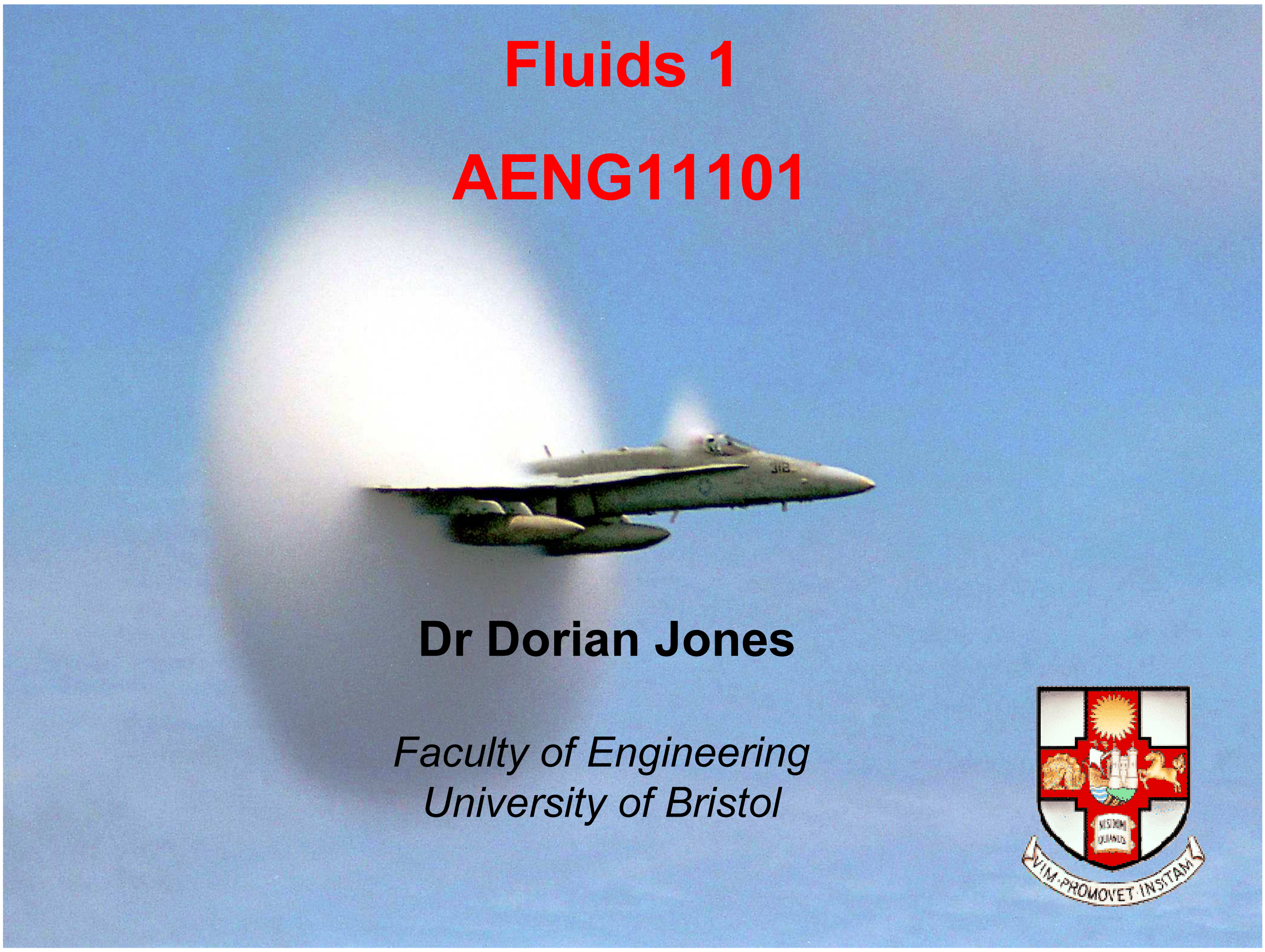


Course Aims

- To establish a *basic understanding* of the fluid flows and their interaction with simple structures
- To provide the *most basic tools* and *fundamental concepts* required for the experimental and theoretical modelling of these flows

Course Content & Assessment

- 18 lectures-(for details of content see blackboard)
- 4 examples classes
- 2 revision classes
- Online assessed Questions 0%
  - feedback on progress and understanding (MUST PASS)

