

A DIABOLICAL BEAST SENT FROM HELL TO TORMENT YOu.

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Due 6/10 1:00 Pm

Portland State University

Hell Itself Inc.

There are 3 types of problems in this exam which will be graded according to the points given. I’ve ranked them from hardest to easiest in my mind.

# False Statements [5 pts]

1 = Identify False Statement

1 = Describe why it is wrong mathematically

1 = Draw a figure, graph, or picture showing why it’s wrong

1 = Show that if it *were* true a contradiction to physics would result. Conservation equations baby.

1 = Think of a something we don’t see in nature that proves it’s not true.

# Math [4 pts]

1 = Correct Expression

1 = Words describing *difficult* algebraic steps (I don’t need you to tell me how to add 2 numbers)

1 = Words describing implications of some of the algebra to physical nature, this is really fun.

1 = Implications of solutions expression (140 char max). Compare to known solutions an ponder.

# Explain [3 pts]

1 = Under 600 Characters (or about 3 tweets)

1 = An equation

1 = A diagram (yes even for 1 and 2)

# Submission Guidelines

## *Header*

Please submit in a pdf form. I am okay if you turn in handwritten sentences if you wish to complete it all on a tablet. If you want to use engineering paper and scan them please follow this format for the header sections. Please keep a page count only for a problem. Come up with a short title of the problem you are solving.

[PROBLEM #]– [NAME] – [TITLE THE PROBLEM] – [PROBLEM TYPE]-[pages] 

Example, say I take **4** pages to complete problem **3** in this exam. I would fill in the top as

[3.a] – [Samuel Mohler] – [Streamfunctions] – [Derivation] – [1/4].

If you are working on a tablet or entirely on Word, LaTeX, anything I would like the same format of header for each problem as well. Some problems have no subproblems so there is no need to for the .x format. Keep the page count the refence the whole problem *not* subproblems. So in this example I’m say it took me 4 pages to solve 3.a, 3.b, etc.

## Cover Page

Provide a summary page of the problems you decided to do with a point tally. You’re turning in your own grading sheet for this. I just need you to turn in a cover sheet with your name, class and term, and a table like so. Add rows to this format…

|  |  |  |  |
| --- | --- | --- | --- |
| Problem Title | # | Type | Points |
| Streamfunction | 3 | Math |  |

## My Grading Equation

I have 4 numbers I will not share with you {**} which you don’t know. Say you attempt *n* problems and get a total of *N* points and attempt *nf* false statement questions and get *N*F points. You will see what false statement questions next page. I also have a secret minimum number of questions *M* you have to attempt to achieve at least an *A.* Now for all you grade junkies out there, try to optimize this with some variables you test it out with, you’ll maybe even see what numbers I’m using. Honestly that would be a gigantic waste of time and you should just do what you can in the exam

## Why I’m Doing This To You

Look this is a take home exam with tons of time given to you well in advanced. There is literally no way for me to prevent everyone even grouping to together in secret clubs trying to tackle this exam. I can’t even stop you from emailing each other solutions on some other communication channel, don’t do it on slack though! I am doing this because I want to see after all the home works and all the hours you have put into the projects which of these problems you feel you can attempt. I am not telling you my min required problems because I don’t think any student should stop automatically stop just because they reached a certain number of problems. **I’m trying to get you to really test your own abilities.**

We have also been living in the very grey fuzzy area of applied this whole class. This is because there are very few truths out there that apply to all problems. Even worse numbers are almost meaningless because most of the time you can’t trust the measurement device, you can’t trust the person that preformed the experiment, and you can even trust the data was entered correctly. All that really matters are the trends equations tell you. All that matter is a firm grasp on the fundamental first principles reasonings. All that matters are the intuition on how these types of problems are gone shake out to after a project level time scale of excel bean counting. I want you to be able to confidently argue the few truths we can hold on to out in the engineering world. The math derivation problems in this exam are to help you see it all the same stuff, plus I imagine there are some math nerds out there (#myteam #fistbump) so I threw them a bone.

Please try your best and **definitely do not attempt all the problems**. Trust me that I’m not trying to humiliate you or be unfair, I have a **very** reasonable minimum required problem count. I am giving you a free personal fluids workout gym where all the machines are available for you to choose from. The question is how buff and swoll you trying to get.

