Imperial College London

Peter B. Johnson
Keith Blackney

The lab is dead. Long live the lab!

Water flow loops: ‘One each’ in the lab – or at home.

Castagna (2021)

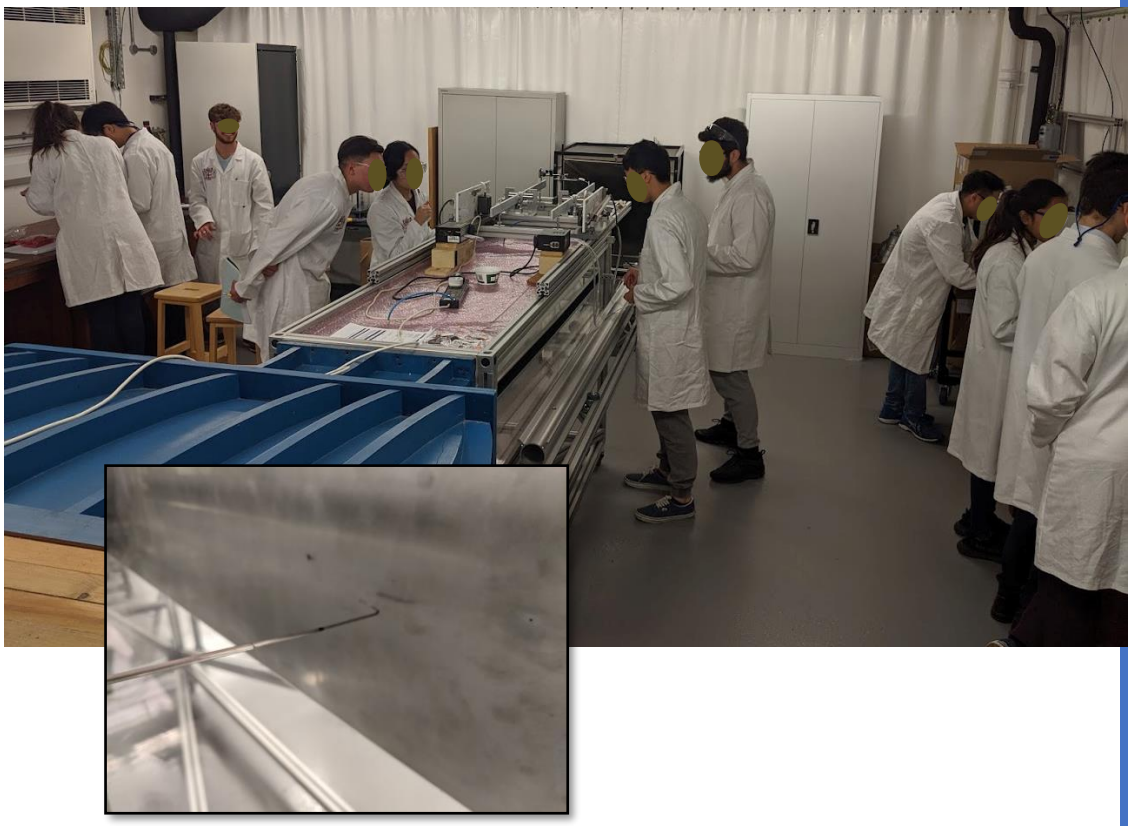
Talking Teaching
Wednesday 10th November 2021

https://www.youtube.com/watch?v=kWHt6j9-1Bo

General aims

"[This] cannot be taught by means of blackboard and chalk or even by experimental lectures and demonstrations alone; individual eyes and hands must be actually and persistently practised from the very earliest period"[1]

[but by] "placing students as far as possible in the attitude of the discoverer — methods which involve their finding out instead of being merely told about things."[2]