- 2 laboratory classes (with online "Pre-Lab") 20%
  - To give you practical experience of fluid behaviour and feedback on basic understanding
  - Online Pre-lab plus online test based on a "discussion document", 2 weeks after completing 2nd laboratory class

- Exam 80%
  - 2 hours (compulsory section plus 2 questions out of 3)

Importance of Examples Sheets

- Examples sheets will be handed out in advance
  - Work through the questions in your own time
  - Each question is important and adds something different
  - Different approach to school where many similar questions posed, and learning is through repetition
  - Here, learning comes from tackling **all** questions and understanding **why** each solution works
  - Use the scheduled examples class to clarify solutions, not as a timetabled slot to have a first attempt at solutions
- Hints & solutions
  - It is infinitely better that you initially try to solve examples yourself using lecture material, and discuss issues with other students and staff.
  - The intelligent use of hints and outline solutions thus comes near the end of the process, in helping to clarify some of the issues involved.
- Numerical vs algebraic questions
  - In the example sheets you have numerical problems with a final number answer so that you know if you have made a mistake. However it does not tell you where the mistake is – hence the examples classes.
  - In the exam there are more algebraic questions so that follow through marking works. Rewarding all understanding.

Commitment

- Attending lectures, labs, etc. is necessary, but private study outside timetabled activities is expected and essential.
- A standard student year is defined as 960 hours over the 24 teaching weeks (i.e. excluding examination-taking and revision).
- Thus you should put in an average total of 80 hours of work for Fluids 1 over the 12 weeks of the unit.
- Nominal division for Fluids 1
  - 2 hours lectures/examples classes per week 18hours
  - 2 lab classes 6hours
  - 2 lab tests 6hours
  - 3 assessed questions 2hours
  - Private study (average 4 per term week) 48hours
  - **TOTAL** **80hours**

Other Sources of Information

- Text books
  - Anderson, 'Fundamentals of Aerodynamics'
  - Massey & Smith, 'Mechanics of Fluids'
  - White 'Fluid Mechanics' – *recommended*
- Library
  - well-stocked library in Queens Building – use it!
  - wide range of online journals
  - online databases – Web of Science, ESDU
  - extensive report holding – NACA, RAE, ARL, AGARD etc etc

Unit Content

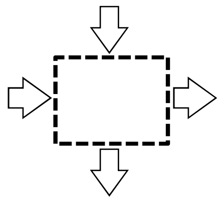
- The unit is broken down into 5 sections, each with an online test and example sheet:
  - Definition of Continuum Newtonian fluids
  - Fluid statics
    - Example sheet
  - Real fluid behaviour- including viscous and compressibility effects
  - Fluid forces and non-dimensionalisation
    - Example sheet and online progress test
  - 1D Incompressible flow (Bernoulli's equation)
    - Example sheet and online progress test
  - Control Volume analysis
    - Example sheet
  - Potential flow analysis
    - Example sheet and online progress test

What is 'Fluid Dynamics'?

- 'A branch of mechanics which deals with the motion of fluids, and with the forces acting on bodies in relative motion'.
- School physics uses the conservation of momentum for a fixed mass moving through space – "Lagrangian" view.

$$\sum F = \underbrace{M}_{\text{constant}} a$$

- In fluid dynamics we consider a fixed box (called a control volume) which the fluid continuously moves through – "Eulerian" view.



