ABEN-ME 479/679 - Fluid Power Systems

Fall 2023, 3 Credits, T,R 3:30-4:45 p.m., Ladd Hall Room 209

Instructor: Dr. Tom Bon
101-G Ladd Hall
Thomas.Bon@ndsu.edu
(218) 770 – 1373 (cell)

Textbook: Fluid Power with Applications 7th ed. by Anthony Esposito. 2009. Pearson Prentice Hall, Upper Saddle River, New Jersey 07458. ISBN 978-0-13-513690-4. You will need access to a copy of the textbook. I do take material from many other references as well.

Pre-reqs: ME 352 or CE 309 or ABEN 263 (or an equivalent courses)

Course Web Page: NDSU Blackboard system

Office Hrs: 1:30 to 3:00 p.m. T, Th, and 2:00 to 4:00 p.m. M and W, Also, by appointment or just drop by and see if I am around. The ABEN Department maintains an open-door policy.

Please see https://www.ndsu.edu/onestop/academic-calendar for key dates and holidays for fall semester of 2022.

Course Rationale

Transportation, construction, agriculture, other off-road applications, machining operations, ship control, space technology, aircraft, and many more applications incorporate fluid power technology. In recent years, the academic world has tried to keep up with the increasing demand for engineering and technical specialists in hydraulic and pneumatic systems by offering new courses, or even a fluid power option. However, properly trained people are still at a premium in this area, and many fluid power manufacturers have undertaken educating their own and their customers' staff members to meet this professional expertise need.

Student Outcomes

At the conclusion of this course, students should be able to (undergraduate and graduate students):

- understand the terminology, functional role, applications and industry practices related to fluid power systems (abet 1);
- use mathematical models to describe the operation, and analyze the performance of various fluid power systems using appropriate statics, dynamics, fluid mechanics, thermodynamics and heat transfer equations (abet 1);
- design a fluid power system starting from its required function. (abet 1);
- use computer software to design, simulate, and analyze various fluid power systems (abet 1);

- have hands-on experience using hydraulic learning stations. Build basic hydraulic systems, operate them, and collect experimental data (abet 6); and.
- effectively communicate their results in problems, labs, and projects (abet 3).

Additional objectives for graduate students:

Graduate students will be required to complete a written report on a project and incorporate mathematical modeling of a hydraulic component into the project as well as the regular requirement of the course. The project will consist of an a literature review of the operation and modeling of a hydraulic component and the mathematical modeling of the component. Each project will be subject to approval from the instructor to ensure appropriate scope and content. The report will include the literature review, the mathematical development of the component, and results of the model after being implemented in either MatLab or Excel spreadsheets. A rough draft of the project will be due four weeks before dead week for comments and feedback from the instructor. This will be 25% of the total credit for the project. The completed project will be due the week before dead week. Additional details and requirements will be provided separately to graduate students enrolled in the course.

Course Outline and Prerequisites

This course will introduce engineering undergraduate and graduate students to fluid power generation, transmission and control aspects. Pipes, compressors, pumps, motors and control valves will be analyzed in detail. In addition, complex components, such as servo actuators and electro-hydraulic servo valves will be discussed.

S**oftware packages** will be available in the computer rooms to design, simulate and animate various fluid power systems. The students will construct schematics by simply dragging and dropping components from a library onto the diagram. Once circuits are completed, the software will generate animations showing the operation of moving components and fluid flow. There will be four computer laboratories during the semester. Due to the large enrollment and limited number of licenses available, students will likely have to work in pairs during the computer laboratory exercises. This course will use Automation Studio 6.3. There are many other software packages in existence having hydraulic sections or focus. These include MatLab and Simulink, Easy 5, and others.

Hydraulic trainers will be used in the ABEN lab area to demonstrate basic hydraulic operation, validate computer-designed circuits and give students hands-on experience. Students will be able to build circuits with pumps, filters, flow and pressure-control valves, actuators and gages by mounting quick-connect pressure lines between these components.

