The University Of Sheffield.

MEC 208 Fluids Engineering

Dr. Cécile M. Perrault

The University Of Sheffield.

Before we start

Fluids Engineering

Dr. Cécile M. Perrault

Course Format

- Lectures:
  - Monday from 10am until 12pm
  - St George's Church
  - 50 minutes lecture, 15 minutes break, 50 minutes lecture
  - 22 lectures + 2 revisions
- Tutorials:
  - Wednesday at 10 am
  - Thursday at 2pm
  - 5 tutorial sheets
  - NO FLUID SUPPORT THIS WEEK
- Labs:
  - More next week

MOLE

MEC208 Fluids Engineering (AUTUMN 2015~16)

MEC 208

General Module Information

Course Syllabus and Timetable

MEC 208 FAQs

Lecture Material

Lecture Notes

Assessment Material

Tutorials

Past Exam Papers

CFD Lab

Additional Material

My Grades

Study Resources

MEC 208

Welcome to MEC208, Fluids Engineering !

MODULE FORMAT:

The module includes 23 lectures, 24 tutorials (TBC) and 5 tutorials sheets. Assessment will take form of a final 2-hours exam during examination week. The exam consists of two parts: Part A is compulsory 10 Questions (each carrying 4 marks), Part B: 2 questions chosen from 3 (each carrying 30 marks). The final mark is 80% final exam and 20% lab report

All lecture and laboratory material is examinable. Old exam papers with the numerical answer can be found in the "past exam papers" section in the left-hand side menu. No step-by-step solutions of past exam papers are available.

LECTURES:

Lectures are on Mondays from 10:00 until 12:00 in St Georges' Church. The format is 50-minutes lecture, followed by a 15-minutes break and another 50-minutes lecture. The summary of the lectures can be found in the "Course Syllabus and Timetable" section in the left-handside menu. You can also find the unfilled lecture notes in the "lecture notes" section. **Please bring those with you for lectures**, and we will complete them together. Filled version of the lecture notes will not be made available. If you miss a lecture, I recommend you ask a colleague for a photocopy of their notes.

TUTORIALS:

Tutorials are held on Tuesdays from 9:00 until 10:00 and Fridays from 11:00 until 12:00. Tutorial sheets can be found in the "tutorials" section on the left-hand side menu.

Tutorials are intended as support for any questions you might have on the course materials. To make the most of the tutorials, we recommend that you work on the tutorial sheets prior to the tutorials and that you come prepared with questions. Step-by-step solutions to the tutorial sheets will not released as announced in lectures.

LABORATORIES:

The lab is an opportunity to explore hands-on the use of FLUENT CFD software. The labs are composed of 2 x 2 hours in the IT centre. The general exercise consist of laminar and turbulent flow through an orifice. You are expected to submit a short report on the FLUENT exercise by the end of the module. The laboratory aspect of this course is administered by Dr Andrew Garrard (a.garrard@sheffield.ac.uk), please contact him directly for queries related to the labs.

For queries regarding the administration of this module, please contact (c.perrault@sheffield.ac.uk). For questions regarding the lab, please contact (a.garrard@sheffield.ac.uk)

Good luck!!

Course Topics

- 1. Fluids in Equilibrium
  - Revision of fluid statics
  - Forces on a fluid element
  - Fluids in linear acceleration
  - Fluids in rigid body rotation

Course Topics

- 2. Control Volume Analysis
  - Fluids in motion (CVs and systems)
  - Revision – continuity equition (MCE)
  - Revision – Force momentum equation (FME)
  - Torque angular momentum equation (TAME)
  - Steady flow energy equation (SFEE)
  - Differential forms of the fundamental laws

Course Topics

- 3. Internal Flow
  - Velocity profiles and flow rates
  - Laminar and turbulent flow (revision)
  - Flow in a circular pipe (Poiseuille)
  - Flow between parallel plates (Couette)
  - Flow between concentric cylinders

Course Topics

- 4. External Flow
  - The boundary layer
  - The momentum integral equations
  - Momentum and displacement thickness
  - Laminar and turbulent boundary layers on flat plates
  - Pressure gradient and separation
  - Drag coefficients