If you want my opinion on grade you can read this NASA intern blog I was asked to write that goes over my thoughts on them.

<https://blogs.nasa.gov/interns/2018/02/08/samuel-mohler/>

I will probably get fired after this class, because I think I’ve broken several conduct codes with how I organized this class with slack, github, almost no defined rubrics, “fight-club”, etc. That being said, I am **enormously** proud of all your hard work and already I would put my lowest grade students against some of the top students that have come out of 322 for the past 8 years. That how long I’ve been here… You have all proven to be much more than simple calculators that sometimes classes produce.

Let’s play help the professor out! I very stupidly made a mistake and asked **5 questions** that have false statements in them. I wrote so many darn questions, and my brain is drained from writing so many notes, I forget which questions they were. If you come across one make sure you correct me and teach me a lesson! Your corrections should use math, physics, and diagrams to put me in my place. I also put in blue my personal favorite questions. They are not hidden clues or mean anything accept me just sharing with you the “machines” I use at the fluid gym.

1. How many independent variables are involved in the Navier Stokes Equations.
2. How many dependent variables are involved in the Navier Stokes Equations, write them as functions of the independent variables
3. Consider the stream function and determine the following

* 1. &
  2. Is it irrotational?
  3. Plot streamlines on the domain and
  4. What is the flowrate passing through the positive *x* axis with length *l*.

1. In reality fluids always has some positive value of viscosity **, but the Euler’s Equations of Motion are a simplification of the Navier-Stokes equation claiming **Give two physical assumptions that could simplify the Navier-Stokes equation to Euler’s Equation of Motion. Use scaling methods in your arguments.
2. Express the Reynolds number in terms of mass flowrate.
   1. Explain why chemical engineers would usually use *this* definition for analysis to compare with experiments
3. Why does the diverge to infinity as , this is where a pipe meets a reservoir in the entrance region?
4. Explain why Turbulent flows have larger entrance lengths?
5. In a *hot wire anemometer* test the readings from your experiment have the following results.
6. What does this say about the velocity of the fluid?
7. Is it reasonable to say this is Turbulent Flow? Think hard about that.
8. Describe 3 processes used to measure velocity for internal flow situations and describe them mathematically, physically, and provide reasons we believe the reading on a screen.
9. Describe the entrance region using the concept of a boundary layer in the inside of the pipe wall
   1. Rationalize why the equation for the entrance length should involve Re.
10. Describe the assumption of Fully Developed Flow.
    1. Mathematically
    2. Physically
11. What is one fundamental law true for Laminar and Turbulent internal flows.
    1. For the turbulent case are any of the variables averages or fluctuations. Think hard about this…
12. Consider the model turbulent velocity profile,
    1. Determine the average velocity .
    2. Determine the flowrate *Q*
13. In a single straight pipe, you have used a hot wire anemometer to measure two data points of velocity and For your measurement positions You’ve measured the diameter *D* and know the fluid in the pipe **You know the flow is turbulent and wish to model it with the power-law provided with a known .
    1. Which is larger or ?
    2. If possible analytically determine { , }, if not describe how could approximately
    3. Determine , pretending you know b.) and c.)
    4. Why is this stupid?
14. The Darcy Friction factor allows engineers to calculate the *viscous* losses of fluids in pipes. However, it is used as a term in the energy equation which is only valid for *inviscid* fluids.
    1. Draw a simple figure showing what variable solves this paradox.
    2. Where does viscosity show up in this variable
    3. Explain why then internal flow analysis of a single straight pipe was necessary.
15. Estimate the *kinematic* viscosity of air by considering the *stoke* unit St. You can not look up the value but must calculate it using other experimental values of air which have dimensions. Think about molecules…
16. Non-Newtonian Fluids have a non-constant viscosity. They can be modeled with a functional relationship involving shear

The simplest functional form could just be a linear relationship .

