

# Fluids 1

## AENG11101

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### 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 2<sup>nd</sup> laboratory class
- Exam 80%
  - 2 hours (compulsory section plus 2 questions out of 3)

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## 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.

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## 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**

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## 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

Fluids I : Slide1.6

## 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

Fluids I : Slide1.7

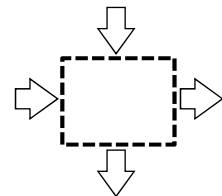
## What is 'Fluid Dynamics'?

- '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.

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

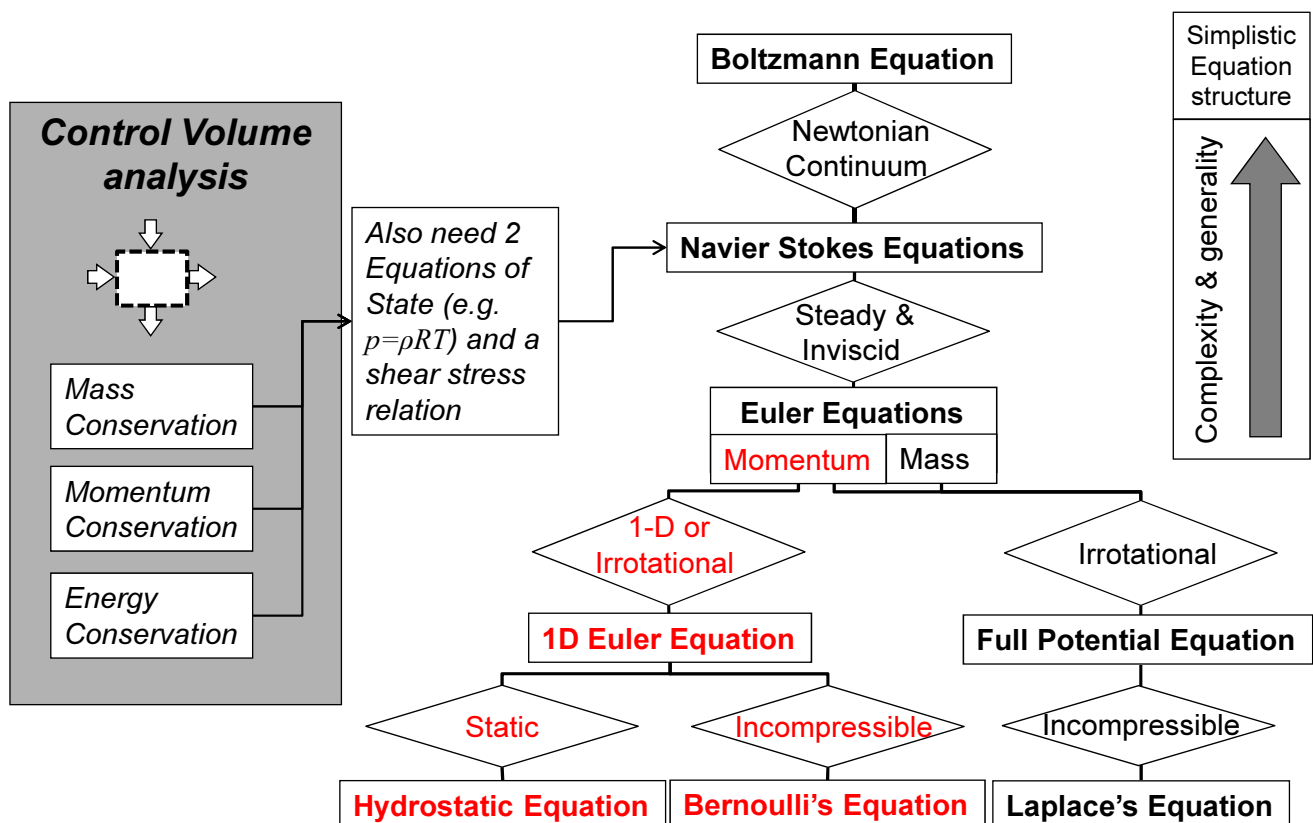
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# Fluid Equations: Reduction or Construction?

- 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.

