The University Of Sheffield.

MEC 208 Fluids Engineering

Exam Format & Revision

The University Of Sheffield.

Fluids Engineering Exam 21st of January -9-11:30 am in Octagon Centre !

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Fluids Engineering Exam

- Part A – 40 marks out of 80
  - Multiple choice
  - 20 questions (one correct answer, wrong answers are -1 mark)
  - 2 marks each
    - one correct answer
    - wrong answers are -1 mark
- Part B – 40 marks out of 80
  - 2 questions
  - 20 marks each

Past papers

- Available on Mole
- Numerical answers available – at the end of the paper
- Worked solutions NOT available
- Three years ago format changed (so early papers slightly different)

FAQ's

- Part A questions are similar in style to MOLE quizzes
- Everything I taught you is examinable (EXCEPT NAVIER-STOKES)
- Most data and equations are in the LBOTF

Where to Get Help

- All filled lecture notes are now on Mole
- I won't be answering questions by email during the Christmas break
- Vacation Week 4 (11^{th} January): all week in office (PLB C+09)

1. Fluids in Equilibrium

Pressure variation within a stationary fluid $\frac{\partial p}{\partial z} = -\rho g$ $\quad p + \rho g z = \text{constant}$

Fluids in Uniform Linear Acceleration $\frac{\partial p}{\partial x} = -\rho a_x$ $\quad \frac{\partial p}{\partial y} = -\rho a_y$ $\quad \frac{\partial p}{\partial z} = -\rho\left(g + a_z\right)$

Fluids in Rigid Body Rotation $\frac{\partial p}{\partial r} = \rho r \omega^2$ $\frac{\partial p}{\partial z} = -\rho g$ $\frac{\partial p}{\partial \theta} = 0$

Total differential

$$\mathrm{d}\,p = \frac{\partial p}{\partial x}\mathrm{d}\,x + \frac{\partial p}{\partial y}\mathrm{d}\,y + \frac{\partial p}{\partial z}\mathrm{d}\,z$$

Lines of constant pressure (i.e. free surface of the fluid) are given by dp=0

2. Control Volume Analysis

Draw a CV so that the boundary crosses regions where you either know the properties or you want to know them.

The Mass Conservation Equation, MCE $\sum \dot{m}_{in} = \sum \dot{m}_{out}$

1D flow $\dot{m} = \rho_{in} A_{in} u_{in} = \rho_{out} A_{out} u_{out}$

The Force Momentum Equation, FME $\sum F_x = \left(\sum \dot{M}_{out} - \sum \dot{M}_{in}\right)_x$

steady 1D incompressible flow $\sum F_x = \dot{m}\left(u_{out} - u_{in}\right)_x$ in LBT

The Torque Angular Momentum Equation, TAME $\sum T_A = \left(\sum \dot{O}_{out} - \sum \dot{O}_{in}\right)_A$ in LBT

Steady 1D incompressible flow $\sum T_A = \dot{m}\left(r_2 u_2 - r_1 u_1\right)$ in LBT

The Steady Flow Energy Equation $\dfrac{\dot{Q} - \dot{W}}{\dot{m}} = \left(e_2 + \dfrac{p_2}{\rho_2} + \dfrac{u_2^2}{2} + g z_2\right) - \left(e_1 + \dfrac{p_1}{\rho_1} + \dfrac{u_1^2}{2} + g z_1\right)$

WRONG in LBT, provided at exam

3. Laminar Flow

For laminar flow $\dot{M}_{out} \approx \dot{M}_{in}$ so $\sum F \approx 0$

Basic concepts $\mathrm{Re} = \dfrac{\rho u d}{\mu}$: Axisymmetric flow $\dot{q} = \int_0^R u 2\pi r dr$: 2D flow $\dot{q} = \int_{-L/2}^{L/2} u B dy$

in LBT

Poiseuille's equation $\dot{q} = -\dfrac{\pi R^4}{8\mu}\dfrac{\mathrm{d}p}{\mathrm{d}x}$ and $\dfrac{\dot{q}}{b} = -\dfrac{h^3}{12\mu}\dfrac{\mathrm{d}p}{\mathrm{d}x}$ in LBT, but ....

Head loss and pressure loss $\Delta p_L = h_f \rho g$

1. draw a fluid element
2. balance the forces (pressure and shear stress)
3. substitute $\tau = \mu \dfrac{\partial u}{\partial y}$
4. integrate to get velocity profile u=f(y)
5. apply boundary conditions.