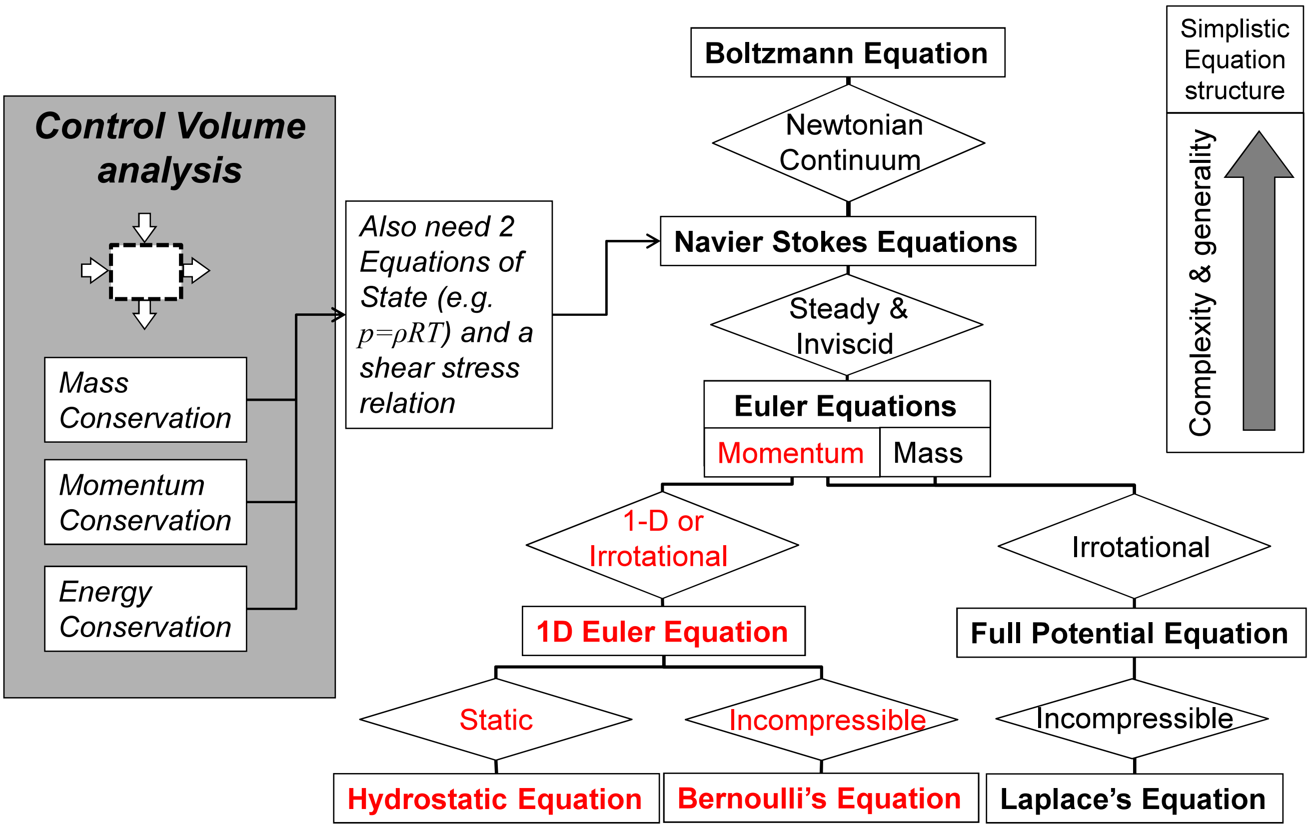
- This means we must also remember to conserve energy and mass as well as momentum.
- With no fixed mass we must consider the more general form of momentum conservation.