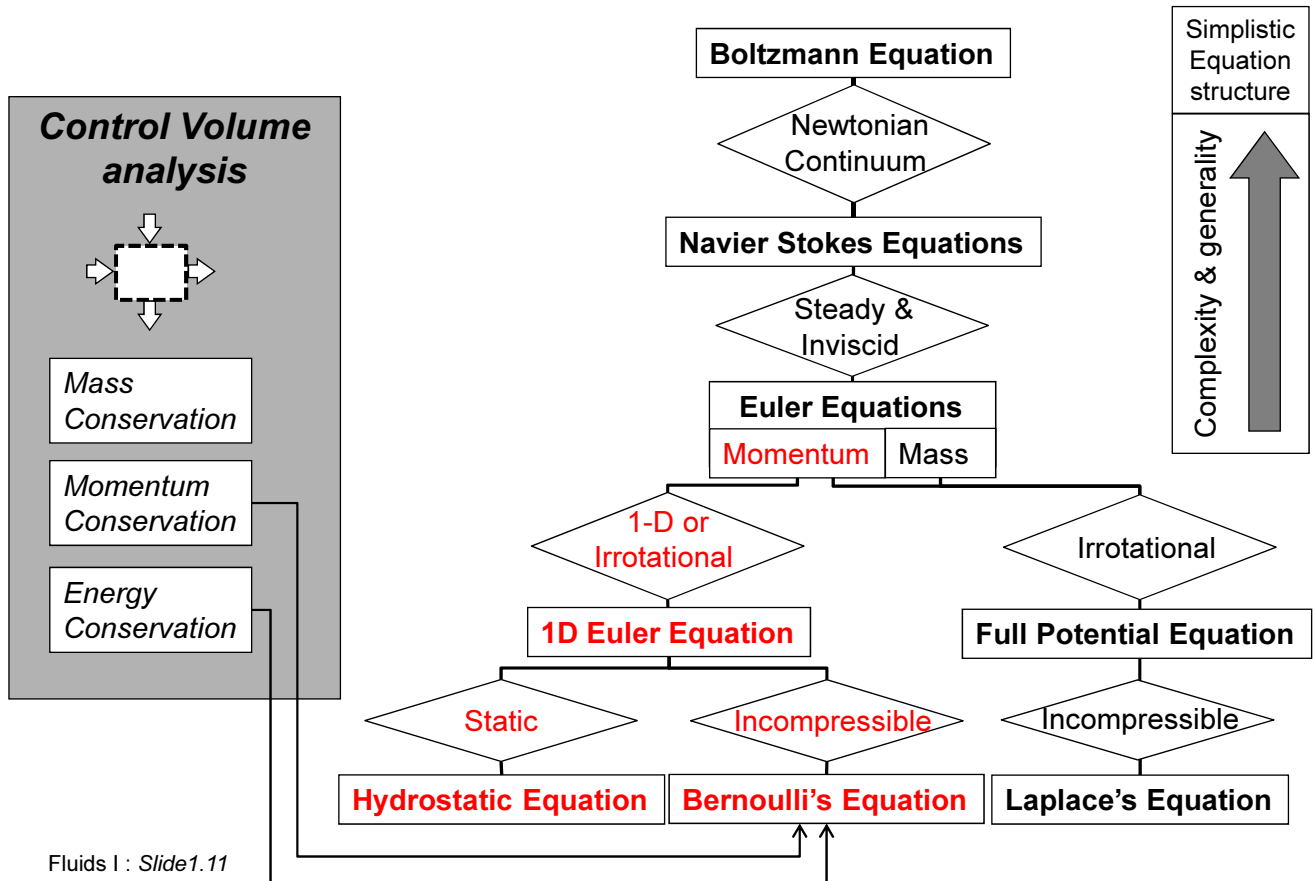
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# Fluid Equations: Reduction or Construction?

