ENGS9AA.F TRANSITION TO TURBULENCE

ENGS9Aa.F **Transition to turbulence in thermoconvection** **and aerodynamics**	**Credits:** **2 ECTS** **Duration:** **21 hours**	**Semester:** **S9**

Person in charge: Emmanuel Plaut, professor

http://emmanuelplaut.perso.univ-lorraine.fr/welcome-e.htm

Keywords: nonlinear phenomena, stability, instability, bifurcation theory

Prerequisites: fluid dynamics elementary course, numerical methods

Objectives: learn relevant ***nonlinear phenomena*** in hydrodynamics with heat transfers (thermoconvection) and aerodynamics; learn some methods to model these phenomena.

Program and contents:

The ***transition to spatio-temporal complexity and turbulence in fluid dynamics***, which is intrinsically ***nonlinear***, is studied by focusing on two families of systems. This is also an occasion to enrich the knowledge and know-how of the students in general fluid mechanics. The families of systems studied are:

1. ***Natural convection*** or ***`thermoconvection'***

   The emphasis is on the `Rayleigh-Bénard' configuration in extended geometry, where ***convection rolls*** set in under the influence of a vertical downward temperature gradient, through an ***instability***. This is an occasion to introduce the ***thermal buoyancy***, the ***Oberbeck - Boussinesq approximation***, the methods of the ***linear and weakly nonlinear stability analyses***, and to evidence a ***supercritical pitchfork bifurcation*** that leads to ***increased heat transfers***. The ***secondary instabilities*** are also briefly discussed. The ***chaos*** is introduced both with the (historical) Lorenz model and the (more realistic) example of the Rayleigh-Bénard convection in a square cell, where chaotic large-scale flow reversals occur. Other geometries and systems are also briefly discussed, for instance, the `differential heating' configuration, where the basic temperature gradient is horizontal, therefore, thermoconvection sets in directly, as it is often the case for heating in buildings.

2. ***Open shear flows***

   The emphasis is on the ***Tollmienn-Schlichting waves*** that set in through an ***instability*** of channel flows. In this different context, the ***linear and weakly nonlinear stability analyses*** already introduced are performed now with ***numerical computations*** (spectral method), to evidence a ***subcritical Hopf bifurcation***. The ***further transition to turbulence*** is also briefly discussed, for channel flows, and also boundary layer flows and airfoils. Openings concerning aerodynamics and wind energy are finally presented.

   Importantly, the ***stability analyses methods*** and the ***theory of bifurcations*** (or `catastrophes') introduced here are, in fact, relevant for any nonlinear deterministic model; applications also exist in other domains of mechanical engineering, in physics, etc...

Please check the web page of this module on **http://emmanuelplaut.perso.univ-lorraine.fr/t2t** : it sketches the planning of this module, gives the lecture notes and instructions, etc... In particular, you will use **Mathematica** to perform formal (symbolic) and numerical computations on your laptop.

Abilities :

Levels	Description and operational vocabulary
Know	Chaos. The physics of the transition to turbulence in channel flows, boundary layer flows and airfoils
Understand	Linear vs nonlinear terms - linear vs nonlinear effects. Supercritical vs subcritical bifurcations. The physics of thermoconvection and thermal buoyancy
Apply	Linear and weakly nonlinear stability analyses. Numerical spectral method
Analyze	Linear and weakly nonlinear stability analyses. Numerical spectral method
Summarize	
Assess	

Evaluation:

☑ Written test	☑ Continuous assessment	☐ Oral presentation	☐ Project	☑ Written report