$$\sum F = \frac{d}{dt}(mv)$$

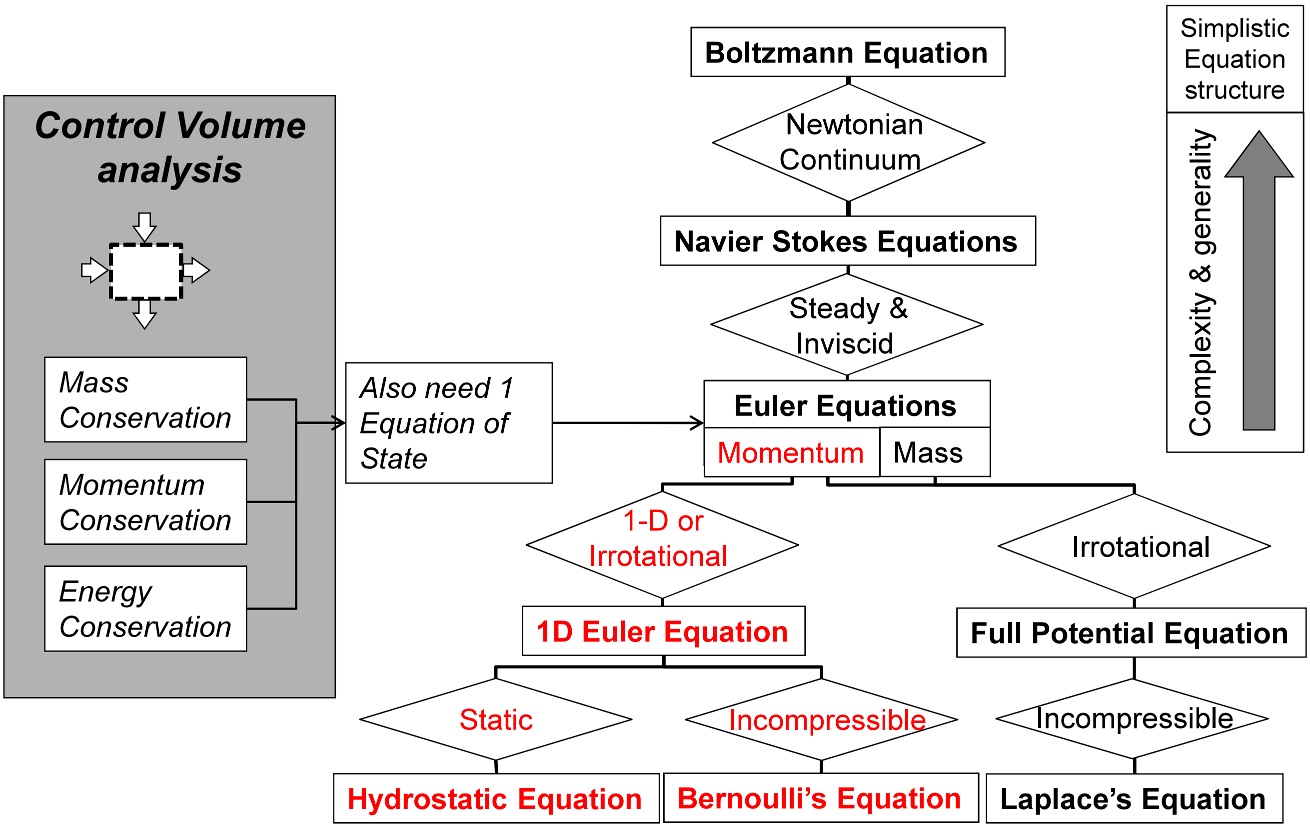
Fluid Equations: Reduction or Construction?

- Fluid dynamics discusses a flow in terms of a fluid model. There are a number of models of varying complexity.
- Each fluid models is written as a single/set of equation/s.
- As a rule of thumb, the generality of the model (the range of cases for which the model works well) is directly proportional to its mathematical complexity.
- Many advanced texts start with a derivation of a suitably complex model (such as the Navier-Stokes equations) which is implied to be a complete description of reality. The equations are then reduced to simpler forms by making assumptions that restrict the generality of the model.
- However, even the most complex equations are derived using simple conservation arguments. In *Fluids1* the equations will usually be constructed from these principles.