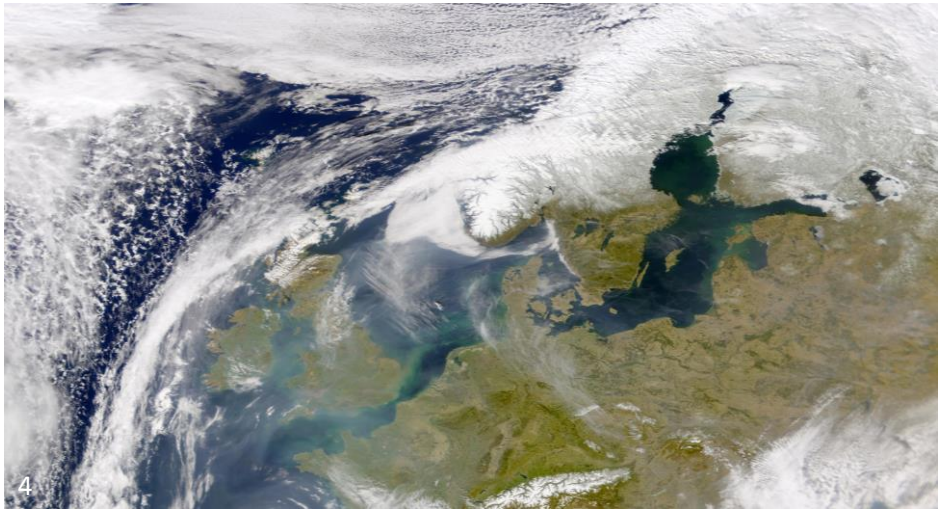
1. Armstrong (1910:9) URL
2. Armstrong (1910:236) URL

Boundary layers


1

2


3


4


5a


5b

1. Watkins URL. 2. Airbus (2019) URL. 3. Pathé (1940) URL. 4. Fugro URL . 5. Kirk (2010) URL

Specific aim

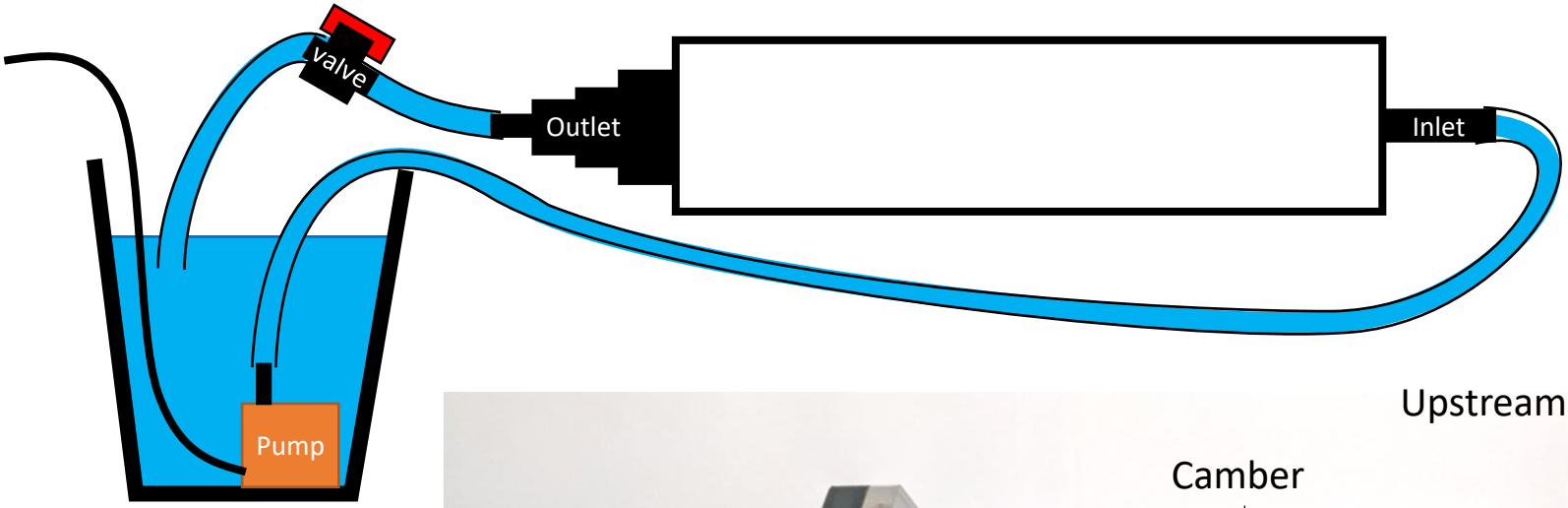
Finally, we need to characterise the relative thickness of the boundary layer, ε, for high Reynolds numbers. For this, we appeal to experiment and make the key observation that Prandtl identified and is evident from our own measurements[3]: *the boundary layer is thin*. Mathematically,