A **design project** will be assigned shortly before the middle of the semester. Teams of three to four students will be assigned to work on the project. This fall, I have agreed to allow teams to self-select. A team report will be due three weeks before finals week. One class period will be reserved for various issues related to the project in the second part of the semester. In the mean time, students are encouraged to contact the instructors with regard to the project after class or during office hours.

The **design project** will also have a team peer evaluation associated with it that will have an impact on the individual grades given for the project. The grade given on the project will be the team grade.

Term project grading:

Individual grading will be adjusted from the team grade by using a distribution weighing method. How this works is the following: Say Jill, Sam, and Mansur are on a team. Along with working on the project, each person will be assigned to divide up $10,000 between their peers on the project. You do not include yourself in the distribution. You can also give some money to charity. Giving to charity is a negative mark against a person.

Enrolled students must have at least **third-year standing** in an engineering curriculum. Statics, dynamics and a course that includes basic fluid mechanics (ME 352, or CE 309, or ABEN 263) is the prerequisite. A course in control theory or instrumentation is helpful, but not required. In addition, you must write a paragraph or two explaining why you made the divisions the way you did. This information will be turned in to the instructor.

Since there are 3 people on this example team, the average amount for each of your peers would be $10,000/2 = $5,000

Let's say the division goes like this:

Jill divides the loot as:	Sam $5,400	Mansur $4,500	and charity $100
Sam divides the loot as:	Mansur $4,700	Jill $5,100	and charity $200
Mansur divides the loot as:	Sam $5,200	Jill 4,800	and charity $0

Also, let's say the instructor gave the term project a grade of 85%

Here's how the initial grading would go for each person: Each person could have gotten a total of $10,000 if the loot was evenly divided.

Jill: $9,900/$10,000 * 85% = 84.2% for the project. A grade of B

Mansur: $9,200/$10,000 * 85% = 78.2% for the project. A grade of C

Sam: $10,600/$10,000 * 85% = 90.1% for the project. A grade of A.

Grading Policies:

Three exams are tentatively scheduled during the semester and a final exam at the end of the semester. The final exam will be comprehensive, but will emphasize the final part of the material. The following weighting will used to calculate the final score:

	ABEN-ME 479	ABEN-ME 679
Exams (3) & quizzes	40%	35%
Final exam	25%	20%
Lab reports	10%	10%
Project	10%	10%
HW	15%	10%
Graduate report		15%

The final exam is Thursday, December 14, 2023 starting at 3:30 p.m.

Final grades will be assigned according to the following scale:

A	90% or better
B	80% "
C	70% "
D	60% "
F	less than 60%

Assignments are due at 5:00 p.m. on the due date. For homework assignments, I may collect the entire assignment or only problems selected at random from the assignment. Again, the entire assignment may be graded or only selected portions of the assignment. Late assignments will be accepted up until the final exam, but are docked 60%. This is still better than getting a zero. My philosophy is that there is benefit in doing the homework.

Exams and Quizzes:

Drop quizzes may be announced or unannounced. Also, quizzes may be individual or group. There are no make-ups for missed drop quizzes. Drop quizzes are only given in the class period, so attending class is important. However, the lowest quiz grade will be dropped. If you miss a quiz, the grade is a 0 and so would be the grade dropped.

Typically, there are 8 to 12 drop quizzes in a semester, but this may vary somewhat. Drop quizzes (except for the Kapookie quiz) are typically worth 10 points each. So, the total quizzes in a semester have approximately as much influence on the student's grade as a class period exam.

Notice of one-class period exams will be given at least one week in advance of the exam. Exams usually include multiple choice, T/F, fill-in-the-blank, short answer, and problems. These exams are typically worth 100 points each. The final exam is typically worth 150 points.

The student is allowed to have 2 sides of crib notes for each exam. This is cumulative, so 2 sides for the first exam, 4 for the second exam, and so on. You are allowed to put whatever you want on your crib sheets and may write them out using a computer, long-hand, or a combination of the two. My limitation on the crib sheets is you cannot use reading aids, such as magnifying glasses and the such and no access to any phone apps, or other internet/web related sources during an exam.

Each student is expected to follow the NDSU Academic Policies and do their own work on exams, quizzes, etc. Some work collaborative (such as the project) requiring teamwork. Working together on homework and studying is beneficial in preparing.

