

MAE 222
Mechanics of Fluids
Princeton University

Assignment # 9

April 15, 1998

Due on Wednesday, 2PM, April 22, 1998

Chapter 9. Flow Over Immersed Bodies. On the course web page, I have posted a "supplementary notes" for this week. Please download it and study it.

§9.1. General External Flow Characteristics. Easy reading of descriptive materials.

§9.2. Boundary Layer Characteristics. Remember what we learned for pipe flow? We have laminar flow below certain critical Reynolds number, and we have turbulent flow above certain critical Reynolds number. The situation for external flow is similar. For a flat plate, the "transition" Reynolds number is about 500,000 based on the freestream velocity and the distance from the leading edge. But depending on other details of the problem, the transition Reynolds number (obtained empirically) can vary quite a bit. A rule of thumb: if you have "favorable pressure gradient," transition is delayed. If you have "unfavorable pressure gradient," transition occurs earlier.

Know the definition and meaning of displacement thickness δ^* and momentum thickness Θ . Study my supplementary notes. Look at Fig. 9.10. It is just like the Moody Diagram! Look at Table 9.1. This is just like the Colebrook formula for circular pipes!

§9.3. Drag. Circular cylinder and sphere are examples of non-streamlined bodies. Look at Fig. 9.15. Do you see the dip in the drag coefficient when Reynolds number is about half a million? For Reynolds number of order unity or smaller, theoretical values for drag are available, giving the "straight line" relation between drag coefficient and Reynolds number on a log-log plot. Very low Reynolds

number flows are sometimes call Stokes flows, and the drag coefficient formula is called Stokes drag.

§9.4. Lift . Pay particular attention to the section on circulation. I have already talked a little on the D'alembert paradox. I will provide supplement to the presentations given in YMO in my lectures.

Problems at end of Chapter 9, page 423:

- Problem 9.1. I probably will not lecture on how to do this problem. Study example 9.1 of the book if you need help. It is totally straightforward.
- Problem 9.3. The pressure exerts a force on the cylinder surface normal to the surface. You need to work out the component of the unit normal in the streamwise direction in order to get the drag.
- Problem 9.7. Use information provided in §9.2.2.
- Problem 9.15. The point of this problem is to show that the precise shape of the velocity profile assumed does not really make that big a difference in the answers.
- Problem 9.22. Equation 9.24 with $C=12$ is called Stokes Drag Law for small Reynolds number (up to about 1). For this problem, the gravitational pull and the bouyancy force (remember Archimedes?) are balanced by the drag estimated by the Stokes drag law.
- Problem 9.31. This is really a question that belongs to the dimensional analysis chapter. Check the dimensions of power \mathcal{P} and velocity U . By the way, what other dimensional parameters should be involved? What happens to power if you wish to double U ?
- Problem 9.54.

Use email or the newsgroup to ask questions.