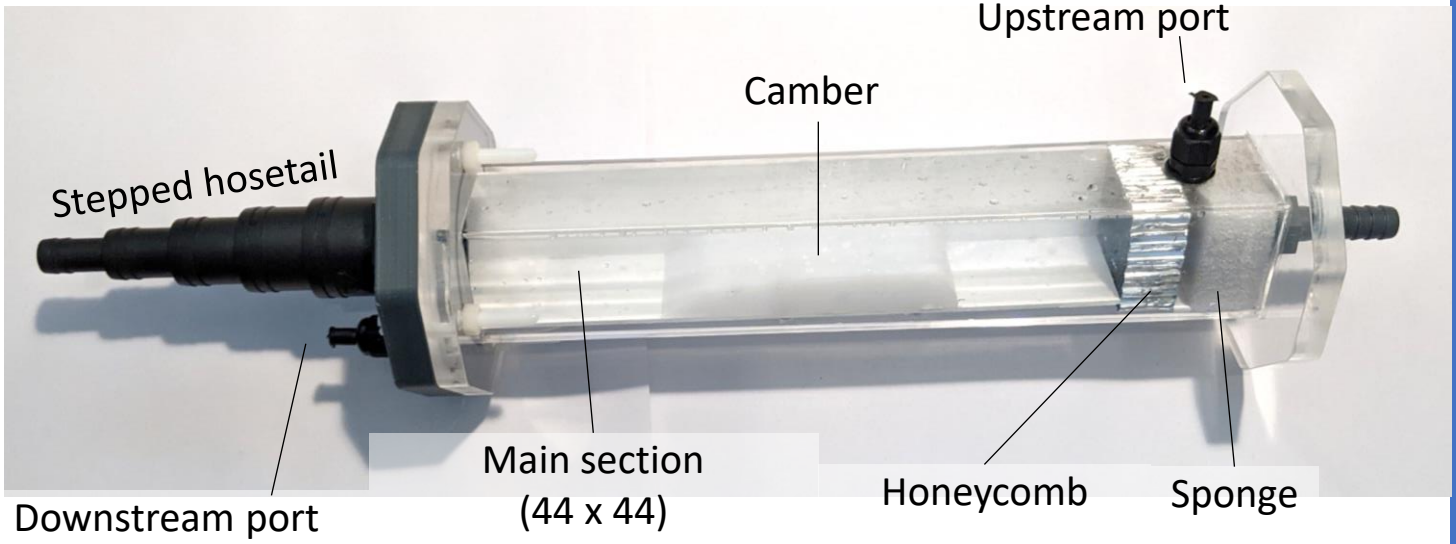
$$\varepsilon \equiv \frac{\delta}{L} \to 0. \tag{14.4}$$

