Assignment #1: Dyn. Similarity and Cons. Laws — ME 412

due 9/9/2015 before class via Learning Suite — 100 possible points

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On each homework I will provide some suggestions on where you should be on the project. Please remember that each project is different and so you may be ahead, behind, or in a completely different direction from these suggestions. These are only guidelines, and will not require you to actually write anything on your homework (with the exception of the next homework when you will choose a topic and team).

Project: Read the project guidelines. Start brainstorming topics that you are interested in. Do some preliminary reading to see if your topic is project-worthy. Start looking around for someone to partner with.

1.1 Logistics: Sign up for Piazza, complete the FERPA Quiz, and answer the following getting to know you questions:

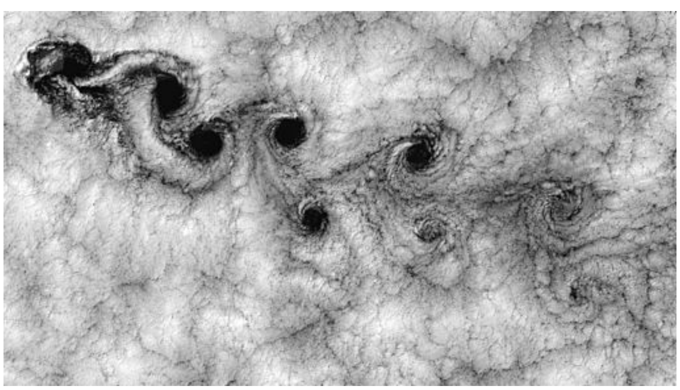
(a) What do you hope to get out of this class (and are there any specific topics/applications that you would be particularly interested in discussing in class)?

(b) How can I help you achieve your learning goals?

(c) Is there anything else I should know about you?

1.2 In aerodynamic wind tunnel testing it can be difficult to simultaneously match the full scale Mach number and Reynolds number. Learn about when this problem might occur, what some of the solutions are, and what the advantages and disadvantages of these approaches are. Describe your findings.

1.3 Computing: Two-dimensional flow around a cylinder sounds simple, but actually has some rather complex Reynolds Number dependent behavior. Figure 9.21 in your text shows some of the interesting behavior, which we will discuss in more detail when we get to viscous flows. For now, we are going to use dimensional analysis to analyze case (C) known as a von Karman vortex street, which occurs around a Reynolds Number of 100. Watch this youtube video, which shows the phenomenon in CFD and in a water tunnel (incidentally this video is a pretty good example of an appropriate project for this class).



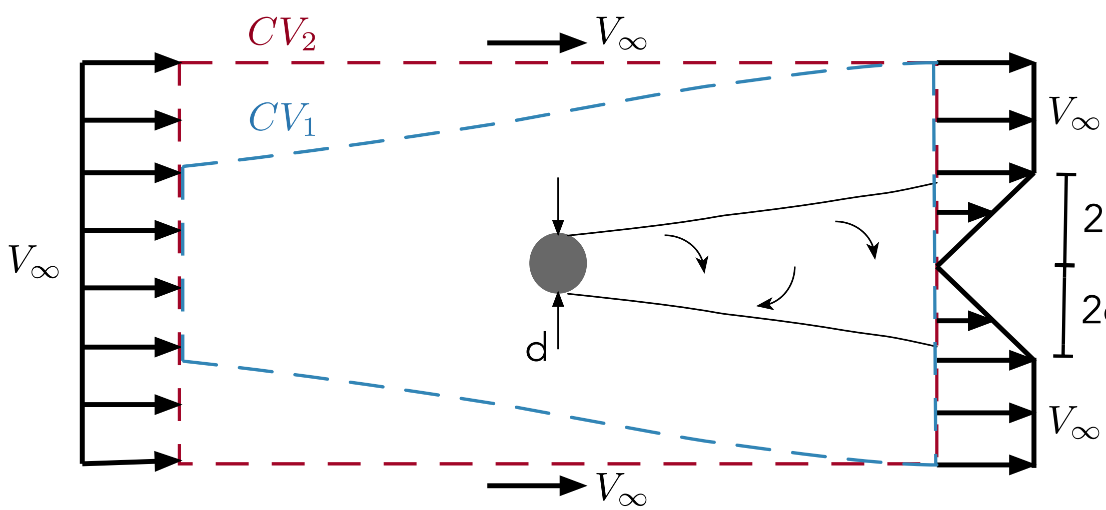
Satellite images of a von Karman vortex street in the clouds behind an island off the Chilean coast.

We want to determine how the shedding frequency ω changes as a function of Reynolds number using experimental data. An experiment was conducted using a rectangular water tunnel with an adjustable flowrate. A dye was injected so that the vortices could be observed and counted. For separate experimental runs the flowrate and cylinder diameter were varied. In each case, a timer was used to find the shedding time for 10 vortices.

An Excel spreadsheet (courtesy of the student companion site for Fundamentals of Fluid Mechanics, 7th Edition) is provided that gives the temperature of the water (T), the width of the channel (b), the volume flowrate (Q), the water depth (y), the cylinder diameter (D), the number of vortices shed (N), and the time it took to shed the vortices (t). You should plot the shedding frequency as a function of freestream velocity, and create a *second* plot showing these relationships using nondimensional parameters.

After plotting the experimental data, overlay your second graph with the equation proposed in this paper: "A new Strouhal–Reynolds–number relationship for the circular cylinder in the range 47 $<$ Re $< 2 \times 10^5$".

1.4 We want to experimentally determine the drag of the cylinder in the previous problem. However, we want to do in a very large wind tunnel so that we can ignore wall effects. Effectively, the flow is unconfined. In this wind tunnel, the Reynolds number is higher and corresponds to case (D) in Fig. 9.21 (i.e., the wake width is reasonably steady). One approach to determining the drag is to use a force-balance measurement. However, an alternative approach is to use a wake-survey. In this approach we just need to measure the velocity profile in the wake. You should assume 2-dimensional, incompressible flow with the wake velocity profile shown below:



What is the drag coefficient of the cylinder based on projected area? Is this a reasonable value (why or why not)? Solve the problem two ways: 1) using a control volume that follows streamlines (blue volume CV_1) and 2) using a rectangular control volume (red volume CV_2).

1.5 **Open-ended:** Would you get less wet by walking or running through the rain? Why? If you needed to cross a football field in the rain, how many ounces of water would your clothes absorb?

1.6 **CFD:** Complete the "Introduction to Star-CCM+" tutorial and turn in some plots showing your work. No discussion in needed for this task.

Star-CCM+ is installed on the CAEDM computers. You can use it locally or login remotely. It is listed under the CAD software folder on Windows machines or as the command "starccm" from the terminal on Linux workstations. The current version should be v10. You may also install a copy of Star-CCM+ on your individual computers if you like. Request a free academic license here (note that it says requests will take at least two weeks).

Tutorials are available under the help menu. Note that as of this morning (9/2), the links were still broken. The system administrators are aware of this and are working to fix it. Check on Piazza for updated information on how to access the tutorials and associated files (hopefully by tomorrow).

Later in the semester we will learn more about how Computational Fluid Dynamics (CFD) works and how to use it effectively, but for now we will work focus on tutorials to get some experience.