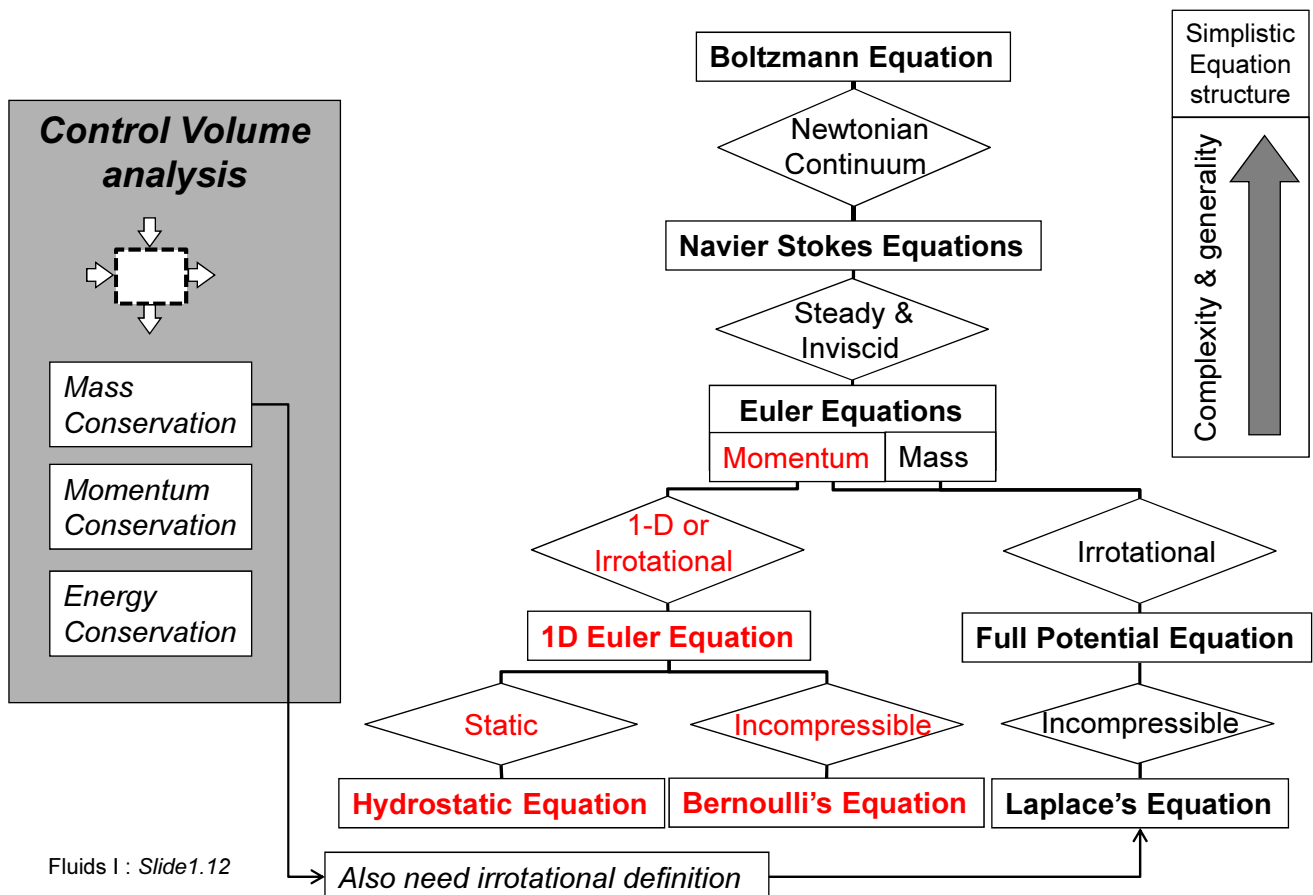


Fluids I : Slide1.10

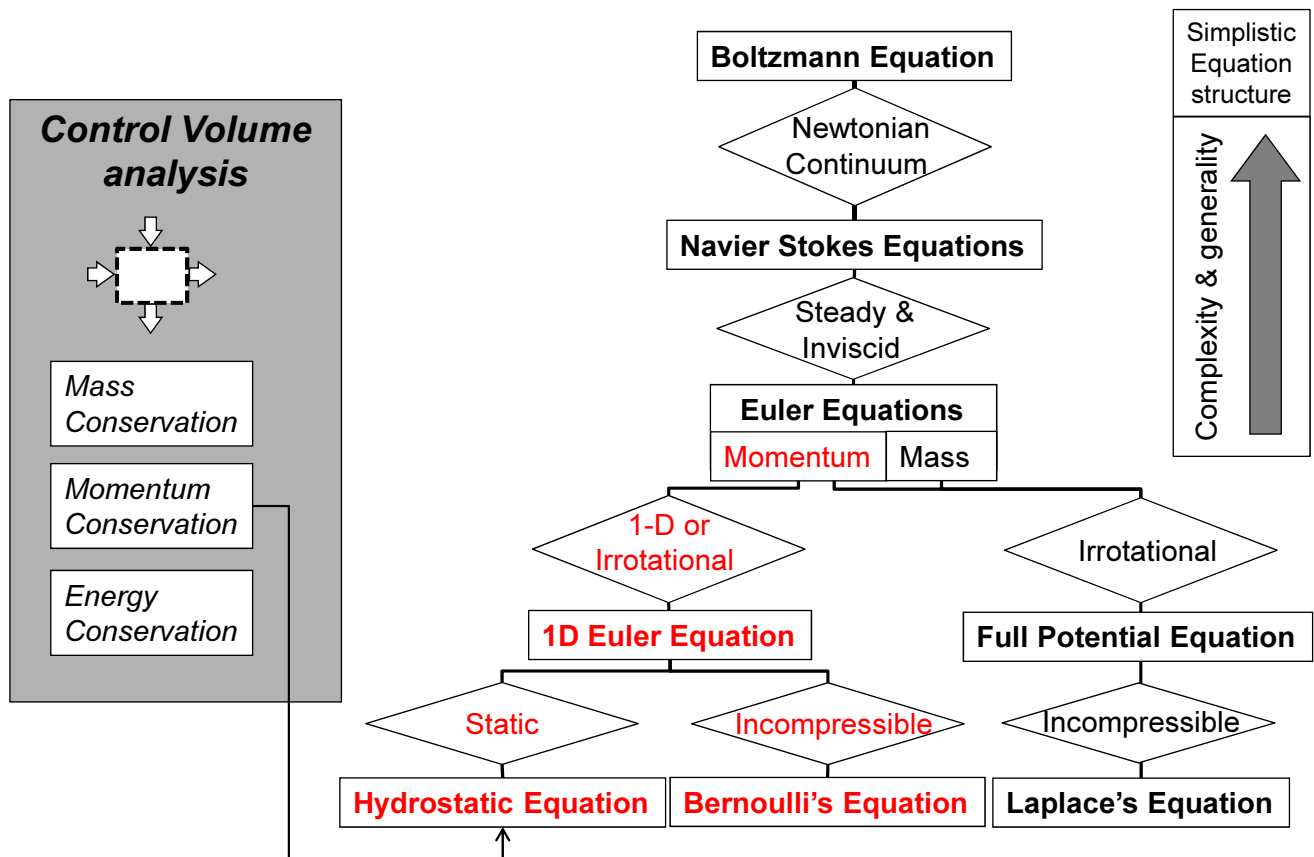
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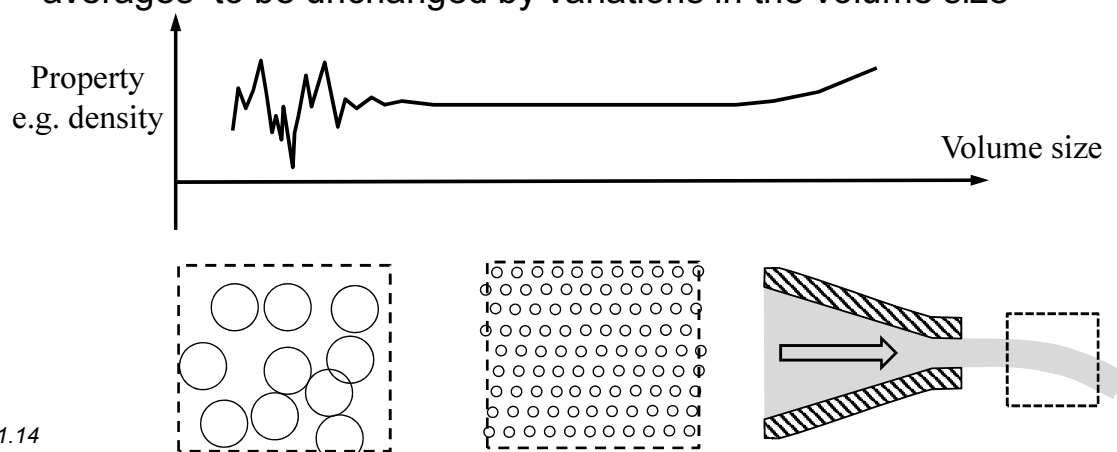
# Fluid Equations: Reduction or Construction?



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## Continuum Approximation

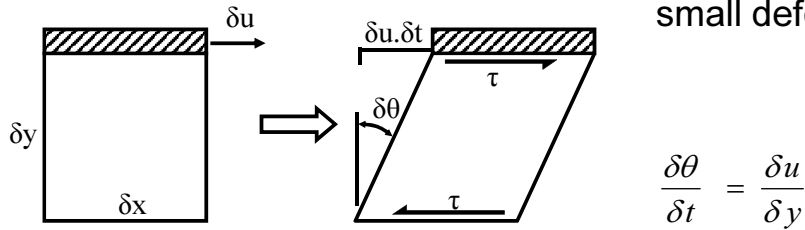
- In reality fluids are made up of molecules:  $3.3 \times 10^{19}$  in  $1 \text{ mm}^3$  of water and  $2.7 \times 10^{19}$  in  $1 \text{ cm}^3$  of air
- The Continuum Approximation assumes that: the fluid is made up of a continuous medium divided into small volumes that are:
  - Many times smaller 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