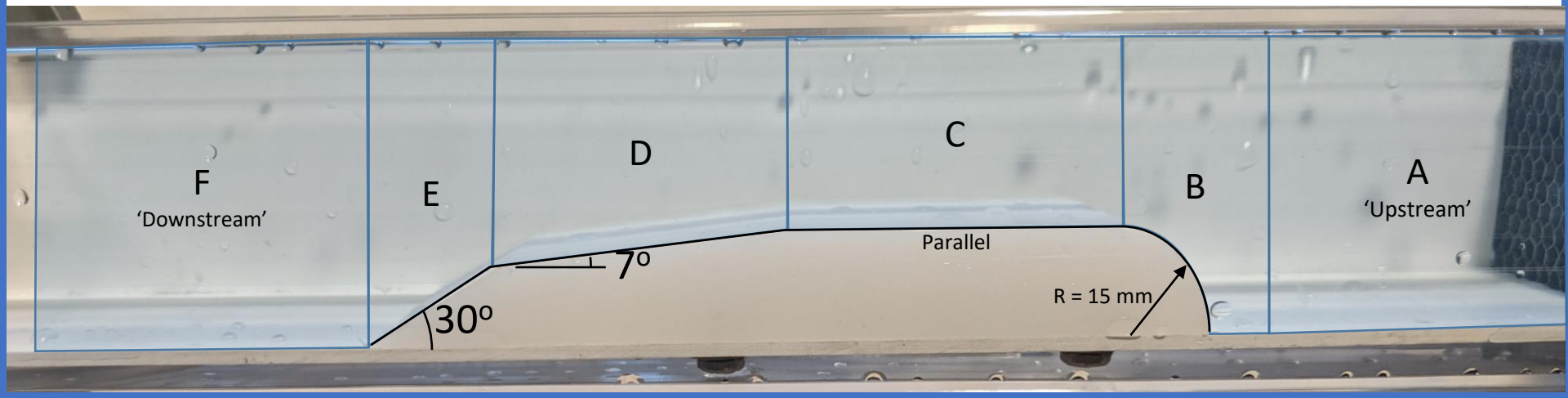
Recalling Equation (13.8) and using (14.2–14.4),

$$u^* \frac{\partial u^*}{\partial x^*} + v^* \frac{\partial u^*}{\partial y^*} = -\frac{\partial p^*}{\partial x^*} + \frac{1}{\mathrm{Re}} \frac{\partial^2 u^*}{\partial x^{*2}} + \frac{1}{\mathrm{Re}.\varepsilon^2} \frac{\partial^2 u^*}{\partial y^{*2}},$$

$$\underbrace{\mathcal{O}(1) + \mathcal{O}(1)}_{\text{Convective acceleration}} = \underbrace{\mathcal{O}(1)}_{\text{Pressure}} + \underbrace{\mathcal{O}\left(\mathrm{Re}^{-1}\right)}_{\text{"streamwise" diffusion}} + \underbrace{\mathcal{O}\left(\mathrm{Re}^{-1}\varepsilon^{-2}\right)}_{\text{transverse diffusion}}. \tag{14.5}$$