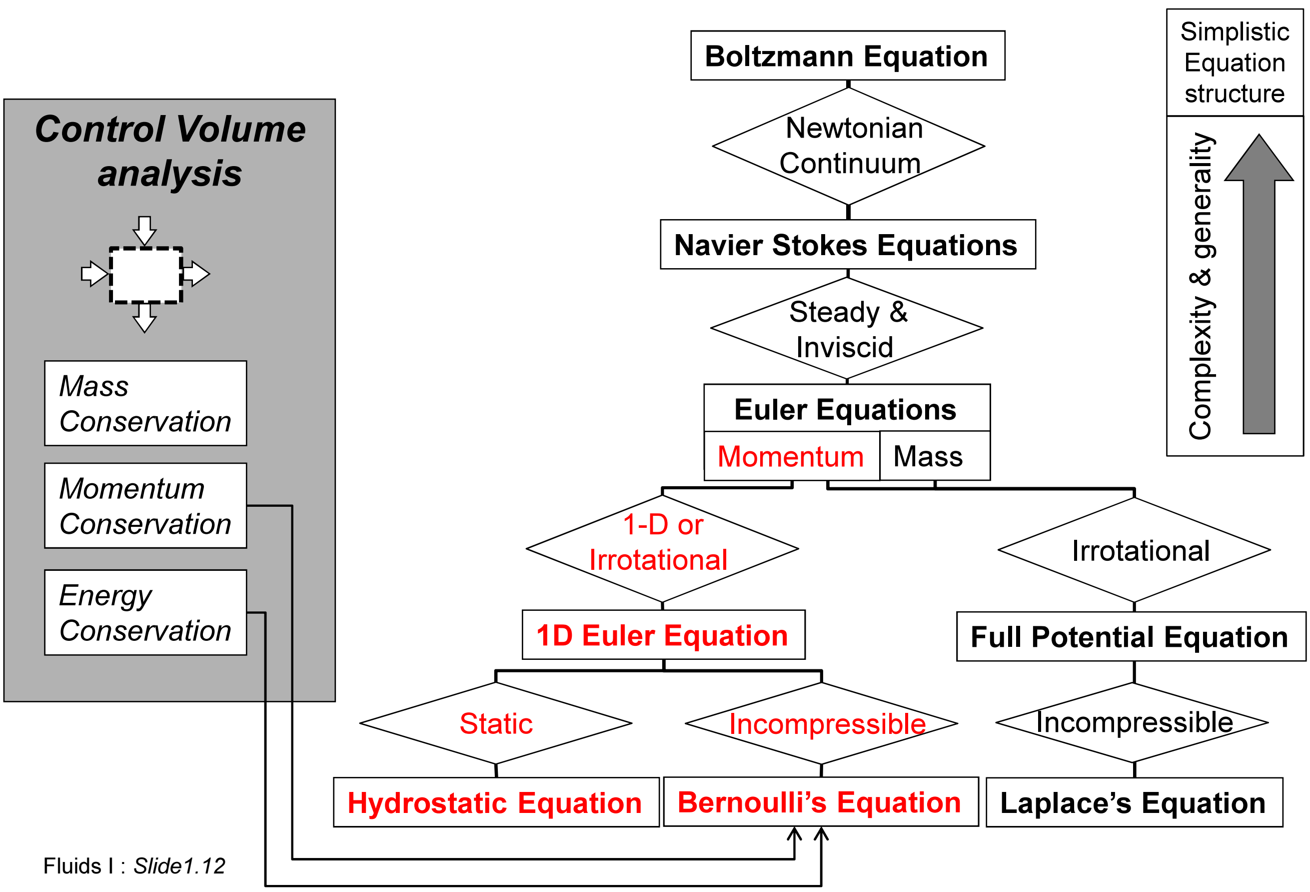
Fluid Equations: Reduction or Construction?



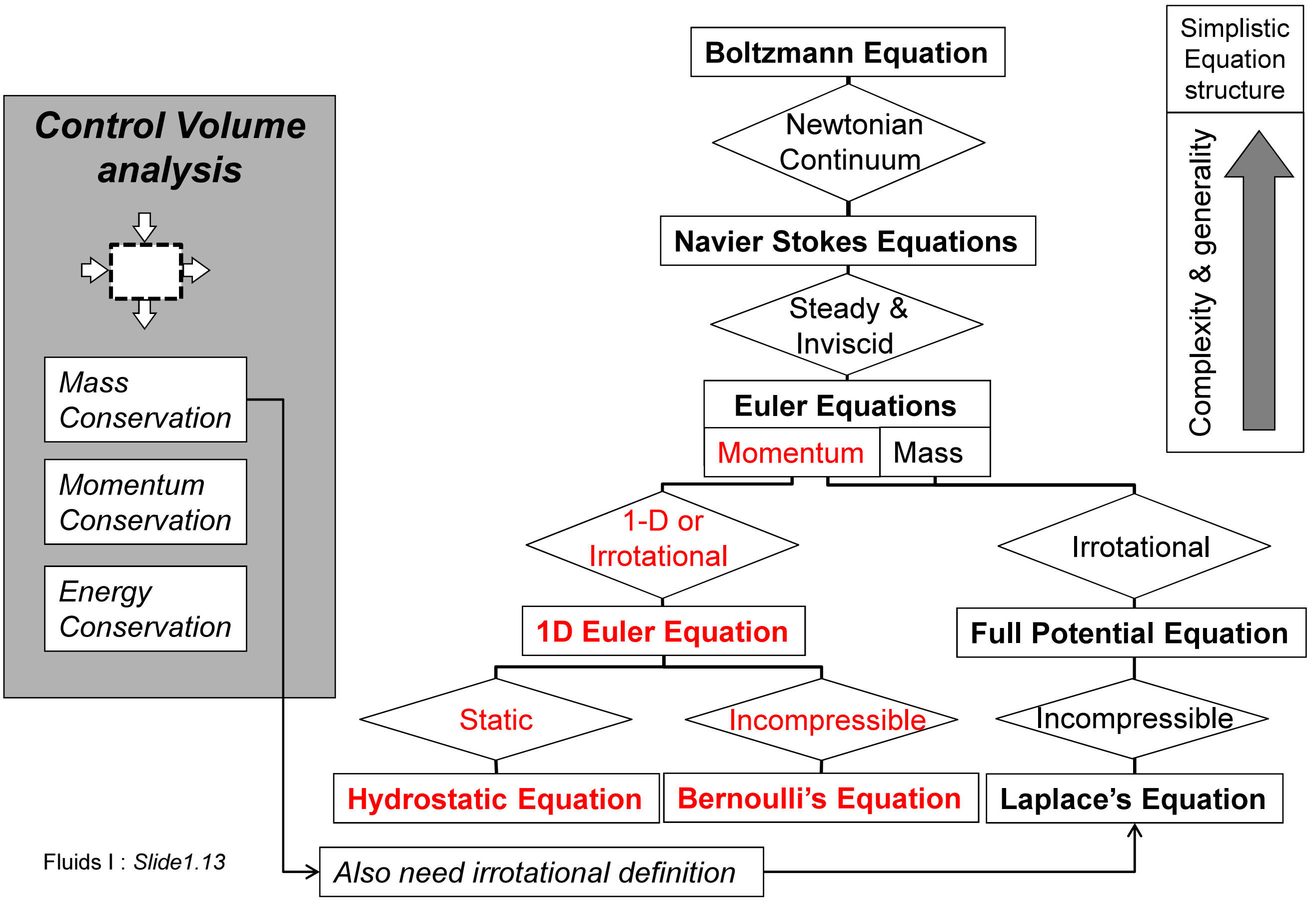
Fluid Equations: Reduction or Construction?