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# Viscosity

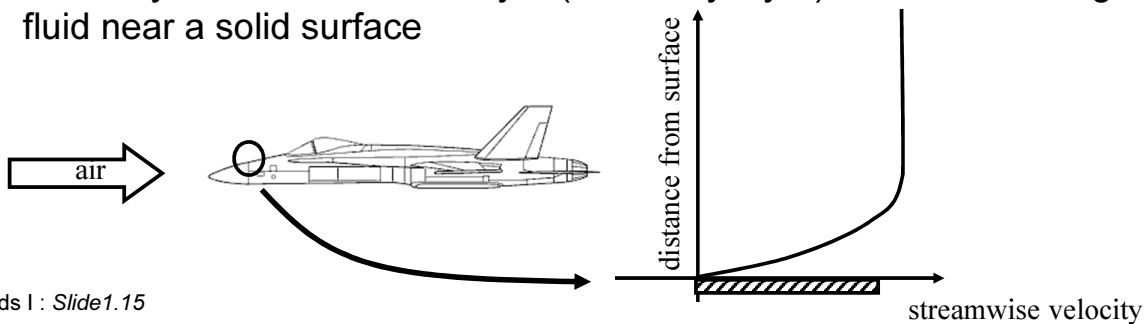
- Consider a fluid element sheared in one direction. In the limit of small deformation



For newtonian fluids, the shear stress,  $\tau$ , is directly proportional to the velocity gradient where the viscosity coefficient,  $\mu$ , is the constant of proportionality.

$$\tau \propto \frac{\delta \theta}{\delta t} \quad \tau = \mu \frac{\delta u}{\delta y}$$

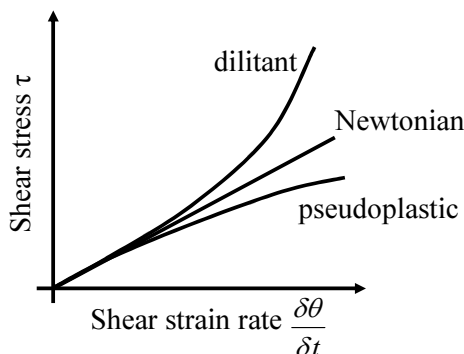
- Viscosity causes the shear layer (boundary layer) of slower moving fluid near a solid surface



Fluids I : Slide1.15

# Viscosity

- Thermodynamic variable
- Strong function of Temperature but a weak function of pressure
- Nonnewtonian fluids are studied in Rheology and can be split into dilatant and pseudoplastic fluids.



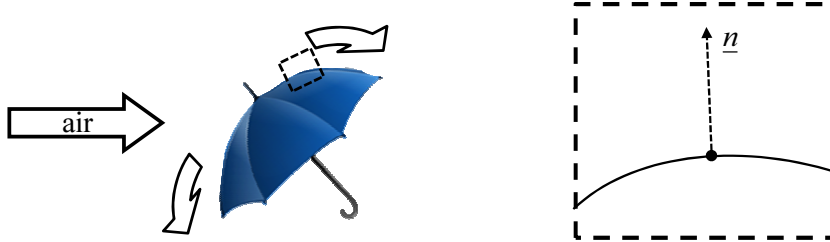
- Other classifications include those fluids that “thicken” or “thin” with time (Rheopectic and Thixotropic respectively) for a fixed strain rate

Fluids I : Slide1.16

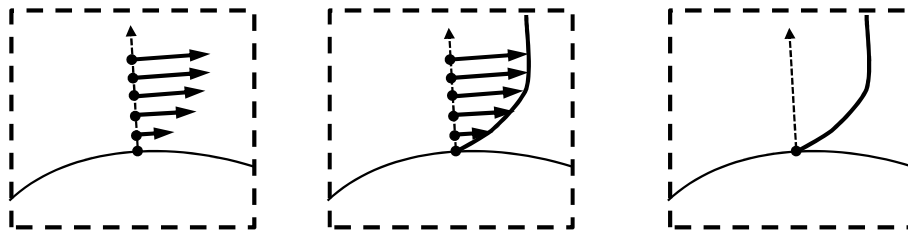


## Another Look at Velocity profiles

- 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

Fluids I : Slide1.17

## 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

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