valve
Outlet
Inlet
Pump

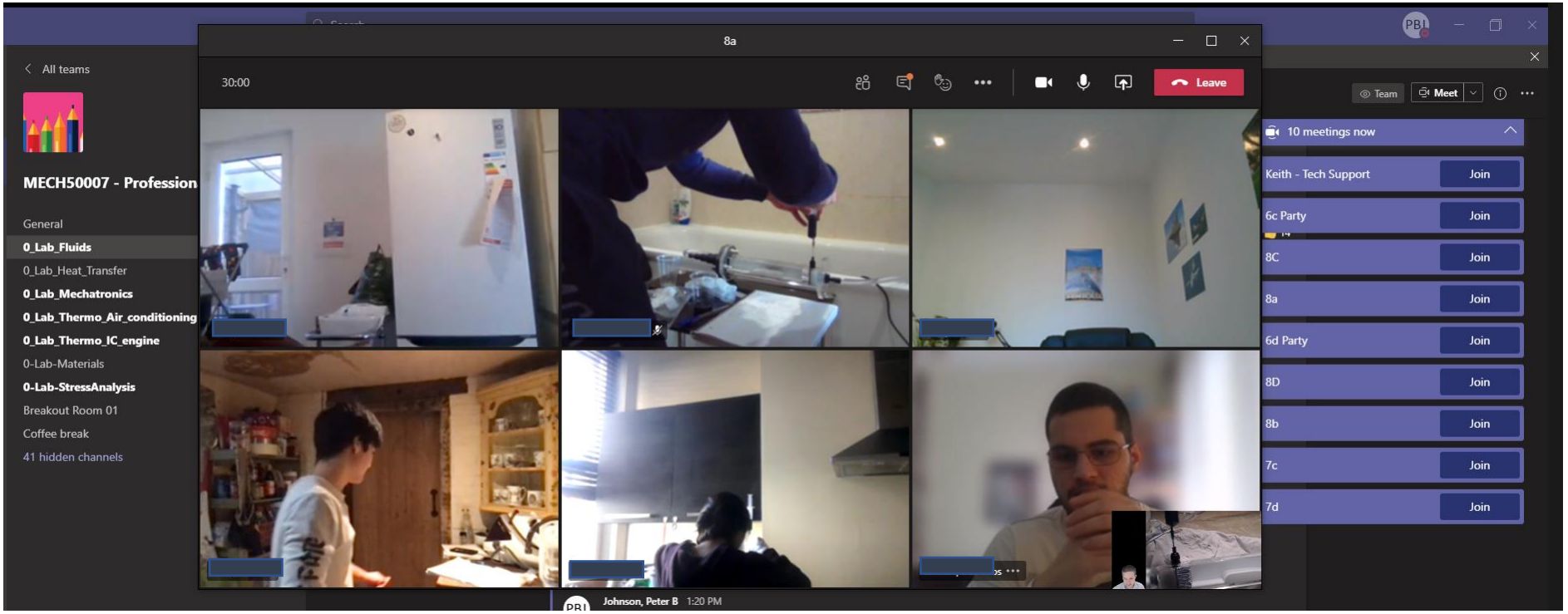

Upstream port
Camber
Stepped hosetail
Main section
(44 x 44)
Honeycomb
Sponge
Downstream port


F
'Downstream'
E
D
C
B
A
'Upstream'
Parallel
7°
30°
R = 15 mm

Demonstration (live)

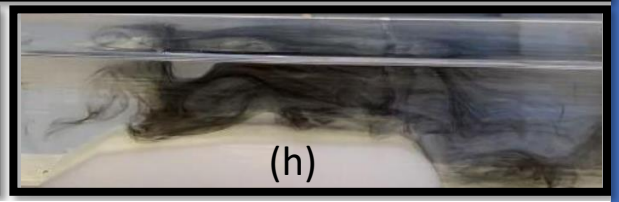
Production in quantity (200)


Leave (Ctrl+Shift+B)


All teams
MECH50007 - Profession
General
0_Lab_Fluids
0_Lab_Heat_Transfer
0_Lab_Mechatronics
0_Lab_Thermo_Air_conditioning
0_Lab_Thermo_IC_engine
0-Lab-Materials
0-Lab-StressAnalysis
Breakout Room 01
Coffee break
41 hidden channels
8a
30:00
Leave
Team
Meet
10 meetings now
Keith - Tech Support
Join
6c Party
Join
8C
Join
8a
Join
6d Party
Join
8D
Join
8b
Join
7c
Join
7d
Join
Johnson, Peter B 1:20 PM

Student work

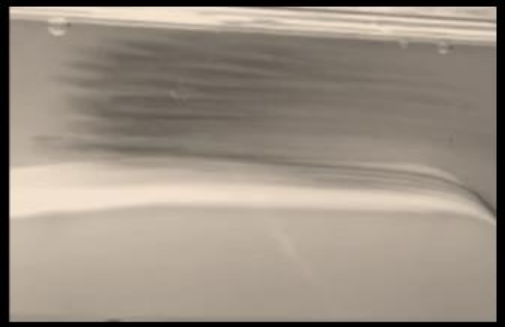
1: O. Quarks, 2: E. Tang , 3: G. Motta, 4: A. Castagna, 5. I. Ng,
6: J. Helsby. 7: J. Ibrahim SalahEldin Mohammd, 8. F. Rivieccio.



(a) Boundary layer behaviour visualised with ink injection[4]. (b), (c): Reynolds number effects[4].
(d) Separation at stagnation[5]. (e) Streamlines[6]. (f) Flow reversal[7]. (g) Jet[2]. (h) turbulence[8].