Graduate students will be required to complete

Tentative Schedule

Introduction to fluid power:

- Introduction to fluid power
- Basic schematic symbols
- Background basics
- Fluid Basics
- Pumps and Motors
- Automation Studio Lab 1 and hands-on lab 1

Exam 1

Fluid power generation

- Cylinders
- Pressure Loss in lines and sizing tubes
- Auxiliary components
- Automation Studio and hands on lab II

Exam 2

Actuators and pneumatics

- Hydraulic cylinders
- Motors
- Fluid conductors
- Hydrostatic Transmission systems
- Automation Studio and hands on lab III
- Automation Studio and hands on lab IV

Exam 3

Systems:

- Pneumatics
- Compensated system
- To be determined

Final Exam:

Final Exam is scheduled for Thursday, December 14, 2023, starting at 3:30 p.m.

Students with disabilities needing special consideration are requested to alert me at the first class.

COVID RELATED INFORMATION:

Health and Safety Expectations

While masks are not required as we begin the 2022 fall semester, NDSU administration has determined that faculty may request mask use in their classroom. In this class, I ask that **you wear a mask** to help protect my health and the health of your peers.

Where possible, please spread out within the classroom, including not sitting in the first row of the classroom, to maximize social distancing.

Attendance Expectations

Please **do not come to class** if

- you are feeling ill, particularly if you are experiencing COVID-19 symptoms, or
- you are infected during your five-day isolation period.

You will still need to complete the assignments, exams, reading, etc. necessary to meet class learning objectives. You can complete missed work by [*add how you expect students complete missed assignments and in-person exams*].

If you were exposed to COVID-19, please follow CDC guidance available here.

If you tested positive for COVID-19, please follow CDC guidance available here.

Free testing kits can be picked up at the NDSU Bookstore, Library or Student Health Service. Rapid and PCR testing is available at the Student Health Service by appointment Monday through Friday during regular business hours for both symptomatic and asymptomatic students.

If public health conditions and directives from NDSU administration change, I will let you know in writing the expectations for our class moving forward.

ACADEMIC HONESTY:

Honor Code

CoE Honor Pledge

"On my honor I will not give nor receive unauthorized assistance in completing assignments and work submitted for review or assessment. Furthermore, I understand the requirements in the College of Engineering Honor System and accept the responsibility I have to complete all my work with complete integrity. Students who are suspected of academic dishonesty may not withdraw from the course in which dishonesty is suspected while the case is under review by the Honor Commission (**NDSU Policy 335**, 5b)."

Academic Dishonesty Defined (Source: **NDSU Policy 335**, 2a-m)

Academic misconduct (intentional or otherwise) includes but is not limited to the following:

1. Plagiarizing, i.e., submitting work that is, in part or in whole, not entirely one's own, without attributing such portions to their correct sources.
   - Cases of apparently unintentional plagiarism or source misuse must be handled on a case-by-case basis and in the context of the instructor's policies. Unintentional plagiarism may constitute academic misconduct.
   - Improper attribution of sources may be a symptom of bad writing and not plagiarism. Instructors are encouraged to recognize that citation skills are developed over time and are contextual.
2. Receiving, possessing, distributing or using any material or assistance not authorized by the instructional staff member in the preparation of papers, reports, examinations or any class assignments to be submitted for credit as part of a course or to fulfill other academic requirements.
3. Unauthorized collaborating on individual assignments or representing work from unauthorized collaboration as independent work.
4. Having others take examinations or complete assignments (e.g., papers, reports, laboratory data, or products) for oneself.
5. Stealing or otherwise improperly obtaining copies of an examination or assignment before or after its administration, and/or passing it onto other students.
6. Unauthorized copying, in part or in whole, of exams or assignments kept by the instructional staff member, including those handed out in class for review purposes.

7. Altering or correcting a paper, report, presentation, examination, or any class assignment, in part or in whole, without the instructional staff member's permission, and submitting it for re-evaluation or re-grading.

8. Misrepresenting one's attendance or the attendance of others (e.g., by PRS or attendance sheet) in a course or practical experience where credit is given and/or a mandatory attendance policy is in effect.