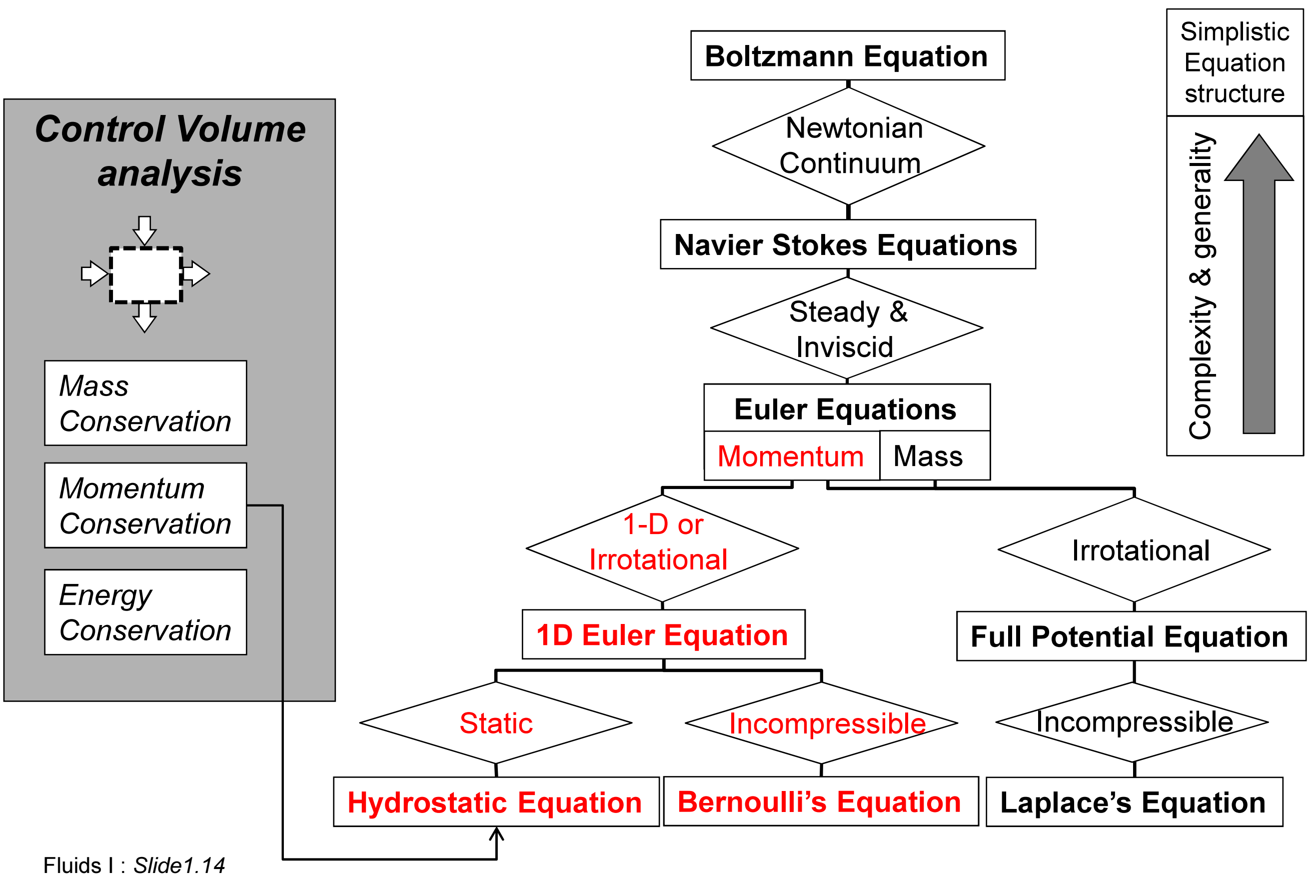
Fluid Equations: Reduction or Construction?