Use during ‘main’ lectures (online)

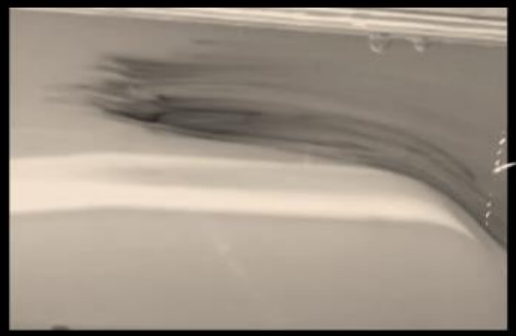
Faster flow ($\mathrm{Re} \gg 1$) - continuous

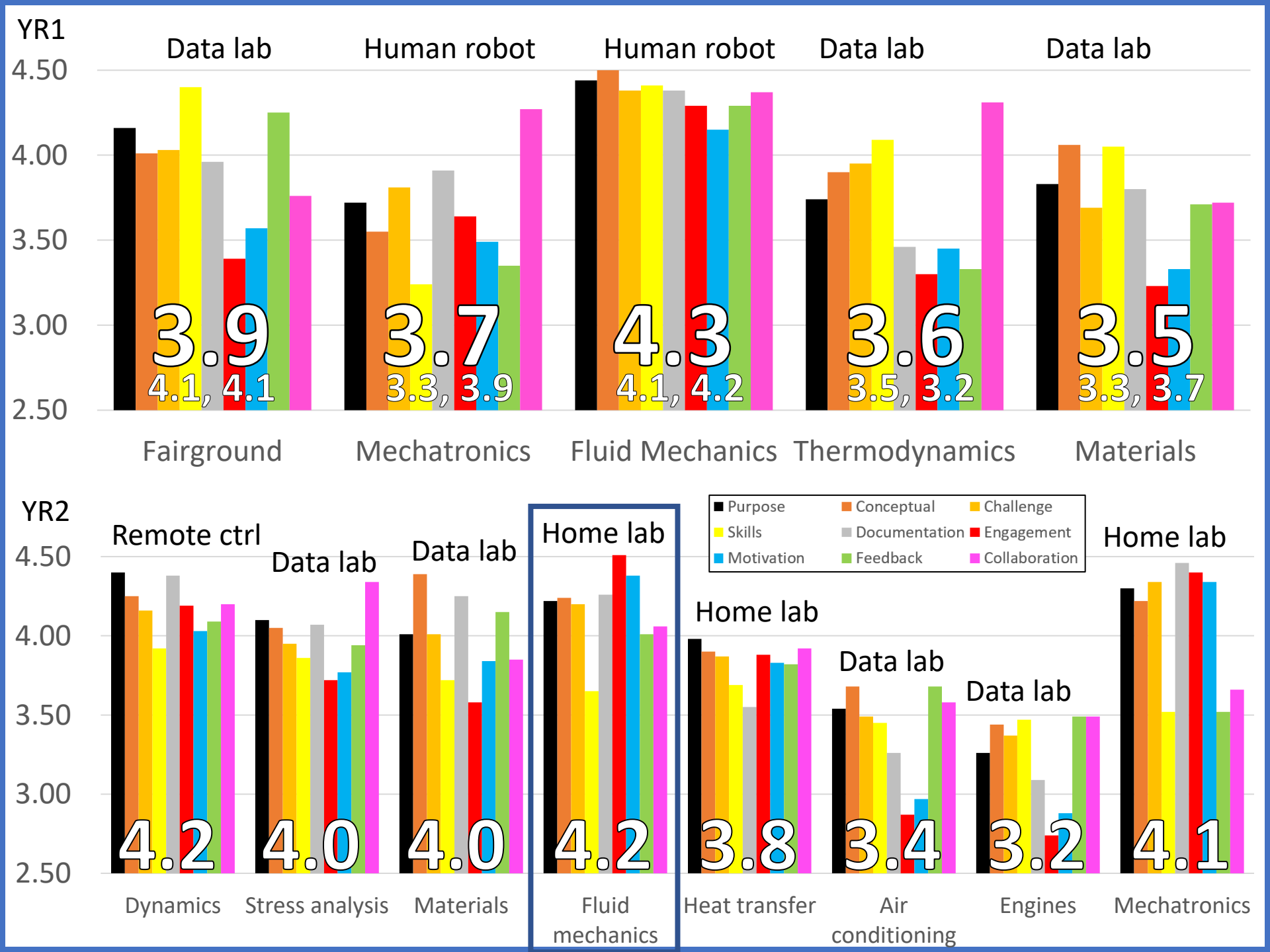


← Fast

Slow →

Viscous effects reduce at high Re.
Pressure scale $\mathrm{P} \equiv \rho U^2$




YR1
Data lab
Human robot
Human robot
Data lab
Data lab
4.50
4.00
3.50
3.00
2.50
3.9
4.1, 4.1
3.7
3.3, 3.9
4.3
4.1, 4.2
3.6
3.5, 3.2
3.5
3.3, 3.7
Fairground
Mechatronics
Fluid Mechanics
Thermodynamics
Materials
YR2
Purpose
Conceptual
Challenge
Skills
Documentation
Engagement
Motivation
Feedback
Collaboration
Remote ctrl
Data lab
Data lab
Home lab
Home lab
Data lab
Data lab
Home lab
4.2
4.0
4.0
4.2
3.8
3.4
3.2
4.1
Dynamics
Stress analysis
Materials
Fluid mechanics
Heat transfer
Air conditioning
Engines
Mechatronics

Evaluation

(Cherry-picked quotes from student survey)

"I liked the experiments where equipment was used personally, and we were split into tutorial groups because there was more discussion than when in larger groups"

"It was easy to understand and I particularly liked how well it was linked to our course."