Course Topics

- 5. Compressible Flow
  - Revision of thermodynamics concepts
  - Isentropic flows and stagnation conditions
  - Sonic velocity, Mach number, critical conditions
  - Area variation in a duct
  - Choking in a converging nozzle
  - Normal shocks
  - Convergent-divergent nozzle

Week	Day/Date	Lecture Number	Lecture Topic	Tutorial Sheet Issued
1	Monday September 28th	1 2	Introduction and Syllabus 1. Fluids in Equilibrium	
2	Monday October 5th	3 4	Lab Lecture 1. Fluids in Equilibrium	1
3	Monday October 12th	5 6	2. Control Volume Analysis	2
4	Monday October 19th	7 8	2. Control Volume Analysis	
5	Monday October 26th	9 10	2. Control Volume Analysis 3. Internal Flow	3
6	Monday November 2nd	11 12	3. Internal Flow	
7	Monday November 9th	12 13	3. Internal Flow 4. External Flow and Drag	4
8	Monday November 16th	14 15	4. External Flow and Drag	
9	Monday November 23rd	16 17	4. External Flow and Drag 5. Compressible Flow	5
10	Monday November 30th	18 19	5. Compressible Flow	
11	Monday December 7th	20 21	5. Compressible Flow	
12	Monday December 14th	22 23	Revision class	
	Monday February 15th		UNIVERSITY EXAMINATION PERIOD	

Laboratory

Hands on use of FLUENT CFD software.
2 x 2 hours in IT centre.

Tutorial exercise
Laminar and turbulent flow through an orifice
Coursework short report on the FLUENT exercise.

Exam

- Final mark: 20% lab report – 80% final exam

- Final Exam:
  - Part A: 20 multiple choice questions, 2 marks each
    - 40 marks
  - Part B: 2 out of 3 questions, 30 marks each
    - 60 marks

- All lecture and laboratory material examinable.

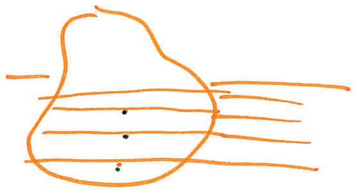
Fluid Mechanics from the 1st Year

From
Solids, Liquids & Gases
Thermofluids
Engineering Mechanics

1. Fluid Statics (pressure, forces on submerged bodies)

pressure : - compression

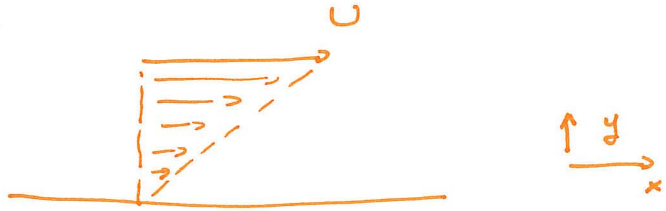
- only varies vertically
- independant of shape of container