4. External Flow

The *displacement thickness* and *momentum thickness* - 'missing' layers of fluid in LBT

The *boundary layer equation* describes the variation of p and u within a boundary layer

The *skin-friction coefficient,* c_f and *drag coefficient,* C_D - convenient ways of ~~wiritng~~ writing wall shear stress and drag force;

$$c_f \equiv \frac{2\tau_w}{\rho U^2} \qquad C_D \equiv \frac{D}{\frac{1}{2}\rho U^2 bL}$$

in LBT

Boundary layer on a flat plate (zero pressure gradient):

Laminar $\frac{\delta}{x} = \frac{5}{\mathrm{Re}_x^{1/2}} \qquad c_f = \frac{0.664}{\mathrm{Re}_x^{1/2}} \qquad C_D = \frac{1.328}{\mathrm{Re}_L^{1/2}}$

Turbulent $\frac{\delta}{x} \approx \frac{0.16}{\mathrm{Re}_x^{1/7}} \qquad c_f \approx \frac{0.027}{\mathrm{Re}_x^{1/7}} \qquad C_D \approx \frac{0.031}{\mathrm{Re}_L^{1/7}}$

Separation and drag on 2D and 3D bodies - qualitative description.

Empirical data for the drag coefficient for various shaped bodies $C_D = \frac{D}{\frac{1}{2}\rho U^2 A}$

Nusselt and Prand ... hL

Thermal boundary laye ...

Flow over a flat plate the relati ...

Laminar: $\mathrm{Nu}_x = \dfrac{h_x x}{k} = 0$ ... $^{0.5}\,\mathrm{Pr}^{1/3}$ when $\mathrm{Re}<5\mathrm{x}10^5$

Turbulent: $\mathrm{Nu}_x =$ ... $^{1/3}$ Nu_L ... $^{1/3}$ $0.6<\mathrm{Pr}<60$ & $5\mathrm{x}10^5<\mathrm{Re}<10$

5. Compressible Flow

$$h = e + \frac{p}{\rho} \qquad de = c_v dT \quad \& \quad dh = c_p dT \qquad \gamma = \frac{c_p}{c_v} \qquad \& \qquad R = c_p - c_v$$

Isentropic process $$\frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{\rho_1}{\rho_2}\right)^{\gamma-1}$$

Stagnation conditions h_0, T_0, p_0 and ρ_0 represent the pressure and density which would be achieved if flow were brought isentropically to rest.

$$h_0 = h + \frac{u^2}{2} \qquad \frac{T_0}{T} = 1 + \frac{u^2}{2c_p T} \qquad \frac{p_0}{p} = \left(1 + \frac{u^2}{2c_p T}\right)^{\frac{\gamma}{\gamma-1}} \qquad \frac{\rho_0}{\rho} = \left(1 + \frac{u^2}{2c_p T}\right)^{\frac{1}{\gamma-1}}$$

If a process from 1 to 2 is *isentropic* $h_{01} = h_{02}$, $T_{01} = T_{02}$, $\rho_{01} = \rho_{02}$, $p_{01} = p_{02}$.

The Mach Number, $M = \dfrac{u}{a}$ Velocity of sound $a = \sqrt{\gamma RT}$

in LBT in LBT in LBT

$$\frac{T_0}{T} = 1 + \left(\frac{\gamma - 1}{2}\right) M^2 \qquad \frac{p_0}{p} = \left[1 + \left(\frac{\gamma - 1}{2}\right) M^2\right]^{\frac{\gamma}{\gamma - 1}} \qquad \frac{\rho_0}{\rho} = \left[1 + \left(\frac{\gamma - 1}{2}\right) M^2\right]^{\frac{1}{\gamma - 1}}$$

Critical Conditions, the fluid properties when the flow is sonic (i.e. M=1)

Subsonic gas accelerates through converging duct & decelerates through diverging duct.

Supersonic gas accelerates through diverging duct & decelerates through converging duct.

Choking - flow is sonic at the throat of the nozzle; M_t=1, then $\dot{m}_{\max} = \rho_c a_c A_t$

Shock wave – sudden reduction in velocity and increase in static pressure. Use shock tables to determine properties before and after shock


That's all Folks!