"I am very grateful for the amount of effort that was put in to ensure the labs could still take place. The mechatronics and fluids lab were especially impressive."

"Fluids and mechatronics were adapted extremely well to remote."

"the fluids lab was really interesting and showed explicitly so many things we learnt in class."

"I really like how hands on the fluids lab"

Acknowledgements

R&D - Keith Blackney

CAD draftsman – Zhengli Lim

Packing – Zhengli Lim, Nour Sebbar, Diyah Babhania

Shipping – Mankela Lamaj

Health and Safety – Julia Easton

GTAs – Zhengli Lim, Mosayeb Shams, Efstratios Kritikos, Siyi Qiu

Strategy – Julie Varley

Teaching – Andrea Giusti

Production – Northern Cast Acrylics Ltd.

YouTube Video – Kang Wei

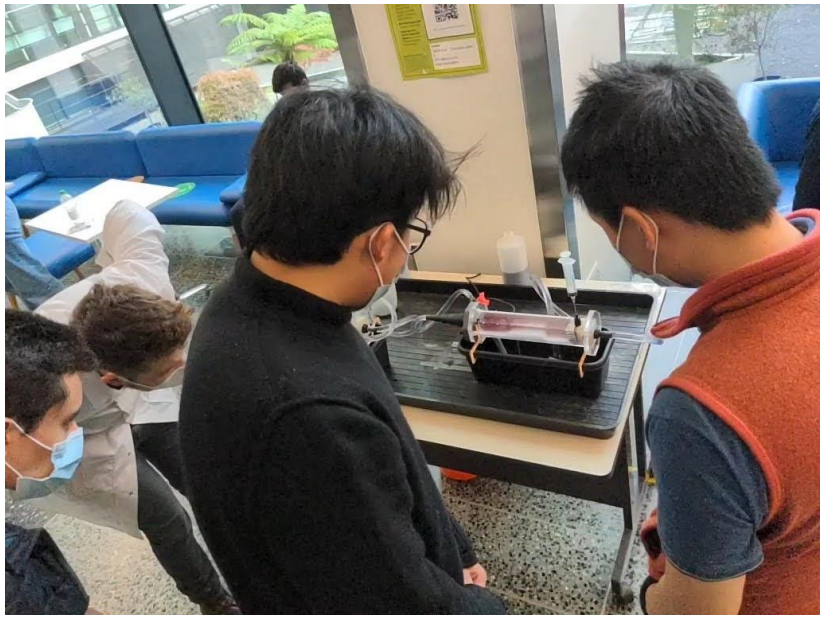
Mechatronics kits featured in video – Ferdinando Baena y Rodriquez, Shen Treratanakulchai, Carlos Sebastien Mancero Castillo

Live demo today – Harry Barnett

Students! – all of the 2020/21 ME2 cohort!

Reflections

"[This] cannot be taught … even by experimental lectures and demonstrations. Individual eyes and hands must be actually and persistently practised"



Take this equipment,
Get out of the lab,
Take it into the classroom
Have *one each*
Use it frequently