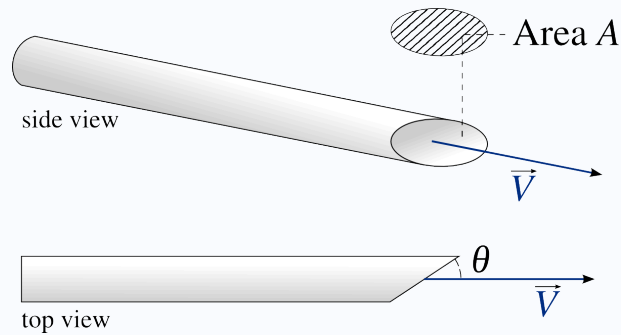
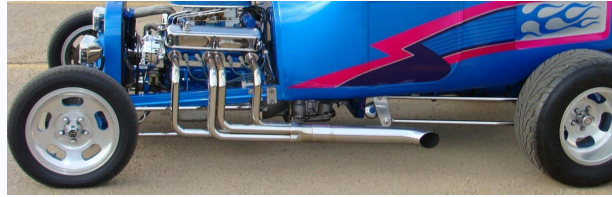


Figure 1.2: Exhaust gas pipe of a car. The outlet cross-section is at an angle θ relative to the axis of the pipe.

Figure CC-0 OC ; Photo cropped, mirrored and edited from an original CC-BY-SA by Kaz Andrew

The outlet velocity is measured at 15 m s^{-1} , and the exhaust gas density is $1,1 \text{ kg m}^{-3}$. The slanted outlet section area A is 420 cm^2 .

1.8.1 What is the mass flow $\dot{m}$ through the pipe?

1.8.2 What is the volume flow $\dot{\mathcal{V}}$ of exhaust gases?

1.9

Which of the following flows can you expect, based on a first calculation, to be turbulent? Look up the fluid properties and main dimensions as needed.

1.9.1 Water flow in the flexible pipe of a shower

1.9.2 Air around a basketball thrown in a three-point throw

1.9.3 Flow around a bee buzzing along in forward flight

1.9.4 Air you exhale after a long breath

1.10

A fluid flows over a 3 m by 3 m flat horizontal plate, in the x -direction as shown in Figure 1.3. Because of this flow, the plate is subjected to uniform shear $\tau_{zx} = 1,65 \text{ Pa}$.

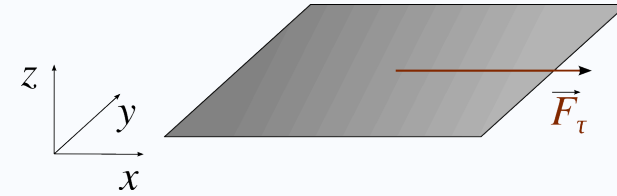


Figure 1.3: Shear force exerting on a plate

Figure CC-0 OC

1.10.1 What is the shear force applying on the plate?

1.10.2 Here's a harder question, which we will learn to tackle in chapter 3. What would be the shear force if the shear was not uniform, but instead was a function of x expressed (in pascals) as $\tau_{zx} = 1,65 - 0,01 \times x^2$?

1.11

Inside a complex, turbulent water flow, we are studying the trajectory of a cubic fluid particle of width $0,1 \text{ mm}$. The particle is accelerating at a rate of $2,5 \text{ m s}^{-2}$.

1.11.1 What is the magnitude of the net force (sum of forces) applying to the particle? (this is the order of magnitude of the forces calculated by computational fluid dynamics software)

1.11.2 Which are the types of forces that could add up to create this net force?

1.12 Optional: do it with AI: get set up

Use your most trusted AI to get setup to work on engineering tasks with AI. Different “levels” you may reach are described below.

- AI is a thing, some kind of a website you ask to manipulate text sometimes.
- you have an AI agent accessible very rapidly, which you can ask questions effortlessly. You can upload files to it, and it knows when to look up or calculate (instead of guess) the answer.
- you have an AI agent that can run code online on a cloud machine. It can write a script (say when requested to “make a plot of $y = x^2$ ”) and then *run* it, debug it, modify it. You can download the script, not just the result.
- you have an AI agent that runs on a local machine, editing your files and running scripts. It uses code versioning (to be able to go back in time) and writes tests (to make sure there are no regressions as you progress), completely routinely, while you focus on the task objectives instead of the code.

Try to move down this list, according to your skills and means.

1.13 Optional: do it with AI: basic plot

As a proof of concept, have your AI create a script that plots the function $y = x^2$. Modify that script yourself so it has different limits on the x -axis, and a different color for the curve.