Fluid Equations: Reduction or Construction?

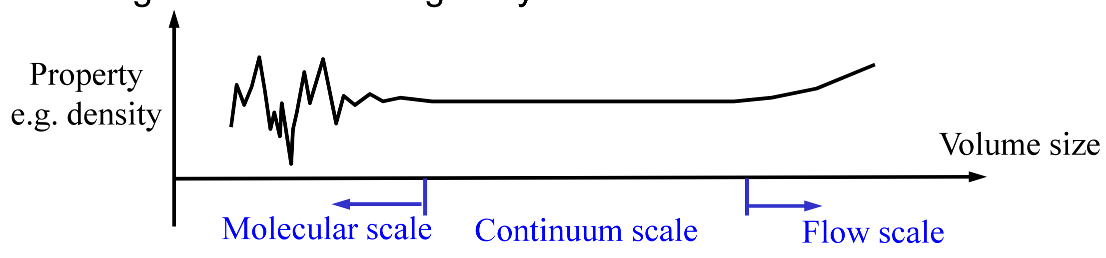


Fluid Equations: Reduction or Construction?



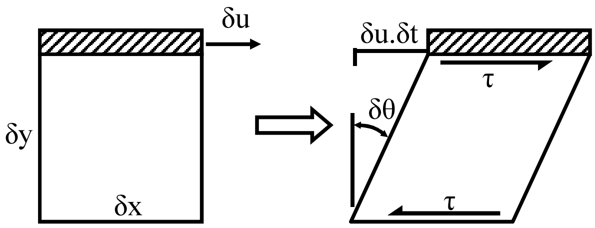
Continuum Approximation

- In reality fluids are made up of molecules: 3.3×10^{19} in 1 mm^3 of water and 2.7×10^{19} in 1 cm^3 of air
- The Continuum Approximation assumes that: the fluid is made up of a continuous medium divided into small volumes that are:
  - Many times smaller than the smallest characteristic length scales of the flow (air & water in usual conditions)
  - Large enough (contain enough molecules) for statistical averages to be unchanged by variations in the volume size



Viscosity

- Consider a fluid element sheared in one direction. In the limit of small deformation