9. Fabricating or falsifying information in research, papers, or reports.

10. Aiding or abetting academic misconduct, i.e., knowingly giving assistance not authorized by the instructional staff member to another in the preparation of papers, reports, presentations, examinations, or laboratory data and products.

11. Unauthorized copying of another student's work (e.g., data, results in a lab report, or exam).

12. Tampering with or destroying materials, (e.g., in order to impair another student's performance).

13. Utilizing false or misleading information (e.g., illness or family emergency) to gain extension or exemption on an assignment or test.

Some information concerning ABET:

Table 1. ABEN program educational objectives and supporting student outcomes.*

Graduates are expected to have established themselves as practicing engineers who, within a few years of graduation:	
A	Successfully address emerging engineering challenges in the design or evaluation of machine systems, processing systems, and natural resources and environmental systems affecting the production of food, feed, and other bio-based products. Technical learning outcomes include student outcomes (1), (2), and (6): 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (a, e)† 2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors (c) 6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (b)
B	Effectively use professional communication, critical thinking, and interpersonal skills as team leaders and team members. Communicational learning outcomes include student outcomes (3) and (5): 3. an ability to communicate effectively with a range of audiences (g) 5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (d)

C Responsibly serve the public and their employers by participating in professional development and by maintaining the highest standard of professional engineering ethics.

Contextual learning outcomes include student outcomes (4) and (7):

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (f, h, j)
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies (i)

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* See https://www.ndsu.edu/aben/about/abet_accredited/ for the current ABEN program educational objectives. See https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/#GC3 for information on ABET student outcomes 1-7, effective as part of the "Criteria for Accrediting Engineering Programs, 2019-2020."

† ABET student outcomes (a) – (k) from the previous review cycle are included for cross-referencing only. Former student outcome (k) is implied in (1), (2), and (3).

NDSU undergraduate engineering programs are accredited by ABET. For more information about ABET, please visit https://www.abet.org/ ABET is also developed and administers the Fundamentals of Engineering (FE) exams and the Professional Engineering (PE) exams.

Problem Format:

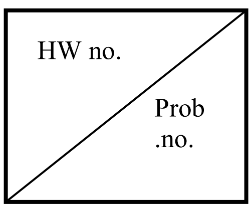
If using ASME engineering paper:

Fill out information including Name, Course, Homework no. and problem no on Problem line, and date due.

ON the sheet, Given: **including a sketch for the problem**, Find: listing the objectives, and the Soln. Include assumptions, show formulas, calculation line (formulas with numbers and units used) and box or underline answers and place ANSW by the answer.

For regular engineering paper or ordinary paper.

Top line: Date due, course, Name and page #/total pages in problem set (exp. 7/10).



Follow the procedure for Given, Find, and Sol'n. as mentioned for the ASME paper. For the ME paper, fill out the sections provided at the top of each sheet. **Every sheet in a problem set should have the basic information at the top of each sheet.**
In the solution section you should have the formula(s) used, formulas if rearranged, values and units in the formulas, and the solution.

HW problems will be scored from 0-10 based on the solution (method and answer). Regardless of the final answer, 1 point will be deducted (per problem, as appropriate) for each of the guidelines not followed.

a) Use proper problem-solving format [Given, Find, Solution].
b) Including all given and assumed information. This should include a sketch when appropriate. Any starting equations should be noted [e.g. T=F·r] and all terms/variables should be clearly defined with units [e.g. r = 14.2 cm].
c) Clearly show <u>all</u> work.
d) Include units clearly in all stages of calculations and show how they cancel out
e) Clearly mark final answer (underline or double underline).
f) Use an appropriate number of significant digits and scientific notation when appropriate.
g) Avoiding cramming too much on the paper – it facilitates mistakes and makes it difficult to follow.
h) Write on only one side of the paper.
i) Remove the frayed edges if using a spiral bound notebook.
j) Staple sheets together.

