EME 303- Fluid Mechanics in Energy and Mineral Engineering

Lecture:	MWF 08:00-08:50a – Blended Class
Location:	001 Chemical and Biomedical Engineering
Text:	*Munson, Young and Okiishi's Fundamentals of Fluid Mechanics,* Gerhart, P.M., Gerhart, A.L., Hochstein, J.I. 9th Edition, John Wiley & Sons, Inc. ISBN: 9781119597308 Hard copy: PSU Bookstore Non-expiring eCopy: https://store.vitalsource.com/digital-textbooks [Search: "Munson"]
Instructor:	Derek Elsworth – 231 Hosler – elsworth@psu.edu
TAs:	Matt Roseboom – 213A Hosler – mgr5160@psu.edu – (Coord. TA; By Appointment) Junpeng Wang – 213A Hosler – jzw6370@psu.edu – (By Appointment) Garrett Ziegler – 111 Hosler – gvz5089@psu.edu –- MWF 11-1; Th 3-7
Online Resources:	*Class resource page:* http://www.ems.psu.edu/~elsworth/courses/eme_303/ *Course Mgmt. Sys.:* http://canvas.psu.edu/
Prerequisites:	MATH 250 or MATH 251 and PHYS 211

Grading:

Weekly Assignments ~13 equally weighted	15%
Group Presentation Assignment	15%
Mid-Term Exams (3 @ 20% each)	60%
Final Exam	10%
Online content quizzes (~7x3 @ 0.33% each)	~7%
	107%

Format:

There are three deliverables for this class: (i) weekly assignments [15%], preparation then delivery of a group presentation [15%], and four sets of exams [70%]. And an opportunity for extra-credit *via* lecture-content quizzes.

Weekly assignments are due on most Thursdays at midnight – questions addressing the topics of week 1 are due on Thursday of week 2, etc. Assignment questions must be downloaded from canvas.psu.edu (do not use the questions in your textbook). Assignment answers are submitted online on canvas.psu.edu with three attempts that include correct/incorrect feedback. Students *may* work together but *must* submit their own work. These deadlines are firm (*i.e.* no retroactive credit) and students are responsible to check that their score is correctly recorded.

Group presentation assignments allow students to explore and report on some interesting or mysterious aspect of fluid mechanics and to complete a simple analysis of the system (see examples on "Class resource page"). These reports are recorded and submitted online.

Mid-term (three sets of three) and Final exams (one set of three) are 30 mins on each of Mon, Wed and Fr in the weeks marked on the calendar (overleaf). These are to be completed at the Pollock Testing Center (red) where you select the timing on the full day marked or remotely (green) when Pollock is not available. All are closed-book/closed-notes but with your calculator and pen/pencil and with testing-center scratch paper, web-calculator web-equation sheet. Questions will be similar to prior exams – with solved examples available to the students (on canvas.psu.edu). Conflict exams are granted only in exceptional circumstances and for satisfactorily documented emergencies. Conflict exams never repeat the scheduled mid-term questions and may be in-person.

For mid-term and final exams, full credit for questions is based on the final answer, only – there is no partial credit for working – due to the nature of these online exams. Answers span a band of +/- 10%. Final scores are final.

Grades: **Final Grades** are based on the following divisions using raw (uncurved) scores:

A (>93.3%); A- (>90.0%)
B+ (>86.6%); B (>83.3%); B- (>80.0%)
C+ (>75.0%); C (>70.0%)
D (>60.0%); F (<60.0%)