2. Fluid Properties (Viscosity and Newton's Law of Viscosity)

viscosity $\underline{\mu}$: fluid resistance to flow

shear stress : $\tau = \underline{\mu} \dfrac{du}{dy}$

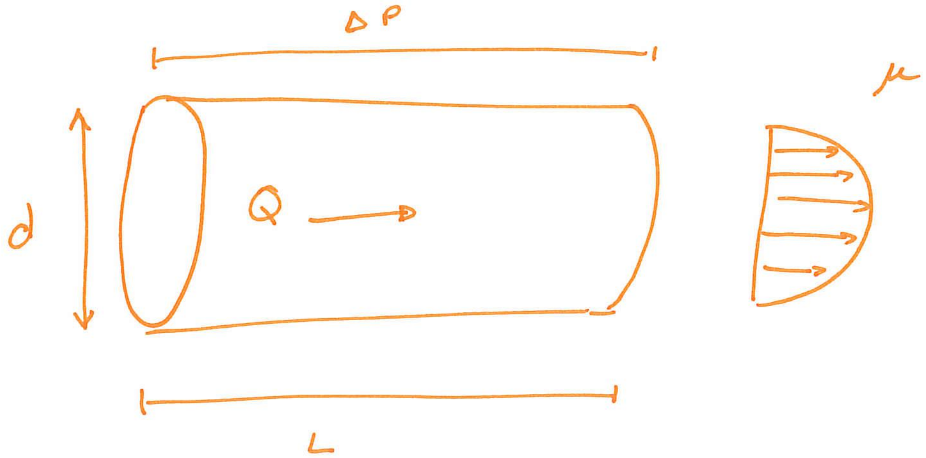


newtonian vs non-newtonian

stress increases linearly w/ strain

laminar vs. turbulent

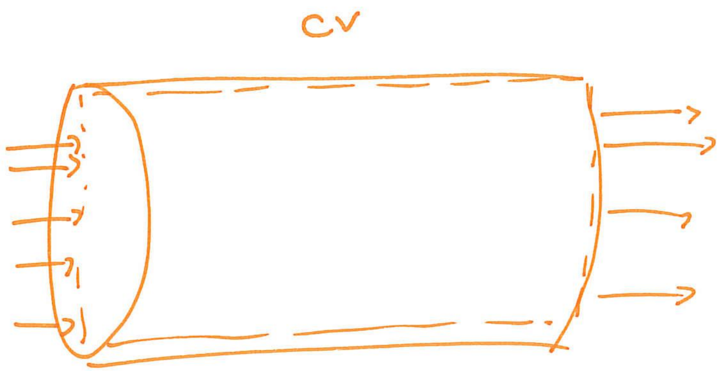
3. Simple Fluid Flow (pipe flow, drag)



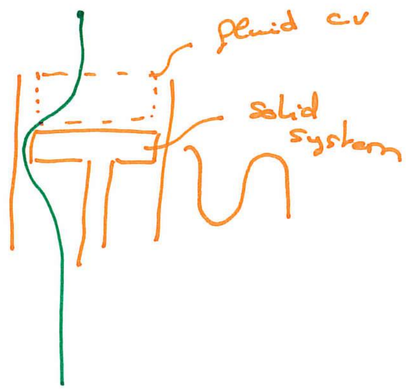
poiseuille equation

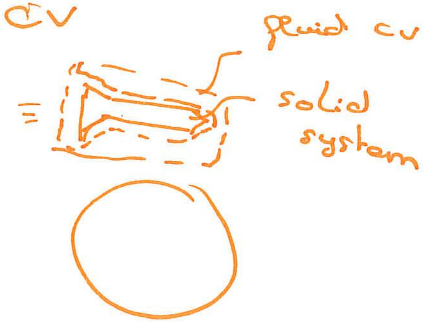
$$U = \frac{d^2 \Delta P}{32 \mu L}$$

4. Control Volumes (Conservation of mass)



system vs CV





https://www.youtube.com/watch?v=f2XQ97XHjVw

5. Bernoulli's Equation

Expresses relations between U, ΔP & h (elevation)

$$0 = \frac{1}{2}\rho\left(U_2^2 - U_1^2\right) + \rho g\left(z_2 - z_1\right) + \left(P_1 - P_2\right)$$

6. Force Momentum Equation

Newton 2nd law

a force is required to produce change of momentum and is proportional to rate of change of momentum

$$\Sigma F = \Sigma (\dot{m}\, U)_{out} - \Sigma (\dot{m}\, U)_{in}$$

7. Steady Flow Energy Equation

$$\cancel{\dot{Q} - \dot{W} = \dot{m}\left(\tfrac{1}{2}\left(v_2^2 - v_1^2\right) + g\left(z_2 - z_1\right)\right) +}$$

$$\left[\frac{\dot{Q} - \dot{W}}{\dot{m}} = \left(e_2 + \frac{p_2}{\rho_2} + \frac{u_2^2}{2} + g z_2\right) - \left(e_1 + \frac{p_1}{\rho_1} + \frac{u_1^2}{2} + g z_1\right)\right]$$

(eq 2.16)

$(e_1 - e_2)$: loss of useful energy

$\frac{e_2 - e_1}{g} = h_f$: head loss

8. Pipe Flow with Losses (turbulent)

in pipe:

losses can be :

- friction losses → Moody
- minor losses : can be a significant portion of head losses

due to secondary flow (curvature, recirculation, expansion)

