

MAE 222
Final Exam Study Hints

Spring Term, 1996

1. The final exam is 3 hours, and will consist of partly open book, and partly closed book exam. Bring your calculator. It will cover chapters 1,2, 3, 4, 5 (covered once in the first mid-term), and chapters 7, 8, 9 and 10 (covered once in the second mid-term), and new materials in chapters 5 and 6 (fluid rotation, vorticity, velocity potentials, etc.).

2. Look at the answer sheets for the first and second mid-terms. They are on the web.

Control volume is a big deal. Archimedes Principle is a big deal. Flux is a big deal. Moment on hinged gates in hydrostatics problems is a big deal. Bernoulli's equation is a big deal (when can it be used?). Momentum balance equation for a control volume is a big deal.

3. On dimensional analysis: The goals here are to find (1) how many dimensionless parameters there are, and (2) what these dimensionless parameters may be. To answer the first question, you need the Buckingham Pi's theorem, and you need to get that matrix, and find out the rank of that matrix. A quick and dirty answer is that the number of parameters is equal to (or less than) the total number of dimensional parameters minus the number of independent primary dimensions involved in the problem. Going thru the whole matrix exercise is just to pin down this precise number of parameters. To answer the second question, you must realize that the answer is not unique. Use the procedure recommended by Fox/McDonald in §7.3, or any other methods you can dream up. Just make sure that the dimensionless parameters you come up with are *independent* ones.

4. You must know why dimensional analysis is important and useful. If you don't, ask me in the review session.

5. You must know how to find head loss of duct flows. You must know that duct flows below certain value of Reynolds number is laminar, and for higher Reynolds number it is turbulent. And surface finish matters in the turbulent regime.

6. You should know how to show that the thickness of a boundary layer on a large Reynolds number flow is very thin (how thin for a laminar boundary layer?). You should know the definitions of displacement and momentum thicknesses.

7. You should know what the *boundary layer approximations* are: the pressure variation normal to the boundary layer is negligible, the boundary layer itself looks flat, and the viscous stress can be represented by the viscous *shearing* stress suggested by Newton alone.

8. You should know where the *momentum integral equation* comes from (§9.4), and what uses it is good for, and what ideas are needed to make it useful (§9-5.2).

9. You must understand the concept of a small disturbance speed \sqrt{gh} , and Froude number. Remember, if a flow is subcritical upstream, and is supercritical

downstream, somewhere inbetween its must have gone through critical (remember the gravy ladle problem?)

10. On open channel flows, study the supplementary notes in assignment #10. The following relations will be given to you if needed:

$$Q = \sqrt{g} b(x) (y_o - h(x))^{3/2} D(F_r)$$

where F_r is Froude Number, and $D(F_r)$ is defined by:

$$D(F_r) = \frac{F_r}{1 + \frac{1}{2} F_r^2}.$$

You should know how to use this relation, assuming that a table or a graph of $D(F_r)$ is available to you. What happens to the Froude number of an open channel flow when the side wall and the channel bottom “squeezes” the flow?

11. You should know what a hydraulic jump is. Remember, a hydraulic jump is possible only if the incoming flow (in the frame where the hydraulic jump is stationary) is supercritical. Remember, the Bernoulli’s equation does not hold across a hydraulic jump; in fact, the Bernoulli’s constant drops. Remember, the free surface depth ratio across the hydraulic jump is a function of the upstream Froude number alone (see eq.(10.55)). You don’t need to memorize this relation. But you need to be able to find it quick.
12. You may be asked to show the momentum balance across a hydraulic jump. You may be asked to translate this English sentence into mathematics: “The net external hydrostatic pressure forces acting in the x-direction of a control volume enclosing a hydraulic jump equals to the net out-flux of x-momentum from the control volume.” This was done in class and in §10-7.2.
13. What is vorticity? (it is twice the average angular velocity of two mutually perpendicular lines in the fluid). How can it be computed from the velocity field \mathbf{V} ? (it is the curl of \mathbf{V}).
14. Under what conditions can we conclude that a flow is without vorticity (an irrotational flow)? If a fluid element once upon a time had no vorticity (such as the fluid elements far upstream of a uniform flow over an obstacle), and the fluid density is constant, and the Reynolds number is very large so that frictional effects are negligible (outside of boundary layers), then that fluid element will remain to have no vorticity.
15. What can we do when we conclude that a flow of interest is irrotational? (we can define a velocity potential so that $\mathbf{V} = \text{grad } \phi$). For constant density flows, the equation satisfied by ϕ is the Laplacian: $\nabla^2 \phi = 0$, which is a *linear* equation!!!! We learned how to superpose elementary solutions to emulate flows of interest. You should know how to use source, sink, doublet, ... and line vortex. You should know how to find pressure at any point of a flow field if the velocity potential $\phi(x,y,z)$ is known.

16. You must understand why subsonic airfoils all have sharp trailing edge, and round and smooth leading edge. You should know the role played by the Kutta condition in the theory of irrotational flows.
17. You should know the limitations of what you have learned in irrotational flows as far as drag is concerned, and the role of vorticity wake in the theory of drag. It would be fair to ask you: What is the D'Alembert's paradox?

You are expected to know certain formula by heart in the closed book part of the test. For example: the Bernoulli's equation, the continuity equation in cartesian coordinates, the Laplace equation in cartesian coordinates, the gradient of a scalar in cartesian coordinates, etc. (but not the hydraulic jump formula, etc.).