Topic	Subject	Reading Assignment	Assignments (7e)	Week
[1]	Orientation, Fluid Properties	Chapter 1: Appendices B and C	[Hw 1] Chapter 1: 1, 5, 13, 25, 41, 45, 51, 55, 79, 93, 97, 119, 123	1
[2]	Fluid statics	Chapter 2: Sections 2.1 – 2.7	[Hw 2] Chapter 2: 5, 9, 23, 33(b), 35, 39, 53, 59, 69, 73	2
[3]	Pressure forces on plane and curved surfaces, buoyancy, floatation and stability	Chapter 2: Sections 2.8 – 2.12	[Hw 3] Chapter 2: 75, 79, 85, 93, 113, 137, 143, 151	3
[4]	Elementary fluid dynamics, Bernoulli Equation	Chapter 3	[Hw 4] Chapter 3: 5, 12, 21, 27	4
		Mid-Term I		
[5]	Elementary fluid dynamics, Bernoulli Equation	Chapter 3	[Hw 5] Chapter 3: 29, 31, 39, 45, 49(a), 57, 63, 69, 81, 107, 113	5
[6]	Control volumes. Reynolds transport Theorem. Conservation of Mass and Continuity Equation	Chapter 4: Sections 4.1-4.4 Chapter 5: Section 5.1	[Hw 6] Chapter 4: 23, 27, 43; Chapter 5: 11, 15, 25	6
[7]	Newton's Second Law. Conservation of linear momentum	Chapter 5: Section 5.2	[Hw 7] Chapter 5: 39, 45, 47, 49, 53, 57, 87	7
		Mid-Term II		
[8]	First Law of Thermodynamics. Energy equation	Chapter 5: Section 5.3 Chapter 6: 6.1-6.2, 6.8-6.9	[Hw 8] Chapter 5: 99, 103, 129 Chapter 6: 69	8
[9]	Similitude. Dimensional analysis. *Pi* Theorem. Modeling.	Chapter 7:	[Hw 9] Chapter 7: 7, 9, 21, 23, 27, 31, 51, 65, 73	9
[10]	Viscous flow in pipes. Laminar -*vs*- turbulent. Head losses, Moody Diagrams	Chapter 8: Sections 8.1 - 8.4.1	[Hw 10] Chapter 8: 7, 9, 17, 21, 22, 25, 39	10
[11]	Viscous flow in pipes, exit/entry & minor losses. Flow calculations. Flow measurement	Chapter 8: Sections 8.4.2 - 8.6	[Hw 11] Chapter 8: 57, 61, 65, 79, 91, 105, 107(a)	11
		Mid-Term III		
[12]	Flow over immersed bodies. Boundary layer concepts. Drag and Lift	Chapter 9	[Hw 12] Chapter 9: 1, 37, 39, 61, 65, 115, 123	12
		Presentations		13
[13]	Open channel flow. Wave hydraulics. Specific Energy & Momentum.	Chapter 10 10.1 – 10.7	[Hw 13] Chapter 10: 3(a), 5, 7, 13, 15	14
[14]	Uniform flow. Chezy and Manning concepts	Chapter 10 10.4	[Hw 14] Chapter 10: 39, 41, 45, 51, 63, 67, 81, 96	15
		Final IV		

Updated: October 26, 2023

Academic Conduct:

Penn State's policy on academic integrity applies to all aspects of course deliverables. Students must submit independent work for all graded deliverables. Further details are available for academic integrity and code of conduct at:
https://www.ems.psu.edu/undergraduate/academic-advising/policies-procedures-and-forms/academic-integrity-undergraduates
Per *AD 42-27* class attendance for this course is encouraged. "A student should attend every class for which the student is scheduled and should be held responsible for all work covered in the courses taken." Absence from exams must be appropriately corroborated (e.g. doctor's note, etc.) before any conflict exam is scheduled or grade given.

This syllabus may be updated during the semester and you will be responsible for abiding with any such changes.

Additional generic Penn State policies that apply to this course are at:
https://www.ems.psu.edu/~elsworth/courses/eme_303/outline_add.docx

Fall 2022 EME 303 Calendar – At-a-Glance [In-class/Online]

Su	Mo	Tu	We	Th	Fr	Sa	Wk	Topic	*Deliv	Topic
August 2023										
20	21	22	23	24	25	26	1	[1]	I-c	Fluid properties
27	28	29	30	31						
September 2023										
					1	2	2	[2]	I-c	Fluid Statics
3	4	5	6	7	8	9	3	[3]	I-c	Fluid Pressures, Buoyancy
10	11	12	13	14	15	16	4	[4]	O-A	Fluid Dynamics
17	18	19	20		22	23	5	[5]	I-c	Fluid Dynamics
24		26		28		30	6	[6]	O-A	Control Volumes
October 2023										
1	2	3	4	5	6	7	7	[7]	I-c	Newton's Law and Consv. of Momentum
8	9	10	11	12	13	14	8	[8]	I-c	Thermodynamics and Energy
15	16	17	18	19	20	21	9	[9]	O-A	Dimensional Analysis
22	23	24	25		27	28	10	[10]	O-A	Flow in Pipes - Moody
November 2023										
29		31		2		4	11	[11]	O-A	Flow in pipes - Networks
5	6	7	8		10	11	12	[12]	I-c	External Flows
12		14		16		18	13	[--]	-	Group Assignment and Presentations
~~19~~	~~20~~	~~21~~	~~22~~	~~23~~	~~24~~	~~25~~				
December 2023										
26	27	28	29		1	2	14	[13]	I-c	Open Channel Flow
3		5		7		9	15	[--]	-	
10	11	12	13	14	15	16				

***Class modalities**
I-c In-class, recorded and posted (no mandatory attendance)
O-A Online-Asynchronous – mandatory online participation when a class-time midterm

(blue circle) Online review session (available)

(red circle) Exam (30 minutes duration on canvas.psu.edu – available all day, Pollock Testing Center)

(green circle) Exam (30 minutes duration on canvas.psu.edu – 8am-8.30am only, at home or in classroom)

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Group Presentation Rubric

One of the deliverables for the course will be a group presentation. This is to (i) encourage you to think critically and creatively about the role of fluids in the world around you, (ii) sharpen your skills of analysis, and (iii) to communicate and share your findings with an audience. Think of it as SpeechCom 100/EMSc 100 with quantification.

