Introduction to Turbulence

Fluid flows can become unstable in a number of ways. Some of those lead to large scale oscillations in the geometry of the flow as exemplified by vortex shedding from a cylinder (see section (Bmc)). However, in this and the following sections, we will address those circumstances in which some region of a flow becomes unstable and those local disturbances grow in magnitude and range of frequency, leading to the phenomenon we call *turbulence*. Often this occurs first in a highly sheared region of the flow and spreads out to adjacent parts of the flow as the unsteadiness envelopes nearby fluid. The most common examples and the examples that will be addressed in detail in the sections which follow are the flows in a pipe and the flow in an initially laminar boundary layer.

Consequently, we first address the issue of the stability of a laminar flow and the methods used to evaluate the stability. Particular attention will be paid to the stability of quite simple flow, namely planar, parallel flow since the analytical challenges presented by more complicated flow are very considerable. Once we have addressed the problem of assessing where and when instability will occur, we briefly address the problem of understanding the growth of the disturbances from their minute origin to observable turbulence. Once turbulence has been substantially developed there are flows such as that in a straight pipe in which the magnitude and frequency content of the turbulence asymptotes toward a steady state. This is termed "fully-developed" turbulence and the later sections in this group focus on the properties and analyses of fully-developed turbulence. Particular attention will be paid to two common geometric configurations namely to "fully-developed" turbulent pipe flow (in both smooth-walled and rough-walled pipes) and to "fully-developed" turbulent boundary layers.