1. Find *u*(*r*).
2. Determine
3. Determine *Q*
4. Determine the average velocity .
5. Reference a Moody Chart and come up with an *average* friction factor that will work suitably well for estimating all problems in your career from now on. You would want an average that ignores smaller values but keeps the large values. Let ***D =* 0.001.
   1. Calculate the Root Mean Square of the Laminar Regime from 0 < Re < 2000.
   2. Calculate the Root Mean Square of the Turbulent Regime form 2000 < Re < 10,000
6. Your company has a new valve component for automobile engine system where *component losses* can become *significant* and you’ve promised your client significant improvement. You have completed the following experiment as a final benchmark for the product. As the project manager these results are slapped down on your desk from the unit testing division. Using intuition alone,
7. What value comes from this graph?
8. Without even a reference to the old product, why will you have to delay the product launch date?
9. What should be your first request to the unit testing division about this experiment
10. Given the head loss equation
    1. Expand *h*loss
    2. How many different problems can be solved using only a)?
    3. Expand *h*pump
    4. How many different problems can be solved using only c)?
11. For a non-circular rectangular duct with *w* = 3 cm, *h* = 2 cm, Re = 1000. Calculate the friction factor *f*.
12. Prove or disprove mathematically that for turbulent flow in a pipe.
    1. The friction factor *f* monotonically decreases with respect to Re
    2. The friction factor *f* monotonically increases with respect to **/*D*
13. For a given engine oil pump system problem you have manually measured pressures along the system and developed the following graph. The design for combustion requires a large positive pressure at the end state.
    1. Which section should be redesigned?
    2. Describe a simple design?
    3. Which section should more measurement be made?
14. For a multiple pipe in series with *N* pipe sections, which problem has an infinite number of solutions, select all that apply.
    1. Determine *N* pipe diameters, given all *L*, **, *h*loss, and *Q*.
    2. Determine *N* – 1 pipe diameters, given all *L*, **, *h*loss, and *Q*.
    3. Determine ** of a single pipe, given all *L*, *N*-1 values of **, *h*loss, and *Q*
    4. Determine the *Q* in every pipe, given all *L, D, * and *h*loss
    5. Determine the *L* of the *N* pipes, given all *Q, D,* and *h*loss
15. For *laminar* flow in a single straight pipe calculate how “*sensitive*” head loss is with respect to flowrate *Q*. Not as simple as it seems…
16. Approximately how tall is the boundary layer for an airplane wing?
17. Why does a sphere fall slower than a teardrop shaped object in a highly viscous fluid?
18. In boundary layer analysis the height of the boundary layer ** for a thin flat plate is proportional to Re-1/2, where exactly do the multiple proportionality constants come from?
19. What are the fundamental assumptions that are required to justify Boundary Layer Analysis. Provide two simple scale relationships.
20. Explain how the Momentum Thickness helps plot streamlines around a body.
21. Rationalize *why* there are losses for pipe bend components using the Boundary Layer.
22. Everything in this class is essentially useless when it comes to simply modeling the blood flowing in and out of your aortas and veins close to your heart. Why?
23. Wikipedia the analytical solution for the non-circular pipe flow. Explain the similarities between our simple laminar circular pipe flow solution.
24. Using the tools of this class describe a simple discrete process that you could limit to give an approximate friction factor *f* value for a straight pipe but variable cross section area. Essentially the maximum radius *R* would change as a function of the axial distance *z.* You would be surprised how close this gets you to a full CFD simulation. I’m talking 20%.
25. The boundary layer velocity profile is modeled with the profile given, define ,
26. Determine shear at the wall *w*(**
27. Determine the displacement thickness ****
28. Calculate a) and b) if ** = 5mm
29. Why is the no-slip condition *u*(0) = 0, violated in Boundary Layer Separation?
30. For an actual pump performance curve explain why “other losses” are the reason for almost all deviations from the ideal pump performance curve at low flowrates.
31. Explain on a pump performance curve why,
    1. *h* is maximum at *Q* = 0
    2. There exists a *Q*max
32. Why does NPSHR increases with *Q* while NPSHA decreases with *Q.*
33. Propellers on boats are notoriously destroyed by cavitation, using External Flow concepts describe where cavitation occurs on propeller blades.