The ground rules for this are as follows:

Students will work in small groups to develop a powerpoint presentation to identify and investigate a curious observation in fluid mechanics and develop an appropriate analysis of the process. Examples of such a presentation will be given early in the course to guide the development of the presentation.

The presentation can be a single but dense slide and should last for 3 minutes. It should be interesting/compelling/enigmatic/professional rather than lengthy.

The best presentations will include:

1. **Observation [30%]** Pick an interesting observation – this will typically be interesting because it is not immediately apparent to the lay observer why the behavior is so – *i.e.* there is an element of mystery. This is the **what** of the observation.

   Native videos, links to YouTube or other online resources or photographs or diagrams are the best option.

2. **Explanation/Hypothesis [30%]** Provide an appropriate explanation – this will describe the mechanics of the observation – **why** it behaves the way it does. The explanation could advance an hypothesis or competing hypotheses. At the minimum it should describe the mechanism in enough detail to be self-contained.

   Identify the points in bullet form and describe them verbally to your audience.

3. **Analysis [30%]** Provide an appropriate analysis of the mechanism(s) – this should describe the process based on the principles of mechanics – fluid mechanics.

   Be as rigorous in your analysis of **how** the system works and as quantitative as possible.

4. **Conclusion [10%]** An Appropriate Conclusion – this should confirm/reject the mechanism(s) through the appropriate analysis of #3.

Deadlines:

Teams will be assigned:	Wednesday of Week 3
First meeting and group meeting:	Wednesday of Week 5
Provide topic:	Wednesday of Week 7
Confirmation of topic:	Wednesday of Week 8 [to ensure no duplication]
Record Presentation:	Before Sunday <u>following</u> Week 13 (Sun. before Thanksgiving)
Upload presentation file:	Sunday midnight <u>following</u> Week 13 (Sun. before Thanksgiving)

Grading:

To be based on submitted final presentation only. Grades to be uniformly distributed in quartiles between 100 (upper), 95 (lower-upper), 90 (upper-lower), 85 (lower) except no-shows and deficient presentations.

Peer-review evaluations within groups will be incorporated for 15% of the grade.

Some Random But Potential Topics – To Get You Thinking

Natural Processes

What drives atmospheric flows? How fast can the atmosphere flow?

What controls the fluid circulation in the oceans? Is there a limiting magnitude of velocities of currents? Which of pressure-driven or density-driven currents are likely to be faster?

How does the sediment capacity of rivers change with flow velocity – if you double the velocity what happens to the sediment carrying capacity?

How much blood does a human heart have to pump to keep us alive? Can you estimate the minimum overpressure and the likely flow rate?

What controls the circulation of the tectonic plates on the planet?

When a droplet of water impacts a surface, what comprises the rebound drop? Is it the original drop? What is the analog with a bouncing ball?

Engineered Systems

BP oil spill – how does PIV work and what corrections need to be applied? How do you separate out liquid and gas fractions to give estimates of flows? How does a bottom kill work? Will the gas or oil reach the surface first? How long will this take and what are the important factors?

What fraction of its intrinsic energy is used in transporting natural gas from the Gulf of Mexico to New York? How is this affected by the diameter of the pipe? How does this scale with pipe cost?

What is the limiting lift of a suction pump, and why? What are methods of exceeding this lift limitation?

Is it really best to leave your windows open in a tornado? Why?

Why do you sometimes see a vapor streak above the wing on high-lift passenger planes? What are the necessary atmospheric and take-off velocity conditions for this?

How fast can you accelerate before your drink overtops its glass and spills? What are the processes in action?

Recreation

Why does a spinning baseball curve? How much spin will give how much curve?

Is spin imparted to a tennis ball glancing the ground? And if so how much?

How can kayakers stay static in whitewater rivers without paddling? What are the conditions necessary to achieve this?

How do yacht sails work? How close into the wind can you sail and what is the limitation? Do airfoils work better than flexible sails?

Why is a long hull faster than a short hull?

How do whole body competitive swim suits work? How much faster to they make it possible to go versus bare skin, and why? And why are golf balls dimpled?

Why does rifling in a barrel and spinning a thrown football help accuracy?

What is terminal velocity and how does it vary for different sized objects? Will a child freefall skydiver fall faster or slower than an adult skydiver?

If you are skiing/snowboarding, is it better to be a child or an adult if you want to go as fast as possible on a given slope?

What happens when Mentos go into Coke? How high can it foam and for how long? How fast can the bottle travel and what is its time history? What is the analog with volcanic eruptions?