Nomenclature

A	cross sectional area (usually perpendicular to direction of flow)
b	width of plate/slider
c_f	skin-friction coefficient
C_D	drag coefficient
E	internal energy of a system
e	internal energy per unit mass (i.e. specific internal energy)
F	force
F_x	force in x direction
H	enthalpy
h	enthalpy per unit mass (i.e. specific enthalpy)
h	thickness, distance between two plates/surfaces
h_f	head loss due to friction (in pipe flow)
L	load
l	length
m	mass
$\dot{M}$	momentum flow rate (i.e. momentum flux)
M	Mach Number
$\dot{O}$	angular momentum flow rate
p	pressure (static pressure)
p^*	piezometric pressure, $p^* = p + \rho g z$
Δp_l	pressure loss
$\dot{q}$	flow rate
Q	heat transfer (positive when added to the system/CV)
q	heat transfer per unit mass (i.e. specific heat transfer
r, R	radius
Re	Reynolds number = $\rho u d/\mu$
t	time
T	temperature
T	torque
u	velocity in x direction
v	velocity in y direction
w	velocity in z direction
W	work transfer (negative when added to the system/CV)
x	Cartesian co-ordinate
y	Cartesian co-ordinate
z	Cartesian co-ordinate, height above a datum
δ	thickness of a boundary layer
δ^*	displacement thickness of a boundary layer
ρ	density
τ	shear stress
μ	viscosity
ω	angular velocity
θ	angle
θ	momentum thickness of a boundary layer

$\cancel{C}$ U

Subscripts and Superscripts

0	stagnation conditions
c	critical conditions (i.e. sonic flow)
x	in the x-direction
1	referring to body/surface 1
atm	atmospheric
max	maximum value
av	average value
w	at a wall (e.g. τ_w)

Glossary of Terms (1)

1D Flow	the fluid flow over a particular cross section is all at one velocity (e.g. we sometimes assume all the fluid enters a pipe at the same velocity). The fluid properties only vary in the direction of flow (and not across the flow).
Absolute Pressure	the actual pressure (measured relative to a perfect vacuum).
Adiabatic	no heat transfer to or from the system or control volume.
Control Volume	a fixed region in space. Fluid may flow into and out of a control volume.
Dynamic Pressure	the quantity $\frac{1}{2}\rho u^2$ for a flow. If a fluid is brought to rest its pressure will increase by this amount (from Bernoulli's equation).
Fully Developed Flow	the velocity profile of the flow does not change in the direction of flow. (E.g. for fluid flowing in a pipe viscous effects will cause the fluid to slow down at the walls. The fluid may enter all at a similar velocity. At some location down the length of the pipe a steady state is achieved. The flow is then said to be fully developed.)
Gauge Pressure	the difference between absolute pressure and atmospheric pressure.
Head Loss	the energy a fluid possesses (by virtue of its velocity, height, pressure, and internal energy) can be expressed as an equivalent 'head' i.e. a height of a column of fluid. Sometimes we express the viscous fluid losses in a flow (e.g. down a pipe) in units of height (m). The head loss is then the reduction in the fluid head caused by these viscous losses.
Ideal Fluid	a fluid which has zero viscosity (and therefore no losses due to viscous interaction). An ideal gas is not necessarily a perfect gas.

Glossary of Terms (2)

Incompressible Fluid	a fluid where a change in the pressure or temperature doesn't cause a change in the density (i.e. a constant density fluid).
Internal Energy	the intrinsic energy a fluid possesses by virtue of the motion of its molecules.
Isothermal	no change in temperature of the system or control volume.
Isoviscous	the viscosity of the fluid is constant throughout the fluid flow.
Newtonian Fluid	a fluid which obeys Newton's Law of Viscosity (i.e. the applied shear stress is proportional to the velocity gradient). Implies that the fluid viscosity does not vary with shear rate.
Perfect Gas	a gas which obeys the gas laws (pV=mRT etc.). Not a perfect gas is not necessarily ideal.
Pressure Head	the group $p/\rho g$ (i.e. the pressure in a flow is visualised as if it consisted of a head of fluid, h where $p=h\rho g$). Has dimensions of length.
Piezometric Pressure	the quantity $p+\rho gz$.
Steady State Flow	the flow and fluid properties do not change with time i.e. velocity, temperature, and pressure at one particular point do not vary.
System	a fixed mass of either a solid of fluid or both. The system can move in space.
Stagnation Conditions	conditions (pressure, temperature, density) measured when the fluid is reduced to rest isentropically (either as a real or imaginary process).