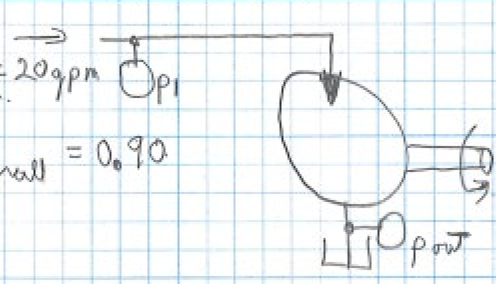
Note: if that does not apply to the problem, the student should note this on the sheet such as, "No assumptions were required." Up to 5 points may be taken off of a problem for formatting issues. Hopefully this does not occur after the first HW assignment or two. My major focus points include putting in the diagram, following the order, and clearly stating the answer with Rough homework examples follow.

Name: Joe Bison Sheet 1 of 12
Course: ABEN-ME 479
Problem: HW#5 Prob #1 Date: 08/22/2019

Given:

$Q_{in} = 20\text{ gpm}$

$\eta_{overall} = 0.90$



$N = 800\text{ rpm.}$

$P_{out} = 25\text{ hp.}$

Find: p_1 for the system.

Solution:

Assumptions: - p_{out} of the motor $= 0$ psig.
- use gage pressures.
- ignore line loses.

More than 1 method could be used to solve this problem.

$$\eta_{overall} = \frac{P_{out}}{P_{in}} = 0.90$$

$$P_{in} = \frac{P_{out}}{\eta_{overall}} = \frac{25\text{ hp}}{0.90}$$

$$P_{in} = 27.7\overline{7}\text{ hp}$$

$$P_{in} = \Delta p = p_1 - p_{out} = p_1 - 0 = p_1$$

$$P_{in} = P_{HYD} = \frac{\Delta P \cdot Q}{1{,}714\ \frac{\text{psi}\cdot\text{gpm}}{\text{hp}}}$$

$$\Delta p = \frac{1714\ \frac{\text{psi}-\text{gpm}}{\text{hp}} \cdot P_{HYD}}{Q} = \frac{1{,}714\ \frac{\text{psi}-\text{gpm}}{\text{hp}} \cdot 27.7\overline{7}\text{ hp}}{20\text{ gpm}}$$

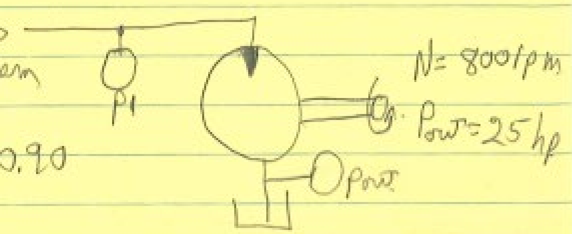
$$\Delta p = 2380.\overline{5}\text{ psig} = p_1$$

$p_1 \cong 2380\text{ psi}$ to $\approx 2{,}400\text{ psig}$ **Answer**

Due: 08/22/2019 ABEN-ME 479 Joe Bison 1/12.

HW #5 / Prob. #1

Given: $Q_{in} = 20\ gpm$, $\eta_{overall} = 0.90$



Find: p_1 for the system.

Solution:

Assumptions:
- $p_{out} = 0\ psig$
- use gage pressures
- ignore line loses

More than one method could be used to solve the problem.

$$\eta_{overall} = \frac{P_{out}}{P_{in}}$$

$$P_{in} = \frac{P_{out}}{\eta_{overall}} = \frac{25\ hp}{0.90}$$

$$P_{in} = 27.7\bar{7}\ hp$$

$$\Delta p = p_1 - p_{out} = p_1 - 0\ psig = p_1$$

$$P_{in} = P_{HYD} = \frac{\Delta p \cdot Q}{1{,}714\ \frac{psi - gpm}{hp}}$$

$$\Delta p = \frac{1{,}714\ \frac{psi \cdot gpm}{hp} \cdot P_{in}}{Q} = \frac{1{,}714\ \frac{psi - gpm}{hp} \cdot 27.7\bar{7}\ hp}{20\ gpm}$$

$$\Delta p = 2380.5\ psig = p_1$$

$p_1 \cong 2380\ psig$ (could also say $p_1 \cong 2{,}400\ psig$) Answer.