34. A system curve is governed by a loss coefficient *K*TOT, rank the effectiveness of changing this value based on all the variables involved from most effective to least effective. Use mathematical equations or numerical plots for your reasoning.
35. Describe two design solutions if your system curve is greater than your pump performance curve at *Q* = 0.
36. Sketch the system curve for
    1. Project One Part 1
    2. Project One Part 2
37. When deriving specific speed in the class it is implied the pumps are operating at 100% efficiency meaning specific speed compares different pumps at best case efficiencies. Where is this assumption implied?
38. For a list of arbitrary design variables {*x*1, *x*2, … *x*n} and for a system flowrate *Q* (*x*1, *x*2, … *x*n). Determine the best operating flowrate *Q*op for the following performance metric metrics
    1. (*Q* – *Q*BEP)2
    2. (*Q* – *Q*BEP)N
39. How would pumps preform on Mars or the Moon compared to Earth. Compare them with plots.
40. How does one populate an efficiency plot for a given pump? Describe the experiment and what must be kept constant and what must vary.
41. Describe how one creates a pump performance curve from measurements.
    1. How and where do you measure *Q*?
    2. How and where do you measure *h*?
    3. Look up the price of your measurement devices and estimate the start-up cost of making this plot.
42. Show the equivalence of the compressible and incompressible equations if ** = constant.
43. For an ideal gas explain why enthalpy is only a function of Pressure.
44. Show mathematically why *cp > cv*
45. For gas dynamics we commonly assume that *cp* and *cv* are constant. Sketch the plots of the results of experiments that would verify this.
46. Estimate the pressure ratio *P*/*Po* for a cyclist at 10 mph, someone skiing at 45 mph, a car driving at 65 mph, and an airplane flying at an altitude of 30,000 ft at 500 mph.
47. Compare Compressible and Incompressible Analysis. Consider air flowing past a probe reads 120kPa. The air pressure is measured at 80kPa. Estimate the air speed *V* and a Ma value for both theories.
    1. Assume Incompressible Flow (Bernoulli Eqn…) and an Ideal Gas
    2. Use Compressible Flow (Figures & Tables)
    3. Calculate the % Errors for Ma and *V.*
48. What type of nozzle is required if the exit flow of a design is 1600ft/s
49. Explain why for Compressible flow Ma is the all mighty number and no longer Re.
    1. What physics changes as a mathematician aimless says let
    2. Highlight a clear similarity between special relativity and compressible flow.
50. A nozzle is to be designed for a supersonic wind tunnel to test rocket foils. The test sections specification are *D* = 6 in, Ma = 3, *P* = 4.36 psi, *T* = 412oR (yeah that’s right Rankine),Testing conditions are for 30,000 ft.
    1. Determine at the throat
    2. Determine nozzle area *A*
    3. Determine the back pressure and temperature *P*0, *T*0
    4. Repeat a, b, and c for Ma = 10 (Hypersonics)
51. Draw the figures that explain the thermodynamic quantities during Normal Shock in a straight duct.
    1. Give a molecular rationalization to this phenomenon.
52. Explain why there is a difference in velocity between the front and back of a shock wave.
53. Imagine you meet a quantum physicist that will not stop talking about how constantly they feel pressure being the most “important” field of physics. Explain why as a fluid dynamist you have a much more difficult job and why their field is mere child’s play compared to yours and why *you* in fact are the ultimate physicist. (This is not one of the false statement questions)
    1. Give a mathematical undeniable reason. Governing equations people…
    2. Why could you win $1,000,000
    3. Look at the history of Turbulence for some ammo on this punk
    4. Explain why all fields of physics are basically in your field.
    5. Let them know how their field’s absolute ridiculous rationalizations will probably crumble due to amazing work by John Bush at MIT. (If you disagree with this contact me, I have literally turned this into my favorite past time to argue with quantum people on this subject. Fluidz 4 Lyfe!)
    6. Look up the history of deciphering Egyptian hieroglyphics and explain to them why their issue of so many different quantum interpretations is following a similar historical trajectory.
    7. Describe why the governing equations of surface tension flows are in fact *more* difficult versions of the simple Einstein Field Equations
    8. Really let them have it that if people did experiments with fluid logic gates at a macro scale why we could advance much faster in Quantum Computing designs, tell them once Manu Prakash’s work are Stanford starts getting some traction they don’t stand a chance.
    9. Explain to them why your love of fluids began a long time ago during the COVID19 crisis when you took the crazy class with a nut ball teacher.