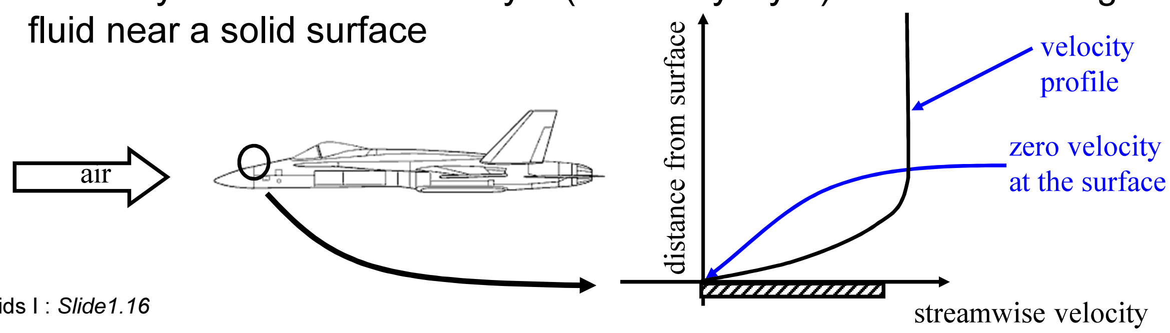


$$\boxed{\tan \delta\theta = \frac{\delta u\, \delta t}{\delta y} = \delta\theta \quad (\delta\theta \to 0)}$$

$$\frac{\delta\theta}{\delta t} = \frac{\delta u}{\delta y}$$

For newtonian fluids, the shear stress, τ, is directly proportional to the velocity gradient where the viscosity coefficient, μ, is the constant of proportionality. $\tau \propto \frac{\delta\theta}{\delta t}$ $\quad \tau = \mu \frac{\delta u}{\delta y}$

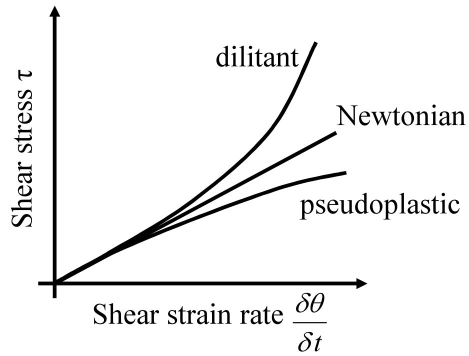
- Viscosity causes the shear layer (boundary layer) of slower moving fluid near a solid surface



Viscosity

- Thermodynamic variable
- Strong function of Temperature but a weak function of pressure

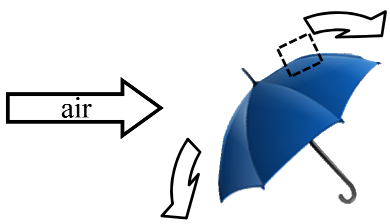
  See Sutherland's, power or logarithmic laws in White p24-25
- Nonnewtonian fluids are studied in Rheology and can be split into dilitant and pseudoplastic fluids.

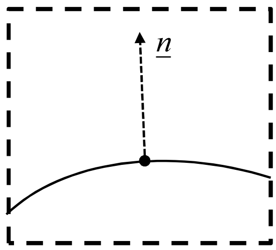


- Other classifications include those fluids that "thicken" or "thin" with time (Rheopectic and Thixotropic respectively) for a fixed strain rate

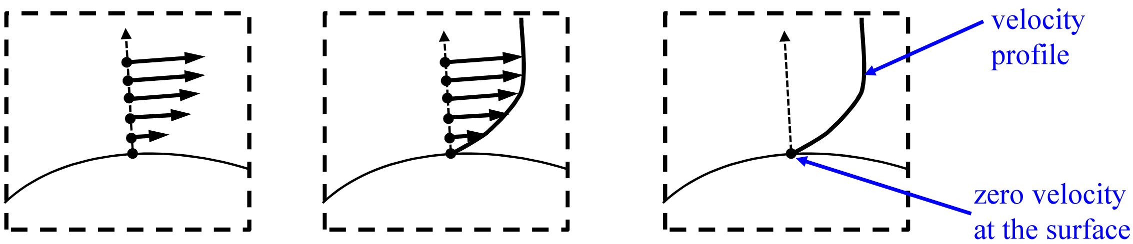
Another Look at Velocity profiles

- Lets consider a fluid flowing over a fixed surface e.g. air over the upper surface of an umbrella.





Consider a point on the surface contained in a 2D slice. The surface normal, $\underline{n}$, defines the points where *tangential* velocity is measured.



The velocity profile represents the magnitude of the 2D tangential velocity as we move away from the surface in the normal direction

Learning Outcomes:
“What you should have learnt so far”

- That there exists an underlying relationship between all fluid and solid mechanics
- The continuum hypothesis means that we do not consider the molecular scale
- The definition of a Newtonian fluid in terms of a simple shear stress relation
- How fluid velocity profiles are drawn